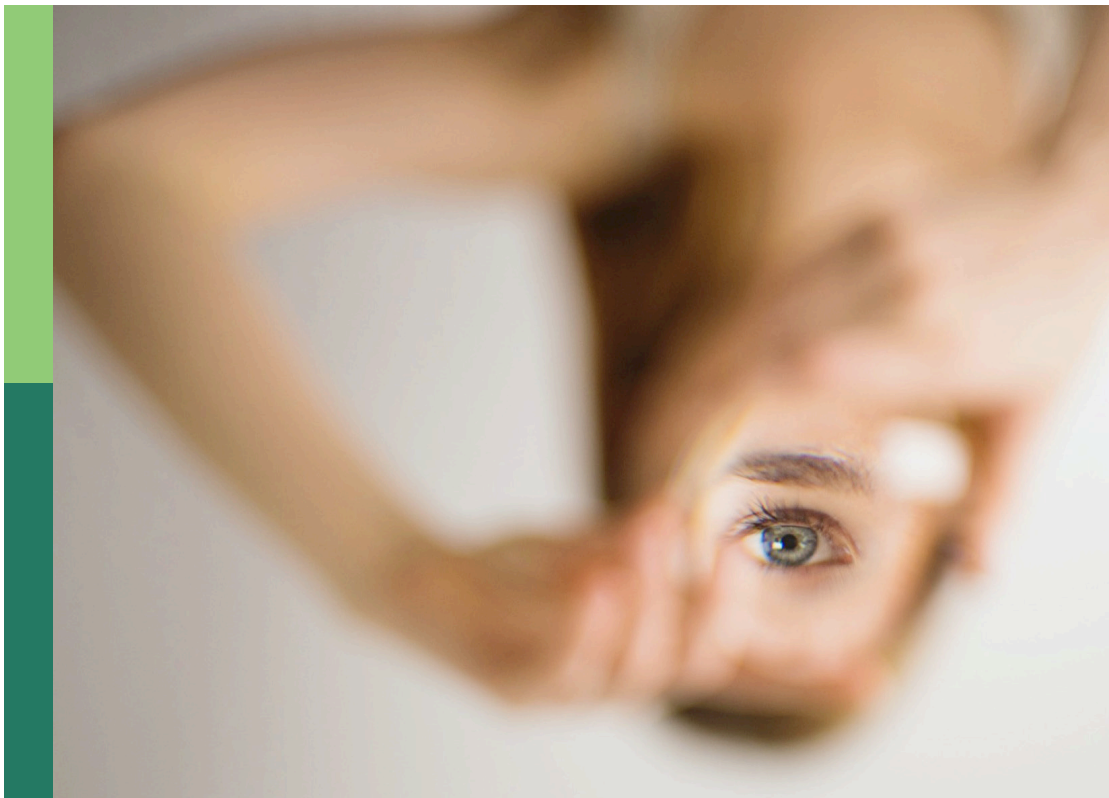
frontiers | Research Topics

Unraveling the role of psychological capital on innovation from the knowledge management perspective

Edited by
Yunlong Duan, Yu Liping, Shanshan Wang and Wei Zhou

Published in
Frontiers in Psychology



ISSN 1664-8714
ISBN 978-2-8325-4121-0
DOI 10.3389/978-2-8325-4121-0

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Unraveling the role of psychological capital on innovation from the knowledge management perspective

Topic editors

Yunlong Duan — Yunnan University of Finance And Economics, China
Yu Liping — Zhejiang Gongshang University, China
Shanshan Wang — Dhurakij Pundit University, Thailand
Wei Zhou — Yunnan University of Finance And Economics, China

Citation

Duan, Y., Liping, Y., Wang, S., Zhou, W., eds. (2023). *Unraveling the role of psychological capital on innovation from the knowledge management perspective*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-4121-0

Table of contents

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 11 November 2022
DOI 10.3389/fpsyg.2022.1045845

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University, China

REVIEWED BY
Fan Chao,
Renmin University of China, China
Lixia Yao,
Zhejiang Gongshang University, China

*CORRESPONDENCE
Haoyang Song
songhy29@mail.sysu.edu.cn

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 16 September 2022
ACCEPTED 25 October 2022
PUBLISHED 11 November 2022

CITATION
Shen Y, Zhang Z, Song H, Zheng J and Bu Q (2022) Being helpful and being innovative: The role of psychological meaningfulness and positive affect. *Front. Psychol.* 13:1045845. doi: 10.3389/fpsyg.2022.1045845

Being helpful and being innovative: The role of psychological meaningfulness and positive affect

Yifei Shen[1], Zhenduo Zhang[1], Haoyang Song[2]*, Junwei Zheng[3] and Qiong Bu[4]

[1]School of Economics and Management, Dalian University of Technology, Dalian, China, [2]School of Information Management, Sun Yat-sen University, Guangzhou, China, [3]Faculty of Civil Engineering and Mechanics, Kunming University of Science and Technology, Kunming, China, [4]China Business Executives Academy, Dalian, China

The present study is developed based on conservation of resources theory (COR) to explore the underlying mechanism and boundary condition for the relationship between helping behavior and innovative behavior. To avoid the shortages of cross-sectional data, the present study collected two-wave and multi-source data. By collecting from 193 full-time Chinese workers and 68 supervisors at two separate time points, this study developed and examined a moderated mediation model using Mplus 7.0. The results show that helping behavior increases innovative behavior through enhancing positive affect, and psychological meaningfulness moderates the indirect relationship between helping behavior and innovative behavior through positive affect. In the condition of high psychological meaningfulness, helping behavior has a stronger indirect impact on innovative behavior through enhancing positive affect. This study enriches the literature on the outcomes of helping behavior. Moreover, this study provides several managerial implications to amplify the positive impact of helping behavior on innovative behavior. This study develops several strategies to enhance psychological meaningfulness and promote the benefits of helping behavior.

KEYWORDS

helping behavior, innovative behavior, psychological meaningfulness, positive affect, conservation of resources theory

Introduction

Helping behavior denotes voluntary assistance given to coworkers in order to accomplish goals or prevent problems (Yue et al., 2017). Given its positive influences on facilitating organizational effectiveness and team performance (Ehrhart et al., 2006), prior research has focused on the antecedents of helping behavior, such as diverse kinds of leadership and human resource management systems (Mossholder et al., 2011).

In recent times, several studies have explored the outcomes of helping behavior from an actor-centric perspective. For example, Gabriel et al. (2018) found that helping behavior caused actors to experience ego depletion daily. Although many studies have explored the psychological and behavioral outcomes of helping behavior, only a few have linked helping behavior to innovative behavior. To help coworkers cope with difficulties at work, employees need to integrate their knowledge to form a coping strategy (Bolino and Grant, 2016). Moreover, helping coworkers may aid them to cultivate positive emotions (Lin et al., 2017). These two resources are key roles in stimulating innovative behavior. In line with prior studies, this study proposes that helping behavior can be transmitted into innovative behavior. Getting insights into this research topic is important because employees are encouraged by their organization to help improve organizational effectiveness. Therefore, organizations should be mindful of the benefits and costs of helping behavior for helpers. The present study provides practical guidance to transform helping behavior into innovative behavior and leverage the management of helping behavior by examining this relationship.

Helping behavior has been regarded as an emotion regulation tool, which assists helpers to maintain positive emotional experiences (Lin et al., 2017). For example, Duan et al. (2019) found that helping behavior aids helpers to acquire positive affective experience. Affect is the "hot unit" that responds to helping behavior instantly. Prior studies have highlighted the "doing good, feeling good, and doing good" effect, which demonstrates how helping behavior promotes helpers' positive affects, thereby encouraging helpers' proactive behavior. For example, Lin et al. (2017) found that helping coworkers increases helpers' positive affects and then promotes the emotional support they provide to their spouses. Due to the positive relationship between helping behavior and innovative behavior, this study proposes that positive affect plays a mediating role in the relationship between helping behavior and innovative behavior.

However, it is should be addressed that Lin et al. (2020) found a paradoxical result indicating that helping behavior could cause emotional exhaustion for the helpers. The potential explanation for these paradoxical research outcomes may be the omission of employees' possessed job resources. Conservation of resources theory (COR) addresses the impacts of resources in facilitating employees' in-role performance, coping with stress, and achievement of work goals (Halbesleben et al., 2014). To explore the boundary condition under which helping behavior is more or less effective in nurturing positive affect, this study introduces psychological meaningfulness as a moderator in the indirect relationship between helping behavior and innovative behavior through positive affect.

Psychological meaningfulness refers to the value of a work goal, judged in relation to an individual's own ideals or standards (May et al., 2004). Psychological meaningfulness is an important job resource that exerts influence on the outcomes of helping behavior (Lin et al., 2020). Enhanced psychological meaningfulness makes employees believe that their investments of personal resources in helping others will be well reciprocated (Kahn, 1990; Lin et al., 2020). Although helping behavior can cause an extra emotional burden for helpers, psychological meaningfulness can work as a shield to helpers experiencing such stressful conditions through facilitating the recovery of resources (Ugwu and Onyishi, 2018). Thus, their helping behavior garners more positive emotional experiences, which can subsequently be beneficial for innovative behavior when psychological meaningfulness is high.

The basic tenet of COR theory, which is that individuals strive to obtain, retain, and protect job resources, has implications for understanding the outcomes of helping behavior. Previous studies have identified helping behavior as both resources-generating and resources-consuming, which shapes subsequent psychological states and behavioral responses. Thus, we developed a moderated mediation model (**Figure 1**), based on COR theory, to explain the ebbs and flows of resources triggered by helping behavior (Halbesleben et al., 2014).

We collected two-wave leader-subordinate dyadic data to test the conceptual model. In doing so, this study makes three contributions to the helping behavior literature and COR theory. First, this study extends our understanding of the outcomes of helping behavior by linking helping behavior to innovative behavior. Prior studies have mainly explored whether helping behavior impedes wellbeing or is transmitted into unethical behavior from an actor-centric perspective (Yam et al., 2017). However, the relationship between helping behavior and innovative behavior is not addressed, which makes the benefits of helping behavior less known. When lending hands to coworkers, helpers are motivated to integrate possessed knowledge and cultivate positive affective experiences through their interactions with coworkers, which are important to enhance innovative behavior (Bolino and Grant, 2016). This study attempts to explore the innovative outcomes of helping behavior, thereby providing a comprehensive insight into the advantages of helping behavior for helpers.

Second, this study uncovers the mediating role of positive affect in the relationship between helping behavior and innovative behavior. The benefits of helping behavior for helpers have been addressed by ample studies, especially for its emotional benefits (Shah et al., 2018; Lin et al., 2020). From the "doing good, feeling good" perspective, this study identifies positive affect as the key resource linking helping behavior to innovative behavior. Positive affect broadens helpers' behavioral and thinking repertories, which is beneficial for their innovative performance. We specify the underlying emotional path through which helping behavior is transmitted into innovative

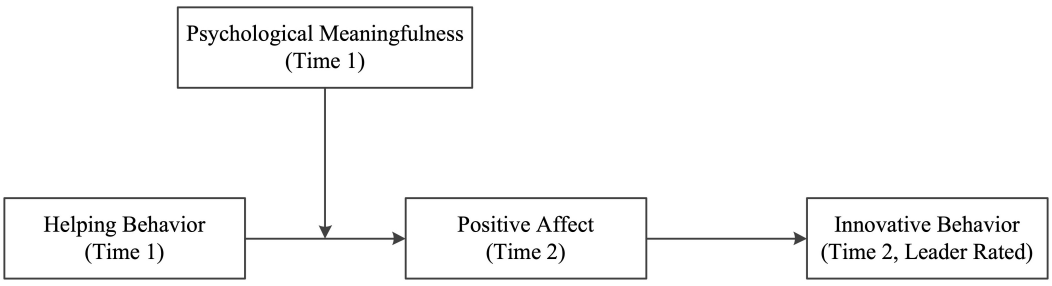


FIGURE 1
The conceptual model.

behavior, thereby contributing to the mechanisms explaining how helping behavior impacts following behaviors.

Third, this study adopts psychological meaningfulness as a moderator, providing a potential explanation for the paradoxical emotional outcomes of helping behavior and extending the scope of the COR theory. Prior studies have provided two different impacts of helping behavior on positive affective experiences. Lin et al. (2017) examined the positive relationship between helping behavior and positive affects. However, Lin et al. (2020) found that helping behavior leads to emotional exhaustion. One of the explanations for these paradoxical outcomes is the neglection of helpers' possessed resources. From the COR perspective, this study adopts psychological meaningfulness, a key resource for helpers, as the moderator specifying the boundary condition that impacts the relationship between helping behavior and positive affects.

Hypothesis development

Helping behavior and innovative behavior

For helpers, the aim of helping behavior is to aid those who seek help in coping with difficulties at work (Yue et al., 2017). To achieve this aim, helpers need to evaluate prior unsuccessful attempts to solve the problem (Yue et al., 2017). This means that helpers and helping seekers confront the same challenge in that they are both exposed to different aspects of the challenging task and diverse information when making problem-solving efforts (Mueller and Kamdar, 2011). Based on this, Perlow and Weeks (2002) proposed that helping behavior is a beneficial opportunity for helpers to improve their skills and fill their knowledge gaps. Helpers need to integrate the knowledge they possess with problem-related information to improve their critical thinking capabilities and to develop more creative ways to solve problems (Yánez Morales et al., 2020). Through helping others, helpers may acquire new knowledge and apply this knowledge in both familiar and unfamiliar situations (Li and Liao, 2017). Through this process, helpers will gain deep insights into the difficulties they have faced and form their cognitive schema by integrating their new knowledge, which is beneficial for developing innovative ideas.

During the problem-solving procedure, helpers and helping seekers may have a beneficial interaction in which they exchange information or necessary resources to overcome their difficulties (Lin et al., 2020). In doing so, it is a necessary condition for helpers to acquire valuable resources to develop novel ideas (Zhang et al., 2022). When successfully helping coworkers, helpers usually obtain gratitude from them. Helping behavior also aids helpers in cultivating a high reputation at work and establishing high-quality social relationships with their coworkers; these are key components of social capital, which are sources of positive emotions (Zhang et al., 2020). Fredrickson (2004) suggested that positive affect enhances individuals' cognitive flexibility and promotes their confidence in engaging in innovative behavior. Combining these arguments, this study puts forward the following hypothesis:

> *H1: Helping behavior is positively associated with innovative behavior.*

Mediating role of positive affect

Positive affect reflects the extent to which a person feels enthusiastic, alert, and active. With high positive affect, individuals are in a state of high energy, full concentration, and pleasurable engagement (Watson et al., 1988). Prior studies have found that helping is a positive and voluntary interpersonal activity that has the potential to enhance helpers' positive affect due to its generation of psychological resources (Lin et al., 2017). Helping behavior is an affiliative endeavor facilitating social cohesiveness by which employees build reciprocal ties with coworkers (Koopman et al., 2016). Furthermore, helping behavior enhances core-self evaluations and helpers usually receive gratitude from recipients because helpers solve work-related problems for them (Lee et al., 2019). Employees thus

gain personal emotional resources and have positive affective experiences after helping coworkers.

COR theory suggests that individuals invest job resources as a means to obtain additional resources, potentially creating virtuous cycles. Both theoretical and empirical studies have found that helping behavior facilitates the cultivation of positive affect from an actor-centric perspective. Bolino and Grant (2016) suggest a positive relationship between helping behavior and positive affect in their review. Lin et al. (2017) found that helping behavior nurtures helpers' positive affect on a daily basis, thus confirming the "doing good-feeling good" effect. Laboratory studies have shown that simple helping behavior enhances individuals' positive affect (Yinon and Landau, 1987). Therefore, the following hypothesis was proposed:

> *H2a: Helping behavior is positively associated with positive affect.*

We propose that work-related positive affect plays a critical role in stimulating the innovative behavior of helpers. COR theory suggests that positive affect is a valuable resource that broadens individuals' behavioral repertories and attention (Fredrickson and Joiner, 2018). Therefore, positive affect facilitates helpers' cognitive flexibility and is associated with a growth mindset (Williamson et al., 2019), thereby boosting divergent thinking and innovative behavior (Yuan et al., 2018).

Positive affect signals an increase in the possibility of achieving favorable outcomes and usually elicits more additional positive affect, which thus further favors innovative performance (Pillay et al., 2020). Prior studies have provided fruitful evidence for the positive relationship between positive affect and innovative behavior. De Rooij and Vromans (2020) used spontaneous eye blink rate to explore the relationship between positive affect and divergent thinking, one of the two thinking processes of creative idea generation. de Buisonjé et al. (2017) indicated that positive affect facilitates creative idea selection.

Moreover, Koopman et al. (2016) posit that the affective boost associated with helping behavior is consequentially turned into affective commitment and job satisfaction. Innovation requires employees to devote certain job resources, such as time and energy (Kwon and Kim, 2020). Both affective commitment and job satisfaction provide helpers with the senses of belonging, stability, and security, which allow helpers to engage in innovative behavior with minimal expenditure of energies and enhance their willingness to devote time to applying novel solutions to improve organizational effectiveness (Lapointe et al., 2011; Gillet et al., 2018). Thus, the following hypothesis was proposed:

> *H2b: Positive affect is positively associated with innovative behavior.*

As aforementioned, the "doing good-feeling good" effect has been confirmed by theoretical and empirical research (Lin et al., 2017). The cultivation of appreciation and anticipated reciprocal support from helped colleagues simulate helpers' positive experiences (Koopman et al., 2016; Lin et al., 2020). Consequently, enhanced positive affect motivates helpers to devote time and energies to engage in innovative behavior. Moreover, positive affect releases cognitive resources and creative thinking, thereby facilitating innovative behavior (Lapointe et al., 2011). Therefore, the following hypothesis was proposed:

> *H2c: Positive affect mediates the positive relationship between helping behavior and innovative behavior.*

Moderating role of psychological meaningfulness

Psychological meaningfulness is defined as the significance a person attaches to an object, event, or situation (Ugwu and Onyishi, 2018). The organizational behavior literature uses meaningfulness of work to indicate the value of a work goal or purpose, judged in relation to an individual's own ideals or standards (May et al., 2004). At work, psychological meaningfulness is beneficial to both employees and organizations. Employees are motivated to seek meaning in daily work (Aguinis and Glavas, 2019). Employees will disengage from their work in the absence of psychological meaningfulness (May et al., 2004). Psychological meaningfulness is a core psychological process connecting perceptions of the work environment with psychological experience (Chaudhary, 2022). It acts as a motivational pathway in which values and purposes derived from the work context are transformed into a fulfilling and positive personalized experience (Mostafa and El-Motalib, 2020).

COR theory suggests the important role of personal resources in shaping individuals' resource conservation and generation processes (Halbesleben et al., 2014). COR theory posits that when individuals regard their job situation as favorable and appreciated, beneficial psychological energies motivate them to undertake helping behavior to contribute to their coworkers' wellbeing, and also to reward themselves with desirable affective experiences and anticipated reciprocation (Halbesleben et al., 2014). Furthermore, aligning with the resource gain spirals tenet of COR theory, employees are more likely to cultivate positive energies from helping behavior when they have access to complementary resources to undermine the effects of potential loss of psychological resources (Zhang et al., 2020). De Clercq et al. (2019) suggested that psychological meaningfulness captures the extent to which employees deem their work to be important. Psychological meaningfulness

enhances helpers' favorable feelings about their job situation and provides them with complementary psychological resources, which invigorates the relationship between helping behavior and favorable emotional experiences. Therefore, the present study adopts psychological meaningfulness, an important job resource, as a moderator in the relationship between helping behavior and positive affect.

Those with high psychological meaningfulness will hold a belief that their investments of job resources in helping coworkers will be well reciprocated, which inhibits their worries about job losses (Kahn and Heaphy, 2013). As well, the sense of meaningfulness enables individuals to overcome job demands and boost the positive affective experiences caused by helping behavior (Ugwu and Onyishi, 2018). In contrast, when helpers have lower levels of psychological meaningfulness, they will expect that there will be few gains in or returns from their investments of personal resources in helping others (Kahn and Heaphy, 2013). This feeling of resource loss will decrease the positive affective experiences induced by helping behavior. Moreover, those with a lower level of psychological meaningfulness are more vulnerable to the job demands caused by helping behavior and have a decreased likelihood that they will experience positive affect. The following hypothesis was thus proposed:

> *H3: Psychological meaningfulness moderates the relationship between helping behavior and positive affect, such that in the condition of higher psychological meaningfulness, the association between helping behavior and positive affect will be stronger.*

As aforementioned, positive affect mediates the relationship between helping behavior and innovative behavior. COR theory suggests that individuals who start with more job resources are less impacted by the uncertainty caused by the loss of job resources (Halbesleben et al., 2014). Psychological meaningfulness has been used in research based on COR theory, and it is viewed as a valuable resource leveraging the sense of fulfillment and positive energies (De Clercq et al., 2019). Therefore, those with high psychological meaningfulness are less sensitive to the loss of job resources caused by helping behavior. Furthermore, psychological meaningfulness is associated with achievements of resource gain spirals. For example, Mostafa and El-Motalib (2020) encourages the investment of positive energies into one's work, which enables helpers to better manage and integrate their social relationships, thereby improving their wellbeing. High psychological meaningfulness enables helpers to reap more positive affect through helping coworkers to deal with difficulties encountered at work and then stimulates more innovative behavior. In contrast, low psychological meaningfulness makes helpers more likely to experience emotional exhaustion due to the interrupted work routine and impedes the work progress triggered by helping behavior without complementary job resources. Therefore, low psychological meaningfulness decreases the likelihood that helpers will obtain positive affect through helping coworkers, thereby inhibiting the performance of innovative behavior at work. Therefore, the following hypothesis was proposed:

> *H4: Psychological meaningfulness moderates the indirect relationship between helping behavior and innovative behavior through positive affect, such that in the condition of higher psychological meaningfulness, this indirect relationship is stronger than in the condition of lower psychological meaningfulness.*

Materials and methods

Participants and procedure

Data were collected from employees in a construction enterprise in Beijing, China. Before data collection began, human resource managers sent an announcement to the group leaders, explaining the research purpose and research procedure, and asked for their willingness to engage in the survey. Ultimately, 73 group leaders gave responses to the announcements. The website links for the survey were sent to the group leaders and they communicated the website links to their employees.

Prior psychological studies have adopted cross-sectional data to collect respondents' attitudes, beliefs, and perceptions of the situations reported by the same person at the same time points. Consequently, there is a possibility that common method variance (CMV) has artifactually inflated the observed correlations between these types of variables. Feldman and Lynch (1988) further suggested that behavioral self-reports could be significantly correlated with job dimensions that are completely meaningless to the respondents if they are required to assess their own performance (i.e., job performance and innovative performance) and then provide ratings of job characteristics and psychological states related to such performance. Podsakoff et al. (2003) has suggested that CMV may result in inflated correlations between variables collected through cross-sectional data and also developed remedies for such bias. The first is to collect data from different time points and the second is to collect data from different sources (Podsakoff et al., 2003). Our research mainly explores the relationship between helping behavior, positive affect, psychological meaningfulness, and innovative behavior. The variables are employees' psychological attitudes and behaviors. If we were to use a cross-sectional design,

the correlations between these variables may be exaggerated, yielding results that are ultimately meaningless (Feldman and Lynch, 1988). For these reasons, we collected survey data at two time points in leader-subordinate dyads to control CMV and enhance the reliability of the results. At Time 1, participants were asked to report their levels of helping behavior and psychological meaningfulness. At Time 2, a month after Time 1, employees were asked to report their positive affect, and the group leaders were asked to report employees' innovative behavior. The leader-reported innovative behavior may enhance the objectivity of the ratings of innovative performance and the two-time point lagged design may decrease the bias caused by CMV (Leung et al., 2011; Peng et al., 2019). In both surveys, employees were asked to report their demographic information, including code, age, education, gender, and position in their organization, which were used to match the data.

Surveys were returned by 227 employees at time 1, and by 212 at time 2 (response rate 93.39%). At time 2, 68 of 73 group leaders finished their questionnaires, giving a response rate of 93.15%. Among the 212 participants, there were 17 employees whose leaders failed to finish the questionnaire, and 2 questionnaires were partially finished. Ultimately, 193 employees nested in 68 group leaders finished the questionnaire, giving an effective response rate of 84.64%. The participants worked in the management department (24.8%), information technology department (15.4%), design department (32.7%), and the frontline department (27.1%). 50.8% of the participants were male; 19.2% of the participants had a college certificate or below, and 17.6% had a master's degree or above. Participants' average age was 32.15 years (±6.25).

Measures

We followed Brislin's (1980) suggestion to conduct a translation-back translation procedure to ensure the accuracy of the measures which were originally developed in English. The measurements used in this study are listed in **Appendix 1**.

Helping behavior

Three items developed by Yue et al. (2017) were used to measure helping behavior at time 1. A sample item is, "I help my colleagues when it is clear their workload is too high." A five-point Likert scale was used to measure how frequently employees engaged in helping behavior in the last month, with 1 = *never* and 5 = *always*.

Psychological meaningfulness

Six items developed by May et al. (2004) were used to measure psychological meaningfulness as rated by employees. A sample item is, "The work I do on this job is very important." A five-point Likert scale was used, ranging from 1 = *strongly disagree* to 5 = *strongly agree*.

Positive affect

The short form of the PANAS scale was used to measure positive affect at time 2 (Thompson, 2007). Employees were asked to report how frequently they felt determined, attentive, alert, inspired, and active in the last month on a five-point Likert scale with 1 = *very slightly* and 5 = *extremely*.

Innovative behavior

The six-item innovative behavior scale developed by Scott and Bruce (1994) was used in the survey and completed by group leaders at time 2. A sample item is, "This worker generates creative ideas." A five-point Likert scale was used ranging from 1 = *strongly disagree* to 5 = *strongly agree*.

Control variables

Considering the influences of gender, age and education on innovative behavior (Newman et al., 2018; Luu, 2019), this study controlled them in the structural equation modeling analysis and regression analysis.

Results

Analytical strategy

Given the nested structure of the innovative behavior ratings [i.e., 193 subordinates and 68 group leaders, ICC(1) = 0.51], the nested-equation path analytic approach was used to analyze the non-independence data (Wu et al., 2016). The "Type = Complex" and "Estimator = MLR" settings were used in Mplus 7.0. This approach was appropriate for this study because this study is concerned with non-independence data structures with data at the employee level (Zheng et al., 2021). After completing the nested-equation path analysis, the bootstrapping test was used to examine the robustness of the results.

Confirmatory factor analysis

We examined the hypothesized measurement model with three factors: helping behavior, psychological meaningfulness, and positive affect. Because innovative behavior was rated by group leaders, it was not adopted in the confirmatory factor analysis (Laulié et al., 2021). The results in **Table 1** showed that the three-factor model has a better fit (χ^2 = 128.40, df = 73, SRMR = 0.05; CFI = 0.97, TLI = 0.97, RMSEA = 0.06) than other models ($\triangle\chi^2 \geq 94.10$), indicating the acceptable discriminant validity of the research variables.

Hypothesis tests

The means (M), standard deviations (SD), composite reliabilities (CR), average variances extracted (AVE), and correlations of all variables are shown in Table 2.

Given the nested nature of the data, we first analyzed the data using the "Type = Complex" and "Estimator = MLR" settings in Mplus 7.0. To test the mediating role of positive affect, we followed the procedure proposed by Kenny (2008). First, innovative behavior was regressed on helping behavior. Second, positive affect was regressed on helping behavior. Third, innovative behavior was regressed on helping behavior and positive affect simultaneously. If helping behavior and positive affect are both significant, but the significance of the helping behavior decreases, this implies that the influence of helping behavior on innovative behavior is partially mediated by positive affect. If helping behavior becomes not significant while positive affect is significant, the influence of helping behavior on innovative behavior is fully mediated by positive affect.

The results in Table 3 indicate that helping behavior is positively associated with innovative behavior (Model 5, $B = 0.26$, $SE = 0.06$, $p < 0.01$), supporting H1. Helping behavior is positively related to positive affect (Model 2, $B = 0.38$, $SE = 0.07$, $p < 0.01$), supporting H2a. When innovative behavior is regressed on helping behavior and positive affect simultaneously, helping behavior is not significant (Model 6, $B = 0.18$, $SE = 0.10$, n.s.), whereas positive affect is still significant (Model 6, $B = 0.23$, $SE = 0.11$, $p < 0.05$). These results support H2b and H2c. The results also indicate that positive affect may play as a full mediating role in the relationship between helping behavior and innovative behavior. To test the whole conceptual model, nested-equation path analysis is used to test the hypotheses, and the results are depicted in Figure 2.

To further explore the mediating role of positive affect in the relationship between helping behavior and innovative behavior, a bootstrapping test is conducted, and the results are presented in Table 4. The results of the bootstrapping test indicate that the indirect relationship between helping behavior and innovative behavior through positive affect is significant [Table 4, Effect = 0.03, $SE = 0.02$, 95% CI = (0.01, 0.07)]. Several studies have suggested that this may be due to the "feeling good, doing good" effect rather than the "doing good, feeling good" effect. Therefore, we recalculate the alternative model about the indirect relationship between positive affect and innovative behavior through helping behavior. The indirect relationship is not significant [Effect = 0.07, $SE = 0.04$, 95% CI = (−0.01, 0.15)]. The insignificant alternative model supports H2c to a certain degree.

In Table 3, the interactive item of helping behavior with psychological meaningfulness is positively associated with positive affect (Model 3, $B = 0.09$, $SE = 0.06$, $p < 0.01$), supporting H3. To further explore the moderating role of psychological meaningfulness in the relationship between helping behavior and positive affect, a simple slope test is conducted, and the results are presented in Table 4. When psychological meaningfulness is high (+1 *SD*), the relationship between helping behavior and positive affect is significant

TABLE 1 Results of confirmatory factor analysis.

Model	Variables	χ^2	df	χ^2/df	$\Delta\chi^2$	SRMR	CFI	TLI	RMSEA
Three-factor model	HB, PM, PA	128.40	73	1.76		0.05	0.97	0.97	0.06
Two-factor model	HB + PM, PA	305.30	75	4.07	176.90**	0.10	0.89	0.87	0.13
Two-factor model	HB, PM + PA	222.50	75	2.97	94.10**	0.07	0.93	0.92	0.10
Two-factor model	HB + PA, PM	266.83	75	3.56	138.43**	0.08	0.91	0.89	0.12
One-factor model	HB + PM + PA	384.11	76	5.05	255.71**	0.11	0.86	0.83	0.15

**$p < 0.01$; $N = 193$. HB, Helping Behavior; PM, Psychological Meaningfulness; PA, Positive Affect.

TABLE 2 Means, standard deviations, CR, AVE, and correlation analysis.

	AVE	CR	Mean	SD	1	2	3	4	5	6	7
1. Gender			1.49	0.50							
2. Age			32.15	6.25	0.03						
3. Education			1.98	0.61	0.21**	0.05					
4. Innovative behavior	0.64	0.91	3.86	0.80	0.00	0.05	−0.04	(0.91)			
5. Helping behavior	0.58	0.81	3.91	0.62	0.05	0.11	−0.02	0.21**	(0.80)		
6. Positive affect	0.53	0.84	3.80	0.60	−0.12	−0.02	0.01	0.22**	0.38**	(0.77)	
7. Psychological meaningfulness	0.76	0.95	4.06	0.69	−0.11	−0.01	0.01	0.12	0.31**	0.71**	(0.95)

**$p < 0.01$; $N = 193$. Values in the parentheses are the Cronbach's alpha.

TABLE 3 Results of hierarchical regression analysis.

	Positive affect						Innovative behavior					
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Gender	0.00	0.01	−0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01
Age	0.04	0.08	0.06	0.07	0.04	0.06	−0.06	0.12	−0.05	0.13	−0.07	0.12
Education	−0.15	0.10	−0.18	0.09	−0.07	0.06	0.02	0.14	0.00	0.14	0.04	0.15
Helping behavior			0.38**	0.07	0.15**	0.05			0.26**	0.10	0.18	0.10
Psychological meaningfulness					0.59**	0.05						
Helping behavior × psychological meaningfulness					0.19**	0.06						
Positive affect											0.23**	0.11
−2LL	−174.78		−158.49		−98.32		−228.91		−224.79		−222.24	
AIC	359.55		328.98		212.63		467.81		461.59		458.47	
BIC	360.03		329.55		238.74		484.13		462.16		481.31	

*$p < 0.05$, **$p < 0.01$; $N = 193$.

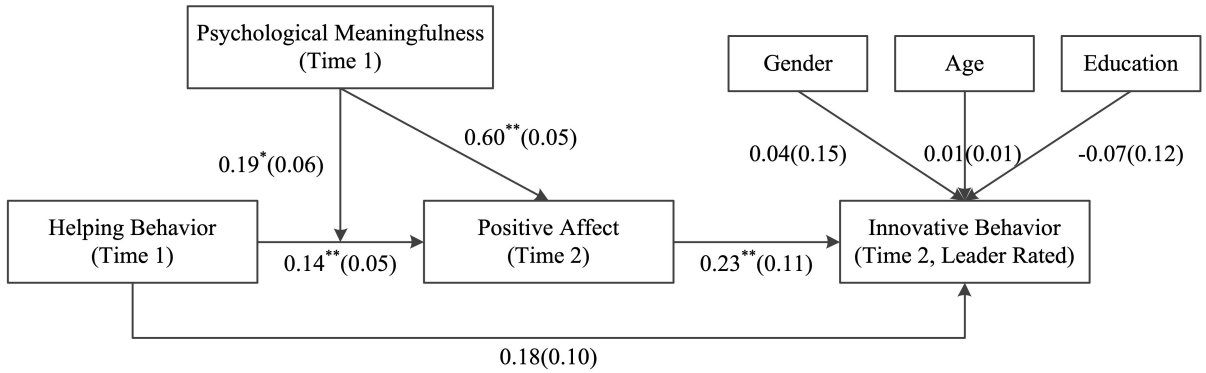


FIGURE 2
Results of nested-equation path analysis. Parameters are unstandardized; Values in the parentheses are standard errors; $N = 193$; *$p < 0.05$; **$p < 0.01$.

[Effect = 0.32, *SE* = 0.08, 95% CI = (0.17, 0.47)]. When psychological meaningfulness is low (−1 *SD*), the impact of helping behavior on positive affect is not significant [Effect = 0.18, *SE* = 0.10, 95% CI = (−0.01, 0.38)]. The difference in the two slopes is also significant [Effect = 0.36, *SE* = 0.11, 95% CI = (0.14, 0.59)]. The moderating effect of psychological meaningfulness is depicted in **Figure 3**, supporting H3.

Finally, this study tested the moderated mediation model by using a bootstrapping test. In the condition of high psychological meaningfulness (+1 *SD*), the indirect relationship between helping behavior and innovative behavior through positive affect is significant [Effect = 0.07, *SE* = 0.04, 95% CI = (0.01, 0.16)]. In the condition of low psychological meaningfulness (−1 *SD*), the indirect relationship is not significant [Effect = −0.01, *SE* = 0.02, 95% CI = (−0.05, 0.03)]. The difference between these two slopes is significant [Effect = 0.08, *SE* = 0.05, 95% CI = (0.01, 0.19)]. H4 is thus supported.

Discussion

Theoretical implications

The present study found an indirect relationship between helping behavior and innovative behavior through positive affect. This indirect relationship is moderated by psychological meaningfulness, and it is significant only in the condition of high psychological meaningfulness. This research thus

TABLE 4 Results of bootstrapping test.

	Effect	SE	95% CI	
			95% LL	95% UL
Moderating effect of psychological meaningfulness				
Low psychological meaningfulness (M − SD)	−0.04	0.07	−0.19	0.10
High psychological meaningfulness (M + SD)	0.32	0.08	0.17	0.47
Difference	0.36	0.11	0.14	0.59
Mediation effect				
Direct effect	0.18	0.10	−0.01	0.38
Indirect effect	0.03	0.02	0.01	0.07
Moderated multiple mediation effect				
Low psychological meaningfulness (M − SD)	−0.01	0.02	−0.05	0.03
High psychological meaningfulness (M + SD)	0.07	0.04	0.01	0.16
Difference	0.08	0.05	0.01	0.19

Bootstrapping = 20,000; CI, Confidence Interval; LL, Lower Level; UL, Upper Level.

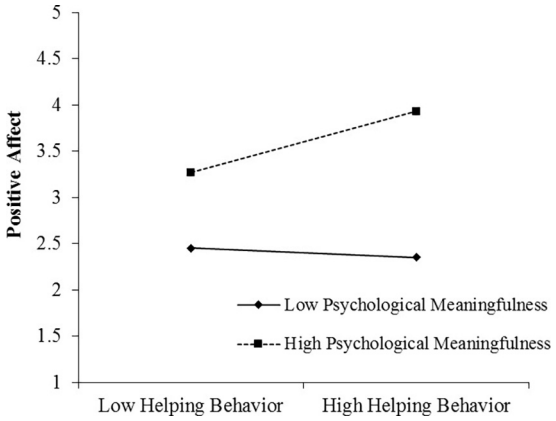


FIGURE 3
Results of moderating role of psychological meaningfulness in the relationship between helping behavior and positive affect.

provides several theoretical implications to the present research concerning helping behavior and COR theory.

First, this study extends our knowledge of the outcomes of helping behavior by exploring the relationship between helping behavior and innovative behavior. Although prior studies have explored both the long- and short-term outcomes of helping behavior (Koopman et al., 2020), less attention has been paid to the impact of helping behavior on the helpers' innovative behavior. The omission of this impact leads to a lack of insights into the positive influence of helping behavior on employees' growth in organizations. Prior studies have linked innovative behavior to employees' career growth at work (Sue-Chan and Hempel, 2016). Helping behavior is a process in which individuals integrate their possessed knowledge and consistently interact with their coworkers (Bolino and Grant, 2016). The present study finds that helpers acquire positive emotional resources in this process, thereby stimulating innovative behavior. Establishing the relationship between helping behavior and innovative behavior improves our understanding of the benefits of helping behavior.

Second, this study uncovers the underlying emotional path through which helping behavior facilitates innovative behavior. Prior studies have demonstrated the positive emotional outcomes of helping behavior at both the within- and between-person levels. For example, Lin et al. (2017) found that daily helping behavior cultivates helpers' positive affect. Prior studies have also found that helping behavior facilitates employees' acquisition of positive emotional resources in the long run (Bolino and Grant, 2016; Duan et al., 2019). Prior studies have found that positive affect enhances individuals' cognitive flexibility and divergent thinking, thereby facilitating innovative behavior (Williamson et al., 2019). From the "doing good, feeling good" perspective, helpers promote their own positive affect by cultivating gratitude and core self-evaluations from the coworkers they have helped to overcome difficulties at work (Lin et al., 2017). These positive affective experiences broaden their behavioral and thinking repertories, which are advantageous for improving their innovative behavior (Fredrickson, 2004). Moreover, this study found that the relationship between helping behavior and innovative behavior is fully mediated by positive affect. Research on links between helping behavior and other forms of behavior has mainly aimed at uncovering the underlying mechanism linking the two. For example, Gabriel et al. (2018) explored the relationship between helping behavior and political acts at the episode level. In their study, they hypothesized that the relationship between helping behavior and political acts is fully mediated by ego depletion. The basic tenet of this line of research is that one kind of behavior leads to changes in psychological states and then results in the other kind of behavior (Loi et al., 2020). This study contributes to this line of research by exploring the indirect relationship between helping behavior and innovative behavior through positive affect.

Third, the present study unveils the boundary condition under which helping behavior impacts innovative behavior through positive affect by exploring the moderating role of psychological meaningfulness. COR theory posits a role for personal possessed resources in shaping individuals' resource conservation and generation process (Halbesleben et al., 2014). Although the majority of research uses the "doing good-feeling good" effect to explain the positive relationship between helping behavior and positive affect, Lin et al. (2020) also found that helping behavior can lead to emotional exhaustion.

Based on COR theory, it is assumed that whether helping behavior acquires or depletes emotional resources depends on helpers' possessed resources. Psychological meaningfulness has been viewed in COR theory as a buffer in the relationship between job demands and emotional reactions (Mostafa and El-Motalib, 2020). Meaningfulness not only enhances helpers' belief in the reciprocity of investing resources to help their coworkers but also gives them resources to cope with the job demands caused by helping behavior to achieve a boost in affect (Tims et al., 2016). Furthermore, previous studies have suggested that psychological meaningfulness are the both outcome and the antecedent of helping behavior (Lin et al., 2020). Extending this line of research, the current study finds that psychological meaningfulness also shapes the emotional outcomes of helping behavior, which ensures the positive mechanism through which helping behavior is transformed into innovative behavior.

Practical implications

This study also provides several practical implications for practitioners. This study finds that helping behavior is an inducement for positive affect and innovative behavior. Therefore, organizations should adopt the necessary strategies to motivate employees' helping behavior. For example, Zhang et al. (2020) suggest that helping behavior can trickle down from leaders to employees. However, it should be noted that helping behavior may interrupt helpers' work progress and increase their workload (Koopman et al., 2016). Thus, organizations should encourage employees to help colleagues strategically to minimize the disadvantages of helping behavior.

Psychological meaningfulness is also regarded as an amplifier in the indirect relationship between helping behavior and innovative behavior through positive affect. The results indicate the indirect emotional path emerges only in the condition of high psychological meaningfulness. Helpers can cultivate higher levels of positive affect through increasing psychological meaningfulness. Therefore, practitioners need to emphasize stimulating helpers' psychological meaningfulness. To achieve this, organizations should redesign jobs to allow for employees' decisions that enhance their impacts on organizations (May et al., 2004). As well, organizations should enable employees to develop deeper social connections with colleagues, allowing employees to understand their impacts on others (Lin et al., 2020).

Limitations and future directions

This research has several limitations that could provide starting points for future research. First, the causal relationship between the focal variables cannot be inferred in this study. Although a two-wave research design was adopted, we did not manipulate the independent variable (i.e., helping behavior), which makes it difficult to infer a causal relationship between helping behavior and innovative behavior. Future research may use an experimental design or a cross-lagged design to make solid conclusions about the relationship between helping behavior and innovative behavior.

Second, CMV cannot be ruled out completely. We collected data at two distinct time points, rated by different subjects (i.e., innovative behavior was rated by supervisors), which can decrease the influence of CMV. However, psychological meaningfulness and helping behavior were measured at time 1 and rated by employees which could raise potential CMV bias. Future research could use coworker-rated or supervisor-rated helping behavior to rule out CMV completely.

Third, an alternative cognitive mechanism linking helping behavior and innovative behavior should be further explored. Bolino and Grant (2016) suggested that helping behavior enhances helpers' personal cognitive information processing capability, which is a critical antecedent to innovative behavior. This study uncovered the emotional path by which helping behavior enhances innovative behavior, by exploring the mediating role of helping behavior. Future research should further investigate cognitive information processing capability and its relationship to the association between helping behavior and innovative behavior.

Finally, this research was conducted in a Chinese context, and this influences the external validity of our findings. Prior studies have found a relationship between collectivist culture and helping behavior (Alkhadher et al., 2020). Due to the prevalence of collectivist culture in Chinese enterprises, the costs and benefits of helping behavior may vary between China and western countries. Future research may conduct a cross-cultural study to compare the differences in the relationship between helping behavior and innovative behavior.

Conclusion

By using a two-wave multi-source research design, this study collected data from 193 leader-supervisor dyads. We adopted nested-equation path analysis to analyze the data and test the conceptual model. The results showed that helping behavior enhances helpers' positive affect, thereby facilitating innovative behavior. Furthermore, this indirect relationship is amplified by psychological meaningfulness, such that this indirect relationship is significant in the condition of high psychological meaningfulness. This research was conducted within the framework of COR theory. This study extended our understanding of the outcomes of helping behavior, and unveiled the emotional mechanism through which helping behavior can be transformed into innovative behavior. Moreover, this study contributes to COR theory by

exploring the moderating role of psychological meaningfulness, which provides new insight into the costs and benefits of helping behavior.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Funding

This research was supported by the Fundamental Research Funds for the Central Universities (DUT21RC[3]089), the National Natural Science Foundation of China (72104256 and 71701083), and the Guangdong Planning Office of Philosophy and Social Science (GD21YTS02).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aguinis, H., and Glavas, A. (2019). On corporate social responsibility, sensemaking, and the search for meaningfulness through work. *J. Manag.* 45, 1057–1086. doi: 10.1177/0149206317691575

Alkhadher, O., Beehr, T., and Meng, L. (2020). Individualism-collectivism and nation as moderators of the job satisfaction-organisational citizenship behaviour relationship in the United States, China, and Kuwait. *Asian J. Soc. Psychol.* 23, 469–482. doi: 10.1111/ajsp.12414

Bolino, M. C., and Grant, A. M. (2016). The bright side of being prosocial at work, and the dark side, too: A review and agenda for research on other-oriented motives, behavior, and impact in organizations. *Acad. Manag. Ann.* 10, 599–670. doi: 10.5465/19416520.2016.1153260

Brislin, R. W. (1980). "Cross-cultural research methods," in *Environment and culture*, eds I. Altman, A. Rapoport, and J. F. Wohlwill (Boston, MA: Springer), 47–82. doi: 10.1007/978-1-4899-0451-5_3

Chaudhary, R. (2022). Deconstructing work meaningfulness: Sources and mechanisms. *Curr. Psychol.* 41, 6093–6106. doi: 10.1007/s12144-020-01103-6

de Buisonjé, D. R., Ritter, S. M., de Bruin, S., ter Horst, J. M.-L., and Meeldijk, A. (2017). Facilitating creative idea selection: The combined effects of self-affirmation, promotion focus and positive affect. *Creat. Res. J.* 29, 174–181. doi: 10.1080/10400419.2017.1303308

De Clercq, D., Ul Haq, I., and Azeem, M. U. (2019). Why happy employees help: How meaningfulness, collectivism, and support transform job satisfaction into helping behaviours. *Pers. Rev.* 48, 1001–1021. doi: 10.1108/PR-02-2018-0052

De Rooij, A., and Vromans, R. D. (2020). The (dis)pleasures of creativity: Spontaneous eye blink rate during divergent and convergent thinking depends on individual differences in positive and negative affect. *J. Creat. Behav.* 54, 436–452. doi: 10.1002/jocb.379

Duan, J., Wong, M., and Yue, Y. (2019). Organizational helping behavior and its relationship with employee workplace well-being. *Career Dev. Int.* 24, 18–36. doi: 10.1108/CDI-01-2018-0014

Ehrhart, M., Bliese, P., and Thomas, J. (2006). Unit-level OCB and unit effectiveness: Examining the incremental effect of helping behavior. *Hum. Perform.* 19, 159–173. doi: 10.1207/s15327043hup1902_4

Feldman, J. M., and Lynch, J. G. (1988). Self-generated validity and other effects of measurement on belief, attitude, intention, and behavior. *J. Appl. Psychol.* 73, 421–435. doi: 10.1037/0021-9010.73.3.421

Fredrickson, B. L. (2004). The broaden–and–build theory of positive emotions. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359, 1367–1377. doi: 10.1098/rstb.2004.1512

Fredrickson, B. L., and Joiner, T. (2018). Reflections on positive emotions and upward spirals. *Perspect. Psychol. Sci.* 13, 194–199. doi: 10.1177/1745691617692106

Gabriel, A. S., Koopman, J., Rosen, C. C., and Johnson, R. E. (2018). "Helping others or helping oneself? An episodic examination of the behavioral consequences of helping at work. *Pers. Psychol.* 71, 85–107. doi: 10.1111/peps.12229

Gillet, N., Fouquereau, E., Coillot, H., Cougot, B., Moret, L., Dupont, S., et al. (2018). The effects of work factors on nurses' job satisfaction, quality of care and turnover intentions in oncology. *J. Adv. Nurs.* 74, 1208–1219. doi: 10.1111/jan.13524

Halbesleben, J. R. B., Neveu, J.-P., Paustian-Underdahl, S. C., and Westman, M. (2014). Getting to the 'COR': Understanding the role of resources in conservation of resources theory. *J. Manag.* 40, 1334–1364. doi: 10.1177/0149206314527130

Kahn, W. (1990). Psychological conditions of personal engagement and disengagement at work. *Acad. Manag. J.* 33, 692–724. doi: 10.2307/256287

Kahn, W. A., and Heaphy, E. D. (2013). "Relational contexts of personal engagement at work," in *Employee engagement in theory and practice*, eds C. Truss, K. Alfes, R. Delbridge, A. Shantz, and E. Soane (London: Routledge), 82–96.

Kenny, D. A. (2008). Reflections on mediation. *Organ. Res. Methods* 11, 353–358. doi: 10.1177/1094428107308978

Koopman, J., Lanaj, K., and Scott, B. A. (2016). Integrating the bright and dark sides of OCB: A daily investigation of the benefits and costs of helping others. *Acad. Manag. J.* 59, 414–435. doi: 10.5465/amj.2014.0262

Koopman, J., Rosen, C. C., Gabriel, A. S., Puranik, H., Johnson, R. E., and Ferris, D. L. (2020). "Why and for whom does the pressure to help hurt others? Affective and cognitive mechanisms linking helping pressure to workplace deviance. *Pers. Psychol.* 73, 333–362. doi: 10.1111/peps.12354

Kwon, K., and Kim, T. (2020). An integrative literature review of employee engagement and innovative behavior: Revisiting the JD-R model. *Hum. Resour. Manag. Rev.* 30:100704. doi: 10.1016/j.hrmr.2019.100704

Lapointe, E., Vandenberghe, C., and Panaccio, A. (2011). Organizational commitment, organization-based self-esteem, emotional exhaustion and turnover:

A conservation of resources perspective. *Hum. Relat.* 64, 1609–1631. doi: 10.1177/0018726711424229

Laulié, L., Tekleab, A. G., and Lee, J. J. (2021). Why grant I-deals? supervisors' prior i-deals, exchange ideology, and justice sensitivity. *J. Bus. Psychol.* 36, 17–31. doi: 10.1007/s10869-019-09670-7

Lee, H. W., Bradburn, J., Johnson, R. E., Lin, S. J., and Chang, C. D. (2019). The benefits of receiving gratitude for helpers: A daily investigation of proactive and reactive helping at work. *J. Appl. Psychol.* 104, 197–213. doi: 10.1037/apl0000346

Leung, K., Huang, K.-L., Su, C.-H., and Lu, L. (2011). Curvilinear relationships between role stress and innovative performance: Moderating effects of perceived support for innovation: Role stress and innovative performance. *J. Occup. Organ. Psychol.* 84, 741–758. doi: 10.1348/096317910X520421

Li, S., and Liao, S. (2017). Help others and yourself eventually: Exploring the relationship between help-giving and employee creativity under the model of perspective taking. *Front. Psychol.* 8:1030. doi: 10.3389/fpsyg.2017.01030

Lin, K. J., Ilies, R., Pluut, H., and Pan, S.-Y. (2017). "You are a helpful co-worker, but do you support your spouse? A resource-based work-family model of helping and support provision. *Organ. Behav. Hum. Decis. Process.* 138, 45–58. doi: 10.1016/j.obhdp.2016.12.004

Lin, W., Koopmann, J., and Wang, M. (2020). How does workplace helping behavior step up or slack off? Integrating enrichment-based and depletion-based perspectives. *J. Manag.* 46, 385–413. doi: 10.1177/0149206318795275

Loi, T. I., Kuhn, K. M., Sahaym, A., Butterfield, K. D., and Tripp, T. M. (2020). From helping hands to harmful acts: When and how employee volunteering promotes workplace deviance. *J. Appl. Psychol.* 105, 944–958. doi: 10.1037/apl0000477

Luu, T. T. (2019). Can diversity climate shape service innovative behavior in Vietnamese and Brazilian tour companies? The role of work passion. *Tour. Manag.*72, 326–339. doi: 10.1016/j.tourman.2018.12.011

May, D., Gilson, R., and Harter, L. (2004). The psychological conditions of meaningfulness, safety and availability and the engagement of the human spirit at work. *J. Occup. Organ. Psychol. Acad. Manag.* 77, 11–37. doi: 10.1348/096317904322915892

Mossholder, K. W., Richardson, H. A., and Settoon, R. P. (2011). Human resource systems and helping in organizations: A relational perspective. *Acad. Manag. Rev.* 36, 33–52. doi: 10.5465/amr.2009.0402

Mostafa, A. M. S., and El-Motalib, E. A. A. (2020). Ethical leadership, work meaningfulness, and work engagement in the public sector. *Rev. Public Pers. Adm.* 40, 112–131. doi: 10.1177/0734371X18790628

Mueller, J. S., and Kamdar, D. (2011). Why seeking help from teammates is a blessing and a curse: A theory of help seeking and individual creativity in team contexts. *J. Appl. Psychol.* 96, 263–276. doi: 10.1037/a0021574

Newman, A., Tse, H. H. M., Schwarz, G., and Nielsen, I. (2018). The effects of employees' creative self-efficacy on innovative behavior: The role of entrepreneurial leadership. *J. Bus. Res.* 89, 1–9. doi: 10.1016/j.jbusres.2018.04.001

Peng, Y., Zhang, W., Xu, X., Matthews, R., and Jex, S. (2019). When do work stressors lead to innovative performance? An examination of the moderating effects of learning goal orientation and job autonomy. *Int. J. Stress Manag.* 26, 250–260. doi: 10.1037/str0000109

Perlow, L., and Weeks, J. (2002). Who's helping whom? Layers of culture and workplace behavior. *J. Organ. Behav.* 23, 345–361. doi: 10.1002/job.150

Pillay, N., Park, G., Kim, Y. K., and Lee, S. (2020). Thanks for your ideas: Gratitude and team creativity. *Organ. Behav. Hum. Decis. Process.* 156, 69–81. doi: 10.1016/j.obhdp.2019.11.005

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., and Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *J. Appl. Psychol.* 88, 879–903. doi: 10.1037/0021-9010.88.5.879

Scott, S. G., and Bruce, R. A. (1994). Determinants of innovative behavior: A path model of individual innovation in the workplace. *Acad. Manag. J.* 37, 580–607. doi: 10.2307/256701

Shah, N. P., Cross, R., and Levin, D. Z. (2018). Performance benefits from providing assistance in networks: Relationships that generate learning. *J. Manag.* 44, 412–444. doi: 10.1177/0149206315584822

Sue-Chan, C., and Hempel, P. S. (2016). The creativity-performance relationship: How rewarding creativity moderates the expression of creativity. *Hum. Res. Manag.* 55, 637–653. doi: 10.1002/hrm.21682

Thompson, E. R. (2007). Development and validation of an internationally reliable short-form of the positive and negative affect schedule (PANA S). *J. Cross Cult. Psychol.* 38, 227–242. doi: 10.1177/0022022106297301

Tims, M., Derks, D., and Bakker, A. B. (2016). Job crafting and its relationships with person-job fit and meaningfulness: A three-wave study. *J. Vocat. Behav.* 92, 44–53. doi: 10.1016/j.jvb.2015.11.007

Ugwu, F. O., and Onyishi, I. E. (2018). Linking perceived organizational frustration to work engagement: The moderating roles of sense of calling and psychological meaningfulness. *J. Career Assess.* 26, 220–239. doi: 10.1177/1069072717692735

Watson, D., Clark, L., and Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect – The PANAS scales. *J. Pers. Soc. Psychol.* 54, 1063–1070. doi: 10.1037/0022-3514.54.6.1063

Williamson, A. J., Battisti, M., Leatherbee, M., and Gish, J. J. (2019). Rest, zest, and my innovative best: Sleep and mood as drivers of entrepreneurs' innovative behavior. *Entrep. Theory Pract.* 43, 582–610. doi: 10.1177/1042258718798630

Wu, C.-H., Liu, J., Kwan, H. K., and Lee, C. (2016). Why and when workplace ostracism inhibits organizational citizenship behaviors: An organizational identification perspective. *J. Appl. Psychol.* 101, 362–378. doi: 10.1037/apl0000063

Yam, K. C., Klotz, A. C., He, W., and Reynolds, S. J. (2017). From good soldiers to psychologically entitled: Examining when and why citizenship behavior leads to deviance. *Acad. Manag. J.* 60, 373–396. doi: 10.5465/amj.2014.0234

Yánez Morales, V. P., Pan, A., and Ali, U. (2020). How helping behaviours at work stimulate innovation in the organization: Evidence from a moderated-mediation model. *Innovation* 22, 71–90. doi: 10.1080/14479338.2019.1632712

Yinon, Y., and Landau, M. (1987). On the reinforcing value of helping-behavior in a positive mood. *Motiv. Emot.*11, 83–93. doi: 10.1007/BF00992215

Yuan, H., Lu, K., and Hao, N. (2018). Interactive effect of motivational motor action and emotion on divergent thinking. *Pers. Individ. Differ.* 131, 93–98. doi: 10.1016/j.paid.2018.04.027

Yue, Y., Wang, K. L., and Groth, M. (2017). Feeling bad and doing good: The effect of customer mistreatment on service employee's daily display of helping behaviors. *Pers. Psychol.* 70, 769–808. doi: 10.1111/peps.12208

Zhang, Z., Li, P., Zhang, L., Zheng, J., and Xue, Z. (2022). Helping neighbors and enhancing yourself: A spillover effect of helping neighbors on work-family conflict and thriving at work. *Curr. Psychol.* 41, 3539–3550. doi: 10.1007/s12144-020-00864-4

Zhang, Z., Zhang, L., Xiu, J., and Zheng, J. (2020). Learning from your leaders and helping your coworkers: The trickle-down effect of leader helping behavior. *Leadersh. Organ. Dev. J.* 41, 883–894. doi: 10.1108/LODJ-07-2019-0317

Zheng, Y., Graham, L., Farh, J.-L., and Huang, X. (2021). The impact of authoritarian leadership on ethical voice: A moderated mediation model of felt uncertainty and leader benevolence. *J. Bus. Ethics* 170, 133–146. doi: 10.1007/s10551-019-04261-1

Appendix 1

Measurement in the study

1. Helping Behavior (Time 1, Yue et al., 2017)
HB1. I help other employees when it is clear their workload is too high.
HB2. I lend a helping hand to coworkers when needed.
HB3. I willingly assist other employees in meeting their job requirements.
2. Psychological Meaningfulness (Time 1, May et al., 2004)
PM1. The work I do on this job is very important to me.
PM2. My job activities are personally meaningful to me.
PM3. The work I do on this job is worthwhile.
PM4. My job activities are significant to me.
PM5. The work I do on this job is meaningful to me.
PM6. I feel that the work I do on my job is valuable.
3. Positive Affect (Time 2, Thompson, 2007)
PA1. I felt determined in the past month.
PA2. I felt attentive in the past month.
PA3. I felt inspired in the past month.
PA4. I felt alert in the past month.
PA5. I felt active in the past month.
4. Innovative Behavior (Time 2, Scott and Bruce, 1994)
IB1. The employee searches out new technologies, processes, techniques, and/or product ideas.
IB2. The employee generates creative ideas.
IB3. The employee promotes and champions ideas to others.
IB4. The employee investigates and secures funds needed to implement new ideas.
IB5. The employee develops adequate plans and schedules for the implementation of new ideas.
IB6. The employee is innovative.

frontiers | Frontiers in Psychology

TYPE Systematic Review
PUBLISHED 17 November 2022
DOI 10.3389/fpsyg.2022.1064256

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University, China

REVIEWED BY
Dejian Yu,
Nanjing Audit University, China
Shouwei Li,
Southeast University, China
Weike Zhang,
Sichuan University, China

*CORRESPONDENCE
Danxue Luo
15123668128@163.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 08 October 2022
ACCEPTED 31 October 2022
PUBLISHED 17 November 2022

CITATION
Meng S, Fu X and Luo D (2022) Knowledge development visualization and mapping path of the psychological capital research. *Front. Psychol.* 13:1064256. doi: 10.3389/fpsyg.2022.1064256

Knowledge development visualization and mapping path of the psychological capital research

Sun Meng, Xinwei Fu and Danxue Luo*

School of Finance, Yunnan University of Finance and Economics, Kunming, China

With the respect to the key factors, namely the psychological state of individuals and organizations, psychological capital (PsyCap) is widely used in various fields, such as management decisions and organizational behavior. To fully show the related studies and their knowledge development and mapping path, in this paper, we examine 2,786 papers about the PsyCap related research from 1970 to 2021. Based on the bibliometric analysis and main path demonstration (the tools are Cite-Space and Pajke, respectively), we derive some conclusions as follows: (1) the publication number about the PsyCap study is growing rapidly and it is a highly cross-cutting research topic. (2) The main authors come from Australia, the United States, and China, and also are the core researchers. (3) Refinement and measurement in the PsyCap study are constant and hot topics. (4) Stress, performance and well-being issues among students, health care workers and corporate employees are core research themes, and team organization, creativity, innovation, and COVID-19 are hot topics in this field. The bibliometric analysis are quantitatively analyzed to provide scholars with a more comprehensive insight into PsyCap research. The main path demonstration helps scholars to understand the main lines and key nodes of development in the field of psychological capital.

KEYWORDS

psychological capital, bibliometric visualization, burst detection, knowledge development, main path analysis

Introduction

The core of Psychological Capital (PsyCap) is an individual's integrated state of development in four psychological resources: Self-efficacy, hope, optimism, and resilience (Luthans et al., 2007; Luthans and Youssef-Morgan, 2017). Hope is defined as "a positive motivational state based on an interactively derived sense of successful,

which includes agency and pathways" (Snyder et al., 1991). Efficacy is defined as "the individual's conviction or confidence about his or her abilities to mobilize the motivation, cognitive resources or courses of action needed to successfully execute a specific task within a given context" (Stajkovic and Luthans, 1998; Luthans and Youssef-Morgan, 2017). Resilience is defined as "the capacity to rebound or bounce back from adversity, conflict, failure or even positive events, progress and increased responsibility" (Luthans, 2002; Luthans and Youssef-Morgan, 2017). optimism can be viewed as "an attributional style that explains positive events through personal, permanent, and pervasive causes and negative events through external, temporary, and situation-specific ones" (Peterson and Steen, 2002; Luthans and Youssef-Morgan, 2017). The growth in the number of PsyCap studies and the expansion of application scenarios has drawn the attention of scholars in other fields to PsyCap, especially in management and organizational behavior.

To promote and lead the healthy development of the field, many classic review articles have been developed, such as Dawkins et al. (2013), Anderson et al. (2014), Newman et al. (2014), Luthans and Youssef-Morgan (2017), and Nolzen (2018). They reviewed PsyCap in terms of background, concepts, theoretical mechanisms, measurement methods, and the current status of research, results, and applications. Also, they pointed out future research directions or gaps in existing research. But these articles tend to focus on a subfield to sort out, for example, Dawkins et al. (2013) concentrated on studies related to the concept and measurement of PsyCap. These researches hardly help beginners quickly understand the full picture of the development of the field (Zhou et al., 2022). Therefore, we employ bibliometric methods and main path analysis to systematically analyze the development trends of PsyCap research. The bibliometric approach provides a relatively complete network diagram of relationships (Li et al., 2020; Wang et al., 2020; Li and Xu, 2021), and measures the influence of authors, journals, institutions, and regions (Baumgartner and Pieters, 2003; Willett, 2007; Zhou et al., 2018), and detects classic literature and research hotspots (Su et al., 2021). For example, to show the knowledge mapping of Mobile learning and humanistic education research (Koon, 2022), present a visual analysis of research on digital transformation (Shi et al., 2022), display the research progress on innovation in the field of social capital (Gu et al., 2022), explore the development trend and frontier of sustainable logistics and supply chain (Wang et al., 2022), excavate the past, present, and future of the mindfulness field (Bunjak et al., 2022). It is also used to analyze the distribution and development of all literature within a given journal: To show the research progress of Mechanism and Machine Theory Journal from 1990–2020 (Flores, 2022), to summarize the research in the Journal of Fashion Marketing and Management (Kumar P. et al., 2022), to explore the emerging topic of European Management Journal (Bhukya et al., 2022).

There are many kinds of software for bibliometric analysis, such as SciMat (Cobo et al., 2012), VOSviewer (Van Eck and Waltman, 2010), CiteSpace (Chen, 2006), and so on. Each tool has its unique advantages. CiteSpace can perform citation bursts, which makes it more consistent with the research in this article. Therefore, this article mainly uses the tool CiteSpace. In addition, we further performed a master path analysis with the help the of Pajek tool, which helped to understand the main lines and important nodes of the development. For example, Yu and Pan (2021) used several different major paths to study the knowledge structure of TOPSIS and described its trends; Yu D. et al. (2022) explored the evolution of intuitionistic fuzzy set theory research themes using a master path analysis approach. Therefore, the results of both methods can be presented graphically, which can help the reader intuitively understand the salient features and changing trends in the PsyCap field. The contributions that this paper made are: (1) the *status quo*, the co-citation analysis, and the burst detection are quantitatively analyzed to provide scholars with a more comprehensive insight into PsyCap research; and (2) The inscription of the global standard main path, local forward main path, and local backward main path helps scholars to understand the main lines and key nodes of development in the field of psychological capital.

The rest of the paper is organized as follows: Section 2 describes the data sources and the specific bibliometric methods. Section 3 gives the results of four analysis types: basic statistical characteristics, collaborative network analysis, classical literature combing, and keyword analysis. Section 4 conducts the main path analysis. In Section 5, the conclusions are organized and research hotspots are discussed.

Data sources and bibliometric methods

Data source

We use the Web of Science (WOS), which is the most widely used tool by researchers (Falagas et al., 2008), to extract and gather reliable documents. To further ensure the quality of the documents, we select only two sub-databases in WOS, which are the Sciences Citation Index Expanded (SCI-Expanded) and Social Sciences Citation Index (SSCI). Then, we enter the search formula "TS = Psychological Capital" for the period 1900–2022 in the advanced search window. 2,786 documents were retrieved, corresponding to the time range 1970–2022.9.6. Finally, we export all the relevant information of the document from WoS in plain text format, including title, author, abstract, keywords, publications, and references.

Analytical tool

We chose Cite Space (Chen, 2006), version 5.1.R8, the more commonly used software, to do the bibliometric analysis of PsyCap. Cite Space is simple to use and suitable for researchers to perform literature analysis quickly. It can precisely capture research hotspots, core authors, important institutions, and classic literature, as well as form clusters and detect bursts (Kleinberg, 2003), which helps scholars quickly grasp the development history and research hotspots in the field. The use of CiteSpace tools can be found in the classic literature, such as Fang et al. (2018), Pan et al. (2018), and Jiang et al. (2019).

In addition, we also apply Pajek to do the main path analysis about PsyCap, which was developed by Vladamir Batagelj from the University of Ljubljana. It is a complex network analysis tool (Batagelj and Mrvar, 1998) that helps to form the main path and sort out the most relevant literature (Olczyk, 2016). The specific information on the key nodes in the main path diagram can be obtained by HistCite Pro (Dan et al., 2021). For the use of Pajek in main path analysis, further references can be made to literature by Liu and Oakland (2016), Yu and Sheng (2020), Dong et al. (2022), and Yu Q. Y. et al. (2022).

Data and methods

Based on the data and bibliometric methods described in the previous section, we further conduct an in-depth and comprehensive analysis of obtained document inWOS. The study was conducted in three dimensions: basic statistical characteristics, cooperation networks, and detection breakout points which focus on authors, institutions, countries or regions, cited literature, and keywords.

Basic statistical characteristics related to psychological capital

Annual indicators of documents

The number of publications per year broadly presents the research process in PsyCap. Therefore, we divide the research into three phases on its growth trend: Steady growth (1970–2007), rapid growth (2008–2017), and high-rapid growth (2018–2022.9), as shown in **Figure 1**.

In the first stage: Steady growth (1970–2007), there are a total of 268 documents. The first article was published in 1970, written by Glodber (1970), which focused on law psychology. In this stage, research is dedicated to the construction of PsyCap theory, and the theme gradually moved from macro-social issues to micro-intervention issues (Luthans et al., 2006). It is worth mentioning that the introduction of positive PsyCap measure methods (Luthans and Youssef, 2007) has contributed to the development of empirical studies.

In the second stage: Rapid growth (2008–2017), a total of 989 papers were published. During the decade, the introduction of core elements such as positive psychology (Avey et al., 2008), politics (Abbas et al., 2014), information technology (Burns et al., 2017), and measurement methods (Wernsing, 2014). Among the important research, objects are happiness, performance, satisfaction, education, and health.

The third stage: High-rapid growth (2018–2022.9). During this period, 1,565 papers were published. Team PsyCap (Tho and Duc, 2021), the mediating role of PsyCap (Kumar D. et al., 2022), and COVID-19 (Brunetto et al., 2022) have become important research themes, further contributing to the development of the field. The relatively small amount of literature for 2022 is caused by the fact that the specific date of the search data is September 9, 2022.

The most productive publications, categories, authors, affiliations, and countries/regions

We obtain the main ten categories and publications from the WOS database, presented in **Table 1** and **Figure 2**, respectively. And the literature covers 155 categories of research. From **Table 1**, we can get the top-10 research categories about PsyCap, which are "Psychology Multidisciplinary," "Management," "Public Environmental Occupational Health," "Psychology Applied," "Business," "Environmental Sciences," "Psychiatry," "Sociology," "Economics," "Environmental Studies." The total number and proportion of the literature in the top ten research categories were 2,318, and 83.23%, respectively, indicating that the research on PsyCap was relatively concentrated.

The top 25 publications shown in **Figure 2**, "Frontiers in Psychology," "International Journal of Environmental Research and Public Health," and "Sustainability" are the main publishers, with the number and percentage of publications (% of 2,786) being 146 (5.24%), 79 (2.84%), and 61 (2.19%). The journals ranked 4th to 10th are "Social Science Medicine," "Plos One," "International Journal of Psychology," "Current Psychology," "BMC Public Health," "Social Behavior and Personality," and "Personnel Review." These journals aggregate a relatively large amount of research in the field of psychological capital.

According to the analysis of the productivity index, this paper further explores the concentration degree of PsyCap research at the author, institution, and country or region. Therefore, we present the top ten productive objects in **Tables 1**, **2**.

In **Table 1**, we can see that the top three authors are Luthans F (42), Wang L (25), Avey JB (20), Kawachi I (20), and Lindstrom M (20). Among them, Luthans F and Avey JB have more cooperation, and the research direction is the same,

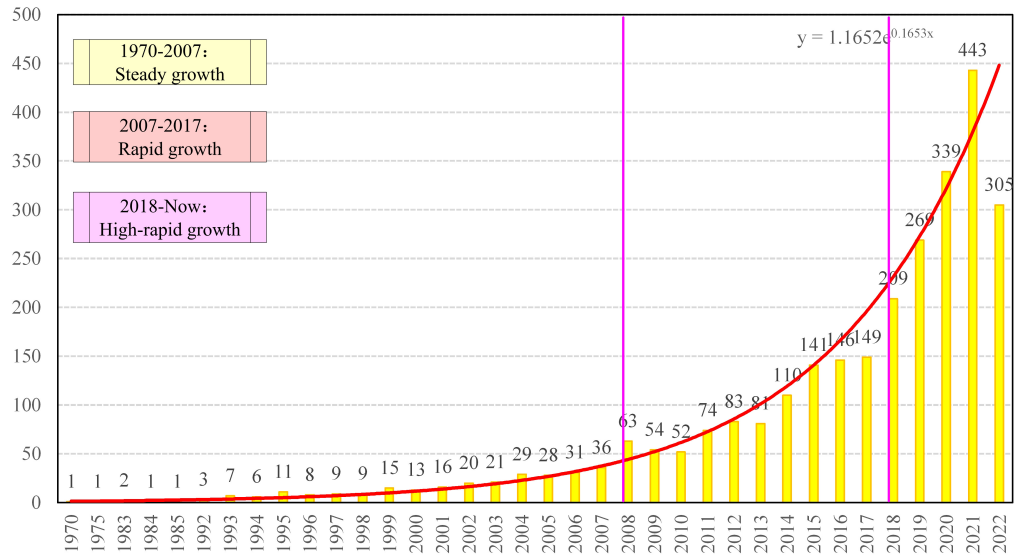


FIGURE 1
Growth of literature related to PsyCap, 1970–2022.

TABLE 1 The top 10 most-productive publications and authors.

Rank	Categories	Count	% of 2,786	Authors	Count	% of 2,786
1	Psychology multidisciplinary	434	15.58%	Luthans F	42	1.51%
2	Management	427	15.33%	Wang L	25	0.90%
3	Public environmental occupational health	383	13.75%	Avey JB	20	0.72%
4	Psychology applied	220	7.90%	Kawachi I	20	0.72%
5	Business	192	6.89%	Lindstrom M	20	0.72%
6	Environmental sciences	179	6.43%	Wang Y	15	0.54%
7	Psychiatry	155	5.57%	Li Y	14	0.50%
8	Sociology	113	4.06%	Liu L	13	0.47%
9	Economics	109	3.91%	Brunetto Y	11	0.40%
10	Environmental studies	106	3.81%	Kim M	11	0.40%

that is, positive PsyCap. Kawachi I focused on the relationship between social capital and mental health. Wang Y, Li Y, and Liu L are concerned with the moderating or mediating effects of PsyCap. Lindstrom M analyzes the role of PsyCap on the population-based. Brunetto Y is more interested in COVID-19 and innovation. Kim M introduces the element of PsyCap into the sports field.

Table 2 shows the top 10 most productive affiliations. They are the University of London, University of Nebraska System, Harvard University, University of Nebraska Lincoln, University of California System, University of North Carolina, University of Texas System, Monash University, China Medical University, and Australian National University. Among them, one is from England, six come from the USA, two are from Australia, and one is from China. We can be seen that the USA, China, England, and Australia are the most productive countries or regions.

Cooperation networks among countries/regions, institutions, and authors

Collaborative network analysis can help to understand the internal relationships of research in the PsyCap. Figure 3 shows the collaboration networks of authors and institutions. The size of the circle responds to the intensity of cooperation, and the larger circle indicates a higher frequency of cooperation and a stronger willingness to cooperate (Chen, 2006; Zhou et al., 2020). Table 3 shows the top 10 cooperative authors and institutions, authors are Luthans F, Wang L, Avey JB, Kawachi I, Li Y, Lindstrom M, Liu L, Wang Y, Brunetto Y, Li J. Among the top 10 most collaborative institutions, China Medical University, Chinese University Hong Kong, and University Hong Kong are from China; Monash University,

FIGURE 2
Visualization tree map of top-25 publications.

TABLE 2 The top 10 most-productive affiliations and countries/regions.

Rank	Affiliations	Count	% of 2,786	Regions	Count	% of 2,786
1	University of London (England)	66	2.37%	United States	737	26.46%
2	University of Nebraska System (United States)	49	1.76%	China	594	21.33%
3	Harvard University (United States)	46	1.65%	Australia	261	9.37%
4	University of Nebraska Lincoln (United States)	44	1.58%	England	222	7.97%
5	University of California System (United States)	42	1.51%	Canada	124	4.45%
6	University of North Carolina (United States)	38	1.36%	South Korea	113	4.06%
7	University of Texas System (United States)	38	1.36%	Spain	99	3.56%
8	Monash University (Australia)	33	1.19%	Germany	94	3.38%
9	China Medical University (China)	32	1.15%	China-Taiwan	87	3.12%
10	Australian National University (China)	29	1.04%	Netherlands	75	2.69%

Australian National University, and Griffith University are from Australia; University Nebraska and Central Washington University are from the United States; University Copenhagen is from Denmark, and Lund University is from Sweden. Analysis Tables 1, 3, we can find that more productive authors had more cooperative experiences.

Further, Table 3 also lists the top 10 most cooperative countries/regions, and summarizes the cooperate count and the centrality. Centrality is an indicator to measure the importance of nodes in the network. CiteSpace uses this indicator to find and measure the importance of a document (Freeman, 1979). Not surprisingly, the top three countries with the highest number of collaborations are the United States (710), China (589), and Australia (252), followed by England (218), Canada (118), South Korea (109), Spain (92), Germany (88), China-Taiwan (82) and Japan (68). As can be seen from Table 3, more than half of the countries have centrality values greater than 0.1, suggesting that they would be seen as crucial nodes with marked influence (Li C. et al., 2017; Li X. et al., 2017). The country with the highest centrality is the United States (centrality is 0.44), indicating that it has extensive exchanges with other countries or regions in the field of PsyCap. Further analysis reveals that countries or regions with more cooperation have a relatively greater centrality.

Citation networks among authors and journal

According to WoS, a total of 7,693 authors have published literature related to PsyCap. Aiming to discover which scholars have made distinguished contributions in this field, we mapped the citation network of authors using Cite Space, as shown in Figure 6.

Figure 4 contains two main elements: The large figure shows the network linkage graph between all authors; the small

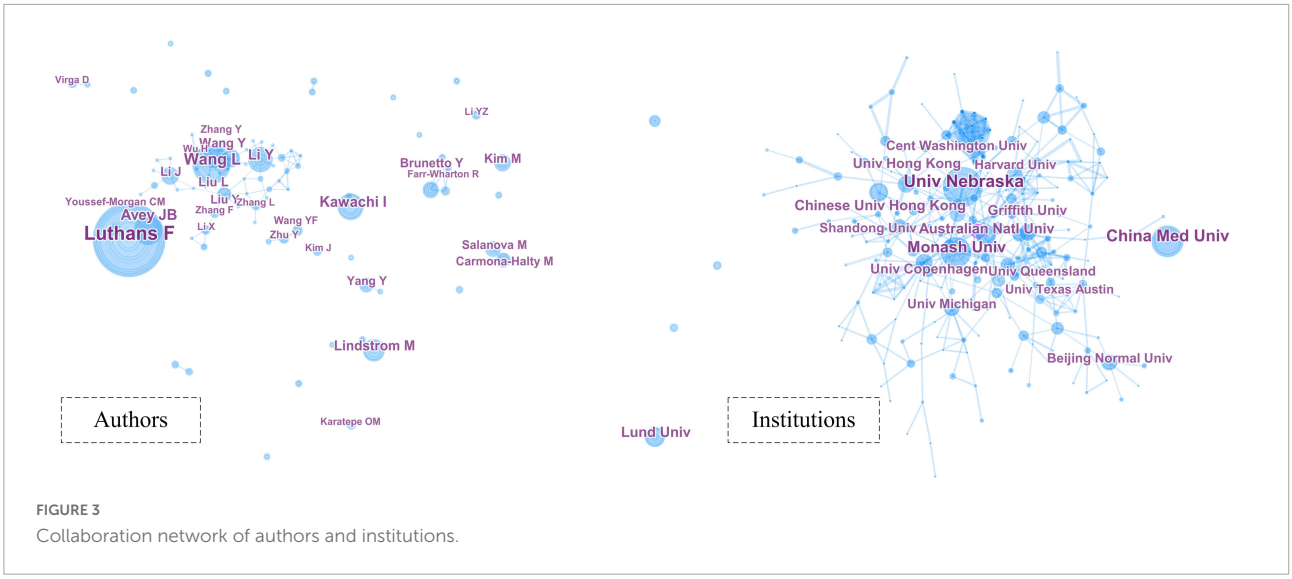


FIGURE 3
Collaboration network of authors and institutions.

TABLE 3 The top-10 most cooperative authors, institutions and regions/countries.

Rank	Authors	Count	Institutions	Count	Regions/Countries (centrality)	Count
1	Luthans F	39	University Nebraska	38	United States (0.44)	710
2	Wang L	20	China Medical University	30	China (0.12)	589
3	Avey JB	15	Monash University	29	Australia (0.15)	252
4	Kawachi I	14	Lund University	19	England (0.29)	218
5	Li Y	13	Australian National University	19	Canada (0.1)	118
6	Lindstrom M	12	Chinese University Hong Kong	18	South Korea (0.01)	109
7	Liu L	10	University Hong Kong	16	Spain (0.12)	92
8	Wang Y	10	University Copenhagen	16	Germany (0.09)	88
9	Brunetto Y	9	Griffith University	16	China-Taiwan (0.01)	82
10	Li J	9	Central Washington University	15	Japan (0.02)	68

Centrality is an indicator to measure the importance of nodes in the network.

figure presents the clustering graph generated based on the authors' citation networks. The twelve largest clusters that can be observed in the small figure are cluster "#0 PsyCap," cluster "#1 efficacy," cluster "#2 supply chain management," cluster "#3 PsyCap," cluster "#4 PsyCap," cluster "#5 PsyCap," "#6 similarity bias," "#9 shared cognitions," "#10 career capital," "#11 social capital," cluster "#12 south Africa" and cluster "#13 national culture." Combined with Table 4, we can see that the top 10 most influential authors are Luthans F, Avey J B, Bandura A, Podsakoff PM, Hobfoll SE, Snyder CR, Coleman JS, Bakker AB, Bourdieu P, and Seligman MEP in the field of PsyCap. Among them, Luthans F, Avey JB, Podsakoff PM, and Bakker AB are the main authors in the cluster of "#3 PsyCap," who are interested in positive PsyCap. Bandura A, Hobfoll S E, Snyder C R, and Seligman M E P worked on the cluster of "#2 supply chain management," Coleman J S and Bourdieu P combined PsyCap with efficiency research. Additionally, Luthans F and Avey J B are also the most published and collaborated authors in this field.

In Table 4, we can also find that the Journal of Applied Psychology is the most influential journal, with 934 citations in the field of PsyCap. From second to fifth places are the Journal of Personality and Social Psychology with 912 citations, the Journal of Organizational Behavior with 907 citations, Personnel Psychology with 812 citations, and the Journal of Management with 809 citations. The core journals that publish research papers on PsyCap are multidisciplinary or interdisciplinary scientific journals in sociology, medicine, management, and organizational behavior.

Reference analysis and keyword analysis

Co-citation analysis of literature

The co-citation network can present the knowledge base of PsyCap research concretely. Therefore, we perform co-citation network analysis and clustering based on the Cite-Space tool for

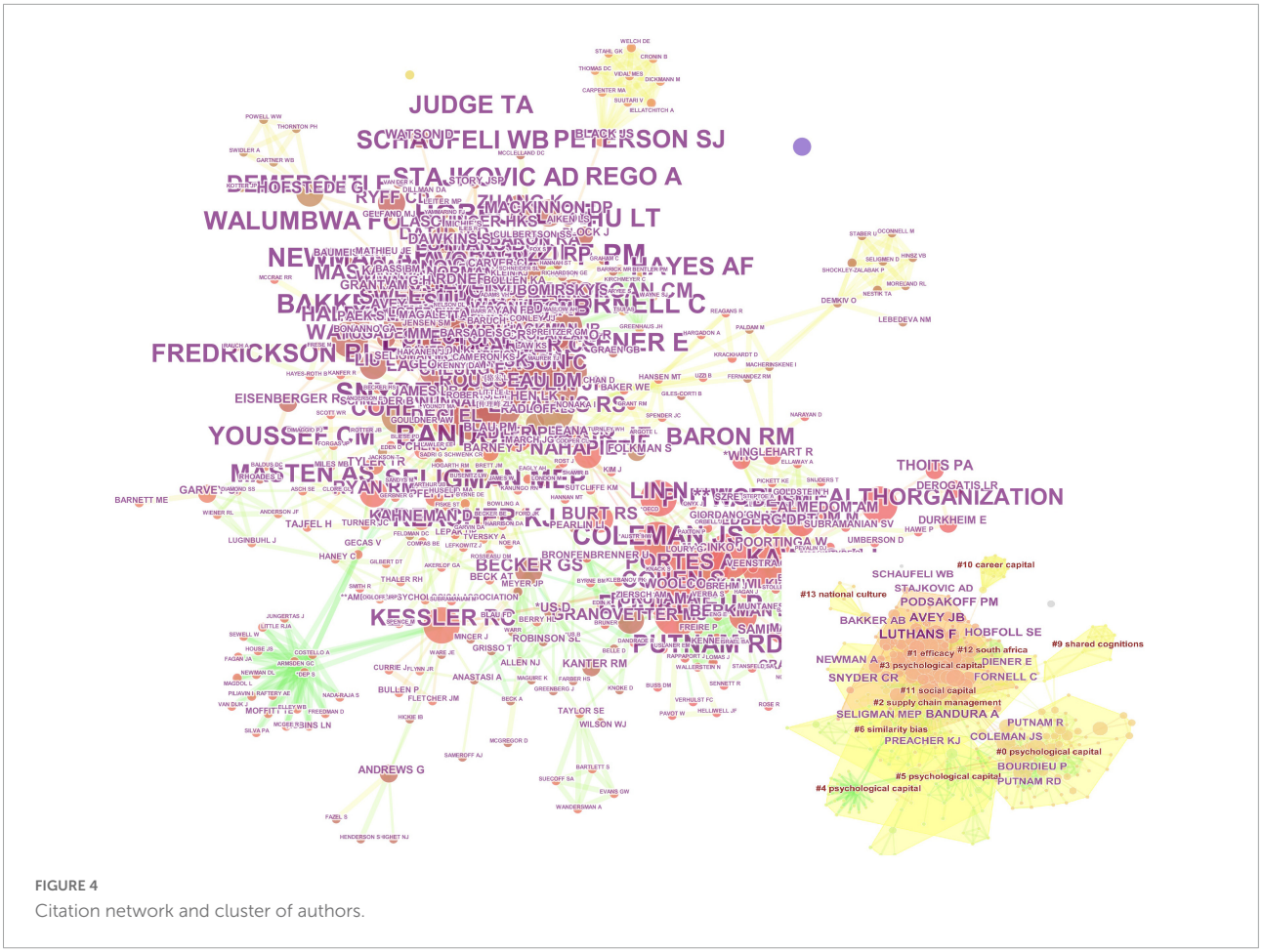


FIGURE 4
Citation network and cluster of authors.

the 118,972 documents involved in this field, and the results are shown in Figure 5. Each node represents literature, and the size of the node corresponds to the number of literature citations. And the larger the node, the more citations the literature has received. The thickness of the connecting lines between nodes reflects the strength of association in the literature.

Table 5 lists the 10 most cited references sorted by the co-citation numbers. Specifically, the classical document that has the most co-citations is "Meta-analysis of the impact of positive PsyCap on employee attitudes, behaviors, and performance" by Avey et al. (2011), published in Human Resource Development Quarterly. This paper has 177 citations, which means that it plays an important role in the research of PsyCap. And this paper quantitatively analyzed the impact of PsyCap on employee attitudes, behaviors, and performance.

Rank at second place in the knowledge bases of PsyCap studies, the paper "PsyCap: A review and synthesis" is a classic literature review, authored by Newman et al. (2014), and published by the Journal of Organizational Behavior. This paper provided a summary of the literature on PsyCap, which provides an important reference for subsequent research. Thus, it has 172 citations.

The third-ranked literature is a literature review that comprehensively reviewed the measurement methods, theoretical mechanism, antecedents and consequences,

TABLE 4 The top 10 most co-cited authors and journals.

Rank	Count	Authors	Count	Journal
1	971	Luthans F	934	Journal of Applied Psychology
2	619	Avey J B	912	Journal of Personality and Social Psychology
3	433	Bandura A	907	Journal of Organizational Behavior
4	400	Podsakoff PM	812	Personnel Psychology
5	347	Hobfoll S E	809	Journal of Management
6	311	Snyder C R	785	American Psychologist
7	240	Coleman J S	695	Psychological Bulletin
8	236	Bakker A B	672	Academy of Management Journal
9	234	Bourdieu P	593	Academy of Management Review
10	227	Seligman M E P	588	Social Science and Medicine

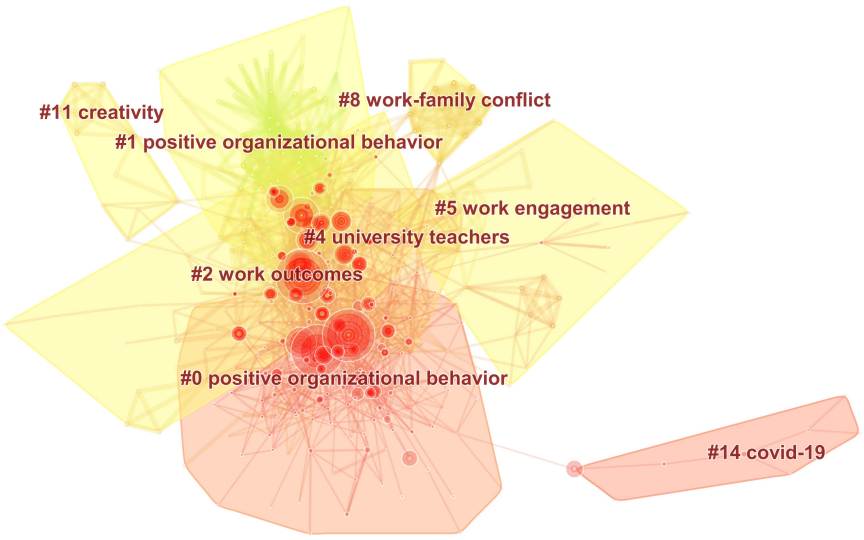


FIGURE 5
Co-citation network and the cluster of references.

TABLE 5 The top-10 most cited references in PsyCap.

Rank	Title	Authors and years	Journal	Citation
1	Meta-analysis of the impact of positive psychological capital on employee attitudes, behaviors, and performance	Avey et al., 2011	Human Resource Development Quarterly	177
2	Psychological capital: A review and synthesis	Newman et al., 2014	Journal of Organizational Behavior	174
3	Psychological capital: An evidence-based positive approach	Luthans and Youssef-Morgan, 2017	Annual Review of Organizational Psychology and Organizational Behavior	170
4	Positive psychological capital: Measurement and relationship with performance and satisfaction	Luthans et al., 2007	Personnel Psychology	126
5	The development and resulting performance impact of positive psychological capital	Luthans et al., 2010	Human Resource Development Quarterly	113
6	Experimental analysis of a web-based training intervention to develop positive psychological capital	Luthans et al., 2008a	Academy Of Management Learning and Education	81
7	The additive value of positive psychological capital in predicting work attitudes and behaviors	Avey et al., 2010a	Journal of Management	79
8	Psychological capital: A positive resource for combating employee stress and turnover	Avey et al., 2009	Human Resource Management	77
9	Impact of positive psychological capital on employee well-being over time	Avey et al., 2010b	Journal of Occupational Health Psychology	76
10	The mediating role of psychological capital in the supportive organizational climate—employee performance relationship	Luthans et al., 2008b	Journal of Organizational Behavior	71

analysis level, and research status of PsyCap. It has 170 citations, authored by Luthans and Youssef-Morgan (2017), and printed by the Annual Review of Organizational Psychology and Organizational Behavior.

The remaining seven articles are devoted to specific studies. Among them, Luthans et al. (2007) used resilience, optimism, effectiveness, and their composite indicators to predict job performance and satisfaction. Luthans et al. (2010) examined the impact of PsyCap interventions on human resource development and performance management. Luthans et al. (2008a) discovered that training interventions can develop positive PsyCap through a randomized trial. Avey et al. (2010a) identified the potential added value of PsyCap in predicting work attitudes and behaviors. Avey et al. (2009) studied the

relationship between PsyCap and occupational stress, and found that PsyCap can counteract the negative effects of job stress. Avey et al. (2010b) examined the dynamic relationship between PsyCap and employee well-being. Luthans et al. (2008b) examined the relationship between PsyCap and employee outcomes. The results of the study showed that PsyCap was positively related to employee performance, satisfaction, and commitment.

Overall, the 10 most cited papers in PsyCap research are concerned about the effects of positive PsyCap on work behavior, work attitudes, and employee performance. Among them, there are four articles with Avey J B as the first author and five articles with Luthans F as the first author. These two authors have co-authored eight articles in the top 10 most cited references.

In addition, we further analyze the clustering information in **Figure 5** can be found: In cluster "#0 positive organizational behavior," Avey (2014), Newman et al. (2014), Youssef-Morgan and Luthans (2015), and Luthans and Youssef-Morgan (2017), are the crucial documents. And these documents are dedicated to sorting out and summarizing the theories, methods, and norms of PsyCap research from different directions. Nevertheless, cluster "#1 positive organizational behavior" is led by Luthans and Youssef (2007), Luthans et al. (2007), Luthans et al. (2008a), and so on, which focus on the impact of positive PsyCap on organizational behavior. In cluster "#2 work outcome," literature such as Avey et al., 2010a,b and Avey et al. (2011), deeply explore the impact of positive PsyCap on performance. The cluster "#4 university teachers," cluster "#5 work engagement," cluster "#8 work-family conflict," cluster "#11creativity," and cluster "#14 COVID-19" are all core themes of PsyCap research, among which "COVID-19" is a new research hotspot.

Detection of burst points in co-cited literature

A systematic review and scrutiny of the relevant literature help to understand the progress of research, thus further complementing and refining the concepts and theories of PsyCap and standardizing research guidelines. These studies promote the healthy development of research in the field. Meanwhile, literature reviews usually analyze and summarize current research hotspots and future research directions, which to a certain extent point the way for research in the field. Therefore, there is no lack of literature review articles in PsyCap.

126 hot-cited references are obtained using burst point detection in the Cite-Space. We select these kinds of literature with the strongest citation burst ending in 2020–2022, displayed in **Table 6**, for a total of 45 articles. Analyzing them can further help us to understand the hot directions within the field of PsyCap in recent years.

Dawkins et al. (2013) provided a comprehensive analysis and review of the theoretical conceptualization and psychometric properties of PsyCap and proposed six indicators to advance PsyCap research. Scholars have expanded the scope of empirical research on PsyCap by recognizing the emotional, cognitive, and motivational psychological states associated with creativity and innovation (Anderson et al., 2014). Thereafter, Newman et al. (2014) sorted out the factors affecting the development of PsyCap from the perspective of empirical analysis and the results of different levels of research. Halbesleben et al. (2014) expanded the theoretical study of PsyCap by combing the literature on resource conservation theory and suggesting the introduction of psychology and management. Underpinning these theoretical and empirical guides, the impact analysis, mediating effects, and practical applications of PsyCap have been further developed, with a comprehensive compendium and elaboration by Luthans and Youssef-Morgan (2017). With the focus on individual characteristics in the field of PsyCap, Nolzen (2018) called for researchers to further investigate the relationship between emotions and PsyCap, and suggests analyzing the effects of PsyCap in the context of strategic human resource management. In addition, Podsakoff et al. (2012) explored studies on the methodological bias, and Hayes and Scharkow (2013) recommend bias-corrected bootstrap confidence intervals as mediated analyses for the most trustworthy tests, which provide technical support for empirical studies of PsyCap.

The above meta-analysis of the literature shows that there has been much research on positive PsyCap and performance, behavior, and attitudes (e.g., satisfaction, commitment, happiness, and willingness to leave). Among them, the research based on individual objects: (1) the influential relationship or mediating role between employees' PsyCap and job demands (Chen and Lim, 2012; Bakker and Demerouti, 2017), job satisfaction (Bergheim et al., 2015; Jung and Yoon, 2015; Karatepe and Karadas, 2015), well-being (Luthans et al., 2013; Youssef-Morgan and Luthans, 2015), performance/innovation performance (Abbas and Raja, 2015; Paek et al., 2015; Mathe et al., 2017; Alessandri et al., 2018), job stress (Laschinger and Fida, 2014; Li et al., 2015), and creativity (Rego et al., 2012; Huang and Luthans, 2015; Hsu and Chen, 2017); (2) the effect or mediating role of students' PsyCap on academic performance (Luthans et al., 2012; Siu et al., 2014; Datu et al., 2018; Carmona et al., 2019), satisfaction (Ortega-Maldonado and Salanova, 2018), and stress (Riolli et al., 2012); (3) the moderating effect of PsyCap on health care workers on family conflict (Wang et al., 2012), performance (Sun et al., 2012), and job burnout (Peng et al., 2013; Ding et al., 2015).

Research based on teams and organizations, for example, Heled et al. (2016) explored the mediating effect of team PsyCap on learning climate, learning outcomes, job satisfaction, and team organizational behavior. Focus on the current special social environment, COVID is a research hotspot in the field of PsyCap. Brooks et al. (2020) found that after the outbreak of coronavirus disease in December 2019, the psychological impact

TABLE 6 45 References with strongest citation bursts (2012–2022).

Title	Years	Strength	Begin	End	2012–2022
Strength in adversity: the influence of psychological capital on job search	2012	4.41	2014	2020	
Work-family conflict and burnout among Chinese doctors: The mediating role of psychological capital	2012	5.92	2015	2020	
The impact of business school students' psychological capital on academic performance	2012	7.94	2016	2020	
Sources of method bias in social science research and recommendations on how to control it	2012	12.13	2016	2020	
Authentic leadership promoting employees' psychological capital and creativity	2012	14.21	2017	2020	
Psychological capital as a buffer to student stress	2012	4.91	2019	2020	
The impact of psychological capital on job embeddedness and job performance among nurses: A structural equation approach	2012	5.52	2019	2020	
Building on the positives: a psychometric review and critical analysis of the construct of psychological capital	2013	6.76	2017	2022	
Meeting the leadership challenge of employee well-being through relationship psychological capital and health capital	2013	7.65	2017	2022	
The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: Does method really matter?	2013	13.74	2018	2022	
The impact of psychological capital on job burnout of Chinese nurses: The mediator role of organizational commitment	2013	5.12	2019	2020	
New nurses burnout and workplace wellbeing: The influence of authentic leadership and psychological capital	2014	6.04	2016	2020	
Psychological capital: A review and synthesis	2014	24.67	2017	2022	
A critical review of the job demands-resources model: implications for improving work and health	2014	4.23	2018	2020	
The left side of psychological capital: new evidence on the antecedents of psychology capital	2014	10.92	2018	2022	
Psychological capital among university students: relationships with study engagement and intrinsic motivation	2014	13.27	2019	2022	
Innovation and creativity in organizations: a state-of-the-science review, prospective commentary, and guiding framework	2014	5.82	2019	2022	
Building the leaders of tomorrow: the development of academic psychological capital	2014	6.99	2020	2022	
Getting to the "COR": understanding the role of resources in conservation of resources theory	2014	11.11	2020	2022	
Do psychological capital and work engagement foster frontline employees' satisfaction? A study in the hotel industry	2015	8.17	2017	2020	
The impact of employees' positive psychological capital on job satisfaction and organizational citizenship behaviors in the hotel	2015	7.87	2018	2022	
Why is hospitality employees' psychological capital important? The effects of psychology capital on work engagement and employee morale	2015	11.57	2018	2022	
Psychological capital intervention (PCI): A replication and extension	2015	11.95	2019	2022	
The relationship between psychological capital, job satisfaction, and safety perceptions in the maritime industry	2015	6.79	2019	2022	
Impact of psychological capital on innovative performance and job stress	2015	10.78	2019	2022	
Linking positive emotions to work well-being and turnover intention among Hong Kong police officers: The role of psychological capital	2015	7.69	2020	2022	
Effects of psychological capital on mental health and substance abuse	2015	9.59	2020	2022	
Toward better understanding of the learning goal orientation–creativity relationship: The role of positive psychological capital	2015	4.99	2020	2022	
Psychological capital and well-being	2015	11.18	2020	2022	
The mediating role of coping style in the relationship between psychological capital and burnout among Chinese nurses	2015	5.56	2020	2022	
The mediating role of psychological capital on the association between occupational stress and job burnout among bank employees in China	2015	6.64	2020	2022	

(Continued)

TABLE 6 (Continued)

Title	Years	Strength	Begin	End	2012–2022
Why entrepreneurs often experience low, not high, levels of stress: The joint effects of selection and psychological capital	2016	7.63	2018	2022	
Psychological capital as a team phenomenon: mediating the relationship between learning climate and outcomes at the individual and team levels	2016	5.94	2019	2022	
Job demands–resources theory: Taking stock and looking forward.	2017	10.47	2019	2022	
Psychological capital: An evidence-based positive approach	2017	47.50	2019	2022	
Psychological capital in the quick service restaurant industry: A study of unit-level performance	2017	5.94	2019	2022	
Test of a mediation model of psychological capital among hotel salespeople	2017	6.79	2019	2022	
The cross-level mediating effect of psychological capital on the organizational innovation climate–employee innovative behavior relationship	2017	5.52	2020	2022	
Psychological capital bolsters motivation, engagement, and achievement: Cross-sectional and longitudinal studies	2018	10.47	2019	2022	
The concept of psychological capital: A comprehensive review	2018	9.24	2020	2022	
Psychological capital and performance among undergraduate students: The role of meaning-focused coping and satisfaction	2018	7.69	2020	2022	
Testing a dynamic model of the impact of psychological capital on work engagement and job performance	2018	9.24	2020	2022	
How psychological capital mediates between study-related positive emotions and academic performance	2019	4.61	2020	2022	
The psychological impact of quarantine and how to reduce it: Rapid review of the evidence	2020	8.08	2020	2022	
The psychological impact of the covid-19 epidemic on college students in China	2020	6.52	2020	2022	

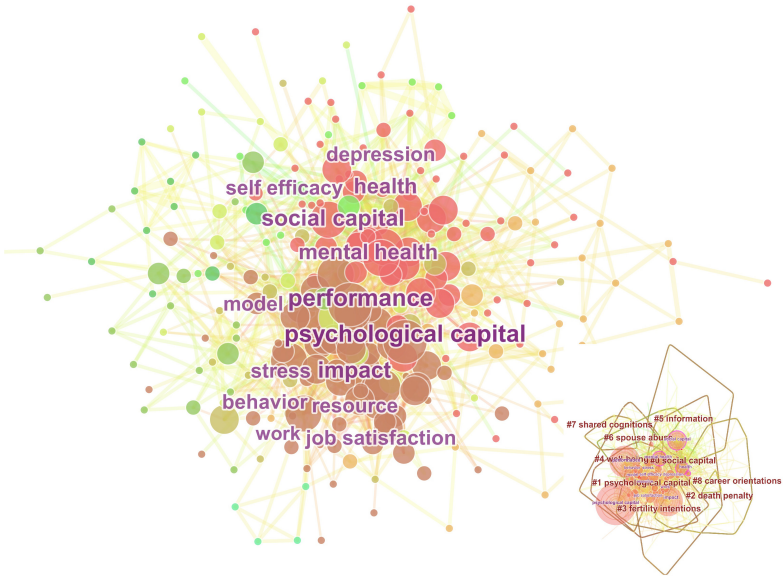


FIGURE 6
co-occurrence network of keywords.

brought by quarantine was extensive and substantial. Cao et al. (2020) studied the impact of COVID-19 on college students' PsyCap.

Research on PsyCap metrics and nurturing interventions are also a research priority. Avey (2014) conducted two separate empirical studies of 1,264 engineers and technicians, and 529 Chinese scientists and technicians from an individual psychological perspective and found that individual differences, leadership ability, and job characteristics were strong predictors of PsyCap. Results from the Luthans et al. (2014) experimental

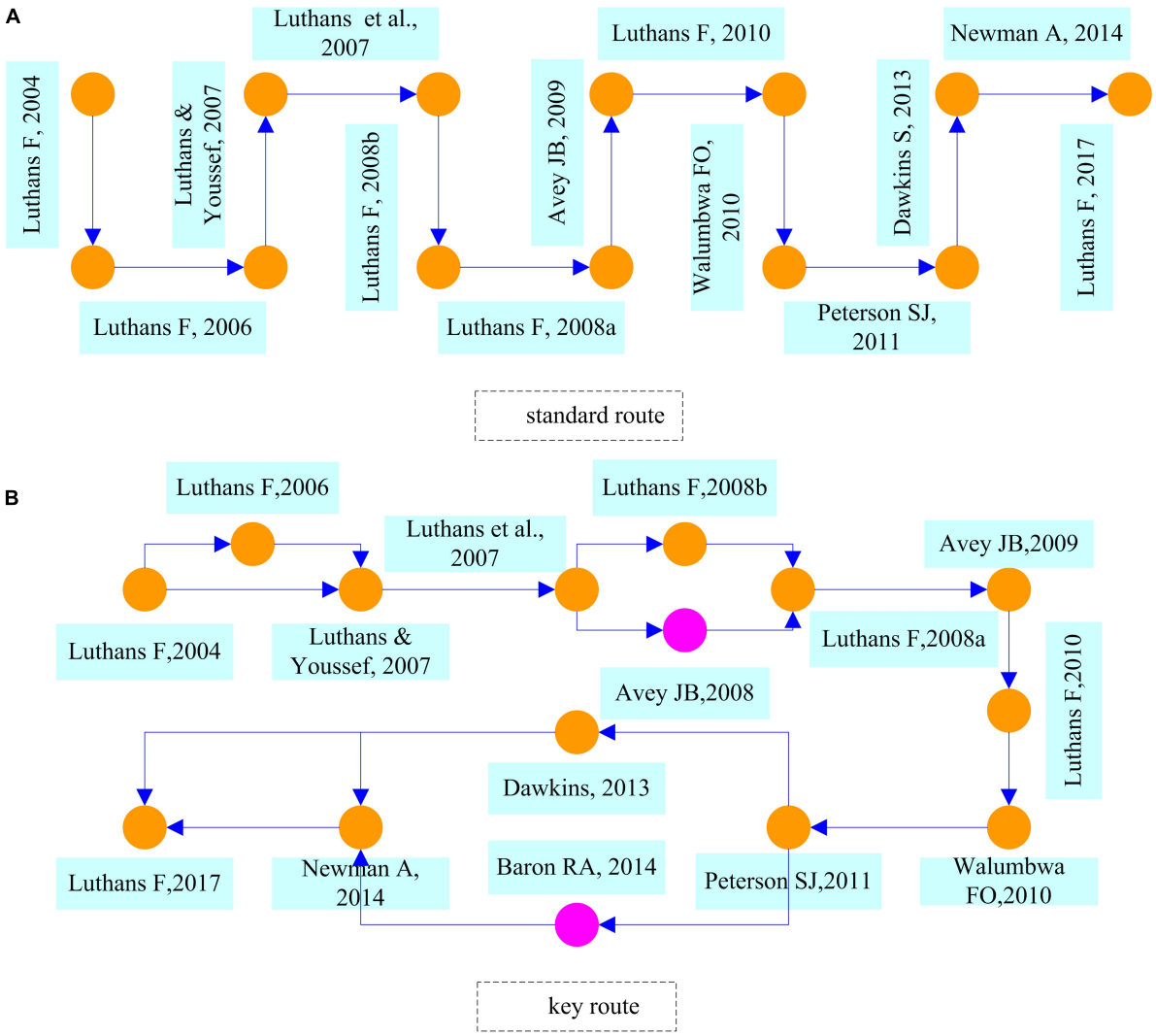


FIGURE 7
Global standard route **(A)** and key route **(B)** in the field of PsyCap.

study provide preliminary support that short-term training interventions can positively impact the academic PsyCap of business students. These two papers focused on short-term interventions for PsyCap, and Russo and Stoykova (2015) further explored the long-term effects of these approaches.

Keywords analysis

In bibliometrics, keyword co-occurrence is used to identify research trends. We employ Cite-Space to generate a keyword co-occurrence network for PsyCap, illustrated in **Figure 6**. Furthermore, we can find 9 clusters, which are formed based on the keyword co-occurrence network. The specific information on clustering is further presented in **Table 7** and **Figure 6**.

From the observation of **Figure 6**, we can see that cluster "#0 social capital" and cluster "#1 Psychological Capital" are the largest clusters, containing more keywords, and they are more closely connected. Cluster "#0 social capital" includes 77 keywords, cluster "#1 Psychological Capital" has 68 keywords, and cluster "#2 death penalty" contains 29 keywords. Cluster "#3 fertility intentions," cluster "#4 well-being," cluster "#5 information," cluster "#6 spouse abuse," cluster "#7 shared cognitions," cluster "#8 career orientations" contain 23, 20, 20, 13, 10, 4 keywords, respectively. And the cluster "#8 career orientations" is the smallest cluster, which only has four keywords, including "labor," "flow," "succe" and "coping." **Table 7** lists the top five co-occurrence keywords with the highest frequency in each cluster.

Furthermore, we obtain 60 hot keywords using burst point detection in the Cite-Space (Ping et al., 2017). We highlighted the ten keywords with the greatest strength. The hot keywords generated during the steady growth (1970–2007) stage are "Self-rated health" (the strength is 11.21, begin at 2007, end

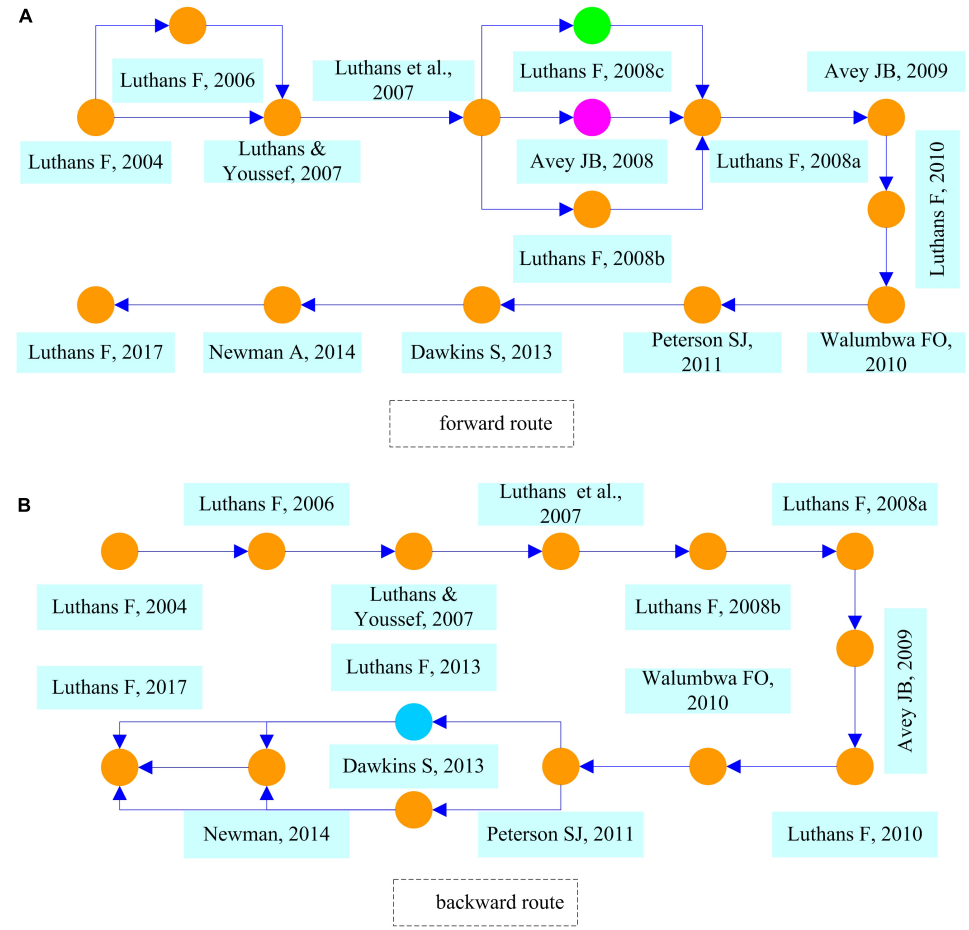


FIGURE 8
Local forward route **(A)** and backward route **(B)** in the field of PsyCap.

TABLE 7 Co-occurrence of keywords in PsyCap.

cluster#0(77)	cluster #1(68)	cluster #2(29)	cluster #3(23)	cluster #4(20)	cluster #5(20)	cluster #6(13)	cluster #7(10)	cluster #8(4)
Social capital (356)	Psychological Capital (636)	Consequence (22)	Perception (65)	Stress (218)	Gender (38)	Women (24)	Network (49)	Labor (2)
Mental health (288)	Performance (510)	Psychological contract (11)	Experience (52)	Well-being (46)	Student (35)	United States (9)	Innovation (16)	Coping (2)
Health (279)	Impact (470)	Human resource management (9)	Children (35)	Commitment (31)	Human capital (27)	Preference (5)	Strength (2)	succe (2)
Depression (186)	Self-efficacy (214)	Identity (9)	Self (32)	Empowerment (17)	Education (24)	Gender difference (5)	Weak ty (2)	Flow (2)
Support (117)	Resource (201)	Intelligence (7)	Context (21)	Happiness (12)	Strategy (11)	Information technology (3)	Social structure (2)	

and in 2016), "social capital" (10.58, 1999–2006), "Mortality" (10.3, 2000–2015) and "Women" (9.70, 2005–2015). The hot keywords generated during the rapid growth stage (2008–2017) are "Trust" (12.83, 2008–2016), "Positive organizational behavior" (11.42, 2010–2018), "Children" (10.64, 2012–2018) and "Organizational behavior" (9.96, 2010–2017). The others generated during the third stage (2018–2022) are "Nurse" (12.55, 2020–2022) and "Motivation" (9.97, 2019–2020). Noted that "Nurse" is a current hot topic of research in PsyCap. Among the related researches, the moderating effect of psychological capital on nurses in the workplace is a research priority. The literature related to the keyword "motivation" focuses on the relationship

between psychological capital and the behavioral motivation of various workplace personnel, such as Datu et al. (2018), Xu et al. (2021), and Li et al. (2022).

Additional discussions: The main path analysis

In this section, we use the main path analysis method to identify the main paths and the key nodes in the development of PsyCap. Specifically, we analyze the development of PsyCap knowledge from four perspectives: global key route, global standard route, local forward route, and local backward route.

As shown in **Figure 7A**, there is only one global standard route for PsyCap research, starting with Luthans and Youssef (2004), and ending with Luthans and Youssef-Morgan (2017). And one node represents one document and the arrows represent the direction of the study along the timeline. Luthans and Youssef (2004) argued that developing and managing employees' positive PsyCap can improve their competitive advantage and suggested the following four channels: (1) developing self-efficacy/confidence, (2) developing hope, (3) developing optimism, and (4) developing resiliency. Luthans et al. (2007) analyzed how to develop a PsyCap approach from a micro-intervention perspective and explored the relationship between PsyCap on financial and investment reporting. Based on the concept of positive psychology (Seligman and Csikszentmihalyi, 2000) and related recommendations (Roberts, 2006) and guidelines (Kilduff, 2006) in organizational behavior, Luthans and Youssef (2007) combed through the literature on positive organizational behavior and laid the groundwork for research on how positive PsyCap affects organizational behavior.

The establishment of related theories has further led to the development of PsyCap research, from experimental (Luthans et al., 2007, 2008a, 2010) to empirical (Avey et al., 2009), from impact analysis to mediated utility (Luthans et al., 2008b; Walumbwa et al., 2010), and from cross-sectional to longitudinal data (Peterson et al., 2011). In addition, scholars continue to sort out and summarize theories, methods, results, and applications in the field of PsyCap through literature reviews, among which the classic literature includes Dawkins et al. (2013), Newman et al. (2014), and Luthans and Youssef-Morgan (2017). This literature provides theoretical support and methodological bolster for subsequent studies.

Figure 7B shows the global key route in the field of PsyCap. There are 2 nodes in purple color, which means that two different documents are generated in the global standard route. Among them, Avey et al. (2008) have specifically studied the impact of positive PsyCap and positive emotions of employees on organizational change. Baron et al. (2016) study found that entrepreneurs have lower levels of stress that are attributable to their stronger PsyCap. And the correlation coefficient between corporate technical innovation and corporate leverage is negative in PsyCap.

Figure 8A illustrates the local forward route in the PsyCap domain. Compared to **Figure 7**, we find a new node which is marked in green. This node represents the literature by Luthans et al. (2008c), which proposed an approach to human resource management based on PsyCap theory that applies to the Chinese environment.

Figure 8B displays the local backward route in the field of PsyCap. There are two main routes and 14 notes, and all paths converge to the node Luthans and Youssef-Morgan (2017) in the end. Meanwhile, a blue node is particularly conspicuous, and it corresponds to the literature that represents the extension of PsyCap to the field of well-being.

There are 17 documents in the four main paths mentioned above, of which five literature reviews lead and guide the development of the field. The remaining 12 essays are groundbreaking works, where PsyCap collides with each of the major themes. As PsyCap collided with other major themes, many seminal articles were produced, such as the 12 remaining articles in the main pathway.

Conclusion

The statistics and analysis of the literature related to the field of PsyCap based on CiteSpace and Pajek provide a unique and meaningful snapshot of the subsequent research. Many conclusions can be drawn from the analysis: (1) The annual publication volume of the literature indicates that research in this field can be broadly divided into three phases: steady growth (1970–2007), rapid growth (2008–2017), and high rapid growth (2018–2022.9). According to the distribution of disciplinary classifications, it is clear that PsyCap has become an interdisciplinary study, mainly involving sociology, environmental studies, medicine, and business administration. Australia, the United States, and China dominate research on PsyCap, while these countries have the most prolific authors and institutions. (2) Grounded in the analysis of collaboration, a highly consistent relationship was found between authors who collaborated more and those authors who were more efficient. The same phenomenon was found in the countries or regions. And the overwhelming majority of the most influential journals are those in psychology and management. (3) Focusing on the clustering analysis of the cited literature, it is found that PsyCap research concentrates on the measurement and development of PsyCap and the influence or mediating role of PsyCap on organizational behavior and employee behavior. It is also interesting to note that the authors of the most cited literature are Luthans and Avey, who are likewise among the most prolific authors. (4) Based on the keyword clustering analysis and emergent point detection, it can be seen that in addition to the theme word "PsyCap," performance, influence, health,

social capital, and stress are the core keywords in this field; organizational behavior, nurses, and motivation have become hot topics in recent years. (5) The analysis of the four main paths reveals that the development of PsyCap research is as follows: theoretical construction to practical application, macro elaboration to micro empirical evidence, and static research to dynamic analysis. In addition, it is worth mentioning that the development of the psychological capital field is closely related to the influence and guidance of relevant policies, especially current research hotspots, such as innovation, well-being, and performance. Meanwhile, the improvement of psychological capital theories, methods, and norms, the expansion of the scope of empirical studies, and the improvement of the accuracy of the results have further improved the effectiveness of policy implementation.

We further summarized the current and future research hotspots in the field of PsyCap, as follows: (1) expand and refine the concept of PsyCap by incorporating other heart resources, such as emotional intelligence, courage, and forgiveness (Luthans and Youssef-Morgan, 2017); (2) The impact and mediating role of PsyCap on individuals, organizations or groups, from the direction of stress, motivation, and innovation, knowledge management; (3) Research on PsyCap development and the methods and effects of long- and short-term interventions; (4) cross-sectional research and use of PsyCap, for example, the impact of managers' PsyCap on strategy and decision making (Nolzen, 2018).

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SM developed the theoretical framework. XF worked on data collection and processing. DL worked on literature review and manuscript writing. All authors contributed to the article and approved the submitted version.

Funding

The authors acknowledge the financial support from Humanity and Social Science Youth Foundation of Ministry of Education of China (Grant No. 18YJC790118) and The Philosophy and Social Science Innovation Team Project of Yunnan Province (No. 2022CX01).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abbas, M., and Raja, U. (2015). Impact of psychological capital on innovative performance and job stress. *Can. J. Adm. Sci.* 32, 128–138. doi: 10.1002/cjas.1314

Abbas, M., Raja, U., Darr, W., and Bouckenooghe, D. (2014). Combined effects of perceived politics and psychological capital on job satisfaction, turnover intentions, and performance. *J. Manag.* 40, 1813–1830. doi: 10.1177/0149206312455243

Alessandri, G., Consiglio, C., Luthans, F., and Borgoni, L. (2018). Testing a dynamic model of the impact of psychological capital on work engagement and job performance, career development international. *J. Execut. Consult. Acad.* 23, 33–47. doi: 10.1108/CDI-11-2016-0210

Anderson, N., Potoènik, K., and Zhou, J. (2014). Innovation and creativity in organizations: A state-of-the-science review, prospective commentary, and guiding framework. *J. Manag.* 40, 1297–1333. doi: 10.1177/0149206314527128

Avey, J. B. (2014). The left side of psychological capital: New evidence on the antecedents of PsyCap. *J. Leadersh. Organ. Stud.* 21, 141–149.

Avey, J. B., Luthan, F., and Youssef, C. M. (2010a). The additive value of positive psychological capital in predicting work attitudes and behaviors. *J. Manag.* 36, 430–452. doi: 10.1177/1548051813515516

Avey, J. B., Luthans, F., Smith, R. M., and Palmer, N. F. (2010b). Impact of positive psychological capital on employee well-being over time. *J. Occup. Health Psychol.* 15, 17–28. doi: 10.1177/0149206308329961

Avey, J. B., Luthan, F., and Jensen, S. M. (2009). Psychological capital: A positive resource for combating employee stress and turnover. *Hum. Resour. Manag.* 48, 677–693. doi: 10.1037/a0016998

Avey, J. B., Reichard, R. J., Luthans, F., and Mhatre, K. H. (2011). Meta-analysis of the impact of positive psychological capital on employee attitudes, behaviors, and performance. *Hum. Resour. Dev. Q.* 22, 127–152. doi: 10.1002/hrm.20294

Avey, J. B., Wernsing, T. S., and Luthans, F. (2008). Can positive employees help positive organizational change? Impact of psychological capital and emotions on relevant attitudes and behaviors. *J. Appl. Behav. Sci.* 44, 48–70. doi: 10.1002/hrdq.20070

Bakker, A. B., and Demerouti, E. (2017). Job demands–resources theory: Taking stock and looking forward. *J. Occup. Health Psychol.* 22, 273–285.

Baron, R. A., Franklin, R. J., and Hmieleski, K. M. (2016). Why entrepreneurs often experience low, not high, levels of stress: The joint effects of selection and psychological capital. *J. Manag.* 42, 742–768. doi: 10.1177/0149206313495411

Batagelj, V., and Mrvar, A. (1998). Pajek-A program for large network analysis. *Connection* 21, 47–57.

Baumgartner, H., and Pieters, R. (2003). The structural influence of marketing journals: A citation analysis of the discipline and its subareas over time. *J. Mark.* 67, 123–139. doi: 10.1509/jmkg.67.2.123.18610

Bergheim, K., Nielsen, M. B., Mearn, K., and Eid, J. (2015). The relationship between psychological capital, job satisfaction, and safety perceptions in the maritime industry. *Saf. Sci.* 74, 27–36. doi: 10.1016/j.ssci.2014.11.024

Bhukya, R., Paul, J., Kastanakis, M., and Robinson, S. (2022). Forty years of European management journal: A bibliometric overview. *Eur. Manag. J.* 40, 10–28. doi: 10.1016/j.emj.2021.04.001

Brooks, S. K., Webster, R. K., Smith, L. E., Woodland, L., and Rubin, G. J. (2020). The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *Lancet* 395, 912–920. doi: 10.1016/S0140-6736(20)30460-8

Brunetto, Y., Saheli, N., Dick, T., and Nelson, S. (2022). Psychosocial safety climate, psychological capital, healthcare SLBs' wellbeing and innovative behavior during the Covid-19 pandemic. *Public Perform. Manag. Rev.* 45, 751–772. doi: 10.1080/15309576.2021.1918189

Bunjak, A., Cerne, M., and Schoelly, E. L. (2022). Exploring the past, present, and future of the mindfulness field: A multitechnique bibliometric review. *Front. Psychol.* 13:792599. doi: 10.3389/fpsyg.2022.792599

Burns, A. J., Posey, C., Roberts, T. L., and Lowry, P. B. (2017). Examining the relationship of organizational insiders' psychological capital with information security threat and coping appraisals. *Comput. Hum. Behav.* 68, 190–209. doi: 10.1016/j.chb.2016.11.018

Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., and Dong, J. (2020). The psychological impact of the COVID-19 epidemic on college students in China. *Psychiatry Res.* 287:112934. doi: 10.1016/j.psychres.2020.112934

Carmona, M., Salanova, M., Llorens, S., and Schaufeli, W. B. (2019). How psychological capital mediates between study-related positive emotions and academic performance. *J. Happiness Stud.* 20, 605–617. doi: 10.1007/s10902-018-9963-5

Chen, C. (2006). Citespace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J. Am. Soc. Inf. Sci. Technol.* 57, 359–377. doi: 10.1002/asi.20317

Chen, D. J. Q., and Lim, V. K. G. (2012). Strength in adversity: The influence of psychological capital on job search. *J. Organ. Behav.* 33, 811–839. doi: 10.1002/job.1814

Cobo, M., López-Herrera, J., Herrera-Viedma, E., and Herrera, F. (2012). SciMAT: A new science mapping analysis software tool. *J. Am. Soc. Inf. Sci. Technol.* 63, 1609–1630. doi: 10.1002/asi.22688

Dan, X., Ying, Y., Shuan, H., and Shuang, X. (2021). Research on the global development of bioinformatics based on the core journals of SCIE br. *Libr. J.* 40, 112–121.

Datu, J. A. D., King, R. B., and Valdez, J. P. M. (2018). Psychological capital bolsters motivation, engagement, and achievement: Cross-sectional and longitudinal studies. *J. Posit. Psychol.* 13, 260–270.

Dawkins, S., Martin, A., Scott, J., and Sanderson, K. (2013). Building on the positives: A psychometric review and critical analysis of the construct of psychological capital. *J. Occup. Organ. Psychol.* 86, 348–370.

Ding, Y. Q., Yang, Y. J., Yang, X. X., Zhang, T. H., Qiu, X. H., He, X., et al. (2015). The mediating role of coping style in the relationship between psychological capital and burnout among Chinese nurses. *PLoS One* 10:e0122128. doi: 10.1371/journal.pone.0122128

Dong, D., Sun, M. L., Xu, D., Han, S., Cui, L. Y., Cao, S., et al. (2022). Mapping the hot spots and evolution main path of whole-body vibration training since the 21st century: A bibliometric analysis. *Front. Bioeng. Biotechnol.* 10:920846. doi: 10.3389/fbioe.2022.920846

Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., and Pappas, G. (2008). Comparison of PubMed. Scopus, web of science, and google scholar: Strengths and weaknesses. *FASEB J.* 22, 338–342. doi: 10.1096/fj.07-9492LSF

Fang, Y., Yi, J., and Wu, B. H. (2018). Climate change and tourism: A scientometric analysis using citespace. *J. Sustain. Tour.* 26, 108–126. doi: 10.1080/09669582.2017.1329310

Flores, P. (2022). A bibliometric overview of mechanism and machine theory journal: Publication trends from 1990 to 2020. *Mech. Mach. Theory* 175:104965. doi: 10.1016/j.mechmachtheory.2022.104965

Freeman, L. C. (1979). Centrality in social networks conceptual clarification. *Soc. Netw.* 1, 215–239. doi: 10.1016/0378-8733(78)90021-7

Glodber, F. (1970). Toward expansion of witherspoon-capital scruples, Jury bias, and use of psychological data to raise presumptions in law. *Harvard Civil Rights Civil Libr. Law Rev.* 5, 53–69.

Gu, Z. Y., Meng, F. C., and Wang, S. Y. (2022). Mapping the field of social capital with innovation and future research agenda: A bibliometric and visualization analysis. *J. Intellect. Cap.* doi: 10.1108/JIC-09-2021-0248

Halbesleben, J. R. B., Neveu, J. P., Paustian-Underdahl, S. C., and Westman, M. (2014). Getting to the "COR": Understanding the role of resources in conservation of resources theory. *J. Manag.* 40, 1334–1364. doi: 10.1177/0149206314527130

Hayes, A. F., and Scharkow, M. (2013). The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: Does method really matter? *Psychol. Sci.* 24, 1918–1927. doi: 10.1177/0956797613480187

Heled, E., Somec, A., and Waters, L. (2016). Psychological capital as a team phenomenon: Mediating the relationship between learning climate and outcomes at the individual and team levels. *J. Posit. Psychol.* 11, 303–314. doi: 10.1080/17439760.2015.1058971

Hsu, M. L. A., and Chen, F. H. (2017). The cross-level mediating effect of psychological capital on the organizational innovation climate–employee innovative behavior relationship. *J. Creat. Behav.* 51, 128–139. doi: 10.1002/jocb.90

Huang, L., and Luthans, F. (2015). Toward better understanding of the learning goal orientation–creativity relationship: The role of positive psychological capital. *Appl. Psychol.* 64, 444–472. doi: 10.1111/apps.12028

Jiang, Y. W., Ritchie, B. W., and Benckendorff, P. (2019). Bibliometric visualization: An application in tourism crisis and disaster management research. *Curr. Issues Tour.* 22, 1925–1957. doi: 10.1080/13683500.2017.1408574

Jung, H. S., and Yoon, H. H. (2015). The impact of employees' positive psychological capital on job satisfaction and organizational citizenship behaviors in the hotel. *Int. J. Contemp. Hosp. Manag.* 27, 1135–1156. doi: 10.1108/IJCHM-01-2014-0019

Karatepe, O. M., and Karadas, G. (2015). Job demands–resources theory: Taking stock and looking forward. *J. Occup. Health Psychol.* 22, 273–285.

Kilduff, M. (2006). Editor's comments: Publishing theory. *Acad. Manag. Rev.* 31, 252–255. doi: 10.5465/amr.2006.20208678

Kleinberg, J. (2003). Bursty and hierarchical structure in streams. *Data Min. Knowl. Discov.* 7, 373–397. doi: 10.1023/A:1024940629314

Koon, V. Y. (2022). Mobile learning and humanistic education: A science mapping approach. *Interact. Learn. Environ.* doi: 10.1080/10494820.2022.2061010

Kumar, D., Upadhyay, Y., Yada, R., and Goyal, A. K. (2022). Psychological capital and innovative work behavior: The role of mastery orientation and creative self-efficacy. *Int. J. Hosp. Manag.* 102:103157. doi: 10.1016/j.ijhm.2022.103157

Kumar, P., Shetty, K., Fitzsimmons, J. R., and Hayes, S. G. (2022). The journal of fashion marketing and management: A bibliometric overview since its inception. *J. Fash. Mark. Manag.* 26, 197–220. doi: 10.1108/JFMM-03-2022-290

Laschinger, H. K. S., and Fida, R. (2014). New nurses burnout and workplace wellbeing: The influence of authentic leadership and psychological capital. *Burn. Res.* 1, 19–28. doi: 10.1016/j.burn.2014.03.002

Li, B., and Xu, Z. S. (2021). A comprehensive bibliometric analysis of financial innovation. *Econ. Res.* 35, 367–390. doi: 10.1080/1331677X.2021.1893203

Li, C., Wu, K., and Wu, J. (2017). A bibliometric analysis of research on haze during 2000–2016. *Environ. Sci. Pollut. Res.* 24, 24733–24742. doi: 10.1007/s11356-017-0440-1

Li, X., Ma, E., and Qu, H. (2017). Knowledge mapping of hospitality research-a visual analysis using CiteSpace. *Int. J. Hosp. Manag.* 60, 77–93. doi: 10.1016/j.ijhm.2016.10.006

Li, J., Ge, C., and Li, S. Y. (2022). The association of volunteer motivation and thriving at work of college students during COVID-19: Job burnout and psychological capital as mediators. *Front. Public Health* 10:923196. doi: 10.3389/fpubh.2022.923196

Li, X. R., Kan, D., Liu, L., Shi, M., Wang, Y., Yang, X. S., et al. (2015). The mediating role of psychological capital on the association between occupational stress and job burnout among bank employees in China. *Int. J. Environ. Res. Public Health* 12, 2984–3001. doi: 10.3390/ijerph120302984

Li, Y., Xu, Z. S., Wang, X. X., and Wang, X. Z. (2020). A bibliometric analysis on deep learning during 2007–2019. *Int. J. Mach. Learn. Cybern.* 11, 2807–2826. doi: 10.1007/s13042-020-01152-0

Liu, S., and Oakland, T. (2016). The emergence and evolution of school psychology literature: A scientometric analysis from 1907 through 2014. *Sch. Psychol. Q.* 31, 104–121. doi: 10.1037/spq0000141

Luthans, B. C., Luthans, K. W., and Jensen, S. M. (2012). The impact of business school students' psychological capital on academic performance. *J. Educ. Bus.* 87, 253–259. doi: 10.1080/08832323.2011.609844

Luthans, B. C., Lutnan, K. W., and Avey, J. B. (2014). Building the leaders of tomorrow: The development of academic psychological capital. *J. Leadersh. Organ. Stud.* 21, 191–199. doi: 10.1177/1548051813517003

Luthans, F. (2002). Positive organizational behavior: Developing and managing psychological strengths. *Acad. Manag. Exec.* 16, 57–72. doi: 10.5465/ame.2002.6640181

Luthans, F., and Youssef, C. A. (2007). Emerging positive organizational behavior. *J. Manag.* 33, 321–349. doi: 10.1177/0149206307300814

Luthans, F., and Youssef-Morgan, C. M. (2017). Psychological capital: An evidence-based positive approach. *Annu. Rev. Organ. Psychol. Organ. Behav.* 4, 339–366. doi: 10.1146/annurev-orgpsych-032516-113324

Luthans, F., and Youssef, C. M. (2004). Human, social and now positive psychological capital management: Investing in people for competitive advantage. *Organ. Dyn.* 33, 143–160. doi: 10.1016/j.orgdyn.2004.01.003

Luthans, F., Avolio, B. J., Avey, J. B., and Norman, S. M. (2007). Positive psychological capital: Measurement and relationship with performance and satisfaction. *Pers. Psychol.* 60, 541–572. doi: 10.1111/j.1744-6570.2007.00083.x

Luthans, F., Youssef, C. M., Sweetman, D. S., and Harms, P. D. (2013). Meeting the leadership challenge of employee well-being through relationship PsyCap and health PsyCap. *J. Leadersh. Organ. Stud.* 20, 118–133. doi: 10.1177/1548051812465893

Luthans, F., Avey, J. B., and Patera, J. L. (2008a). Experimental analysis of a web-based training intervention to develop positive psychological capital. *Acad. Manag. Learn. Educ.* 7, 209–221. doi: 10.1186/1471-2458-14-685

Luthans, F., Norman, S. M., Avoli, B. J., and Avey, J. B. (2008b). The mediating role of psychological capital in the supportive organizational climate-employee performance relationship. *J. Organ. Behav.* 29, 219–238. doi: 10.1002/job.507

Luthans, F., Avey, J. B., Clapp-Smith, R., and Li, W. X. (2008c). More evidence on the value of Chinese workers' psychological capital: A potentially unlimited competitive resource? *Int. J. Hum. Resour. Manag.* 19, 818–827.

Luthans, F., Avey, J. B., Avolio, B. J., and Peterson, S. J. (2010). The development and resulting performance impact of positive psychological capital. *Hum. Resour. Dev. Q.* 21, 41–67. doi: 10.1002/hrdq.20034

Luthans, F., Avey, J. B., Avolio, B. J., Norman, S. M., and Combs, G. M. (2006). Psychological capital development: Toward a micro-intervention. *J. Organ. Behav.* 27, 387–393. doi: 10.1002/job.373

Mathe, K., Scott-Halsell, S., Ki, S., and Krawczyk, M. (2017). Psychological capital in the quick service restaurant industry: A study of unit-level performance. *J. Hosp. Tour. Res.* 41, 823–845.

Newman, A., Ucbasaran, D., Zhu, F., and Hirst, G. (2014). Psychological capital: A review and synthesis. *J. Organ. Behav.* 35(Suppl. 1), S120–S138. doi: 10.1002/job.1916

Nolzen, N. (2018). The concept of psychological capital: A comprehensive review. *Manag. Rev. Q.* 68, 237–277. doi: 10.1007/s11301-018-0138-6

Olczyk, M. (2016). Bibliometric approach to tracking the concept of international competitiveness. *J. Bus. Econ. Manag.* 17, 945–959. doi: 10.3846/16111699.2016.1236035

Ortega-Maldonado, A., and Salanova, M. (2018). Psychological capital and performance among undergraduate students: The role of meaning-focused coping and satisfaction. *Teach. High. Educ.* 23, 390–402. doi: 10.1080/13562517.2017.1391199

Paek, S., Schuckert, M., Kim, T. T., and Lee, G. (2015). Why is hospitality employees' psychological capital important? The effects of psychological capital on work engagement and employee morale. *Int. J. Hosp. Manag.* 50, 9–26. doi: 10.1016/j.ijhm.2015.07.001

Pan, X. L., Yan, E. J., Cui, M., and Hua, W. N. (2018). Examining the usage, citation, and diffusion patterns of bibliometric mapping software: A comparative study of three tools. *J. Inform.* 12, 481–493. doi: 10.1016/j.joi.2018.03.005

Peng, J. X., Jiang, X. H., Zhang, J. X., Xiao, R. X., Song, Y. Y., Feng, X., et al. (2013). The impact of psychological capital on job burnout of Chinese nurses: The mediator role of organizational commitment. *PLoS One* 8:e84193. doi: 10.1371/journal.pone.0084193

Peterson, C., and Steen, T. (2002). "Optimistic explanatory style," in *Handbook of positive psychology*, eds C. R. Snyder and S. Lopez (Oxford: Oxford University Press), 244–256.

Peterson, S. J., Luthans, F., Avolio, B. J., Walumbwa, F. O., and Zhang, Z. (2011). Psychological capital and employee performance: A latent growth modeling approach. *Pers. Psychol.* 64, 427–450. doi: 10.1111/j.1744-6570.2011.01215.x

Ping, Q., He, J., and Chen, C. (2017). How many ways to use citespace? A study of user. Interactive events over 14 months. *J. Assoc. Inf. Sci. Technol.* 68, 1234–1256. doi: 10.1002/asi.23770

Podsakoff, P. M., Mackenzie, S. B., and Podsakoff, N. P. (2012). Sources of method bias in social science research and recommendations on how to control it. *Annu. Rev. Psychol.* 63, 539–569. doi: 10.1146/annurev-psych-120710-100452

Rego, A., Sousa, F., Marques, C., and Cunha, P. E. (2012). Authentic leadership promoting employees' psychological capital and creativity. *J. Bus. Res.* 65, 429–437. doi: 10.1016/j.jbusres.2011.10.003

Riolli, L., Savicki, V., and Richards, J. (2012). Psychological capital as a buffer to student stress. *Psychology* 3, 1202–1207. doi: 10.4236/psych.2012.312A178

Roberts, L. M. (2006). Shifting the lens on organizational life: The added value of positive scholarship. *Acad. Manag. Rev.* 31, 292–305. doi: 10.5465/amr.2006.20208681

Russo, S. D., and Stoykova, P. (2015). Psychological capital intervention (PCI): A replication and extension. *Hum. Resour. Dev. Q.* 26, 329–347. doi: 10.1002/hrdq.21212

Seligman, M. E. P., and Csikszentmihalyi, M. (2000). Positive psychology. *Am. Psychol.* 55, 5–14. doi: 10.1037/0003-066X.55.1.5

Shi, L., Mai, Y. P., and Wu, Y. J. (2022). Digital transformation: A bibliometric analysis. *J. Organ. End User Comput.* 37, 1–20. doi: 10.4018/JOEUC.302637

Siu, O. L., Bakker, A. B., and Jiang, X. H. (2014). Psychological capital among university students: Relationships with study engagement and intrinsic motivation. *J. Happiness Stud.* 15, 979–994. doi: 10.1007/s10902-013-9459-2

Snyder, C. R., Irving, L., and Anderson, J. (1991). "Hope and health: Measuring the will and the ways," in *Handbook of social and clinical psychology*, eds C. R. Snyder and D. R. Forsyth (Elmsford, NY: Pergamon Prees), 285–305.

Stajkovic, A. D., and Luthans, F. (1998). Social cognitive theory and self-efficacy: Going beyond traditional motivational and behavioral approaches. *Organ. Dyn.* 26, 62–74. doi: 10.1016/S0090-2616(98)90006-7

Su, M., Peng, H., and Li, S. F. (2021).). A visualized bibliometric analysis of mapping research trends of machine learning in engineering. *Expert Syst. Appl.* 186:115728. doi: 10.1016/j.eswa.2021.115728

Sun, T., Zhao, X. W., Yang, L. B., and Fan, L. H. (2012). The impact of psychological capital on job embeddedness and job performance among nurses: A structural equation approach. *J. Adv. Nurs.* 68, 69–79. doi: 10.1111/j.1365-2648.2011.05715.x

Tho, N. D., and Duc, L. A. (2021). Team psychological capital and innovation: The mediating of team exploratory and exploitative learning. *J. Knowl. Manag.* 25, 1745–1759. doi: 10.1108/JKM-06-2020-0475

Van Eck, J. V., and Waltman, L. (2010). Software survey: Vosviewer, a computer program for bibliometric mapping. *Scientometrics* 84, 523–538. doi: 10.1007/s11192-009-0146-3

Walumbwa, F. O., Peterson, S. J., Avolio, B. J., and Hartnell, C. A. (2010). An investigation of the relationships among leader and follower psychological capital, service climate, and job performance. *Pers. Psychol.* 63, 937–963. doi: 10.1111/j.1744-6570.2010.01193.x

Wang, J. X., Lim, M. K., Wang, C., and Tseng, M. L. (2022). Comprehensive analysis of sustainable logistics and supply chain based on bibliometrics: Overview, trends, challenges, and opportunities. *Int. J. Logist. Res. Appl.* doi: 10.1080/13675567.2022.2052823

Wang, X. X., Xu, Z. S., and Skare, M. (2020). A bibliometric analysis of economic research ekonomska istrazivanja (2007–2019). *Econ. Res.* 33, 865–886. doi: 10.1080/1331677X.2020.1737558

Wang, Y., Liu, L., Wang, J. N., and Wang, L. (2012). Work-family conflict and burnout among Chinese doctors: The mediating role of psychological capital. *J. Occup. Health* 54, 232–240. doi: 10.1539/joh.11-0243-oa

Wernsing, T. (2014). Psychological capital: A test of measurement invariance across 12 national cultures. *J. Leadersh. Organ. Stud.* 21, 179–190. doi: 10.1177/1548051813515924

Willett, P. (2007). A bibliometric analysis of the journal of molecular graphics and modelling. *J. Mol. Graph. Model.* 26, 602–606.

Xu, L. P., Liao, J. B., Wu, Y. S., and Da Kuang, H. (2021). Effect of psychological capital of volunteers on volunteering behavior: The chained mediation role of perceived social support and volunteer motivation. *Front. Psychol.* 12:657877. doi: 10.3389/fpsyg.2021.657877

Youssef-Morgan, C. M., and Luthans, F. (2015). Psychological capital and well-being. *Stress Health.* 31, 180–188. doi: 10.1002/smi.2623

Yu, Q. Y., Wang, Z. H., Li, Z. Y., Liu, X. J., Agyeman, F. O., and Wang, X. X. (2022). The hierarchical structure of depression knowledge network and co-word analysis of focus areas. *Front. Psychol.* 13:920920. doi: 10.3389/fpsyg.2022.920920

Yu, D., and Sheng, L. (2020). Knowledge diffusion paths of blockchain domain: The main path analysis. *Scientometrics* 125, 471–497. doi: 10.1007/s11192-020-03650-y

Yu, D., and Pan, T. (2021). Tracing knowledge diffusion of TOPSIS: A historical perspective from citation network. *Expert Syst. Appl.* 168:114238. doi: 10.1016/j.eswa.2020.114238

Yu, D., Sheng, L., and Xu, Z. S. (2022). Analysis of evolutionary process in intuitionistic fuzzy set theory: A dynamic perspective. *Inf. Sci.* 601, 175–188. doi: 10.1016/j.ins.2022.04.019

Zhou, W., Kou, A. Q., Chen, J., and Ding, B. (2018). A retrospective analysis with bibliometric of energy security in 2000–2017. *Energy Rep.* 4, 724–732. doi: 10.1016/j.egyr.2018.10.012

Zhou, W., Luo, D. X., Fang, H. R., Gou, X. J., and Chen, J. (2020). Bibliometric overview and retrospective analysis of fund performance research from 1966 to 2019. *Econ. Res. Ekon. Istraživanja* 33, 1510–1537. doi: 10.1080/1331677X.2020.1755879

Zhou, W., Luo, D. X., and Xu, Z. S. (2022). Review of fuzzy investment research considering modelling environment and element fusion. *Int. J. Syst. Sci.* doi: 10.1080/00207721.2022.2031340

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 28 November 2022
DOI 10.3389/fpsyg.2022.1054349

OPEN ACCESS

EDITED BY
Yunlong Duan,
Yunnan University of Finance and Economics, China

REVIEWED BY
Hai Lin,
China Agricultural University, China
Haiyan Zhou,
The University of Texas Rio Grande Valley, United States
Xiaoli Wang,
Henan University, China

*CORRESPONDENCE
Bingxin Ming
mbx20222022@163.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 26 September 2022
ACCEPTED 31 October 2022
PUBLISHED 28 November 2022

CITATION
Zhao M, Ming B, Li Y, and Shi J (2022) Peer effects of working capital management: Considering the moderating effect of knowledge flow.
Front. Psychol. 13:1054349.
doi: 10.3389/fpsyg.2022.1054349

Peer effects of working capital management: Considering the moderating effect of knowledge flow

Mingyuan Zhao, Bingxin Ming*, Yingqing Li and Junran Shi

Pan-Asia Business School, Yunnan Normal University, Kunming, China

An important form of human learning and cognition is imitation. In environments where uncertainty is more incremental, imitation of peers is a natural response to uncertainty. While there are substantial literature documenting peer effects in other settings, the study of peer effects in working capital management is novel; little research exists on peer effects in working capital management and their impact mechanism. Using data of China's listed firms from 2010 to 2021, we empirically demonstrate significant peer effects due to working capital management. Firstly, we find that the behavior of working capital management of firms in the same industry is positively related to a firm's working capital management. We used peer firms' target debt ratio as an instrumental variable to address potential endogeneity problem. Secondly, the moderating effects test shows that the positive relationship between the behavior of working capital management of firms in the same industry and a firm's working capital management behavior is moderated by knowledge flow. Meanwhile, the peer effects in the high group of knowledge flow are greater than that of in the low group of knowledge flow. The study is based on the Active Intermodal Matching theory of psychology. It enriches the research findings on the moderating effect of peer effects and has important implications for policymaking to stimulate the economy.

KEYWORDS

working capital, peer effect, knowledge flow, social cognition, Active Intermodal Matching theory

Introduction

The social psychology literature shows that the behavior of a subject is influenced by the behavior of other subjects in its group, which is a phenomenon known as the "peer effects." Early evidence on psychological theories of behavioral imitation and social learning was presented by Bandura et al. (1961). Psychological group selection theory suggests that small groups of trust and cooperation are the basic, universal, form of sociality in the networks of usual cooperators. In the social network in which firms are embedded, the circle of peers is often one of the small groups. In dire straits, peer support seems to be clearly an advantage (Acedo-Carmona and Gomila, 2015). Psychological peer effects have received extensive attention in various fields including accounting and finance. The

economic decisions of market participants are often influenced by each other, and the economic behavior of firms is not only based on the characteristics of their own resources and capabilities, but is also influenced by the behavior of peer firms (Crotty, 2003). Many studies have shown that there are significant peer effects in a firm's investment behaviors (Brunner and Ostermaier, 2019), financing decision-making (Leary and Roberts, 2014), stock divisions (Adhikari and Agrawal, 2018) and tax avoidance (Gao et al., 2021). While there are substantial literature documenting peer effects in other settings, the study of peer effects in working capital management remains largely unexplored in the literature; little research exists on peer effects in working capital management and their impact mechanism. In this study, we investigate the role of peer effects in working capital management.

Many psychological theories have envisaged the combination of behavior parameters to explain the imitation behavior, but there is no way to put the brain's consciousness into the parameter model, resulting in the lack of ability to explain the imitation behavior, so the AIM (Active Intermodal Matching) model was created. AIM theory proposes that the macro state of imitation consciousness can be explained by three parameters. The first parameter is A. Parameter A indicates information processing capacity. When the value of parameter A value is low, people have little ability to process information, their brains are in a coma, and people are unconscious. When the value of parameter A is high, people have great ability to process information and their brains are awake. The second parameter is I. The parameter I indicates the information source. When the value of parameter I is low, it indicates that the channel for information exchange is closed. At this time, people only pay attention to the information generated within the brain system. When the value of parameter I is high, it indicates that the information exchange channel is opened, and people pay attention to the information exchanged between the system and the outside world. The third parameter is M. The parameter M represents the chemical pattern that controls the brain. The significance of AIM model is that in the study of imitation consciousness, two groups of variables with different properties need to be involved each time. One is the variable of behaviorism method, and the other is the variable that can only be understood through human thinking (Hobson et al., 2000). The "idea" of an action can be awakened by perceiving the action, action imitation is therefore a natural by-product of action perception (Prinz et al., 2009). The AIM theory of psychology has held that imitation is intentional or goal-directed and the goal is to achieve a match between perceived and executed actions (Meltzoff, 2010).

Imitation is shown not only in the presentation of behavior, but also in psychological speculation and simulation (Meltzoff, 2007). When there is a shortage of funds for long-term investment activities such as fixed asset investment and innovation investment, firms can allocate their working capital investment to long-term investment projects to ensure that the projects are carried out smoothly and continuously because of the advantages of lower adjustment cost and easy realization to avoid the cost loss from frequent adjustment of fixed capital (Ding et al., 2013). Therefore, when peer firms change their working capital allocation decisions to cope with market shocks and gain sustainable development, the firms begin redesigning their working capital holdings, and this behavioral imitation is of two types: (1) information transmitted through previous communication channels between the prior adopter and the firm; and (2) information inferred from the results of the actions of industry pioneers (Reppenhagen, 2010). Research on the social influence of psychology suggests that there are a variety of different mechanisms that promote the diffusion of behavior (Bikhchandani et al., 1992). Some of mechanisms are economically rational, while others are driven by human psychology. The social norms interpretation of behavioral imitation suggests that when individuals identify with a social group, the behavior of others in that social group has a greater influence on the social norms of the observer. Such behavior can also be observed in firms. For example, the perceptions of subordinate managers can be influenced by their superiors' evaluation styles.

Due to the existence of information asymmetry in the market, imitation of peers is a natural response to uncertainty (Lieberman and Asaba, 2006). Compared to developed Western countries, working capital management in China is relatively weak, and the influence of cultural embeddedness and informal institutions on economic activities is much more prevalent and profound in China than in the West, suggesting that Chinese firms are more likely to be influenced by other firms' working capital management approaches when they undertake working capital management. Many supermarkets have seen the success of Wal-Mart in the U.S. in using the OPEM financing model to obtain funds for global expansion, and supermarkets of a certain size in China have copied the model, with some firms achieving success, such as Gome, and others failing, such as Suning. Do the similar working capital management patterns of these listed firms imply the existence of peer effects? If so, what the mechanisms work? The existing literature does not provide a reasonable explanation for these questions.

This study investigates the industry peer effects of firms' working capital management using a sample of non-financial firms listed in Chinese A-shares from 2010 to 2021. This study finds that there is an industry peer effect in the working capital management of listed firms, and the working capital management decisions are significantly and positively influenced by firms in the same industry; the formation mechanism of the peer effects is empirically tested, and the moderating effect of knowledge flow is verified.

The possible marginal contributions of the study are: Firstly, based on the theory of AIM in psychology, the study expands the research on working capital management theory considering the moderating effect of knowledge flow. Secondly, although the international psychological community has recently begun to pay attention to the peer effect of accounting behavior, the literature is still small and limited to the existence test of peer effects of accounting behavior, and there is a lack of consensus and rigorous

empirical test on the formation mechanism of peer effects. This study empirically demonstrates knowledge flow as a mechanism of peer effects in working capital management and conducts a rigorous empirical test of it, which will enrich the theoretical findings of peer effects.

Theoretical background and hypotheses

Peer effects mechanisms

Peer influence was defined as getting a balance between being oneself and conforming to group behavior (Hou et al., 2021). Working capital holding acts as a buffer against unexpected shocks to investment (Ben-Nasr, 2016), but there is an optimal threshold for its holding, and a reasonable amount of working capital can contribute to the improvement of corporate performance as well as the increase of value (Kieschnick et al., 2013). If the firm holds too much working capital, although it can meet the liquidity needs of the firm, it will reduce the return on assets of the firm because of its low return; if the firm holds too little working capital, the firm will incur the risk of capital chain breakage. The firm needs to make a trade-off between profitability and liquidity to determine the optimal level of working capital investment (Baños-Caballero et al., 2013).

Decision-making is a complicated process that includes various neural and psychological activities (Jin et al., 2017). How to determine the appropriate working capital holdings? Firms can make decisions either through rational calculations based on their own realities or by imitating the results of behaviors that other firms have implemented. Early research explained the convergence of corporate accounting behavior as an imitative strategy due to weak financial management skills or conservative managers facing decision ambiguity, and attributed this herding behavior of abandoning private information to the role of signaling mechanisms (Manski, 2000). In recent years, with the introduction of peer theory in social psychology, researchers have found that the influence among firms in the same industry is complex and that managers make merger and acquisition decisions (Shue, 2013), investment decisions (Foucault and Fresard, 2014; Leary and Roberts, 2014), and surplus management (Jackson et al., 2017), among other Financial decisions may be made either by directly imitating the results of decision making of peer firms or by updating the results of their own decision basis after learning knowledge of the financial behavior of other firms in the same industry.

In the face of economic downturn and uncertainty, imitating similar factors of peers can partially replace rational calculation factors, and the extent to which firms make decisions based on reference peers shows a positive relationship with the degree of uncertainty (Abrahamson and Rosenkopf, 1997). In the prospectuses published in China, many prospectuses benchmark the working capital management indicators of peers as a basis for judging the reasonableness of firms' working capital holdings. Firms are often faced with uncertainty when making decisions. Logically, firms can reduce the uncertainty of their decisions by imitating the working capital management behavior of other peer firms (Haunschild, 1993). In inter-firm imitation activities, large firms that perform better and are more efficient are more likely to be the targets of imitation and are imitated to a greater extent. While firms are influenced by peer firms when making decisions about working capital holdings, they do not imitate mechanically, but decide on specific imitation strategies by observing information obtained from peer firms' financial statements and other information sources. Accounting information disclosed by peer firms has incremental value and good predictive power for future revenues, working capital management ability, financial distress and bankruptcy risk, and their disclosures have positive spillover effects on users of accounting statements (Durnev and Mangen, 2020). The sales revenue and capital expenditure voluntarily disclosed by peer firms in accounting statements can help managers reading the statements to make more accurate estimates of market demand and supply conditions, gain timely insight into potential investment opportunities, reduce uncertainty about future cash flows of investment projects, and thus make better decisions (Bonsall IV et al., 2013).

Over-holding of working capital can lead to missed opportunities for mergers and acquisitions and lost opportunities to explore new markets, thus damaging the value of the firm, and reallocation of inefficiently allocated assets can improve the firm's share price and its performance in the later years (Denis and Kruse, 2000). Since firms in the same industry face a similar market environment and are highly comparable, the experience of each other is more meaningful for the working capital decision, therefore, when making the decision on working capital holdings, listed firms are likely to obtain information from firms in the same industry and use the working capital management indexes of their peers as a reference, choose a higher working capital holding than their peers, and wait for a higher payout. The impact of peer firms' financing decisions on other firms is more prominent than any other observable factor (Leary and Roberts, 2014). When firms observe that the working capital holdings of other peer firms can generally increase firm value, they will likely be more willing to imitate their peers by holding higher levels of working capital than peer firms; conversely, if they observe that the amount of working capital held by peer firms generally yields poorer performance, they will be less willing to imitate.

Another reason why firms are influenced by peer firms is spillover correlation, which means that prior adoption may change the net benefit of a later adopter's decision. For example, prior adoption by an industry competitor will increase the likelihood that the firm will make a similar decision (Francis and Michas, 2013). Firms in the same industry with similar business activities are natural peers, as they face the same business environment, and perhaps, might be followed by the same media and financial analysts. Firms in the same industry are regularly compared by financial analysts and creditors. Since firms in the same industry

are in a similar environment, they may choose the same similar accounting practices, such as identical mechanisms of earnings management (Kedia et al., 2015). Therefore, in the current study, hypothesis 1 is proposed, as follows:

> *H1*: working capital management has peer effects; that is, the behavior of working capital management of firms in the same industry is positively related to a firm's working capital management.

The moderating effect of knowledge flow

The AIM model of psychology can explain that the imitation consciousness depends on the second parameter I and the combination of I and the other two parameters A and M. The brain is always receiving internal and external information. Only when it is aware of the objective existence of the external world can the brain repeatedly identify the reliability of external information and compare it with internal information to know what external information represents. However, what makes the brain aware of the existence of the external world? This can only be known through introspection and speculation (Hobson et al., 2000). The AIM model is beneficial for working capital management that firms' manager should open the channels of knowledge flow. Knowledge flow can enhance the thinking ability of firm managers, enable them to better cope with the market competition of firms, and help them attain better performance for firms (Zhou and Caroline Bingxin, 2012).

Knowledge flow is one of the many "flows" such as capital flow and logistics, and it is particularly important for firms in the era of intellectual capital and human capital, and it has become a trend to integrate knowledge flow into enterprise supply chain management in order to realize firms' value. Inter-firm competition leads to the flow of knowledge within the network, and imitative competition among neighboring firms has the most direct and intense impact on firm behavior and performance (Gnyawali and Madhavan, 2001). The former refers to imitation behavior in which firms are motivated to obtain information valuable for decision making through imitation and learning, while the latter refers to firms' imitation of their competitors in response to competitive needs. Both types of model behavior are premised on the flow of knowledge. Knowledge flows are knowledge exchanges and interactions among members of social networks driven by motives such as interest or innovation, and mainly include knowledge transfer, sharing, integration, learning, and utilization (Khelladi et al., 2022). From the learning psychology perspective, it is an effective way for entrepreneurs to quickly acquire and accumulate experience through knowledge flow and to do so faster than through their own experiential learning (Baum et al., 2000). Knowledge flows include both symbolic and coded explicit knowledge flows such as joint ventures, alliances and contractual transactions, and tacit knowledge flows such as culturally embedded experiences and insights (Von Krogh and Geilinger, 2014). In the process of working capital management, explicit knowledge includes visualized or textualized knowledge such as various financial periodic reports, securities analysts' reports, stock exchange prospectuses, and various inquiry letters. The flow of such knowledge is usually flowed and acquired by means of online materials. On the other hand, tacit knowledge is mainly hidden in the management experience, decision-making judgment and management methods of key management or technical personnel themselves, and its flow mainly relies on informal ways such as face-to-face communication. Knowledge always develops and improves according to the continuous development from tacit to explicit, generating new explicit knowledge from old explicit knowledge, and then turning to new tacit knowledge that is more conducive to enterprise innovation (Azan et al., 2017).

Essentially, the core of the working capital holding decision is the process of weighing the impact of working capital holding on the value creation and risk level of the firm, and the optimal level of working capital holding should be the level at which the firm's value is maximized and the financial risk is minimized. In the real environment, due to differences in individual firm characteristics and external frictions, the firm's working capital tends to deviate from the optimal level and is constantly adjusted. The determination of the optimal level is a difficult problem (Baños-Caballero et al., 2013). According to the knowledge flow theory, accounting information disclosed by peer firms can help firms preparing investment decisions to reduce investment uncertainty, especially when this firm is subject to common needs with the firm disclosing the information. The financial statements, management discussion and analysis disclosed in the annual reports of listed firms have high reference value for information user. The forward-looking letter of reports analyses the future business performance, development strategies and business policies of firms. The positive tone of management discussion and analysis in the reports may imply optimistic judgments about the future, which will change the information set of readers and affects the behavior of their investment decisions (Roychowdhury et al., 2019). Of course, if peer firms' disclosures are truthful, their disclosures can generate positive externalities for the firms concerned, but negative externalities can also arise if peer firms misrepresent their performance.

Changes in resource operations and investment and financing decisions of peer competitors can put pressure on firms, forcing them to maintain a high level of innovation sensitivity, proactively absorb new knowledge, and adopt self-regulation and absorption of external knowledge to converge themselves with leading firms (Hoffmann et al., 2018). The flow of knowledge increases financial reporting transparency and reduces adverse selection behavior of corporate managers, thus reducing the cost of capital, enabling efficient resource allocation by increasing total factor productivity, keeping working capital in line with peers, and allocating more capital to higher-yielding projects such as innovation investments,

thus enabling the follower firms to benefit from competition (Hashmi, 2013). The increasing quality of regulatory supervision of financial and non-financial information has improved the quality of information disclosure of peer firms and increased the comparability and relevance of information. This knowledge flow will enable firms to keep abreast of the capital allocation status of their peers and reduce the allocation of working capital with low yields in a timely manner. In addition, with the advancement of computer text analysis technology, the textual characteristics of non-financial information can be better portrayed, providing information users with incremental knowledge that was not available through previous channels, and providing feasible technical support for peers to learn from the accessibility of non-financial information disclosed mainly in textual form (Yuan et al., 2022). The availability of big data and sophisticated data analytics tools increases access to knowledge of peer working capital decisions. With the increase of knowledge, managers have reduced the investment decision-making errors caused by behavioral biases such as overconfidence, limited attention span, loss aversion and misjudgment. Sensible managers do not allocate capital to working capital that does not yield high returns (Baker and Wurgler, 2013). Based on this argument it can be reasonably inferred that the knowledge flow among peers can reduce managers' uncertainty about their own firm's growth opportunities, increase the allocation of higher-yielding long-term investments and reduce the allocation of lower-yielding working capital. Therefore, hypothesis 2 is proposed, as follows:

> *H2*: The positive relationship between the behavior of working capital management of firms in the same industry and a firm's working capital management behavior is moderated by knowledge flow.

Study design

Data source

The samples are taken from all A-share listed firms in China from 2010 to 2021. we sort data as the following criteria: (1) exclude insolvent firms; (2) exclude ST, ST* firms and financial firms; (3) exclude firms with total assets, total liabilities, operating revenue, and operating costs equal to 0 or missing. The financial data involved in the study are gathered from the CSMAR database. Since the firm management methods of Hong Kong, Macao and Taiwan firms and foreign-funded firms are different from those of domestic firms, we exclude these firms from the sample so that we can achieve the goal of an in-depth study on the heterogeneity of knowledge flow. When calculating the industry indicator variables, firms with less than 10 industries are also excluded to avoid their interference with the test results. At the same time, in order to avoid the influence of extreme variables on the study results, the continuous variables below the 1% and above the 99% quantile are subjected to winsorize. We obtain a maximum sample of 35,074 Chinese firms.

Model specifications and measurement of variables

In order to verify the hypotheses proposed in Section "Peer Effects Mechanisms," the following regression models are constructed as follows:

$$\begin{aligned} \mathrm{DNWC}_{it} &= \beta_0 + \beta_1\ \mathrm{peerNWC}_{it} \\ &+ \beta_2^{`}\mathrm{Cont1}_{it} + \beta_2^{`}\mathrm{Cont2}_{it} + \epsilon_{it} \end{aligned} \tag{1}$$

The dependent variable, DNWC_{it} is a proxy variable for working capital management as firm *i* in year *t*, and considering an incremental investment in working capital, $\mathrm{DNWC} = \mathrm{DNWC}_{it} - \mathrm{DNWC}_{it-1}$, and divided by total assets to eliminate the size effect. Following the study of Iqbal and Zhuquan (2015), working capital is defined as the value of NWC calculated in Table 1 and divided by total assets to eliminate the size effect; another measure of working capital is the method of Baños-Caballero et al. (2014), NWC1 = Current Assets - Current liabilities, $\mathrm{DNWC1} = \mathrm{DNWC1}_{it} - \mathrm{DNWC1}_{it-1}$, In the baseline regression model, DNWC is used in the study; in the robustness test, DNWC1 is substituted in the study.

The independent variable, peerNWC, is a proxy variable for working capital management of peer firms in the same industry as firm *i* in year *t*. We exclude firm i's working capital management in computing the average frequency to avoid a mechanical correlation. We include firm-level control variables (Cont1) that are regarded as primary determinants of firms' working capital management.

Referring to existing research (Kedia et al., 2015; Gao et al., 2021), this study controls other factors possibly influencing the working capital management including firm size, firm age, firm growth, gearing ratio, TobinQ, cash to total assets ratio, and return on assets (De Almeida and Eid 2014). We also include peer firm averages variables (Cont2) to control for the contextual effects and denote them by the prefix "peer" (Boone and White, 2015). ϵ_{it} is the random error term of the model. In addition, industry and year dummy variables are also set in the study. The model focuses on the regression coefficient of working capital management of peer firms. If the working capital management behavior of peers directly affects the working capital management behavior of firms, β1 is significant positive, indicating the peer effects of working capital management. Table 1 provides details of the main variable.

Statistical analysis

Descriptive statistics of all the dependent variable and independent variables involved in the regression model are illustrated in Table 2.

TABLE 1 Description of variables.

Variable	Abbreviation	Definition
Working capital	NWC	Current assets-current liabilities
	NWC1	(Net notes receivable + Net accounts receivable + Net prepayments + Net inventory) − (Notes payable + Accounts payable + Receipts in advance + Employee remuneration payable + Taxes payable)
Working capital of peer companies	peerNWC	(Industry total capital-Company's own capital)/(N-1)
Knowledge flow	KF	The firm's stock idiosyncratic return
Enterprise size	Size	ln(total assets)
Business age	Age	ln(Year of company establishment+1)
Business growth	Grow	Annual operating income growth rate
Balance sheet ratio	lev	The ratio of total debt to total assets
Tobin's value	TobinQ	The ratio of the firm market value to total assets.
Cash holding ratio	cashR	The ratio of total debt to total assets
Net return on assets	ROA	The ratio of net profit to total assets
Peer company size	peersize	Average size of other companies in the same industry
Peer business age	peerage	Average age of other companies in the same industry
Peer business growth	peergrowth	Sales growth rate of peer companies
Peer balance sheet ratio	peerlev	Gearing ratio of peer companies
Tobin's value	peerTobinQ	Tobin's value of peer companies
Peer cash holding ratio	peercashR	Cash holding ratio of peer companies
Peer net return on assets	peerROA	Net return on assets of peer companies

TABLE 2 Descriptive statistics for the sample.

Variable	*N*	Mean	Sd	Min	p25	p50	p75	Max
DNWC	30,589	0.014	0.233	−6.633	−0.020	0.011	0.047	33.081
peerNWC	30,581	0.012	0.021	−0.263	0.006	0.013	0.021	0.151
KF	21,926	0.077	0.243	−0.616	−0.023	0.024	0.117	1.074
Size	35,074	22.098	1.361	13.763	21.149	21.916	22.848	28.637
Age	35,075	2.870	0.362	0.000	2.639	2.944	3.135	4.159
lev	35,074	0.441	1.095	−0.195	0.249	0.410	0.578	178.345
ROA	35,074	0.037	0.702	−48.316	0.015	0.039	0.070	108.366
Growth	30,633	5.438	773.906	−2.733	−0.024	0.109	0.274	134,600.000
cashR	35,074	0.193	0.144	0.000	0.092	0.152	0.250	1.000
TobinQ	30,100	2.173	2.834	0.641	1.243	1.636	2.380	259.146
peersize	35,065	22.098	0.543	19.527	21.821	22.040	22.107	24.014
peerage	35,066	2.870	0.177	1.386	2.765	2.896	2.992	3.407
peerlev	35,065	0.441	0.083	0.128	0.386	0.416	0.455	0.929
peerROA	35,065	0.037	0.028	−0.155	0.024	0.034	0.048	0.182
peergrowth	30,625	5.205	157.010	−0.348	0.174	0.381	0.488	5,852.680
peercashR	35,065	0.193	0.049	0.087	0.172	0.178	0.202	0.605
peerTobinQ	30,093	1.855	0.564	0.821	1.536	1.759	2.089	13.003

Because the firms engage in different industries and have different sizes, their working capital management levels vary. The maximum, mean and minimal values of variables presented in Table 2 indicate this argument. At the same time, it can be found from the table that the mean value ratio of the incremental working capital allocation is 1.36%, which indicates that the working capital of Chinese listed firms is showed a slight increase, which is in line with the situation that the GDP growth rate of China has been declining in recent years; the mean value of the working capital allocation growth of peer firms is 1.24%, but the growth rate is lower than the mean value of individual firms. This initially indicates that the working capital allocation of individual firms is higher than that of the peer firms. In Table 2, we can also find that the average age of Chinese listed firms is 2.87 years; the average value of asset liability ratio is 44%; the average value of return on assets is 3.67%; the average value of sales revenue growth is 5.4%, which is very volatile and very unbalanced between firms despite extreme values are processed by winsorize

mode; the average value of the ratio of cash to assets is 19%; the average value of TobinQ is 2.17.

Result and discussion

Testing of hypotheses

In this study, the main variables are analyzed for correlation. Except that the correlation coefficient between the net return on assets and the proportion of working capital holdings is 0.7881, the correlation coefficient between other variables is less than 0.5. This shows that there is little possibility of multicollinearity between other variables. Due to the length limitation of this research, the correlation coefficient between variables is not listed in the table.

In Table 3, Model 1 shows the results of the multiple regression analysis controlling for all control variables, and the correlation coefficient between the independent and dependent variables is 0.7810, which is significantly positive at the 1% level. In terms of economic significance, the behavior of working capital management of firms in the same industry is positively related to a firm's working capital management, which statistically and empirically holds hypothesis H1, indicating the existence of a working capital allocation peer effect. Similar findings were reported by Machokoto et al. (2022), who found that the effect of peer influence is positive in working capital management.

From the OLS analysis of control variables: Firstly, at the firm-level, firm size, firm growth, and cash to total assets ratio are negatively related to firms' working capital allocation; firm age, and return on assets are positively related to firms' working capital allocation; asset liability ratio, and TobinQ are not related to firms' working capital allocation. Secondly, at the peer level, only the ROA of peer firms is negatively related to the working capital allocation of firms, while other variables are not related to the working capital allocation of firms. Although the OLS analysis does not control for endogeneity issues, it provides explicit premises about the effect of the findings and provides a minimum validation of the model.

Robustness tests

Changing the measuring method of the dependent variable and independent variables

To further verify the robustness of the baseline model, this section presents robustness tests conducted from the aspects of changing the measurement of working capital management and peer firms. In the robustness test, we replace DNWC, peerNWC with DNWC1 and peerNWC1, respectively. The regression results are shown in Model 2 of Table 3. In this case, the peer effects of working capital management are significant positive ($\beta_1 = 0.121$, $p < 0.05$) at the 5% level, and the magnitudes are very robust.

TABLE 3 Peer effect regression results.

	Model 1	Model 2	Model 3
	Baseline regression	Changing dependent and independent variables	Firm level fixed effects
Variables	DNWC	DNWC1	DNWC
peerNWC	0.781***		0.784***
	(13.615)		(21.675)
peerNWC1		0.121**	
		(2.489)	
Size	−0.002**	0.007***	0.006***
	(−2.016)	(4.276)	(4.023)
Age	−0.010***	0.023***	−0.040***
	(−5.867)	(10.905)	(−4.187)
lev	0.004	−0.034**	−0.026***
	(0.413)	(−1.975)	(−4.274)
ROA	0.299***	0.456***	0.305***
	(6.818)	(8.138)	(43.160)
Growth	−0.000**	−0.000***	−0.000
	(−2.442)	(−2.855)	(−1.596)
cashR	−0.067***	0.107***	−0.104***
	(−8.247)	(10.721)	(−15.553)
TobinQ	−0.000	−0.000	0.001**
	(−0.102)	(−0.556)	(2.104)
peersize	0.009	−0.017**	−0.001
	(0.739)	(−2.047)	(−0.376)
peerage	−0.013	−0.011	−0.038*
	(−0.509)	(−0.332)	(−1.933)
peerlev	−0.014	−0.023	0.011
	(−0.605)	(−0.887)	(0.531)
peerROA	−0.125***	−0.119**	−0.122***
	(−4.205)	(−2.334)	(−4.316)
peergrowth	0.000	−0.000	0.000
	(0.672)	(−0.222)	(0.216)
peercashR	0.044	−0.199***	0.049
	(0.836)	(−4.614)	(1.535)
peerTobinQ	−0.000	0.003	−0.001
	(−0.172)	(1.130)	(−0.421)
Firm\year fixed effects	YES	YES	Only firm
Constant	−0.060	0.214	
	(−0.217)	(0.992)	
N	28,710	28,710	28,312
R^2	0.131	0.198	0.264

Robust t-statistics in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Firm-level fixed effects

In the baseline OLS model, there may be omitted variables not mentioned in the literature that affect working capital allocation, thus creating an endogeneity problem. Every firm has its specific

attributes that may affect the independent or dependent variables, so we need to control the fixed effect at the firm level to avoid such situation. Hausman's test for (fixed effects—random effects) is $\chi^2(40) = 331.58$ with value of p of 0.000. The statistical outcome suggests that a fixed effects model should be used. The fixed effect model eliminates those time-invariant characteristics to assess the net effect of the independent variable on the result variable. We substitute the baseline OLS model with the fixed effects model that controls for the effects of firm and time, and the outcomes are displayed in Model 3 of Table 3. The estimated coefficient is 0.7838, and the test results are still significant at the 1% level. This suggests that the core conclusion of our research, "a firm's working capital management is positively influenced by peer effect of firms" still holds.

Endogeneity test

From the logic of the interaction between the peer effects on the firm's working capital allocation, there may be an endogeneity problem between them caused by mutual causality and sample selectivity bias. To reduce the endogeneity problem, we employ the instrumental variable method to test the endogeneity of explanatory variable.

Therefore, we refer to the relevant work of Denis and McKeon (2012) and Chang et al. (2014) and choose target debt ratio (peertr) as an instrumental variable because it satisfies the selection criteria of instrumental variables: Firstly, target debt ratio meets the exogenous assumption of instrumental variables, which excludes industry and market effects in the calculation of target debt ratio, and thus can accurately reflect the information of firm-level working capital management. Secondly, target debt ratio meets the correlation assumption of instrumental variables, where the target debt ratio is correlated with the peer firms' working capital allocation. Table 4 shows the outcomes of instrumental variables tests. In Model 4, the outcomes of the first stage indicates that peertr is significantly negatively correlated with peerNWC. In Model 5, the second stage results indicate that the regression coefficient of peerNWC is significantly positively correlated with DNWC at the 1% level, and the F-statistic value is 930.078, which is greater than the empirical value of 10, indicating that the target debt ratio has a strong explanatory power for peerNWC and is unlikely to have a weak instrumental variable problem. Furthermore, after the exogeneity tests of the variable are carried out, the Durbin (score) chi2(1) is 4.36005($p = 0.0368$), proving that the explanatory variable is endogenous. The outcomes of the study are Robust.

TABLE 4 Regression results with two-stage least square (2SLS).

	Model 4	Model 5
	First stage	Second stage
Variables	peerNWC	DNWC
peertr	−0.179***	
	(0.006)	
peerNWC		0.875***
		(0.204)
Size	0.000***	−0.003***
	(0.000)	(0.001)
Age	−0.001**	−0.010***
	(0.000)	(0.002)
lev	−0.001**	0.010***
	(0.001)	(0.003)
ROA	−0.001	0.296***
	(0.001)	(0.006)
Growth	0.000	−0.000
	(0.000)	(0.000)
cashR	−0.001	−0.065***
	(0.001)	(0.005)
TobinQ	0.000	−0.000
	(0.000)	(0.000)
peersize	0.044***	0.004
	(0.001)	(0.008)
peerage	−0.081***	0.004
	(0.004)	(0.033)
peerlev	−0.070***	−0.003
	(0.004)	(0.028)
peerROA	0.174***	−0.140***
	(0.004)	(0.046)
peergrowth	0.000	0.000
	(0.000)	(0.000)
peercashR	−0.205***	0.059
	(0.006)	(0.043)
peerTobinQ	0.003***	−0.001
	(0.000)	(0.002)
Year\industry fixed effects	YES	YES
Constant	−0.597***	−0.015
	(0.028)	(0.164)
N	28,140	28,140
R^2	0.571	0.116
First stage F statistic	930.078	

Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Moderating effect test

To test whether there is a moderating effect of knowledge flow (KF) between the allocation of working capital of the peer firms and the allocation of working capital of the firms, Equation (2) is developed in a bid to verify H2 as follows:

$$\mathrm{DNWC}_{it} = \beta_0 + \beta_1\,\mathrm{peerNWC}_{it} + \beta_2 \mathrm{peerNWC}_{it} * \mathrm{KF} + \beta_3\,\mathrm{KF} + \beta_4^{`}\,\mathrm{Cont1}_{it} + \beta_5^{`}\mathrm{Cont2}_{it} + \in_{it} \quad (2)$$

Where, i and t represent firm, year, respectively. $\in$ denotes residuals. DNWC, peerNWC and Controls are in keeping with how the variables are defined in the previous baseline regression. The moderating variable, KF, is a proxy variable for knowledge flow. Knowledge is inherently intangible and knowledge flow is in

a constant state of change, so measuring the degree of knowledge flow becomes very difficult (Nissen, 2019), especially for tacit knowledge. The number of citations or citations of patent and non-IP documents are often used by scholars to measure knowledge flow because of their tangible and traceable knowledge flow relationship, but they are mainly used to reflect the flow trajectory of explicit knowledge and cannot reflect the flow of tacit knowledge (Wu and Mathews, 2012). Further, some scholars compute the number of clicks on patents, brands and publications of Baidu and Google search engine firms to reflect the firms' knowledge flow. However, due to the current trend of mobile applications to replace computer search engines, the accuracy of this indicator is questioned. Regardless of the above-mentioned methods, it is impossible to make accurate measurement of knowledge flow intensity. It is especially important to choose appropriate methods in the face of different application research purposes and scenarios, especially to combine subjective and objective methods to jointly evaluate Knowledge Flow intensity from multiple perspectives. According to the efficient market theory, all information and knowledge flow are fully or partially reflected in the stock price, and the stock idiosyncratic return is a suitable metric for knowledge flow. Referring to the study of Liu et al. (2019), the intensity of the KF is computed as follows:

$$\mathrm{KF}_{it} = \alpha + \beta_{ijt}^{M}\left(\gamma_{t}^{M} - rf_{t}\right) + \beta_{ijt}^{\mathrm{ind}}\left(\gamma_{ijt}^{\mathrm{peer}} - \mathrm{rf}_{t}\right) + \varepsilon_{ijt} \quad (3)$$

where the indices *i*, *j*, and *t* correspond to firm, region, and month, respectively. γ^{M} denotes the market rate of return, γ^{peer} denotes the peer firms' stock yield. rf_t denotes the risk-free rate of return. The specific computing steps are as follows: Firstly, at the beginning of each year, the monthly data of the industry for the previous 36 months are used to regress Equation (3), and the corresponding coefficient values are calculated. The regression coefficients at the beginning of the year are used to calculate the expected value of corporate stock returns for each month, and the actual stock returns for each month are subtracted from the expected stock returns to obtain the volatility of corporate stock returns for each month, i.e., the firm stock idiosyncratic returns for each month in the year. Secondly, the arithmetic mean of the firm's stock idiosyncratic return for each month of the year is calculated to obtain the annual firms' stock idiosyncratic return. Thirdly, the average annual stock idiosyncratic return of other firms in the same industry is calculated and used as a proxy variable for knowledge flow in the study.

Model 6 is developed to test the hypothesis (H2). We added knowledge flow (KF) as a moderator variable to our Model 6. The coefficient of KF is also positively significant with the peerNWC in Model 6 ($t = 5.071$, $p < 0.01$). When we implement our full interaction models peerNWC × KF, the coefficient is positively significant with the peerNWC in Model 6 and supports H2 ($t = 3.316$, $p < 0.01$). The results confirm that knowledge flow acts as a moderator. The economic implications of this outcome indicate that knowledge flow has an enhanced relationship between the behavior of working capital management of firms in the same industry and a firm's working capital management behavior. In other words, the stronger the knowledge mobility is, the more firms and peers communicate is, the greater the amount of information acquired is, and the more significant the peer effects is.

Moreover, to further explain the moderating effect of knowledge flows, the research samples are divided into two subsamples, including the low group of knowledge flow and the high group of knowledge flow. We define the sample group with knowledge flow greater than the industry median as the high group of knowledge flow and the sample group with knowledge flow lower than the industry median as the low group of knowledge flow. The value of the high group is coded "1," otherwise it is coded "0." This study still uses the empirical model constructed by Equation (2), and the regression outcomes are reported in Table 5.

In the two subsamples of low group and high group, the regression results can be seen in Model 7 and Model 8 of Table 5: in the low group of knowledge flow, the coefficient of moderating effect is 0.843, which is significant at the level under 1%; in the high group of knowledge flow, the coefficient of peer effects is 0.985, which is significant at the level under 1%. In the study, after doing a mean comparison test for the difference in coefficients between groups, the results show that the difference in means is significant at the 1% level. This indicates that the difference in coefficients between the two groups is comparable. This also suggests that the moderating effect of knowledge flow in the high group of knowledge flow are greater than that of in the low group of knowledge flow, explaining the paradox of why the full sample knowledge flow has a negative effect on the peer effects. In the high group of knowledge flow, the correlation coefficient of ROA for the financial characteristics of the group of firms is significantly different from zero, indicating that a firm adjusted their working capital management by imitating and learning the financial characteristics of peer firms.

The peer effects of working capital management consist of three components: subject, the imitated behavior and environment. Among them, the imitation ability of imitators in the subject determines the effective implementation of the imitated behavior. Firstly, from the perspective of the imitated, their high working capital allocation ratio indicates a lack of confidence in the future and an increased incentive to prevent saving; a low working capital allocation ratio indicates that the firm mainly relies on long-term investment layout to support its development and is confident in the future. Therefore, the working capital allocation behavior of industry leaders is significant for industry followers and can attract them to imitate it. For industry followers, the uncertainty of economic policies can significantly increase the loan cost of firms in the process of GDP downturn. By imitating and learning to adjust their working capital and long-term capital structure, firms can not only reduce the financing cost, but also effectively reduce the financial risk caused by investment misjudgment.

TABLE 5 Moderating effect of knowledge flow.

	Model 6	Model 7	Model 8
	All samples DNWC	Low group DNWC	High group DNWC
peerNWC	0.396***	0.231***	0.524***
	(5.071)	(2.831)	(6.642)
peerNWC*KF	1.038***	0.843***	0.985***
	(3.316)	(4.219)	(3.431)
KF	−0.014**		
	(−2.041)		
Size	−0.002***	−0.001	−0.002***
	(−3.582)	(−1.450)	(−2.915)
Age	−0.011***	−0.011***	−0.011***
	(−7.112)	(−4.400)	(−4.422)
lev	−0.004	−0.005	−0.003
	(−0.703)	(−0.991)	(−0.556)
ROA	0.250***	0.274***	0.217***
	(11.346)	(22.661)	(16.275)
Growth	−0.000***	−0.000*	0.000***
	(−2.593)	(−1.798)	(5.046)
cashR	−0.067***	−0.071***	−0.064***
	(−11.364)	(−10.382)	(−9.432)
TobinQ	0.001	0.000	0.003***
	(1.095)	(1.002)	(6.303)
peersize	−0.014	−0.021**	−0.004
	(−1.506)	(−2.045)	(−0.397)
peerage	0.014	−0.008	−0.014
	(0.439)	(−0.182)	(−0.332)
peerlev	−0.003	−0.024	−0.006
	(−0.101)	(−0.686)	(−0.169)
peerROA	−0.037***	−0.035***	−0.048***
	(−2.169)	(−1.857)	(−3.216)
peergrowth	0.000	−0.000	0.000
	(0.143)	(−1.055)	(1.111)
peercashR	−0.038	−0.114**	0.018
	(−0.954)	(−2.295)	(0.388)
peerTobinQ	−0.000	−0.000	0.001
	(−0.090)	(−0.127)	(0.389)
_cons	0.374	0.577**	0.218
	(1.553)	(2.142)	(0.820)
Year\industry fixed effect	YES	YES	YES
N	17,758	8,821	8,872
Adj. R^2	0.084	0.099	0.077

T statistics in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Secondly, in terms of imitators, it is generally small firms that imitate large firms, and few large firms imitate small firms. The imitation behavior reflects management's risk preference in the investment process (Zhou and Xu, 2019). The lower the risk-taking level of management is, the weaker the risk appetite will be, and the more liquid assets such as trading financial assets will be allocated. The more stable the working capital decisions of firms become, the stronger the need for managers to refer to similar decisions of peer firms. The more obvious the peer effect of working capital management is, the stronger the ability of imitating other firms to allocate assets is.

Thirdly, working capital allocation decisions are not only determined by the internal resources and capabilities of firms, but also closely related to the external macro environment. The environment of knowledge flow will affect the firms' ability to adjust long- and short-term capital structure. In addition, the rise and fall of the industry will also affect the demand for working capital of firms, and thus affect the willingness and direction of firms' working capital adjustment.

Conclusion

Based on the Active Intermodal Matching theory of psychology, this study investigates the peer effects of working capital management using data from listed firms in China from 2010 to 2021 to draw the following conclusions: Firstly, there is a peer effect in firms' working capital allocation. Secondly, the amount of corporate working capital allocation increases with the increase of peer firms' working capital allocation. Thirdly, the peer effect of working capital works through the channel of knowledge flow, and the peer effects in the high group of knowledge flow are greater than that of in the low group of knowledge flow.

Theoretical implications

The study has important theoretical contributions. Firstly, it verifies the existence of the peer effects of working capital allocation decisions and analyzes the mechanism of the peer effects of working capital decisions qualitatively through the channel of knowledge flow. It is different from most of the prior study that only analyzes the peer effect through the mechanism of imitation and learning. It answers the question, "What channels do firms learn from their peers?"

Secondly, it conducts a rigorous empirical test of knowledge flow as a mechanism of peer effects in working capital management, which will enrich the international research on accounting behavior and provide a reference for other studies on the peer effects of accounting behavior.

Practical implications

The study also has important practical implications. Firstly, it reveals the facts that for firm practitioners, adjusting the amount of working capital allocation is an important means to hedge against economic uncertainty; and imitating the behavior of peer firms can reduce the uncertainty of decision making.

However, when the competition in the same industry becomes more and more intense, it is easy to form vicious competition and produce over-investment or under-investment, therefore, firms should focus on considering the behavior of competitors when making relevant decisions to maintain competitive parity or limit competition. Since 2020, the COVID-19 epidemic has increased the economic uncertainty and the operating risks of firms. The firms' managers have been exploring possible pathways to manage and overcome financial distress and crisis. The practical significance of peer effects is to guide managers to respond to the crisis by imitating the excellent firm behavior of peers. Thus, the firm should take steps to increase its imitation capabilities. For example, as the top financial officer of the firm, the CFO should pay greater attention to peers' activities and behaviors.

Secondly, working capital holdings are negatively correlated with the net profit margin of peer assets, indicating that to obtain higher profit margins, working capital holdings must be reduced, but working capital is closely related to operating cash flow, and the timing and amount of operating cash flow is uncertain, as well as the mismatch between cash inflows and outflows in time, making the firm often have a cash flow gap, which increases the firm's inability to timely repay debt. This increases the risk that the firm will not be able to pay its debts on time. The solution to this dilemma is to accelerate working capital turnover and support as much operating income with as little working capital as possible in order to keep the firm free from solvency risk.

Thirdly, knowledge flow among peer firms is an important channel to transfer information. Information acquisition not only comes from the financial characteristics of peers, but also from information outside the peer firms. The government has more information advantages than firms, and should establish an effective information disclosure platform to regularly provide true and reliable investment information. At the same time, the government should communicate and exchange investment information policies with firms in a timely manner to enable firms to obtain more comprehensive information, so that firms improve the quality and efficiency of working capital management.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MZ contributed to establishment of the theory, the writing—original draft preparation, and the software. BM helped to analyze the data and editing. YL contributed to the calculations. All authors have read and agreed to the published version of the manuscript.

Funding

This research was supported by the project of a core course for graduate students of Yunnan Normal University under Grant No. YH2020-C09 and by the project for Case Database-Building of Yunnan Provincial Department of Education.

Acknowledgments

The authors sincerely thank all the participants of this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abrahamson, E., and Rosenkopf, L. (1997). Social network effects on the extent of innovation diffusion: a computer simulation. *Organ. Sci.* 8, 289–309. doi: 10.1287/orsc.8.3.289

Acedo-Carmona, C., and Gomila, A. (2015). Trust matters: a cross-cultural comparison of northern Ghana and Oaxaca groups. *Front. Psychol.* 6:661. doi: 10.3389/fpsyg.2015.00661

Adhikari, B., and Agrawal, A. (2018). Peer influence on payout policies. *J. Corp. Financ.* 48, 615–637. doi: 10.1016/j.jcorpfin.2017.12.010

Azan, W., Bootz, J. P., and Rolland, O. (2017). Community of practices, knowledge transfer, and ERP project (ERPP). *Knowl. Manag. Res. Pract.* 15, 238–256. doi: 10.1057/s41275-017-0047-9

Baker, M., and Wurgler, J. (2013). "Behavioral corporate finance: an updated survey," in *Handbook of the Economics of Finance*. eds. G. M. Constantinides, M. Harris and R. M. Stulz, vol. *2* (Amsterdam: Elsevier), 357–424. doi: 10.1016/B978-0-44-453594-8.00005-7

Bandura, A., Ross, D., and Ross, S. A. (1961). Transmission of aggression through imitation of aggressive models. *J. Abnorm. Soc. Psychol.* 63, 575–582. doi: 10.1037/h0045925

Baños-Caballero, S., García-Teruel, P. J., and Martínez-Solano, P. (2013). The speed of adjustment in working capital requirement. *Eur. J. Financ.* 19, 978–992. doi: 10.1080/1351847X.2012.691889

Baños-Caballero, S., García-Teruel, P. J., and Martínez-Solano, P. (2014). Working capital management, corporate performance, and financial constraints. *J. Bus. Res.* 67, 332–338. doi: 10.1016/j.jbusres.2013.01.016

Baum, J. C., Li, S. X., and Usher, J. M. (2000). Making the next move: how experiential and vicarious learning shape the locations of chains' acquisitions. *Adm. Sci. Q.* 45, 766–801. doi: 10.2307/2667019

Ben-Nasr, H. (2016). State and foreign ownership and the value of working capital management. *J. Corp. Finan.* 41, 217–240. doi: 10.1016/j.jcorpfin.2016.09.002

Bikhchandani, S., Hirshleifer, D., and Welch, I. (1992). A theory of fads, fashion, custom, and cultural change as informational cascades. *J. Polit. Econ.* 100, 992–1026. doi: 10.1086/261849

Bonsall, S. B. IV, Bozanic, Z., and Fischer, P. E. (2013). What do management earnings forecasts convey about the macroeconomy? *J. Account. Res.* 51, 225–266. doi: 10.1111/1475-679x.12007

Boone, A. L., and White, J. T. (2015). The effect of institutional ownership on firm transparency and information production. *J. Financ. Econ.* 117, 508–533. doi: 10.1016/j.jfineco.2015.05.008

Brunner, M., and Ostermaier, A. (2019). Peer influence on managerial honesty: the role of transparency and expectations. *J. Bus. Ethics* 154, 127–145. doi: 10.1007/s10551-017-3459-9

Chang, Y. K., Chou, R. K., and Huang, T. H. (2014). Corporate governance and the dynamics of capital structure: new evidence. *J. Bank. Financ.* 48, 374–385. doi: 10.1016/j.jbankfin.2014.04.026

Crotty, J. (2003). The neoliberal paradox: the impact of destructive product market competition and impatient finance on nonfinancial corporations in the neoliberal era. *Rev. Radic. Polit. Econ.* 35, 271–279. doi: 10.1177/0486613403255533

De Almeida, J. R., and Eid, W. (2014). Access to finance, working capital management and company value: evidences from Brazilian companies listed on BM & FBOVESPA. *J. Bus. Res.* 67, 924–934. doi: 10.1016/j.jbusres.2013.07.012

Denis, D. J., and Kruse, T. A. (2000). Managerial discipline and corporate restructuring following performance declines. *J. Financ. Econ.* 55, 391–424. doi: 10.1016/S0304-405X(99)00055-0

Denis, D. J., and McKeon, S. B. (2012). Debt financing and financial flexibility evidence from proactive leverage increases. *Rev. Financ. Stud.* 25, 1897–1929. doi: 10.1093/rfs/hhs005

Ding, S., Guariglia, A., and Knight, J. (2013). Investment and financing constraints in China: does working capital management make a difference? *J. Bank. Financ.* 37, 1490–1507. doi: 10.1016/j.jbankfin.2012.03.025

Durnev, A., and Mangen, C. (2020). The spillover effects of MD & a disclosures for real investment: the role of industry competition. *J. Account. Econ.* 70:101299. doi: 10.1016/j.jacceco.2020.101299

Foucault, T., and Fresard, L. (2014). Learning from peers' stock prices and corporate investment. *J. Financ. Econ.* 111, 554–577. doi: 10.1016/j.jfineco.2013.11.006

Francis, J. R., and Michas, P. N. (2013). The contagion effect of low-quality audits. *Account. Rev.* 88, 521–552. doi: 10.2308/accr-50322

Gao, Y., Cai, C., and Cai, Y. (2021). Regional peer effects of corporate tax avoidance. *Front. Psychol.* 12:744371. doi: 10.3389/fpsyg.2021.744371

Gnyawali, D. R., and Madhavan, R. (2001). Cooperative networks and competitive dynamics: a structural embeddedness perspective. *Acad. Manag. Rev.* 26, 431–445. doi: 10.5465/amr.2001.4845820

Hashmi, A. R. (2013). Competition and innovation: the inverted-U relationship revisited. *Rev. Econ. Stat.* 95, 1653–1668. doi: 10.1162/REST_a_00364

Haunschild, P. R. (1993). Interorganizational imitation: the impact of interlocks on corporate acquisition activity. *Adm. Sci. Q.* 38:564. doi: 10.2307/2393337

Hobson, J. A., Pace-Schott, E. F., and Stickgold, R. (2000). Dreaming and the brain: toward a cognitive neuroscience of conscious states. *Behav. Brain Sci.* 23, 793–842. doi: 10.1017/S0140525X00003976

Hoffmann, W., Lavie, D., Reuer, J. J., and Shipilov, A. (2018). The interplay of competition and cooperation. *Strateg. Manag. J.* 39, 3033–3052. doi: 10.1002/smj.2965

Hou, T., Hou, K., Wang, X., and Luo, X. R. (2021). Why I give money to unknown people? An investigation of online donation and forwarding intention. *Electron. Commer. Res. Appl.* 47:101055. doi: 10.1016/j.elerap.2021.101055

Iqbal, A., and Zhuquan, W. (2015). Working capital management and profitability evidence from firms listed on Karachi Stock Exchange. *Int. J. Bus. Manag.* 10:231. doi: 10.5539/ijbm.v10n2p231

Jackson, A. B., Rountree, B. R., and Sivaramakrishnan, K. (2017). Earnings co-movements and earnings manipulation. *Rev. Acc. Stud.* 22, 1340–1365. doi: 10.1007/s11142-017-9411-5

Jin, J., Zhang, W., and Chen, M. (2017). How consumers are affected by product descriptions in online shopping: event-related potentials evidence of the attribute framing effect. *Neurosci. Res.* 125, 21–28. doi: 10.1016/j.neures.2017.07.006

Kedia, S., Koh, K., and Rajgopal, S. (2015). Evidence on contagion in earnings management. *Account. Rev.* 90, 2337–2373. doi: 10.2308/accr-51062

Khelladi, I., Castellano, S., Hobeika, J., Perano, M., and Rutambuka, D. (2022). Customer knowledge hiding behavior in service multi-sided platforms. *J. Bus. Res.* 140, 482–490. doi: 10.1016/j.jbusres.2021.11.017

Kieschnick, R., Laplante, M., and Moussawi, R. (2013). Working capital management and shareholders' wealth. *Rev. Financ.* 17, 1827–1852. doi: 10.1093/rof/rfs043

Leary, M. T., and Roberts, M. R. (2014). Do peer firms affect corporate financial policy? *J. Financ.* 69, 139–178. doi: 10.1111/jofi.12094

Lieberman, M. B., and Asaba, S. (2006). Why do firms imitate each other? *Acad. Manag. Rev.* 31, 366–385. doi: 10.5465/amr.2006.20208686

Liu, J., Stambaugh, R. F., and Yuan, Y. (2019). Size and value in China. *J. Financ. Econ.* 134, 48–69. doi: 10.1016/j.jfineco.2019.03.008

Machokoto, M., Sikochi, A. S., and Gyimah, D. (2022). A cross-country study of peer effects on working capital management. Available at: https://ssrn.com/abstract=4020577

Manski, C. F. (2000). Economic analysis of social interactions. *J. Econ. Perspect.* 14, 115–136. doi: 10.1257/jep.14.3.115

Meltzoff, A. N. (2007). The 'like me' framework for recognizing and becoming an intentional agent. *Acta Psychol.* 124, 26–43. doi: 10.1016/j.actpsy.2006.09.005

Meltzoff, A. N. (2010). "Bridging between action representation and infant theory of mind," in *Cognition and Neuropsychology: International Perspectives on Psychological Science*. eds. P. A. Frensch and R. Schwarzer (Park Drive: Psychology Press), 29–48.

Nissen, M. E. (2019). Initiating a system for visualizing and measuring dynamic knowledge. *Technol. Forecast. Soc. Chang.* 140, 169–181. doi: 10.1016/j.techfore.2018.04.008

Prinz, W., Aschersleben, G., and Koch, I. (2009). "Cognition and action," in *Oxford Handbook of Human Action*. eds. E. Morsella, J. A. Bargh and P. M. Gollwitzer, vol. *2* (Oxford: Oxford University Press), 35–71.

Reppenhagen, D. A. (2010). Contagion of accounting methods: evidence from stock option expensing. *Rev. Acc. Stud.* 15, 629–657. doi: 10.1007/s11142-010-9128-1

Roychowdhury, S., Shroff, N., and Verdi, R. S. (2019). The effects of financial reporting and disclosure on corporate investment: a review. *J. Account. Econ.* 68:101246. doi: 10.1016/j.jacceco.2019.101246

Shue, K. (2013). Executive networks and firm policies: evidence from the random assignment of MBA peers. *Rev. Financ. Stud.* 26, 1401–1442. doi: 10.1093/rfs/hht019

Von Krogh, G., and Geilinger, N. (2014). Knowledge creation in the eco-system: research imperatives. *Eur. Manag. J.* 32, 155–163. doi: 10.1016/j.emj.2013.04.002

Wu, C. Y., and Mathews, J. A. (2012). Knowledge flows in the solar photovoltaic industry: insights from patenting by Taiwan, Korea, and China. *Res. Policy* 41, 524–540. doi: 10.1016/j.respol.2011.10.007

Yuan, D., Shang, D., Ma, Y., and Li, D. (2022). The spillover effects of peer annual report tone for firm innovation investment: evidence from China. *Technol. Forecast. Soc. Chang.* 177:121518. doi: 10.1016/j.techfore.2022.121518

Zhou, K. Z., and Caroline Bingxin, L. (2012). How knowledge affects radical innovation: knowledge base, market knowledge acquisition, and internal knowledge sharing. *Strateg. Manag. J.* 33, 1090–1102. doi: 10.1002/smj.1959

Zhou, W., and Xu, Z. (2019). Hesitant fuzzy linguistic portfolio model with variable risk appetite and its application in the investment ratio calculation. *Appl. Soft. Comput.* 84:105719. doi: 10.1016/j.asoc.2019.105719

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 01 December 2022
DOI 10.3389/fpsyg.2022.1068375

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University, China

REVIEWED BY
Yuxin Li,
Shandong Institute of Business and Technology, China
Jin Chen,
Kunming University of Science and Technology, China

*CORRESPONDENCE
Deping Xiong
ksdream@126.com;
xiongdeping@126.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 12 October 2022
ACCEPTED 14 November 2022
PUBLISHED 01 December 2022

CITATION
Ren L, Liu D and Xiong D (2022) Impact of technological innovation on corporate leverage in China: The moderating role of policy incentives and market competition. *Front. Psychol.* 13:1068375. doi: 10.3389/fpsyg.2022.1068375

Impact of technological innovation on corporate leverage in China: The moderating role of policy incentives and market competition

Lin Ren[1], Dan Liu[2] and Deping Xiong[1]*

[1]School of Finance, Yunnan University of Finance and Economics, Kunming, China, [2]School of Economics, Yunnan University of Finance and Economics, Kunming, China

Due to its capital-related nature, corporate leverage is highly exposed to financial risk, and optimizing corporate leverage is an effective method of mitigating financial risk to maximize corporate value. We use a two-way fixed effects model to examine the impact of technological innovation on corporate leverage using panel data of A-share listed companies in the Chinese manufacturing sector from 2012 to 2020. The results show that technological innovation and corporate leverage exhibit significant heterogeneity in cross-sectional, spatial and temporal dimensions. By further distinguishing between the effects of policy incentives and market competition, we find that the former exerts an "investment crowding out" effect and the latter an "innovation spillover" effect. These factors mitigate the negative relationship between technological innovation and corporate leverage. In general, this study provides empirical evidence for the rational allocation of resources by the Chinese government, the development of innovation capabilities, and the adjustment of leverage by firms from various regions.

KEYWORDS

technological innovation, corporate leverage, policy incentives, market competition, China

Introduction

As financial markets have developed rapidly, leveraged operations and expansion have become a global trend among corporations. For example, at one point, China's non-financial corporate sector leverage ratio had risen to 272.5%, exceeding not only emerging economies but also developed economies such as the United States, Europe,

and Japan. In a market economy, it makes sense for businesses to use external funding for operations and expansion. However, issues such as diminishing marginal benefits of corporate investment increased risk of default, and erosion of corporate performance due to over-leverage have become insurmountable business obstacles for businesses (Campello, 2006; Berk et al., 2010; Reinhart and Rogoff, 2010; Schularick and Taylor, 2012). Consequently, corporate leverage adjustment is widely adopted and utilized.

Following the theory of trade-offs, corporate leverage adjustment assists firms in coping with various risks arising from uncertainty and maximizes corporate value by achieving the desired capital structure. The empirical study demonstrates that firm heterogeneity and asymmetry result in different leverage adjustment costs at different leverage levels. The leverage effect is only triggered when firms' profitability is sufficient to cover the adjustment costs (Aivazian et al., 2005; Galvao and Montes-Rojas, 2010). Consequently, corporate leverage adjustment is viable for companies to deal with uncertainty and attain their desired capital structure. Additional research into corporate leverage factors is necessary to achieve sustainable corporate growth.

Schumpeter's concepts of "creative destruction" and "creative accumulation" concerning corporate innovation hold that innovation can be used as a new production function by altering the original conditions of production or by adding new factors of production to form a new system, thereby becoming a force for sustained economic growth. Moreover, according to research, technological innovation determines a company's market value, comparative advantage, and return on investment, which is crucial for competitiveness, survival, and sustainable development (Myers, 1977; Porter, 1992). Therefore, technological innovation presents an opportunity for corporate leverage.

In China, the pattern of economic growth is shifting from factor-driven to technology-driven, and technological innovation has emerged as a determining factor for high-quality economic development. In the 14th 5-Year Plan for National Economic and Social Development and the 2035 Vision Plan (effective 2021), the Chinese government has proposed to improve the national innovation system and promote the concentration of various innovation factors in Chinese enterprises. At the firm level, innovative firms are the foundation for developing an innovative nation, and Chinese firms must enhance their market competitiveness by developing innovative products and services (Lee et al., 2021). On the one hand, they must manage their financial risks and continually optimize their leverage to maximize their company's value. Notably, as Chinese firms have gradually shifted their innovation financing from a high reliance on foreign capital and international trade to domestic investment and government-subsidized innovation, this shift has had a unique effect on the relationship between technological innovation and firm leverage in Chinese firms. China is worth studying as an example of significant market failures and government interventions in emerging economies.

From 2012 to 2020, we empirically examine the relationship between technological innovation and corporate leverage using the financial data of A-share listed companies on China's Shanghai and Shenzhen stock exchanges. The two variables have a significant negative correlation. By distinguishing further between the effects of policy incentives and market competition, we find that policy incentives have an "investment crowding out" effect. In contrast, market competition has an "innovation spillover" effect. These factors mitigate the negative relationship between technological innovation and corporate leverage. In addition, the relationship between the two is influenced by the nature of the firm, industry characteristics, location, and the firm's life cycle.

Our research makes the following contributions: First, the relationship between technological innovation and corporate leverage is reconsidered. In contrast to answering the question of what types of corporations are conducive to innovation (He and Tian, 2013; Hsu et al., 2014; Cornaggia et al., 2015; Iqbal et al., 2022), the purpose of this study is to determine whether technological innovation can drive corporate leverage adjustment. Second, we investigate the effect of policy incentives and market competition on the relationship between technological innovation and corporate leverage. On this basis, we also observe regional differences to make the study more realistic. Thirdly, we contribute to the existing literature on corporate leverage by investigating the various effects of technological innovation on corporate leverage through cross-sectional, spatial, temporal, and leverage interval differentiation.

The remainder of the article is structured as follows: Section "Hypothesis development" is devoted to the formulation of hypotheses, Section "Data and methods" to the description of data and methods, Section " Analysis results" to the analysis results, Section "Robustness tests" to robustness tests, and Section "Conclusion" to the conclusion.

Hypothesis development

Capital structure theory has become one of the most exciting areas of study in finance due to its unique insights into various issues about corporate leverage and firm value, as well as its vast and far-reaching implications for corporate financing decisions (Ma, 2021). It clarifies the significance of debt in the capital structure of a company. Companies no longer merely leverage users, but leverage designers, making selective and targeted adjustments to maximize company value and balance the internal and external environments.

Previous research on corporate leverage has generally focused on external ("taxation," "bankruptcy") and internal ("information transmission," "agency costs") factors, such as

the cost of leverage adjustment, the soft budget constraint, the level of government control, the marketization process, policy influences, economic cycles, financial crises, and product market competition (MacKay and Phillips, 2005; Faulkender et al., 2012; Tsoy and Heshmati, 2017). However, the impact of technological innovation on corporate leverage has received scant attention.

Technological innovation and corporate leverage

Early research on corporate leverage appeared unrelated to the firm's value, as they did not consider the insolvency risk. Nevertheless, according to trade-off theory, during an economic downturn, financial crisis and bankruptcy risks force a firm's market value into a paradox of "increased debt" and "financial risk" because of both its operating performance and the external environment (e.g., an infectious disease pandemic or loose monetary policy). A firm's leverage can vary from its target capital structure. To maximize corporate value, additional adjustments to corporate leverage are necessary. Nonetheless, because the cost of adjustment exceeds its benefit, some businesses lack the incentive to leverage adjustment, which is detrimental to the interests of shareholders and severely restricts the development of the business (Fischer et al., 1989; Leary and Roberts, 2005; Ogawa, 2007; Strebulaev, 2007; Cook and Tang, 2010; Li et al., 2017). Consequently, it is necessary to elaborate on the factors driving the leverage adjustment.

In addition to influencing the sustainability of corporations, technological innovation integrates internal and external resources to spur environmental innovation (Horbach, 2008; Cai and Zhou, 2014). As a result, several academics have pondered whether technological innovation can facilitate corporate leverage adjustment. Some academics contend that technological innovation produces an innovative performance that drives rapid firm growth and has a tax shield effect that reduces financing costs. Therefore, technological innovation is having a deleveraging impact, which means that the more firms focus on innovation, the less debt they carry (Del Canto and Suarez Gonzalez, 1999; Graham, 2003; Graham and Tucker, 2006; Honore et al., 2015). Others contend that the opposite is true. They conclude that firms' technological innovation capabilities are positively related to their debt levels because they are more willing to leverage and have higher debt levels because of the inherent consistency of their technological innovation goals, which reduce innovation risk and increase financial risk tolerance (David et al., 2000).

Indeed, technological innovation has two significant effects on corporate leverage: externally, by enhancing product market competitiveness, and internally, by strengthening corporate governance capabilities. These effects manifest themselves in sustained excess profits and industry-specific advantages. Because capital structure can reflect product market expectations of future competition, particularly for overleveraged firms, product market competition can force technological innovation and adjust leverage through monopoly rents and profits from intellectual property (e.g., patents) (Brander and Lewis, 1986; Showaher, 1995). In addition, technological innovation can help firms engage in capacity governance. These include creating differentiated new demand, transforming excess capacity into efficient capacity, and further optimizing distorted firm leverage by offsetting the cost of firm recapitalization with higher marginal product returns (Liu and Huang, 2016).

Consequently, based on the analysis presented above, we propose the following hypothesis:

> **Hypothesis 1 (H1).** Technological innovation has a negative correlation with corporate leverage.

Impact of policy incentives

Since technological innovation is a high-investment, long-cycle, and high-risk behavior, decision-makers neglect to invest in innovation when debt financing creates a constraint on free cash flow to maximize shareholders' interests promptly (Jensen, 1986). In addition, because technological innovation involves patent protection and externality risks, corporations' exogenous financing becomes extra cautious, discouraging R&D investment (Galende Del Canto and Suarez Gonzalez, 1999). Therefore, most technological innovation requires policy incentives.

Policy incentives are government interventions to redistribute resources in a market economy, avoiding value transfer caused by interest payments by reducing the cash consumption of technological innovation by businesses to stimulate technological innovation via direct or indirect policy assistance. Government subsidies, tax incentives, inter-institutional cooperation, and others are the primary policy incentives (Spence, 1984; David et al., 2000; Giudici and Paleari, 2000; Nishimura and Okamur, 2011). As China's institutional development continues to advance, the government, as an innovation policymaker and strategist, is very concerned with fostering technological innovation in businesses by formulating pertinent policies. Nevertheless, due to the uncoordinated and uneven regional economic development, policy incentives in China may result in regional disparities.

Numerous studies have confirmed the correlation between policy incentives and the technological innovation of businesses. Positive studies indicate that policy incentives not only alleviate the financing constraints associated with technological innovation and effectively promote R&D in high-precision end technologies but also regulate firms' cost, equity, and R&D budgets, with the potential to improve firms' capital structure (Honore et al., 2015; Xia and Roper, 2016; Howell, 2017; Li

et al., 2017; Wade, 2017; Chen et al., 2020). Consequently, in terms of the direct effects of policy incentives, firms that receive government assistance always receive more funding, greater tax benefits, an increase in innovation output, and an improvement in innovation performance in their innovation investments (Gonzalez et al., 2005). On the other hand, pessimistic studies contend that policy incentives can lead to a decline in the quality of corporate R&D, R&D investment crowding out, corruption and rent-seeking, and a distortion of the policy's original intent (Belenzon and Berkovitz, 2010; Bernini and Pellegrini, 2011; Lee, 2011; Liu et al., 2019; Kong, 2020). Therefore, one cannot ignore the indirect effects of policy incentives.

First, policy incentives can have an "investment crowding out" effect on firms' technological innovation. Firms may reduce their innovation investment to seek policy support and restructure their technological innovation projects, substituting long-term quality innovation with simple short-term innovation, resulting in the innovation of lower quality (Wallsten, 2000; Czarnitzki et al., 2011; Aghion et al., 2013; Stuart and Wang, 2016). Second, according to signaling theory, obtaining policy support can help firms send positive signals, causing investors to anticipate that the firm is undervalued and to readily attract lower-cost external financing, which may contribute to the increase in firm leverage (Takalo and Tanayama, 2010).

Based on the analysis presented above, we propose the following hypothesis:

> **Hypothesis 2 (H2).** The negative relationship between technological innovation and corporate leverage is weakened by policy incentives.

Impact of market competition

The study of firm leverage must pay close attention to the market competition of firms (Barton and Gordon, 1988; O' Brien, 2003). Debt's purpose is to give managers an incentive to manage more efficiently and reduce discretionary cash outlays that are not in the shareholders' best interests. However, managers make decisions regarding leverage based on the firm's competitive environment, which also reflects the firm's industry (Williamson, 1963). As a result, competition can serve as an alternative to debt, limiting managers' use of available cash flow. The greater the market competition, the greater the number of customer comparisons and options and the lower the firm's excess returns. It is no longer advantageous for firms to increase their leverage, while it also exposes them to greater risk and uncertain outcomes (Williamson, 1975; Jensen and Meckling, 1976; Kohli and Jaworski, 1990; Botosan and Plumlee, 2005). With increased market competition, companies are consequently more cautious with leverage. It also suggests that firms tend to reduce their leverage as the market becomes more competitive, even without the influence of technological innovation.

In addition, because the external institutional environment influences technological innovation, market competition, a critical external governance mechanism, can be a good indicator of external environment changes (Torkkeli et al., 2019). According to the well-known "Schumpeter effect," competition reduces firms' excess profits, and monopoly is the most effective innovation driver. A high level of market competition increases the likelihood that innovation will be imitated or substituted, which tends to generate technological innovation spillover effects, resulting in a decline in innovation performance and discouraging firms from innovating. In other words, innovation declines as market competition rise (Schumpeter, 1942; Grossman and Helpman, 1993).

China's reform and opening up have accelerated its marketization process. However, even though market mechanisms have been unleashed and have driven economic development, there is still the dilemma of significant differences in regional market competition and uncoordinated economic growth. On the one hand, regions with intense market competition exhibit a concentration of industry factors, resulting in "innovation spillover," which deprives the private sector of the incentive to innovate. On the other hand, most of the leverage in China's manufacturing sector is held by state-owned enterprises (SOEs), whose proximity to the government grants them access to exogenous financing, promoting higher leverage.

Considering the above analysis, market competition may dampen the relationship between technological innovation and corporate leverage. We propose the following hypothesis:

> **Hypothesis 3 (H3).** The negative relationship between technological innovation and corporate leverage is weakened by market competition.

Data and methods

Data

Our initial sample consists of China's A-share-listed manufacturing companies. The sample period spans 2012 through 2020. In addition, the China Stock Market & Accounting Research Database (CSMAR) and the East Money Data Platform provide information on the key independent variable, technological innovation (CHOICE). The remaining data comes from financial reports of publicly traded companies and the National Bureau of Statistics of China's website.

The initial sample is screened based on the following four criteria: (1) the exclusion of companies designated as special treatment (ST) or special transfer (PT) during the sample period;

(2) the removal of post-2012 listings; (3) the exclusion of companies with missing data during the sample period; and (4) the exclusion of companies with abnormal financial conditions, such as gross assets below zero and gearing below or above one. In addition, we eliminate the top and bottom 1% of each variable's data set to avoid estimation bias. After completing the preceding steps, we obtained 8,841 valid sample observations.

Variable definition

Corporate leverage

This study's dependent variable is corporate leverage. Observing the change in corporate leverage reveals the adjustment pattern of corporate leverage. According to empirical studies, book value is favored over market value when discussing financial leverage (Stonehill et al., 1974). Therefore, corporate leverage is defined as the ratio of total debt to the book value of total assets.

Technological innovation

In this study, the independent variable is technological innovation. In this paper, technological innovation refers to technological innovation at the firm level, where a company creates a new product, offers a new service, or implements a new process. To reduce noise in measuring technological innovation, we introduce innovation intensity, which uses the ratio of R&D expenditures to operating revenue to measure corporations' technological innovation (Nosheen et al., 2016).

Control variables

We control the size (Size), Return on Net Assets (ROE), Year-on-Year Growth Rate of Operating Income (Gro_oper), Financial Expenses (Debt), Liquidity of Assets (Liq_ass), and Corporate Age (Age) (Ramaswamy, 2001; Frank and Goyal, 2003; Mithas et al., 2012; Lusardi and Tufano, 2015; Klobucar and Orsag, 2019; Berger et al., 2022). The definitions and descriptive statistics for these variables are provided in **Table 1**.

Moderating variables

We utilized policy incentives and market competition to moderate the relationship between technological innovation and firm leverage. The China Marketization Index is used as a proxy variable for market competition, while government subsidies are used as a proxy variable for policy incentives. In place of specific government subsidy data, this study uses government subsidies in the income statements of publicly traded corporations divided by total assets (Jia et al., 2021). In addition, the China Marketization Index utilized in this paper is derived from Wang et al.'s (2019) "China Provincial Marketization Index Report," which began in 1997 and has since published nine reports covering 31 provinces in China. These reports include government-market relations, the development of the non-state economy, the development of product markets, the development of factor markets, the development of market intermediary organizations, and the rule of law environment. It consists of seventeen fundamental indices in five areas and is a comprehensive index that can more accurately reflect marketization. As the index is only updated to 2019, the data for this analysis spans 2012 through 2019.

Methods

The following empirical model was developed to examine the impact of technological innovation on corporate leverage.

$$Lev_{i,t} = \alpha + \beta \times R\&D_{i,t} + \theta \times Control_{i,t} + \omega_i + \delta_t + \xi_{i,t} \quad (1)$$

The subscripts i and t represent firms and years, respectively. $Lev_{i,t}$ represents corporate leverage while $R\&D_{i,t}$ represents innovation intensity. $Control_{i,t}$ represent the multiple control variables. In this study, we also control for year fixed effectsδ_t and firm fixed effects δ_i. To investigate further the impact of policy incentives and market competition on the relationship between technological innovation and corporate leverage, we augment models (2) and (3) with interaction terms.

$$\begin{aligned} Lev_{i,t} = \ & \alpha_0 + \alpha_1 \times R\&D_{i,t} + \beta_1 \\ & \times Gover_{i,t} + \beta_2 \times R\&D_{i,t} \times Gover_{i,t} + \theta \\ & \times Control_{i,t} + \omega_i + \delta_t + \xi_{i,t} \end{aligned} \quad (2)$$

$$\begin{aligned} Lev_{i,t} = \ & \alpha_0 + \alpha_1 \times R\&D_{i,t} + \beta_1 \times Market_{i,t} + \beta_2 \times R\&D_{i,t} \\ & \times Market_{i,t} + \theta \times Control_{i,t} + \omega_i + \delta_t + \xi_{i,t} \end{aligned} \quad (3)$$

$Gover_{i,t}$ and $Market_{i,t}$ are measures of policy incentives and market competition, $R\&D_{i,t} \times Gover_{i,t}$ denotes the moderating effect of policy incentives on the relationship between technological innovation and corporate leverage, and $R\&D_{i,t} \times Market_{i,t}$ denotes the moderating effect of

TABLE 1 Definitions of the variables.

Variables	Definition
Lev	Total liabilities divided by total assets
R&D	R&D expenditure divided by operating income
Size	Take the natural log of total assets
ROE	Return on equity is measured by the ratio of net profit to net assets
Gro_oper	Operating income year-on-year growth rate in the previous period
Debt	Take the natural log of financial expenses
Liq_ass	Current assets divided by total assets
Age	Take the natural log of the years of establishment of the enterprise
Market	Marketization Index of China
Gover	Government subsidies divided by total assets
Scien	The natural log of regional science expenditure

market competition on the relationship between technological innovation and corporate leverage.

Analysis results

Statistical analysis

Descriptive statistics

Table 2 displays descriptive statistics for the most critical variables. Based on the average leverage value, Chinese manufacturing companies' average annual leverage ratio was 0.401. Regarding the leverage structure, short-term leverage accounted for 83.8%, and long-term leverage accounted for 16.2%, indicating that the sample manufacturing enterprises' debt financing was primarily short-term. The range of technological innovation values is from 0.001 to 0.198, with a mean, standard deviation, and median of 0.042, 0.029, and 0.037, respectively, indicating that corporations vary widely in terms of innovation intensity, but the majority are also incompetent. Also included in Table 2 are summary statistics for our control variables.

Correlation coefficient test

The correlation coefficient between corporate technical innovation and corporate leverage is negative, as demonstrated in Table 3.

Baseline result

The impact of technological innovation on corporate leverage is examined in Table 4. Column (1) does not include control variables. The coefficient on technological innovation is negative and statistically significant (–0.596, p-value < 0.01), according to the regression results. In column (2), which contains the independent variables, the technological innovation coefficient remains negative and statistically significant (–0.412, p-value < 0.01). Our findings concur with national studies (Singh and Faircloth, 2005; Min and Smyth, 2016). It supports H1, in which technological innovation correlates negatively with corporate leverage.

First, the tax shield effect of leverage provides a broader scope for technological innovation and cheaper financial support through profitability signals (Brown and Petersen, 2011). Second, technological innovation increases firms' productivity and facilitates their rapid growth. Third, it increases the industry's competitiveness and market share and can motivate the firm to adjust its leverage to achieve its desired capital structure (Ciftci and Cready, 2011). Fourth, incentives for technological innovation can also reduce firms' innovation expenses and boost their profitability (Czarnitzki and Licht, 2006; Hewitt-Dundas and Roper, 2010). Lastly, from the perspective of the relationship between excess capacity and distortionary leverage, technological innovation assists firms in governing their capacity, enables them to increase profits despite excess capacity, and shifts their leverage toward an optimal band (Almeida and Campello, 2007; Yu, 2017).

Impact of policy incentives

The effect of policy incentives on the relationship between technological innovation and corporate leverage is then investigated. In column (1) of Table 5, the effects of policy incentives are detailed. Before constructing the interaction terms, all variables are centralized to prevent multicollinearity issues. Column (1) demonstrates that the coefficient on technological innovation is significantly negative at the 1% level. In comparison, the coefficient on the interaction term between government subsidies and innovation intensity is significantly

TABLE 2 Descriptive statistics of the variables.

	N	Mean	SD	Skewness	Kurtosis	P25	P50	P75	Min	Max
Lev	8,841	0.401	0.174	−0.828	0.126	0.262	0.397	0.533	0.055	0.852
Shor_lev	8,841	0.336	0.151	−0.631	0.279	0.215	0.327	0.442	0.043	0.755
Lon_lev	8,841	0.065	0.066	1.017	1.289	0.014	0.039	0.1	0	0.314
R&D	8,841	0.042	0.029	4.46	1.689	0.025	0.037	0.052	0.001	0.198
Size	8,841	8.378	1.066	0.01	0.573	7.61	8.261	8.997	6.287	11.81
ROE	8,841	0.068	0.091	−1.163	8.905	0.027	0.065	0.114	−0.483	0.353
Gro_oper	8,841	0.113	0.222	2.421	0.979	−0.022	0.089	0.215	−0.444	1.22
Debt	8,841	0.007	0.01	−0.076	0.382	0	0.006	0.013	−0.017	0.036
Liq_ass	8,841	0.569	0.149	−0.674	−0.135	0.46	0.573	0.684	0.195	0.89
Age	8,841	2.871	0.303	1.511	−0.415	2.708	2.89	3.045	0.693	4.174
Market	7,833	9.410	1.465	−1.103	4.240	8.607	9.656	10.560	3.359	11.494
Gover	8,562	0.006	0.006	6.472	95.412	0.002	0.004	0.007	0	0.154

Table 1 reports the summary statistics of key variables.

TABLE 3 Pearson correlation coefficients of the variables.

	Lev	R&D	Size	ROE	Gro_oper	Debt	Liq_ass	Age	Market	Gover
Lev	1									
R&D	−0.239**	1								
Size	0.499**	−0.187**	1							
ROE	−0.168**	−0.059**	0.108**	1						
Gro_oper	−0.025*	0.018	0.002	0.296**	1					
Debt	0.673**	−0.214**	0.241**	−0.244**	−0.064**	1				
Liq_ass	−0.114**	0.112**	−0.142**	0.127**	0.024*	−0.343**	1			
Age	0.113**	−0.067**	0.218**	−0.037**	−0.089**	0.074**	−0.089**	1		
Market	−0.073**	0.092**	−0.040**	0.022*	0.019	−0.075**	0.008	0.168**	1	
Gover	0.382**	0.010	0.701**	0.091**	−0.013	0.184**	−0.126**	0.172**	−0.015	1

*Statistical significance at the 10 % level, **statistical significance at the 5% level, ***statistical significance at the 1% level.

positive at the 5% level, suggesting that policy incentives have a dampening effect on them, which supports the hypothesis of H2 that policy incentives weaken the negative relationship between technological innovation and corporate leverage.

The possible explanation is that, contrary to positive intuition, while the direct effect of policy incentives makes firms more innovative. The indirect effect of policy incentives also has an "investment crowding out" effect on firms' technological innovation. As observed, China's manufacturing sector is more consistent with the "investment crowding out" effect. In previous studies, Liu et al. (2019) suggested the need for a more targeted use of government subsidies to incentivise firms to innovate.

Impact of market competition

To further examine the relationship between technological innovation and firm leverage, we incorporate market competition into the model. Column 2 of Table 5 reported the moderating effects of market competition. Controlling for other variables, the coefficient on technological innovation is significantly negative at the 5% level. In contrast, the coefficient on the interaction term between technological innovation and market competition is significantly positive at the 10% level, indicating that market competition mitigates the negative relationship between technological innovation and corporate leverage. H3 is supported, i.e., market competition mitigates

TABLE 4 Impact of technological innovation on corporate leverage.

Dependent variable	Lev (1)	Lev (2)
R&D	−0.596***	−0.412***
	(−5.24)	(−4.71)
Size		0.070***
		(14.42)
Age		0.056**
		(1.98)
ROE		−0.100***
		(−6.57)
Gro_oper		0.028***
		(6.19)
Debt		7.255***
		(29.95)
Liq_ass		−0.006
		(−0.31)
Constant		−0.341***
		(−3.95)
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	8,841	8,841
Within *R*-sq	0.0477	0.4285

*Statistical significance at the 10 % level, **statistical significance at the 5% level, ***statistical significance at the 1% level. *T*-value are reported in parentheses.

TABLE 5 Impact of policy incentives and market competition on the relationship between technological innovation and corporate leverage.

Dependent variable	Lev (1)	Lev (2)
R&D	−0.502***	−1.087**
	(−5.11)	(−2.48)
Gover	−0.439	
	(−1.48)	
Gover*R&D	0.119**	
	(2.36)	
Market		0.006*
		(1.80)
Market*R&D		0.077*
		(1.69)
Control variables	Yes	Yes
Constant	−0.323***	−0.357***
	(−3.67)	(−3.76)
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	8,562	7,833
Within *R*-sq	0.4268	0.4222

***Indicates significance at the 1% level, **indicates significance at the 5% level, and *indicates significance at the 10% level.

the negative relationship between technological innovation and corporate leverage.

The result can be explained by market competition's "innovation spillover" effect. Specifically, the involuntary welfare spillover to peers and society, for which there is no return, undermines firms' incentive to innovate. However, it should also be noted that in highly competitive markets, excessive competition can reduce firms' excess profits, resulting in a greater emphasis on survival and a selective reduction in firms' willingness to take risks and incentives to innovate (Schumpeter, 1942; Xie and Wei, 2016). Consequently, the impact of technological innovation on firms' deleveraging can be moderated by market competition and is variable.

Further analysis

To observe additional regional heterogeneity in the moderating effect, we refer to the division of economic regions in the Opinions of the Central Committee of the Communist Party of China and the State Council on Promoting the Rise of the Central Region and the Opinions of the State Council on the Implementation of Certain Policy Measures for the Development of the Western Region and divide them into three major economic regions for group regression: East, West and Central. The classifications are as follows: East: Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Shandong, Shanghai, Tianjin, Zhejiang, Liaoning, Jilin, Heilongjiang; Central: Anhui, Henan, Hubei, Hunan, Jiangxi, Shanxi; West: Gansu, Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Tibet, Xinjiang, Yunnan, Chongqing.

The results of regional differentiation for the effects of policy incentives and market competition are presented in **Tables 6**, **7**, respectively. The estimated results of the baseline regression are presented in columns (1), (2), and (3). Meanwhile, the regression of the moderating effects is presented in columns (4), (5), and (6). The coefficient on R&D in column (1) of **Table 6** for the eastern region is significantly negative and statistically significant (–0.478, p-value < 0.01), indicating that technological innovation in the eastern region can effectively contribute to corporate deleveraging. The coefficient on Gover*R&D is statistically significant and significantly positive in column (4) of **Table 6** (0.154, p-value < 0.1), and the coefficient on Market*R&D is statistically significant and significantly positive in column (4) of **Table 7** (0.152, p-value < 0.05). It demonstrates that the east's policy incentives and market competition mitigate the negative relationship between technological innovation and corporate leverage. The coefficient on R&D in column (3) of **Table 6** is negative but not statistically significant; the coefficient on Gover*R&D in column (6) of **Table 6** is significantly positive and statistically significant (0.343, p-value < 0.01), and the coefficient on Market*R&D in column (7) of **Table 7** is significantly positive and statistically significant (0.266, p-value < 0.05). In other words, policy incentives and market competition dampen the technology innovation-corporate leverage relationship in the western region. The central region lacks a significant moderating effect.

In contrast to the negative relationship between technology innovation and corporate leverage in the benchmark regression, the coefficients on Gover*R&D and Market*R&D are significantly positive for both the eastern and western regions when the effects of policy incentives and market competition are accounted for. In addition, when both are present, the deleveraging effect of technological innovation in the western region changes from negligible to significant. Possible causes include the injection of political and economic dynamism into China's western regions through strategies such as developing the west and revitalizing the countryside. In addition, it can effectively facilitate access to innovation support (e.g., policies, resources, technology) and cheaper funding for innovation projects (e.g., government grants, loans for inclusive finance projects) for businesses in the west. Therefore, it is implicitly a policy recommendation that continued improvements in the institutional and economic environment are more conducive to exploiting the adverse effects of technological innovation on corporate leverage.

Lastly, the insignificance of the central region may be due to the unbalanced development strategies implemented in China, such as priority development in the east, development in the west, and revitalization of old industrial bases, which have objectively created a "depression" in the macroeconomic pattern of the central region. It results in the total economic development of the central region being lower than that of the eastern region, and the growth rate of the central region is slower than that of the eastern region. As a result, the total economic development of the central region is lower than that of the eastern region, and the growth rate of economic development in the central region is lower than that of the western region.

Robustness tests

In this section, we conduct several checks on the reliability of our key findings.

IV regression results

We chose science expenditure as the instrumental variable to address the potential endogeneity issue. There are reasons for the selection of instrumental variables. Firstly, as regional science expenditure is macro-policy support, unlike profit-seeking firms on the market, the government intends to

TABLE 6 A comparison of regression results on the relationship between technological innovation and corporate leverage in different regions before and after the inclusion of policy incentives.

Variables	(1) Lev(E)	(2) Lev(C)	(3) Lev(W)	(4) Lev(E)	(5) Lev(C)	(6) Lev(W)
R&D	−0.478***	−0.200	−0.312	−0.581***	−0.162	−0.559*
	(−4.48)	(−1.15)	(−1.07)	(−4.88)	(−0.79)	(−1.95)
Gover				−0.553	0.211	−1.840**
				(−1.44)	(0.29)	(−2.30)
Gover*R&D				0.154*	−0.046	0.343***
				(1.91)	(−0.53)	(3.46)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.396***	0.132	−0.435	−0.361***	0.119	−0.492
	(−3.92)	(0.74)	(−1.51)	(−3.55)	(0.66)	(−1.54)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6,301	1,495	1,045	6,096	1,464	1,002
Within *R*-sq	0.4456	0.3776	0.4355	0.4460	0.3722	0.4280

Dependent variable: Lev(E) represents manufacturing companies in the East, Lev(C) represents Manufacturing companies in the Central, Lev(W) represents Manufacturing companies in the West. This table reports the changes in the relationship between technological innovation and corporate leverage for different regions before and after the inclusion of policy incentives. *T*-values are reported in parentheses l.
***Statistical significance at the 1% level.
**Statistical significance at the 5% level.
*Statistical significance at the 10% level.

TABLE 7 A comparison of regression results on the relationship between technological innovation and corporate leverage in different regions before and after the inclusion of market competition.

Variables	(1) Lev(E)	(2) Lev(C)	(3) Lev(W)	(4) Lev(E)	(5) Lev(C)	(6) Lev(W)
R&D	−0.478***	−0.200	−0.312	−1.952***	1.755	−2.161**
	(−4.48)	(−1.15)	(−1.07)	(−3.21)	(1.08)	(−2.24)
Market				0.001	0.006	0.013
				(0.32)	(0.41)	(1.28)
Market*R&D				0.152**	−0.222	0.266**
				(2.49)	(−1.20)	(2.01)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.396***	0.132	−0.435	−0.365***	−0.044	−0.293
	(−3.92)	(0.74)	(−1.51)	(−3.21)	(−0.18)	(−1.13)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6,301	1,495	1,045	5,600	1,325	908
Within *R*-sq	0.4456	0.3776	0.4355	0.4422	0.3634	0.4377

Dependent variable: Lev(E) represents companies in the East, Lev(C) represents companies in the Central, Lev(W) represents companies in the West. This table reports the changes in the relationship between technological innovation and corporate leverage for different regions before and after the inclusion of market competition. *T*-values are reported in parentheses l.
***Statistical significance at the 1% level.
**Statistical significance at the 5% level.
*Statistical significance at the 10% level.

optimize the regional structure and will provide support to firms across the region without an explicit preference for supporting certain firms. Second, when GDP is the primary metric for measuring political performance, governments have a self-interested investment preference to favor production over innovation due to innovation's long-term and unpredictable nature, resulting in a high degree of regional variation in science spending. Lastly, regional science expenditure typically reflects the level of support for innovation and the conditions for innovation that the region can provide to firms. It is closely related to the paper's subject's technological innovation. Table 8 displays the results of the two-stage least squares regression for the IV method, which indicates that technological innovation has a negative regression coefficient. The test

TABLE 8 The results of the instrumental variables approach to regression.

Dependent variables	Lev
R&D	−1.256**
	(−2.49)
Control variables	Yes
Constant	−0.201***
	(−4.98)
Industry FE	Yes
Year FE	Yes
First-stage regression	
IV	0.003***
	(8.12)
N	8,841
Adj *R*-sq	0.1715
Robust F	65.92
Prob > F	0.000

This table presents IV approach results that use Government Science Expenditure as an instrumental variable. *T*-values are reported in parentheses. ***Indicates significance at the 1% level, **indicates significance at the 5% level, *indicates significance at the 10% level.

results for the weak instrumental variables indicate that the F-statistic for the first stage is 65.29, which is well above the critical value of 10 for the weak instrumental variables (Hausman et al., 2005).

Different model designs

We test the robustness of the model by substituting the proxy variables for technological innovation with one lag of technological innovation (L.R&D), one period of R&D expenditure taking the natural logarithm (Innov), and one period of lag R&D expenditure (L.Innov) while maintaining the original control variables. The regression results are in columns (1) through (3) of Table 9. After replacing the core explanatory variables in the benchmark model with each of the three new independent variables, we find that the coefficient on L.R&D is significantly negative at the 1% significance level in the two-fixed effects panel regression. At the same time, the coefficients on Innov and L.Innov are also significantly negative at the 5% significance level, respectively. In this instance, the negative effect of technological innovation on firm leverage is once more demonstrated.

TABLE 9 The results of different models and variables.

Dependent variables	Lev (1)	Lev (2)	Lev (3)
L.R&D	−0.403***		
	(−4.42)		
Innov		−0.007**	
		(−2.12)	
L.Innov			−0.007**
			(−2.30)
Control variables	Yes	Yes	Yes
Constant	−0.399***	−0.379***	−0.434***
	(−3.70)	(−4.34)	(−3.97)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	7,319	8,841	7,319
Within *R*-sq	0.3856	0.4256	0.3829

This table presents the results of a robustness test of different model designs and variables. *T*-values are reported in parentheses. ***Indicates significance at the 1% level, **indicates significance at the 5% level, *indicates significance at the 10% level.

TABLE 10 Cross-sectional analysis of ownership status and industry effects.

Dependent variables	(1) Lev(S)	(2) Lev(N)	(3) Lev(H)	(4) Lev(T)
R&D	−0.476***	−0.378***	−0.568***	−0.338***
	(−3.08)	(−3.59)	(−4.94)	(−2.80)
Control variables	Yes	Yes	Yes	Yes
Constant	−0.430**	−0.291***	−0.553***	−0.246**
	(−2.49)	(−2.94)	(−3.96)	(−2.37)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	2,728	6,113	2,015	6,826
Within *R*-sq	0.3942	0.4435	0.4703	0.4241

Dependent variable: Lev(S) represents state-owned enterprises, Lev(N) represents non-state-owned enterprises, Lev(H) represents high tech enterprises; Lev(T) represents traditional enterprises. ***Indicates significance at the 1% level, **indicates significance at the 5% level, and *indicates significance at the 10% level.

Cross-sectional heterogeneity test

Different ownership

Table 10 shows the outcomes of grouped regressions by ownership and industry to determine under what conditions the impact of technological innovation on firm leverage would increase. Column (1) is for SOEs with a statistically significant negative coefficient on R&D (−0.476, p-value < 0.01); column (2) is for non-SOEs, with a statistically significant negative coefficient on R&D (−0.378, p-value < 0.01). (|−0.476| > |−0.378|) demonstrates that technological innovation negatively affects SOE leverage.

Two-thirds of the leverage in China's non-financial sector is held by SOEs, and the leverage ratio of SOEs is growing faster than that of private enterprises, giving them more room for downward adjustment. Additionally, SOEs have stronger incentives and conditions for technological innovation because they must transform their production processes and optimize their production capacity through innovation. In addition, the Chinese government has

advocated for the active participation of SOEs in technological innovation, resulting in an external effect-induced skewing of SOEs' policies.

Different industries

Table 10, columns (3) and (4) display the results of regressions grouped by industry characteristics. The coefficient on R&D in high-tech industries is negative and statistically significant (−0.568, p-value < 0.01); the coefficient on R&D in traditional manufacturing industries is also negative and statistically significant (−0.338, p-value < 0.01). Our comparison reveals that the effect of technological innovation on deleveraging is significantly greater in high-tech industries than in traditional industries.

This difference may be attributed to the knowledge-intensive nature of high-tech industries, which necessitates efficient innovation for firms to gain market share rapidly. Despite the fiercer market competition, high-tech firms' high innovation capacity can reduce innovation costs. As a result, decision-makers are more likely to invest more resources in innovation, rapidly increasing technological innovation and enhancing its deleveraging effect.

Different firm lifecycle stages

Our lifecycle classification is based on Dickinson's cash flow-based method for determining the stage of a company's lifecycle (Dickinson, 2006). In Table 11, we present the regression results for three different lifecycle firms to investigate the firm's lifecycle impact. (The start-up period is excluded from the test because we are examining publicly traded corporations). In columns (1), (2), and (3), the coefficient on R&D is significantly negative and statistically significant (−0.318, p-value < 0.01), (−0.546, p-value < 0.01) and (−0.537, p-value < 0.01). It indicates that the negative effect of technological innovation on firm leverage persists regardless of the firm's growth, maturity, or recessionary status. In |−0.546| > |−0.537| > |−0.318|, the period of maturity has the greatest effect, followed by the period of recession, and the period of growth has the least.

It may be because mature firms have greater profitability and market competitiveness, preparing them for deleveraging. In addition, firms with increasingly stable innovation resources can effectively increase their innovation success at a lower innovation cost, resulting in the greatest deleveraging effect of technological innovation on mature-stage businesses. In addition, possessing increasingly stable innovation resources can reduce innovation costs and increase a company's innovation success rate. Therefore, firms can achieve the greatest deleveraging effect of technological innovation at the mature stage.

TABLE 11 Impact analysis of business life cycle.

Dependent variables	(1) Lev(G)	(2) Lev(M)	(3) Lev(R)
R&D	−0.318***	−0.546***	−0.537***
	(−2.68)	(−4.67)	(−2.98)
Control variables	Yes	Yes	Yes
Constant	−0.133	−0.352***	−0.833***
	(−1.00)	(−3.51)	(−4.16)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	3,832	3,552	1,457
Within *R*-sq	0.3998	0.4727	0.5203

Dependent variable: Lev(G) represents growth stage enterprises, Lev(M) represents mature enterprises; Lev(R) represents recession enterprises. ***Indicates significance at the 1% level, **indicates significance at the 5% level, and *indicates significance at the 10% level 4.

TABLE 12 Impact analysis of different leverage intervals.

Dependent variables	(1) Lev(low)	(2) Lev(high)
R&D	−0.337***	−0.212*
	(−4.05)	(−1.65)
Control variables	Yes	Yes
Constant	−0.124*	−0.00004
	(−1.67)	(−0.00)
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	4,493	4,348
Within *R*-sq	0.3323	0.2678

Lev(low) refers to the sample of firms with leverage less than or equal to the mean (0.401); Lev(high) refers to the sample of firms with leverage greater than the mean (0.401). ***Indicates significance at the 1% level, **indicates significance at the 5% level, *indicates significance at the 10% level.

Different leverage intervals

In Table 12, we present the regression results for the low and high-leverage intervals to investigate the effect of technological innovation on the various leverage intervals. The R&D coefficients in columns (1) and (2) are both significantly negative and statistically significant (−0.337, p-value < 0.01) and (−0.212, p-value < 0.1). It indicates that low and high-leverage firms can deleverage through technological innovation, further supporting our findings.

Conclusion

Due to its capital-related nature, corporate leverage is highly exposed to financial risk, and optimizing corporate leverage is an effective method of mitigating financial risk. We present new evidence on the relationship between technological

innovation and corporate leverage using China-specific data. Unlike previous research, this study investigates technological innovation while considering the effects of policy incentives and market competition. The relationship between technological innovation and corporate leverage is generally negative. Simultaneously, they exhibit significant cross-sectional, spatial, and temporal heterogeneity. Furthermore, policy incentives produce an "investment crowding out" effect, whereas market competition produces an "innovation spillover" effect. Both factors inhibit the relationship between technological innovation and corporate leverage. Further differentiating by region, it is observed that both policy incentives and market competition in the eastern and western regions can have a significant negative moderating effect on the relationship between technology innovation and corporate leverage.

The effectiveness of China's Structural Deleveraging Policy and National Innovation Strategy is reflected in our analysis. Technological innovation plays a significant role in the adjustment of corporate leverage. By encouraging firms to engage in technological innovation, policymakers in emerging economies can maximize corporate leverage levels. The heterogeneity tests also indicate that by actively guiding state-owned firms, high-technology firms, and mature firms toward technological innovation, governments can improve the efficiency of firms' leverage adjustment, increase their investment in innovation, and decrease their reliance on low-end products. Moreover, continued focus on and improvement of the policy, investment, and legal environments can better leverage the moderating effect of technological innovation on corporate leverage.

Our study has some limitations. In the first place, when measuring technological innovation, we have only considered innovation inputs. Other factors, such as innovation output and efficiency, should also be considered. Second, due to our reliance on financial data, we have yet to measure the regional impact of technological innovation. Future research will expand the measurement of spatial spillover effects. In addition, the response of firm leverage to technological innovation is influenced by various factors, such as financial inclusion and emergencies, all of which merit further investigation in future studies.

Data availability statement

The original data supporting the conclusions of this article will be provided by the corresponding author.

Author contributions

DX developed the theoretical framework. DL worked on data analysis. LR worked on literature review and manuscript writing. All authors contributed to the article and approved the submitted version.

Funding

The authors acknowledged the financial support from the Science Foundation of Ministry of Education of China project (19YJC630136).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aghion, P., Van Reenen, J., and Zingales, L. (2013). Innovation and institutional ownership. *Am. Econ. Rev.* 103, 277–304. doi: 10.1257/aer.103.1.277

Aivazian, V. A., Ge, Y., and Qiu, J. P. (2005). The impact of leverage on firm investment: Canadian evidence. *J. Corp. Financ.* 11, 277–291. doi: 10.1016/S0929-1199(03)00062-2

Almeida, H., and Campello, M. (2007). Financial constraints,asset tangibility,and corporate investment. *J. Finan. Stud. Rev.* 20, 1429–1460. doi: 10.1093/rfs/hhm019

Barton, S. L., and Gordon, P. J. (1988). Corporate strategy and financial leverage. *J. Strateg. Manage.* 9, 623–632. doi: 10.1002/smj.4250090608

Belenzon, S., and Berkovitz, T. (2010). Innovation in business groups. *Manage. Sci.* 56, 519–535. doi: 10.1287/mnsc.1090.1107

Berger, A. N., Guedhami, O., Kim, H. H., and Li, X. M. (2022). Economic policy uncertainty and bank liquidity hoarding. *J. Finance Intermed.* 49, 100893.

Berk, J. B., Stanton, R., and Zechner, J. (2010). Human Capital. bankruptcy, and capital structure. *J. Finance* 65, 891–926. doi: 10.1111/j.1540-6261.2010.01556.x

Bernini, C., and Pellegrini, G. (2011). How are growth and productivity in private firms affected by public subsidy? Evidence from a regional policy. *Reg. Sci. Urban Econ.* 41, 253–265. doi: 10.1016/j.regsciurbeco.2011.01.005

Botosan, C. A., and Plumlee, M. A. (2005). Assessing alternative proxies for the expected risk premium. *Account. Rev.* 80, 21–53. doi: 10.2308/accr.2005.80.1.21

Brander, J., and Lewis, T. (1986). Oligopoly and financial structure: The limited liability effect. *Am. Econ. Rev.* 76, 956–970.

Brown, J. R., and Petersen, B. C. (2011). Cash holdings and R&D smoothing. *J. Corp. Finance* 17, 694–709. doi: 10.1016/j.jcorpfin.2010.01.003

Cai, W. G., and Zhou, X. L. (2014). On the drivers of eco-innovation: Empirical evidence from China. *J. Clean. Prod.* 79, 239–248. doi: 10.1016/j.jclepro.2014.05.035

Campello, M. (2006). Debt financing: Does it boost or hurt firm performance in product markets? *J. Financ. Econ.* 82, 135–172. doi: 10.1016/j.jfineco.2005.04.001

Chen, S. S., Chen, Y. S., Liang, W. L., and Wang, Y. Z. (2020). Public R&D spending and cross-sectional stock returns. *Res. Policy* 49:103887. doi: 10.1016/j.respol.2019.103887

Ciftci, M., and Cready, W. M. (2011). Scale effects of R&D as reflected in earnings and returns. *J. Account. Econ.* 52, 62–80. doi: 10.1016/j.jacceco.2011.02.003

Cook, D. O., and Tang, T. (2010). Macroeconomic conditions and capital structure adjustment speed. *J. Corp. Finance* 16, 73–87. doi: 10.1016/j.jcorpfin.2009.02.003

Cornaggia, J., Mao, Y. F., Tian, X., and Wolfe, B. (2015). Does banking competition affect innovation? *J. Financ. Econ.* 115, 189–209. doi: 10.1016/j.jfineco.2014.09.001

Czarnitzki, D., Hanel, P., and Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. *Res. Pol.* 40, 217–229.

Czarnitzki, D., and Licht, G. (2006). Additionality of public R&D grants in a transition economy. *Econ. Trans.* 14, 101–131. doi: 10.1111/j.1468-0351.2006.00236.x

David, P. A., Hall, B. H., and Toole, A. A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Res. Policy* 29, 497–529. doi: 10.1016/S0048-7333(99)00087-6

Del Canto, J. G., and Suarez Gonzalez, I. (1999). A resource-based analysis of the factors determining a firm's R&D activities. *Res. Policy* 28, 891–905. doi: 10.1016/S0048-7333(99)00029-3

Dickinson, V. (2006). *Future profitbility and the Role of Firm Life Cycle. Working paper*. Gainesville, FL: University of Florida, 247–256.

Faulkender, M., Flannery, M. J., Hankins, K. W., and Smith, J. M. (2012). Cash flows and leverage adjustments. *J. Financ. Econ.* 130, 632–646. doi: 10.1016/j.jfineco.2011.10.013

Fischer, E. O., Heinkel, R., and Zechner, J. (1989). Dynamic capital structure choice: Theory and tests. *J. Finance* 44, 19–40. doi: 10.1111/j.1540-6261.1989.tb02402.x

Frank, M. Z., and Goyal, V. K. (2003). Testing the pecking order theory of capital structure. *J. Financ. Econ.* 67, 217–248. doi: 10.1016/S0304-405X(02)00252-0

Galende Del Canto, J., and Suarez Gonzalez, I. (1999). A resource-based analysis of the factors determining a firm's R&D Activities. *Res. Policy* 28, 891–905.

Galvao, A. F., and Montes-Rojas, G. V. (2010). Penalized quantile regression for dynamic panel data. *J. Stat. Plan. Infer.* 140, 3476–3497. doi: 10.1016/j.jspi.2010.05.008

Giudici, G., and Paleari, S. (2000). The provision of finance to innovation: A survey conducted among Italian technology-based small firms. *Small Bus. Econ.* 14, 37–53. doi: 10.1023/A:1008187416389

Gonzalez, X., Jaumandreu, J., and Pazo, C. (2005). Barriers to innovation and subsidy effectiveness. *RAND J. Econ.* 36, 930–950.

Graham, J. R. (2003). Taxes and corporate finance: A review. *Rev. Financ. Stud.* 16, 1075–1129. doi: 10.1093/rfs/hhg033

Graham, J. R., and Tucker, A. L. (2006). Tax shelters and corporate debt policy. *J. Financ. Econ.* 81, 563–594. doi: 10.1016/j.jfineco.2005.09.002

Grossman, G. M., and Helpman, E. (1993). Innovation and growth in the global economy. *Mit Press Books* 1, 323–324.

Hausman, J., Stock, J. H., and Yogo, M. (2005). Asymptotic properties of the Hahn-Hausman test for weak-instruments. *Econ. Lett.* 89, 333–342. doi: 10.1016/j.econlet.2005.06.007

He, J., and Tian, X. (2013). The dark side of analyst coverage: The case of innovation. *J. Financ. Econ.* 109, 856–878. doi: 10.1016/j.jfineco.2013.04.001

Hewitt-Dundas, N., and Roper, S. (2010). Output additionality of public support for innovation: Evidence for Irish manufacturing plants. *Eur. Plan. Stud.* 18, 107–122. doi: 10.1080/09654310903343559

Honore, F., Munari, F., and de La Potterie, B. V. (2015). Corporate governance practices and companies'. *R&D Intensity* 44, 533–543. doi: 10.1016/j.respol.2014.10.016

Horbach, J. (2008). Determinants of environmental innovation - New evidence from German panel data sources. *Res. Policy* 37, 163–173. doi: 10.1016/j.respol.2007.08.006

Howell, S. T. (2017). Financing innovation: Evidence from R&D Grants. *Am. Econ. Rev.* 107, 1136–1164. doi: 10.1257/aer.20150808

Hsu, P. H., Tian, X., and Xu, Y. (2014). Financial development and innovation: Cross-country evidence. *J. Financ. Econ.* 112, 116–135. doi: 10.1016/j.jfineco.2013.12.002

Iqbal, N., Xu, J. F., Fareed, Z., Wan, G., and Ma, L. (2022). Financial leverage and corporate innovation in Chinese public-listed firms. *Eur. J. Innov. Manag.* 25, 299–323. doi: 10.1108/EJIM-04-2020-0161

Jensen, M. (1986). Agency costs of free cash flow, corporate finance and takeovers. *Am. Econ. Rev.* 76, 323–329.

Jensen, M. C., and Meckling, W. H. (1976). Theory of the fifirm, managerial behaviour, agency costs and ownership structure. *J. Financ. Econ.* 3, 305–360. doi: 10.1016/0304-405X(76)90026-X

Jia, L. L., Nam, E., and Chun, D. (2021). Impact of Chinese government subsidies on enterprise innovation: Based on a three-dimensional perspective. *Sustainability* 13:1288. doi: 10.3390/su13031288

Klobucar, D., and Orsag, S. (2019). *Sustainable forest management for the future - the role of managerial economics and accounting*. (Zagreb: University of Zagreb), 353–361.

Kohli, A. K., and Jaworski, B. J. (1990). Market orientation: The construct, research propositions, and managerial implications. *J. Mark.* 54, 1–18. doi: 10.1177/002224299005400201

Kong, L. (2020). Government spending and corporate innovation. *Manage. Sci.* 66, 1584–1604. doi: 10.1287/mnsc.2018.3252

Leary, M. T., and Roberts, M. R. (2005). Do firms rebalance their capital structures? *J. Finance* 60, 2575–2619. doi: 10.1111/j.1540-6261.2005.00811.x

Lee, C. Y. (2011). The differential effects of public R&D support on firm R&D: Theory and evidence from multi-country data. *Technovation* 31, 256–269. doi: 10.1016/j.technovation.2011.01.006

Lee, I. H., Kim, S. M., and Green, S. (2021). Social enterprises and market performance: The moderating roles of innovativeness, sectoral alignment, and geographic localization*. *J. Bus. Res.* 132, 491–506. doi: 10.1016/j.jbusres.2021.04.033

Li, W. F., Wu, C., Xu, L. P., and Tang, Q. Q. (2017). Bank connections and the speed of leverage adjustment: Evidence from China's listed firms. *Account. Finance* 57, 1349–1381. doi: 10.1111/acfi.12332

Liu, D. Y., Chen, T., Liu, X. Y., and Yu, Y. Z. (2019). Do more subsidies promote greater innovation? Evidence from the Chinese electronic manufacturing industry. *Econ. Model.* 80, 441–452. doi: 10.1016/j.econmod.2018.11.027

Liu, Q. R., and Huang, J. C. (2016). How does product innovation affect firm's markup. *J. World Econ.* 11, 28–53.

Lusardi, A., and Tufano, P. (2015). Debt literacy, financial experiences, and overindebtedness. *J. Pension Econ. Finance* 14, 332–368. doi: 10.1017/S1474747215000232

Ma, G. Q. (2021). *Financial theory and policy*. Shanghai: Fudan University Press.

MacKay, P., and Phillips, G. M. (2005). How does industry affect firm financial structure? *Rev. Financ. Stud.* 18, 1433–1466. doi: 10.1093/rfs/hhi032

Min, B. S., and Smyth, R. (2016). How does leverage affect R&D intensity and how does R&D intensity impact on firm value in South Korea? *Appl. Econ.* 48, 5667–5675. doi: 10.1080/00036846.2016.1181836

Mithas, S., Tafti, A., Bardhan, I., and Goh, J. M. (2012). Information technology and firm profitability: Mechanisms and empirical evidence. *MIS Q.* 36, 205–224. doi: 10.2307/41410414

Myers, S. C. (1977). Determinants of corporate borrowing. *J. Financ Econ.* 5, 147–175.

Nishimura, J., and Okamur, H. (2011). Subsidy and networking: The effects of direct and indirect support programs of the cluster policy. *Res. Pol.* 40, 714–727.

Nosheen, S., Sadiq, R., and Rafay, A. (2016). "The Primacy of Innovation in Strategic Financial Management-Understanding the Impact of Innovation and Performance on Capital Structure," in *International Conference on Management of Innovation and Technology (Icmit)*, 280–285. doi: 10.1109/ICMIT.2016.7605048

O' Brien, J. P. (2003). The capital structure implications of pursuing a strategy of innovation. *Strateg. Manage. J.* 24, 415–431. doi: 10.1016/j.heliyon.2021.e07599

Ogawa, K. (2007). R&D investment and technological progress: A panel study of Japanese manufacturing firms' behavior during the 1990s. *J. Jpn. Int. Econ.* 21, 403–423. doi: 10.1016/j.jjie.2007.02.004

Porter, M. E. (1992). Capital disadvantage: America's failing capital investment system. *Harvard Bus. Rev*. 70, 65–82.

Ramaswamy, K. (2001). Organizational ownership, competitive intensity, and firm performance: An empirical study of the Indian manufacturing sector. *Strateg, Manage. J.* 22, 989–998.

Reinhart, C. M., and Rogoff, K. S. (2010). Growth in a time of debt. *Am. Econ. Rev.* 100, 573–578. doi: 10.1257/aer.100.2.573

Schularick, M., and Taylor, A. M. (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *Am. Econ. Rev.* 102, 1029–1061. doi: 10.1257/aer.102.2.1029

Schumpeter, J. A. (1942). The theory of competitive price. *Amer. Econ. Rev.* 32, 844–847.

Showaher, D. (1995). Oligopoly and financial structure: Comment. *Am. Econ. Rev.* 85, 647–654.

Singh, M., and Faircloth, S. (2005). The impact of corporate debt on long term investment and firm performance. *Appl. Econ.* 37, 875–883. doi: 10.1080/00036840500076762

Spence, M. (1984). Cost reduction, competition, and industry performance. *Econometrica* 52, 101–121.

Stonehill, T. N. A., Remmers, L., Wright, R., and Beekhuisen, T. (1974). Comparative international study of growth, profitability, and risk as determinants of corporate debt ratios in the manufacturing sector. *J. Finance Quant. Anal.* 9, 875–886. doi: 10.2307/2329684

Strebulaev, I. A. (2007). Do tests of capital structure theory mean what they say? *J. Finance* 62, 1747–1787.

Stuart, T., and Wang, Y. B. (2016). Who cooks the books in China, and does it pay? Evidence from private, high-technology firms. *Strateg. Manage. J.* 37, 2658–2676.

Takalo, T., and Tanayama, T. (2010). Adverse selection and financing of innovation: Is there a need for R&D subsidies? *J. Tech. Transfer* 35, 16–41. doi: 10.1007/s10961-009-9112-8

Torkkeli, L., Kuivalainen, O., Saarenketo, S., and Puumalainen, K. (2019). Institutional environment and network competence in successful SME internationalisation. *Int. Market. Rev.* 36, 31–55. doi: 10.1108/IMR-03-2017-0057

Tsoy, L., and Heshmati, A. (2017). *Impact of financial crises on dynamics of capital structure:Evidence from Korean listed companies. IZA Discussion Paper No.10554*. Bonn: IZA. doi: 10.2139/ssrn.2923637

Wade, R. H. (2017). The American paradox: Ideology of free markets and the hidden practice of directional thrust. *Cambridge J. Econ.* 41, 859–880. doi: 10.1093/cje/bew064

Wallsten, S. J. (2000). The effects of government-industry R&D programs on private R &D: The case of the small business innovation research program. *RAND J. Econ.* 31, 82–100.

Wang, X. L., Fan, G., and Hu, L. P. (2019). *Marketization Index of China's Provinces; NERI Report 2018*. Beijing: Social Science Academic Press.

Williamson, O. E. (1963). "A model of rational managerial behaviour," in *A behavioural theory of the firm*, eds R. M. Cyert and J. G. March (Englewook Cliffs, NJ: Prentice-Hall).

Williamson, O. E. (1975). *Market and hierarchies: Analysis and antitrust implications*. New York, NY: Free Press.

Xia, T. J., and Roper, S. (2016). Unpacking open innovation: Absorptive capacity, exploratory and exploitative openness, and the growth of entrepreneurial biopharmaceutical firms. *J. Small Bus Manage.* 54, 931–952. doi: 10.1111/jsbm.12220

Xie, W. M., and Wei, H. Q. (2016). Market competition, organizational redundancy and enterprise R&D investment. *China Soft Sci.* 8, 102–111.

Yu, B. (2017). Does technological innovation advance enterprise deleveraging? Transmission channel and acceleration mechanism. *J. Financ. Econ.* 113–127.

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 December 2022
DOI 10.3389/fpsyg.2022.1082889

OPEN ACCESS

EDITED BY
Shanshan Wang,
Dhurakij Pundit University,
Thailand

REVIEWED BY
Wei Luo,
Henan University,
China
Haibin Xie,
University of International Business and Economics, China
Pornthip Tantivisethsak,
Dhurakij Pundit University,
Thailand

*CORRESPONDENCE
Yuyue Li
millie_liy@163.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 October 2022
ACCEPTED 23 November 2022
PUBLISHED 13 December 2022

CITATION
Zhao M, Li Y and Lu J (2022) The effect of audit team's emotional intelligence on reduced audit quality behavior in audit firms: Considering the mediating effect of team trust and the moderating effect of knowledge sharing.
Front. Psychol. 13:1082889.
doi: 10.3389/fpsyg.2022.1082889

The effect of audit team's emotional intelligence on reduced audit quality behavior in audit firms: Considering the mediating effect of team trust and the moderating effect of knowledge sharing

Mingyuan Zhao, Yuyue Li* and Jie Lu

Pan-Asia Business School, Yunnan Normal University, Kunming, China

Reduced audit quality behavior is widespread in the auditor's practice and is an important factor threatening audit quality. Some prior studies have investigated the relationship between auditors' psychological contract violation and reduced audit quality behavior. However, the research of relationship between emotional intelligence (EI) and auditors' behavior is still in its infancy despite the fact that the auditing profession would benefit greatly from improving audit team's EI. This study examines whether and why the audit team's EI restrains the audit quality reduction behavior in audit firms. In the study, our hypotheses are tested using a data set collected from 326 respondents in Chinese audit firms. The results are as follows: firstly, audit team's EI is directly negatively related to reduced audit quality behavior. Secondly, EI is indirectly related to reduced audit quality behavior, through team trust. The results of structural equation modeling (SEM) indicate a mediation model where team trust is negatively related to reduced audit quality behavior. Thirdly, knowledge sharing is a significant mechanism that moderates the effects of different types of EI on audit quality reduction behavior. In the audit team with high knowledge sharing, the audit team's EI can refrain the audit quality reduction behavior; In the audit team with low knowledge sharing, the audit team's EI has no significant effect on audit quality reduction behavior. This study expands the factors affecting audit quality to the psychological level of audit teams, enriches the literature on audit team's behavior characteristics, and provides direct evidence for the relationship between audit team's psychological characteristics and audit quality.

KEYWORDS

audit team, emotional intelligence, team trust, knowledge sharing, reduced audit quality behavior, social exchange perspective

Introduction

This study examines whether and why the audit team's emotional intelligence (EI) restrains the audit quality reduction behavior in audit firms. Emotional intelligence refers to the ability of individuals to perceive, express, and manage their own emotions, recognize the emotions of others, and use this information to guide their own thinking and actions (Joseph and Newman, 2010). When high-level interpersonal interaction and emotional clues appear in the audit team, the impact of individual EI can be reflected to the team level through the activated interpersonal communication mechanism, and the aggregation of individual EI will form a group EI at the team level. The EI of an audit team is the ability of an audit team to develop a set of norms for managing emotional processes. These norms encourage the expression and regulation of emotional dynamics within and outside the team, thus helping team members to deal with emotional problems more effectively (Curseu et al., 2015).

Auditing is naturally a team-based attribute. This is because in terms of cost inputs for an audit firm, no matter how much emphasis is placed on the importance of IT, management coordination, logistics, or other related inputs for the audit firm as a whole, labor costs have always been and will remain a core part of audit costs in the future. When doing a particular audit project, instead of devoting all of the firm's human resources to a single client, only one audit team needs to be dispatched. Most of the audit work is carried out in an audit team organization. To better manage audit teams and achieve results, recent studies have highlighted the importance of EI for teams to achieve performance (Montenegro et al., 2021; Zhu et al., 2021). Audit teams consist of individual auditors with a variety of skills. Individual auditors influence the level of audit quality, but auditors do not work in isolation; they are influenced by the EI of the audit team they work with. It has been argued that firms that effectively manage emotions within their organizations deliver better performance and higher returns than firms that ignore them (Parmar et al., 2010). Audit quality is the most central performance indicator of the audit team and is one of the most important topics in the audit profession. However, reduced audit quality behavior is widespread in auditors' practice and is an important factor threatening audit quality. Reduced audit quality behavior is defined as actions taken by an auditor during an engagement that reduce evidence-gathering effectiveness inappropriately (Herrbach, 2001). The behaviors related to the reduction of audit quality are of concern to audit firms and industry regulators, because they seem to be systematic. Previous studies have shown that more than half of the auditors admit to participating in at least one of the behaviors of reducing audit quality (Coram et al., 2003). In prior studies, the main variables for reduced audit quality are as follows: auditor firms' quality control and review procedures (Aobdia, 2020), time budget pressure (Coram et al., 2004), auditors' personality type (Gundry and Liyanarachchi, 2007), auditor independence and competence (Dart and Chandler, 2013), and high workloads (Persellin et al., 2019). The quality of the audit process is considered high if the auditor is able to detect and report existing material misstatements (Mohamed and Habib, 2013).

To restrain the behavior of auditors' quality reduction depends not only on the competence or competency of audit team members, but also on being able to manage their emotional intelligence. According to view of Goleman (2001), the more complex the job, the more important emotional intelligence becomes, and emotional intelligence affects a person's behavior from within. People with high EI are able to make informed decisions, cope better with environmental demands and pressures, handle conflict effectively, communicate in an exciting and assertive manner, and make others feel better in their work environment (Love et al., 2011). Although the effects of team project leaders (Lennox et al., 2018), auditor overconfidence (auditor overconfidence), auditor narcissism (Khaksar et al., 2021), auditor resilience (Smith and Emerson, 2017), and auditors' psychological contract violation (Herrbach, 2001) on audit behavior have been explored in EI management research, the relationship between the audit steam's EI and reduced audit quality behavior has not been described. Therefore, the first key research question of this study is as follows.

Q1. What is the relationship between the audit team's EI and reduced audit quality behavior?

In addition, the relationship between audit team's EI and reduced audit quality behavior may be complex and cannot be explained simply by direct effects. EI is a group of abilities to process emotional information, and its effectiveness depends on the degree of effective recognition and utilization of emotional information (Fineman, 2006). EI is consciously released during interactions with team members to drive and screen the responses of others. In this process, EI can not only be publicly displayed but also identify emotions from others (Ashkanasy and Dorris, 2017). People with high EI are more likely choose emotional strategies, such as eliciting, faking, promoting, and inhibiting emotions, to display their EI to team members by adopting the best strategy (Humphrey, 2013). EI is usually positively correlated with extraversion and negatively correlated with neuroticism, while it also shows a small significant positive correlation with openness, agreeableness, and conscientiousness (Saklofske et al., 2003). Based on the research base of this literature, this study aims to provide evidence on how audit teams' EI affects reduced audit quality behavior, and address the second question:

Q2. What is the mechanism of audit team's EI impacts on reduced audit quality behavior?

In order to solve these two problems, based on the literature on the social exchange theory (Obrenovic et al., 2020) and the theory of planned behavior (Ajzen, 1991), this study established a theoretical model related to the five hypotheses. According to social exchange theory, social behavior involves a social exchange in which individuals are motivated to obtain a reward, for which they must give up something valuable (Obrenovic et al., 2020). Therefore, reduced audit quality behavior is a result influenced by the teams' EI. Auditors are willing to refrain the audit quality reduction behavior and according to expectancy theory, they aim to gain monetary or non-monetary rewards such as bonuses, promotions, and trust. Central here is the concept of reciprocity.

Theory of planned behavior suggests that attitudes and subjective norms can be used to explain audit quality reducing behaviors. Individuals are more willing to comply with norms when they believe that the team's EI facilitates behaviors that improve audit quality. Trust among audit team members affects auditors' attitudes toward their audit engagements.

The five hypotheses were obtained through questionnaires. After reliability and validity tests, a structural equation model was constructed to test the theoretical model. The results show that the audit team's EI can restrain the behavior of auditors' quality reduction. After data analysis, we propose a specific mechanisms of how high EI individuals use emotional information to influence others' knowledge. The mechanism involves the process of influencing oneself. Individuals with high EI are good at using emotional clues to change their emotions, are willing to share their knowledge with team members, and promote the professional competence of team members through knowledge sharing to ensure audit quality. The mechanism is also to consciously release emotional information in social interaction, stimulate other's emotion of knowledge sharing, or dynamically evaluate emotional state at any time, and then take beneficial strategies to achieve the desired goal.

Our theoretical views will make significant contributions to research on reduced audit quality behavior: Firstly, this study expands the research on emotional intelligence in audit behavior by introducing the research on inhibition and reduction of audit behavior by emotional intelligence of audit teams, and contributed to the literature on emotional psychology. Secondly, this paper reveals that in audit teams with high audit EI, knowledge sharing is conducive to inhibiting the behavior of reducing audit quality, and contributes to the literature of knowledge sharing. Thirdly, this study expands the channel research of EI on project results. The prior research of channel mostly focuses on positive behavior, on work context and on leadership types (Cavazotte et al., 2012). Our empirical results show that team trust is the channel through which audit team's EI affects audit quality.

The following section reviews relevant literature regarding the theory of EI intelligence and audit quality reduction behavior, and proposes five hypotheses among key constructs; subsequently, a methodology for collecting 326 usable questionnaires, measuring constructs, and testing for reliability and validity are displayed. Then, the regression model of data is provided. Finally, the study's findings, discussion, theoretical implications, managerial implications, and limitations are presented.

Literature review and hypotheses

Audit team's EI and team trust

There are two views on EI, one is the ability EI, and the other considers EI in a more mixed perspective. This study is based on the theory of ability EI, and draws on the existing calculation methods. When calculating the audit team's EI score, the audit team's EI is realized by the accumulation of individual EI, that is, first measure the individual EI, then add them up and average them.

Team trust is a positive expectation of traits, such as competence, sincerity, integrity, and reliability of others in the team. Managers with high EI are able to demonstrate their vision more persuasively to their employees and manage social networks effectively, which not only helps them to build and maintain trust with stakeholders, but also to access information and resources (Naude et al., 2014). Team EI can improve team satisfaction, trust levels, and increase team cohesion, among others (Chang et al., 2012). When team EI is low, teams often adopt a negative approach to deal with problems, which has a negative impact on team trust, etc.; when team EI is high, teams are more likely to adopt a cooperative approach to deal with problems and resolve conflicts, which has a positive impact on team trust. In audit teams, team EI still plays a similar role. The relationship between the two dimensions of team EI on team trust is discussed separately below:

Analysis at individual level

There is a positive relationship between individual dimensions of EI and trust (Chun et al., 2010). Individuals with high EI are more likely to perceive intra-team trust. The logic is that, firstly, people with high EI can effectively identify trustworthy behaviors in a given context. During social interactions, most people want to present themselves in a trustworthy manner and want this behavior to be perceived by others. People with high EI have stronger social interaction and relationship management skills, and the above skills and abilities help them make correct attributions about the motivations and behaviors of team members, thus creating a stronger sense of trust in the team.

Secondly, in dealing with negative events, people with low EI usually exhibit distrustful behaviors, while the opposite is true for people with high EI. In the process of teamwork, people with low EI usually feel helpless when faced with others' misbehavior such as not completing work tasks on time or not meeting work requirements, and give up the opportunity to further seek the real cause of the misbehavior, and often attribute the misbehavior to lack of ability or intentional behavior, and this attribution tends to make them think that the other party is not trustworthy. When faced with the same situation, people with high EI are more likely to trust others, and they tend to attribute the misconduct to uncontrollable factors (e.g., lack of professional competence), and to learn the true cause through further communication or other means, while thinking more about how to improve the situation and taking the right actions (e.g., sharing audit experience, giving moral motivation, etc.) to remedy it. This trust makes it easier to develop trust in the team.

Thirdly, people with high EI are more likely to experience positive emotions than those with low EI (Fredrickson, 2001). Positive emotions expand the ability of team members to think and act instantaneously. When audit team members are in a positive emotional state, they are more open to information, more flexible and integrated in their thinking, and more likely to find positive meaning in events and generate more positive evaluations.

Analysis at team level

Social network theory asserts that in the context of a team project, team members must divide the work among themselves and communicate adequately during the project in order to complete the task within a given time frame. EI influences the selection of others as friendly partners through the perception of team trust. When one chooses others as friendly partners, this positive expectation of the overall team influences one to have positive emotional experiences with team members, which in turn motivates more interactions and results in others choosing oneself as a friendly partner, thus effectively building team identity and team trust (Sparrowe et al., 2001). Teams with higher levels of EI usually have frequent communication, cooperation, and mutual understanding among their members and are prone to trusting cognitive behaviors. Therefore, this study proposes the following hypothesis:

> *H1:* In the audit team, EI has a positive impact on team trust.

Audit team's EI and reduced audit quality behavior

From the point of view of audit practice, audit work should be "people-oriented," but also "team work." The individual auditor is an important determinant of project quality, and individual behavior is necessarily dependent on the work team, and the individual interests of the auditor are integrated with the interests of the team. At the same time, because auditors interact with client management extensively during the audit process, auditing is a job with strong EI implications. More generally, the reputation of the audit firm and the reasonableness of its charge level require that it have a high integrity image. In the long run, the audit firm cannot have negligent employees. In this sense, the reduced audit quality behavior must still be the concern of audit firms, especially in the case of continuous evolution of audit methods. In this case, the individual auditor has more freedom. A more judgmental approach leaves more room for auditor initiatives. This is positive to some extent, but the new approach also depends more on the conscience of individual auditors. The relationship between the two levels of team EI on reduced audit quality behavior is discussed separately below:

Analysis at individual level

Firstly, personal EI can help audit team members improve their interaction skills with others and exchange audit experience in the industry. The perception and understanding of industry experience are conducive to the audit team to cope with changes in environment. The auditor's personal industry experience reflects the auditor's professional competence, specifically, the auditor has accumulated and mastered the business characteristics, transaction processes, and special accounting policies of the customer's industry. Auditors with high EI can help employees perceive problems from multiple perspectives, thereby improving employees' self-awareness and skills (Sheldon et al., 2014). This helps other auditors make reasonable audit judgments and propose effective audit implementation plans, thus improving audit quality. In collaborative teams, communication and coordination mechanisms appear to be more important than control and command relationships (Chin et al., 2022). In addition, EI enables individuals to have a keen understanding of the dynamics of interpersonal relationships. It enables individuals to adjust their emotions more quickly according to the environment, which helps to strengthen personal interpersonal skills and improve social and political skills (Zaccaro et al., 2018).

Secondly, individual EI can promote auditors' proactive behavior. Due to effective emotion regulation, members with high EI are more likely to show positive behaviors than those with low EI (Kim et al., 2005). This motivates auditors to use their specific industry expertise to gain a deeper understanding of their clients' operating characteristics, transaction processes, and the accounting policies customary in the industry to better identify the risks of their clients' financial reports and more accurately assess the fairness of their clients' financial report generation and disclosure. The auditor's expertise prevents the risk of potential audit failures from threatening and damaging the team's reputation, thereby improving audit quality. In addition, in order to develop social relations, individuals with high EI may also adopt positive behaviors related to emotions (such as using humor to manage conflicts), obtain higher performance through emotional motivation, and establish relationships with others through self-monitoring (Cheung and Tang, 2009). This development of social relations has promoted the formation of the audit team's cooperation ability. Team cooperation ability is an important "soft power" support behind the high-quality audit services provided by the firm. If the audit team has no "cooperation," it will be degraded to "self-employed." In the audit team, teamwork is particularly important.

Thirdly, individual EI can promote auditors to obtain more excellent performance outcomes. More and more studies have proved the positive relationship between EI and performance outcomes (Deming, 2017), which include decision quality, task performance, and productivity. Specifically, individuals with high EI also affect others' emotional state or behavior tendency through the exchange of social emotional resources, thus affecting others' work performance (Vidyarthi et al., 2014). Auditors with high EI can well control their emotions, exchange information with customers in the process of interaction with them by virtue of the social skills brought by EI, obtain sufficient and appropriate audit evidence, provide reasonable basis for issuing audit opinions, and efficiently refrain the audit quality reduction behaviors.

Analysis at team level

Firstly, team EI facilitates the emotional climate of emotional expression and experience of the members of the

formal audit team. Emotions are often considered to be drivers of behavior and ultimately affect employee performance (Ashkanasy et al., 2017). Project leaders with high EI can create or maintain a cohesiveness within the team by stimulating positive group identity, establishing group norms, or encouraging team members to engage in emotional expression (Wilderom et al., 2015). This cohesiveness can alleviate the auditor's multiple pressures of work deadlines, performance appraisals, and liability risks, enhance professional discretion, and improve audit quality.

Secondly, team EI can facilitate conflict management in teams. Conflict is a reflection of the emotions in a team (Jordan and Troth, 2004). Because team leaders with high EI are able to more accurately understand their own internal emotions and needs, they can also develop workplace norms that are accepted by the group, thereby reducing the occurrence of team conflict and maintaining a harmonious atmosphere in the team (Wilderom et al., 2015). Conflict reduction facilitates the formation of emotional alliances and alliances of interest in the audit team to ensure that the expected audit quality is achieved.

Thirdly, team EI helps audit teams to make better decisions to improve audit efficiency. There is a positive relationship between group EI and team efficiency (Jamshed and Majeed, 2019). Groups with high EI create an emotional climate that enables members to perceive the information expected by the organization and generate the corresponding emotions or motivations. For example, an atmosphere of openness and cooperation promotes the emergence and proliferation of new ideas. In this case, emotional contagion among audit team members will help improve the review process of audit and refrain an act of audit quality reduction. Therefore, this study proposes the following hypothesis:

> *H2:* In the audit team, EI has a negative impact on reduced audit quality behavior.

Team trust and reduced audit quality behavior

Trust is the basis of all economic exchange. An environment with a high level of trust increases organizational efficiency (Williamson, 1993). In an audit team, the quality and effectiveness of each member's work assignments are often not fully under his or her control, as each member's work assignments are more related to the work of others. If members are to do their assigned work well, the more critical factor is to gain the trust of others and make other team members willing to work with them. If trust is lacking, the work of the audit team cannot be carried out properly and in a timely manner.

By perceiving trust in the team, team members develop perceived cohesion, integrate organizational goals with their personal goals, and are more willing to work creatively. Attitude, as an internal psychological tendency, affects audit results. Early in the establishment of virtual teams, 2/3 of high-performing teams exhibit rapid trust and are able to maintain and sustain trust throughout the team's duration (Kanawattanachai and Yoo, 2002). Trust helps to enhance the psychological security of team members, reduce the risk of trust among team members, believe that it is relatively safe to take interpersonal risks within the team, encourage team members to propose innovative audit ideas and methods, give full play to each team member's professional and collaborative abilities, and improve the efficiency of audit team collaboration. Trust helps team members to be consistent in their understanding of important audit judgments and audit conclusions, improves the efficiency of audit procedures, reduces or avoids inefficient work caused by mistrust and disagreement, and ensures that audit quality reduction behavior is minimized. Therefore, this study proposes the following hypothesis:

> *H3:* In the audit team, team trust has a negative effect on reduced audit quality behavior.

The mediating role of team trust

In the audit team, higher team EI can effectively establish emotional norms, so that team members can put aside their doubts and guesses as soon as possible, and establish team trust. This atmosphere is conducive to the sharing of professional knowledge and insight audit information among team members. Employees with high EI who share resources will gain the trust and respect of other employees in the organization, obtain emotional satisfaction, and establish a good reputation, which will in turn make them more motivated to perform high-quality audits (Yan et al., 2016).

In contrast, when the EI of the audit team is low, team members are in a relatively unfamiliar environment and are prone to emotional reactions such as suspicion and skepticism, resulting in mistrust among members and a failure to cooperate and share. A distrustful working atmosphere can cause auditors to behave in a dysfunctional manner, which in turn leads to an increase of audit quality reduction behaviors (Lopez and Peters, 2012). According to the basic principles of the theory of planned behavior, when planning behavior, alternative choices are analyzed to determine that the choice is most likely to achieve the desired goal. When auditors believe that working together makes the accomplishment of the target assignment more likely, they will be willing to regulate their audit behavior under conditions of trust in order to obtain the achievement of the team's audit objectives. Therefore, this study proposes the following hypothesis:

> *H4:* In an audit team, team trust plays a mediating role between audit team's EI and reduced audit quality behavior.

The moderating role of knowledge sharing

Audit firms as a knowledge-intensive organization, knowledge is more important component of core competency for their audit teams. Knowledge sharing is the basis for firms to acquire and sustain competitive advantage (Felin and Hesterly, 2007). To perform an efficient and effective audit, an auditor must have knowledge of several aspects, such as general domain knowledge of accounting and auditing standards, sub professional knowledge related to specific industries or customers, and general business knowledge. When working with alliance partners with heterogeneous knowledge, auditors can acquire humanistic and audit knowledge that reflects personal insights through mutual learning (Cohen and Caner, 2016; Chin et al., 2021). By the social exchange theory, the willingness to share knowledge is high in the expectation of reciprocal benefits.

More frequent communication between audit team leaders and members can also reduce the latter's role conflict and ambiguity, thus promoting more, and more focused, proactive transmissions. Audit team members share knowledge with other members and diffuse knowledge from individuals to teams, which facilitates the construction of a firm's competitive advantage. Knowledge sharing in audit teams is demonstrated by the fact that rapid team trust in the development process facilitates knowledge sharing among members, and good knowledge sharing also positively affects rapid trust (Chow et al., 2008). Knowledge sharing can improve audit quality by increasing the audit team's ability to adequately use accumulated industry expertise to better identify and respond to risks of material misstatement of financial statements.

In teams with a high level of knowledge sharing, team members are willing to share their knowledge to other members. This creates a harmonious atmosphere and good member relationship for the team, improves the overall capability of the team members, and brings high quality audit opinions to the audit team. In contrast, in teams with low knowledge sharing, members are reluctant to share their knowledge, skills, etc. to other members. These team members keep knowledge confidential and guard against knowledge transmissions. This may make team members less inclined to seek advice from other members or to reveal adverse audit findings. These behaviors reduce the quality of the audit. In other words, knowledge sharing has an enhanced effect on audit quality. Previous studies also confirm that effective knowledge sharing may contribute to audit quality and efficiency (Duh et al., 2020). Therefore, this study proposes the following hypothesis:

> *H5:* Knowledge sharing plays a moderating role between audit team's EI and reduced audit quality behavior.

To summarize, this study constructed a model of the relationships between audit team's EI, team trust, and reduced audit quality behavior. The theoretical model is depicted in Figure 1.

Materials and methods

Measurements of variables

To ensure that the reliability and validity met the requirements of the study, questionnaires measured each variable by drawing from existing common scales in the publicly available literature. Reliability and validity were pretested using data from 326 valid questionnaires. Apart from dependent variable and control variables, all variables were measured using a five-point Likert scale, i.e., score 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree, which is shown in Table 1.

Independent variable

The independent variable in this study was emotional intelligence (denoted by EI), which was measured using four dimensions of Wong and Law (2002). An example dimension is, "I have a good sense of why I have certain feelings most of the time." This scale has been used in many studies conducted in the Chinese project context (Law et al., 2008).

Dependent variable

The dependent variable in this study was reduced audit quality behavior (denoted by RAQB). Using the instrument developed by from Smith and Emerson (2017), we measured reduced audit quality behavior using five items ranging from "never" to "nearly always," such as "During the past year, how often have you acted in the following manner when carrying out an audit: accepted weak client explanations."

Intermediary variable

The intermediary variable in this study was team trust (denoted by TT), which was assessed using scale items from work of Yilmaz and Hunt (2001). The scale is more in line with audit team's situation. Team trust was assessed using five items, such as "I consider my co-workers as people who(m) can be trusted."

Moderating variable

The moderating variable of this study was knowledge sharing (denoted by KS). Referring mainly to Lin (2007), we measured knowledge sharing by four interview questions. Participants were asked to evaluate their knowledge sharing behavior. Examples of these scale items are as follows: "I share my job experience with my co-workers" and "I share my professional knowledge at the request of co-workers."

Control variables

We included a set of control variables following prior research on audit quality in the statistical analysis (Gul et al., 2013). We controlled the potential influence of the following variables: educational background (1 = Major in finance, accounting and auditing, 2 = other), experience in auditing (1 = less than or equal to 15 years, 2 = between 16 and 25 years, 3 = more than or equal to 26 years), gender (1 = male, 2 = female),

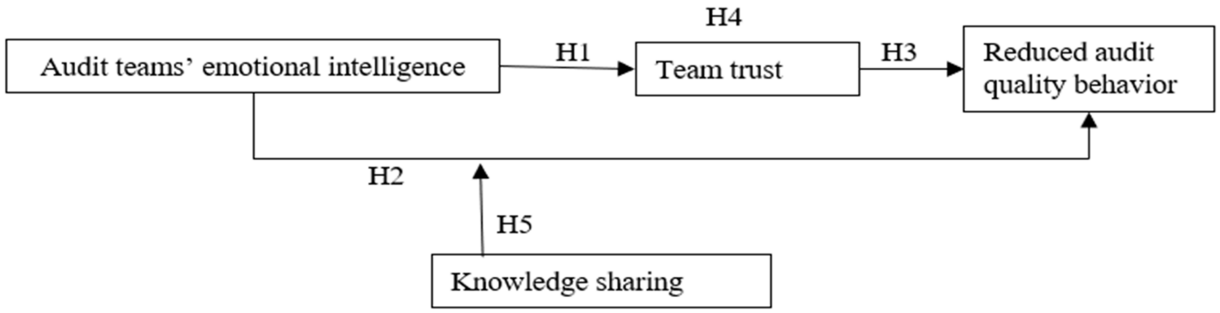


FIGURE 1
The theoretical model.

rank (1 = partner, 2 = manager, 3 = other), and level of education (1 = college degree or below, 2 = undergraduate, 3 = Master's degree or above).

Description of the sample

Since the variables included in this study were not available from public information, we collected data using a large-scale audit firm questionnaire. The scope of this study was 426 audit firms of different sizes registered in 16 provincial-level administrative regions in China, and the specific respondents were CPAs practicing in the target firms. A total of 426 questionnaires were distributed and collected on site through the opportunity of business training conducted by the Chinese Institute of CPA, and through the distribution of questionnaires by the first author's former colleagues in audit firms. The returned questionnaires were screened according to the principle of deleting the questionnaires that were not filled in, not selected, and those with less than 18 questions, in order to ensure the validity of the information in the recovered questionnaires, and therefore the analysis of the questionnaires no longer involves missing data. A final total of 326 usable questionnaires were obtained, with an overall efficiency rate of 76.53%. The reason why the questionnaire response rate is not high is that the survey objects cover a wide range of regions and there are many questionnaires excluded according to the screening conditions.

Table 2 shows the descriptive statistics of the sample. Among the total number of respondents, 65.95% were male, and 34.05% were female; over 43% of subjects majored in finance, accounting, and auditing; holders of a college degree or below accounted for 12.27%, holders of an undergraduate degree accounted for 76.69%, and holders of a Master's degree or above accounted for 11.04%. Respondents with less than or equal to 15 years auditing experience accounted for 28.53%, those between 16 and 25 years of auditing experience accounted for 46.93%, and those with more than or equal to 26 years of auditing experience accounted for 24.54%. Respondents with partner rank accounted for 10.74%, those with manager rank accounted for 24.85%, and those with other rank accounted for 64.42%.

Testing for reliability and validity

The Cronbach's α coefficients for audit team's emotional intelligence, team trust, and reduced audit quality behavior scales were 0.874, 0.908, and 0.915, respectively. These results indicated that the items had good internal consistency and reliability.

An exploratory factor analysis was conducted using the Kaiser-Meyer-Olkin test and Bartlett's test of sphericity. The Kaiser-Meyer-Olkin values for audit team's EI, team trust, and reduced audit quality behavior were 0.835, 0.897, and 0.901, respectively, and passed Bartlett's spherical test ($p = 0.000 < 0.01$), which indicated that the construct validity of the questionnaire was good.

We constructed a measurement model containing four latent variables and 18 observed variables. The parameters of the model were estimated and tested using the maximum likelihood method of the covariance structure model, and the fit indices of the hypothesized four-factor model were obtained as follows: χ^2 / df = 1.951 (<3), RMSEA = 0.054 (<0.08), GFI = 0.921 (>0.90), and CFI = 0.971 (>0.90). According to the criteria for a good model fit, the data were well-fitted, providing support for the distinctiveness of the four constructs in the study.

We compared the square root of the average variance extracted (AVE) value of the latent variable itself with the correlation coefficient between different latent variables to determine the discrimination validity, and found that the square root of AVE of each variable was greater than the correlation coefficient between the variable and other variables, indicating that the measurement scale had good discrimination validity. Variable AVE and correlation coefficient are shown in Table 3.

Results

Testing of hypotheses

Firstly, to verify the H1 proposed in Section "audit team's EI and team trust," the following regression models were constructed as follows:

TABLE 1 Description of variables.

Variable	Number	Measurement items
Emotional intelligence (EI)	EI_1	I have a good sense of why I have certain feelings most of the time.
	EI_2	I always know my friends' emotions from their behavior.
	EI_3	I always set goals for myself and then try my best to achieve them.
	EI_4	I am able to control my temper so that I can handle difficulties rationally.
Team trust (TT)	TT_1	I consider my co-workers as people who can be trusted.
	TT_2	I consider my co-workers as people who can be counted on to do what is right.
	TT_3	I consider my co-workers as people who can be counted on to get the job done right.
	TT_4	I consider my co-workers as people who are always faithful.
	TT_5	I consider my co-workers as people who I have great confidence in.
Knowledge sharing (KS)	KS_1	I share my job experience with my co-workers.
	KS_2	I share my expertise at the request of my co-workers.
	KS_3	I share my ideas about jobs with my co-workers.
	KS_4	I talk about my tips on jobs with my co-workers.
Reduced audit quality behavior (RAQB)	$RAQB_1$	Accepted weak client explanations.
	$RAQB_2$	Failed to research an accounting principle.
	$RAQB_3$	Made superficial reviews of documents.
	$RAQB_4$	Prematurely signed-off on an audit step.
	$RAQB_5$	Reduced work below what you considered reasonable.

$$TT = \beta_0 + \beta_1 EI + \beta_2' CONT + \in \quad (1)$$

Where, CONT represents control variables (gender, educational background, experience in auditing, rank, and education); $\in$ denotes residuals. TT and EI are in keeping with how the variables are defined in Table 1. The regression outcomes of equation (1) in Model 2 showed that audit team's EI was positively related to team trust ($\beta_1 = 0.386$, $p < 0.01$). Therefore, the H1 was supported.

We then examined the mediating effect of team trust between audit team's emotional intelligence and reduced audit quality behavior, drawing on the four conditions for establishing mediation proposed by Baron and Kenny (1986). Audit team's EI was negatively related to reduced audit quality behavior (Model 3, $\beta = -0.276$, $p < 0.01$). Therefore, the H2 was supported.

Team trust was negatively related to reduced audit quality behavior (Model 4, $\beta = -0.302$, $p < 0.01$). Therefore, Hypothesis 3 was supported.

When team trust was added, the relationship between audit team's emotional intelligence and reduced audit quality behavior was weaker, although still significant (Model 4, $\beta = -0.159$, $p < 0.01$), which suggests partial mediation. To further evaluate the mediating effect, we used the Mode 4 of PROCESS (Hayes, 2012) to test the indirect effect. When the 95% CI of the sample-based Bootstrap does not contain zero, the indirect effect of team trust is significant. After controlling for the control variables, results showed that the mediating effect of team trust on the relationship between audit team's emotional intelligence and reduced audit quality behavior was −0.302 and the 95% CI of sample-based Bootstrap (5,000) was (−0.416, −0.188; excluded zero). Taken together, Hypothesis 4, team trust mediated the relationship between audit team's emotional intelligence and reduced audit quality behavior, was thus supported.

To further evaluate the moderating effect, we used the Mode 5 of PROCESS (Hayes, 2012) to test Hypothesis 5. H5 predicted that knowledge sharing moderated the relationship between audit team's emotional intelligence and reduced audit quality behavior. After controlling for the control variables, the outcomes in Table 4 showed that the interaction between audit team's emotional intelligence and knowledge sharing (EI*KS) is negatively related to reduced audit quality behavior (Model 5, $\beta = -0.118$, $p < 0.01$). To test for the existence of a moderating effect, it is inevitable that the contrast of such moderating effect is very sharp, i.e., the regression of the moderating effect is significant in the full sample of data, but this significance will only continue to exist in one of the subsamples, while this significance does not exist in the other subsample. Based on the above logic, we divided knowledge sharing into strong and weak subsample groups for the regression. Figure 2 showed that the negative relationship between audit team's emotional intelligence and reduced audit quality behavior was significantly stronger, when knowledge sharing was at high group ($\beta = -0.319$, $p < 0.01$) than at low group ($\beta = -0.043$, ns), the difference is significant ($\Delta = -0.276$, $p < 0.01$). Therefore, the H5 was supported.

Conclusion and discussion

Conclusion

The goal of this study is to investigate whether, how, and when audit team's EI influences reduced audit quality behavior.

TABLE 2 Descriptive statistics for the sample.

Characteristic	Classification	Frequency	Percentage (%)	Characteristic	Classification	Frequency	Percentage (%)
Gender	Male	215	65.95	Education	College degree or below	40	12.27
	Female	111	34.05		Undergraduate	250	76.69
Educational background	Major in finance, accounting and auditing	141	43.25		Master's degree or above	36	11.04
	Other	185	56.75	Rank	Partner	35	10.74
Experience in auditing	Less than or equal to 15 years	93	28.53		Manager	81	24.85
	Between 16 and 25 years	153	46.93		Other	210	64.42

TABLE 3 Value of AVE variable and correlation coefficient of potential variable.

Variable	Ave	Correlation coefficient			
		RAQB	TT	KS	EI
RAQB	0.684	0.827			
TT	0.663	−0.347**	0.814		
KS	0.741	−0.339**	0.399**	0.861	
EI	0.636	−0.253**	0.381**	0.110*	0.797

**Significant at $p < 0.01$ (two-tailed); *Significant at $p < 0.05$ (two-tailed); The diagonal number is the square root of the variable AVE.

We introduce team trust and knowledge sharing as the mediator and moderator, respectively. Using a survey based on 326 respondents from Chinese audit firms, we confirm that audit team's EI is negatively related to reduced audit quality behavior, and team trust negatively mediate the above relationship. In addition, knowledge sharing negatively moderates the relationship between audit team's EI and reduced audit quality behavior. Specially, our findings suggest that audit firms' knowledge sharing can reduce the behavior of absolute discretionary accruals and is positively related to the issuance of unfavorable audit opinions. Both of which indicate that when the knowledge sharing is higher, the audit quality reduction behavior can be reduced. The findings point to the importance of studying how audit team's EI affects reduced audit quality behavior in audit firms, especially through the mediating role of team trust and moderating role of knowledge sharing.

Theoretical implications

Our findings have several theoretical implications. Firstly, the research on reduced audit quality behavior has been mainly conducted from the cultivation of competence of auditors, audit independence, innovation and improvement of audit technology and methods, breach of psychological contract, improvement of audit standards and quality control system, etc. (Kusuma and Sukirman, 2017). This study actively explored the reduced audit quality behavior from the perspective of audit team's EI in audit firms, constructed a theoretical model of audit team's EI and reduced audit quality behavior, and obtained data through questionnaires, using structural equation model for empirical testing. Audit team's EI can help improve audit quality by minimizing the tendency of auditors to participate in reduced audit quality behavior. This research outcome is consistent with that of Yang et al. (2018), who believe that EI can effectively reduce auditors' dysfunctional behavioral tendencies and improve audit quality.

Secondly, over the past few decades, a large number of studies have found that positive behaviors, work contexts, and leadership types have a mediating effect between EI and work results (Kim et al., 2005; Cavazotte et al., 2012; Vidyarthi et al., 2014), and few studies have paid attention to the mediating effect of team trust. This study examined the audit team's EI through the team trust variable in the causal chain to alleviate the audit quality reduction behavior.

Thirdly, the outcomes of this study established the mechanism of knowledge sharing in the audit team's audit quality reduction behavior. At present, many researches regard EI as an important factor affecting audit quality, and find that EI is positively related to job satisfaction, work behavior, and work performance (Momm et al., 2014). Our findings are further based on this concept. It is found that the audit team with high knowledge sharing will have the audit quality reduction behavior only when its EI is high; In the audit team with low knowledge sharing, the audit team's EI has no significant effect on reducing the audit quality behavior. Knowledge sharing, such as on-the-job training, experiences sharing in coping with difficult decisions, exchange of knowledge about new regulations and professional standards, and exchange of time-saving audit methods, will not only increase the audit team's EI, but also improve the audit quality by converting knowledge into ability. Knowledge sharing can help audit firms leverage the skills, knowledge, and best practices of their professional staff (Vera-Munoz et al., 2006). Therefore, this study provides a new perspective and ideas for the audit quality management in audit firms, and expands and improves the research on audit quality.

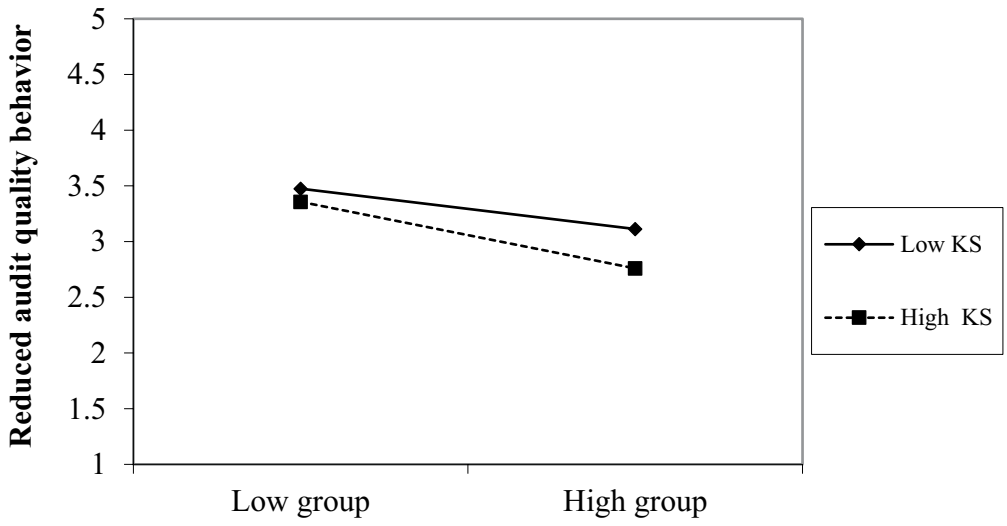


FIGURE 2
Interaction between audit team's emotional intelligence and reduced audit quality behavior.

TABLE 4 Results of relationship between audit team's emotional intelligence and reduced audit quality behavior (N=326).

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
	RAQB	TT	RAQB	RAQB	RAQB
Constant	2.300***	2.022***	3.244***	3.854***	3.294***
Gender	0.08	0.096	0.06	0.089	0.021
Educational background	0.291***	−0.086	0.338***	0.312***	0.281***
Experience in auditing	0.055	−0.063	0.052	0.033	0.044
Rank	0.009	0.140***	0.016	0.058	0.044
Education	0.086	−0.131	0.036	−0.003	−0.067
EI		0.386***	−0.276***	−0.159***	−0.181***
TT				−0.302***	−0.197***
KS					−0.236***
EI*KS					−0.118***
R^2	0.018	0.16	0.085	0.397	0.467
$Adj\text{-}R^2$	0.002	0.145	0.068	0.157	0.218
F	1.16	18.964***	4.969***	8.472***	10.16***

***Significant at $p < 0.01$.

Managerial implications

Our findings have several practical implications. Firstly, this study provides guidance for human resource allocation and audit team building. EI is the lubricant to promote the harmonious and efficient work of the team, which can significantly reduce the audit quality reduction behavior. When more and more audit team members organize individuals from different regions, with different professional backgrounds, and at different ages to complete auditing together, EI is particularly important. In audit practice, managers or partners of audit firms need to understand the EI status of the audit team. In the absence of high EI talents, the use of a team organization system with a mix of high and low EI may help alleviate the plight of the lack of high EI talents. The audit firm's managers can reduce and eliminate the adverse effects of reduced audit quality behavior through the emotional management of the audit team.

Secondly, this study promotes the audit firms to fully develop the value of EI of the audit team. EI is a potential resource that depends on individuals. This resource can play two roles, one is individual level, and the other is team level. For auditors, it is necessary to manage and control their EI during the audit process. For audit firms, it is also important to leverage the team trust channel and enhance the team's EI to improve the audit quality. The organization can provide employees with mandatory regular EI training as a stress management technology, which will improve their work performance (Slaski and Cartwright, 2002).

Thirdly, knowledge sharing has a moderating effect on the relationship between audit team's EI and reduced audit quality behavior. Therefore, audit firms' managers should develop relevant policies and incentives in the usual management process to allow more knowledge to be shared within the audit firm, such as encouraging work suggestions and self-development so that employees can share their knowledge with others. Managers can motivate employees to share their knowledge with others by encouraging them to participate in goal setting and self-realization. In addition, managers can encourage audit teams to participate in decision-making so that employees have the opportunity to share knowledge with others. Through knowledge sharing, audit team members can enhance a greater sense of identification with their profession and become more willing to regulate their audit behavior in the process of implementing audit engagement (Knechel, 2013).

The knowledge required to perform an audit may be unevenly distributed among audit firms or audit team members, and facilitating knowledge sharing can alleviate the audit quality reduction behavior.

Limitations and future research

Three limitations of the present study should be mentioned. Firstly, this study only studied the impact of the audit team's EI on reduced audit quality behavior. In the future, we can also explore whether and how the audit team's time pressure, responsibility, leadership style, job satisfaction, task complexity, and other factors affect the audit team's behavior of reducing audit quality. Secondly, this study only explored the mediating role of team trust and the moderating role of knowledge sharing. In the future, we can also explore whether there are other mediating variables and moderating variables that play a role between audit team's EI and reduced audit quality behavior. Thirdly, due to the limitation of economic resources, the sample data we investigated only involved 426 audit firms, and only involved China. Therefore, there is still room for improvement in data collection, and the theoretical extrapolation validity needs to be further explored.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MZ contributed to establishment of the theory, the writing—original draft preparation, and the software. YL helped to analyze the data and editing. JL contributed to the calculations. All authors contributed to the article and approved the submitted version.

Funding

This research was supported by the project of a core course for graduate students of Yunnan Normal University under grant no. YH2020-C09 and by the project for Case Database-Building of Yunnan Provincial Department of Education.

Acknowledgments

The authors sincerely thank all the participants of this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T

Aobdia, D. (2020). The economic consequences of audit firms' quality control system deficiencies. *Manag. Sci.* 66, 2883–2905. doi: 10.1287/mnsc.2019.3301

Ashkanasy, N. M., and Dorris, A. D. (2017). Emotions in the workplace. *Annu. Rev. Organ. Psych. Organ. Behav.* 4, 67–90. doi: 10.1146/annurev-orgpsych-032516-113231

Ashkanasy, N. M., Humphrey, R. H., and Huy, Q. N. (2017). Integrating emotions and affect in theories of management. *Acad. Manag. Rev.* 42, 175–189. doi: 10.5465/amr.2016.0474

Baron, R. M., and Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* 51, 1173–1182. doi: 10.1037/0022-3514.51.6.1173

Cavazotte, F., Moreno, V., and Hickmann, M. (2012). Effects of leader intelligence, personality and emotional intelligence on transformational leadership and managerial performance. *Leadersh. Q.* 23, 443–455. doi: 10.1016/j.leaqua.2011.10.003

Chang, J. W., Sy, T., and Choi, J. N. (2012). Team emotional intelligence and performance: interactive dynamics between leaders and members. *Small Group Res.* 43, 75–104. doi: 10.1177/104649641141569

Cheung, F. Y., and Tang, C. S. (2009). The influence of emotional intelligence and affectivity on emotional labor strategies at work. *J. Individ. Differ.* 30, 75–86. doi: 10.1027/1614-0001.30.2.75

Chin, T., Meng, J., Wang, S., Shi, Y., and Zhang, J. (2021). Cross-cultural metacognition as a prior for humanitarian knowledge: when cultures collide in global health emergencies. *J. Knowl. Manag.* 26, 88–101. doi: 10.1108/JKM-10-2020-0787

Chin, T., Shi, Y., Singh, S. K., Agbanyo, G. K., and Ferraris, A. (2022). Leveraging blockchain technology for green innovation in ecosystem-based business models: a dynamic capability of values appropriation. *Technol. Forecast. Soc. Chang.* 183:121908. doi: 10.1016/j.techfore.2022.121908

Chow, C. W., Ho, J. L., and Vera-Munoz, S. C. (2008). Exploring the extent and determinants of knowledge sharing in audit engagements. *Asia Pac. J. Account. Econ.* 15, 141–160. doi: 10.1080/16081625.2008.9720815

Chun, J. U., Litzky, B. E., Sosik, J. J., Bechtold, D. C., and Godshalk, V. M. (2010). Emotional intelligence and trust in formal mentoring programs. *Group Org. Manag.* 35, 421–455. doi: 10.1177/1059601110378293

Cohen, S. K., and Caner, T. (2016). Converting inventions into breakthrough innovations: the role of exploitation and alliance network knowledge heterogeneity. *J. Eng. Technol. Manag.* 40, 29–44. doi: 10.1016/j.jengtecman.2016.03.002

Coram, P., Ng, J., and Woodliff, D. (2003). A survey of time budget pressure and reduced audit quality among Australian auditors. *Aust. Account. Rev.* 13, 38–44. doi: 10.1111/j.1835-2561.2003.tb00218.x

Coram, P., Ng, J., and Woodliff, D. R. (2004). The effect of risk of misstatement on the propensity to commit reduced audit quality acts under time budget pressure. *Audit. J. Pract. Theory* 23, 159–167. doi: 10.2308/aud.2004.23.2.159

Curseu, P. L., Pluut, H., Boros, S., and Meslec, N. (2015). The magic of collective emotional intelligence in learning groups: no guys needed for the spell. *Br. J. Psychol.* 106, 217–234. doi: 10.1111/bjop.12075

Dart, E., and Chandler, R. (2013). Client employment of previous auditors: shareholders' views on auditor independence. *Account. Bus. Res.* 43, 205–224. doi: 10.1080/00014788.2012.707968

Deming, D. J. (2017). The growing importance of social skills in the labor market. *Q. J. Econ.* 132, 1593–1640. doi: 10.1093/qje/qjx022

Duh, R. R., Knechel, W. R., and Lin, C. C. (2020). The effects of audit firms' knowledge sharing on audit quality and efficiency. *Audit. J. Pract. Theory* 39, 51–79. doi: 10.2308/ajpt-52597

Felin, T., and Hesterly, W. S. (2007). The knowledge-based view, nested heterogeneity, and new value creation: philosophical considerations on the locus of knowledge. *Acad. Manag. Rev.* 32, 195–218. doi: 10.5465/amr.2007.23464020

Fineman, S. (2006). On being positive: concerns and counterpoints. *Acad. Manag. Rev.* 31, 270–291. doi: 10.5465/AMR.2006.20208680

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. *Am. Psychol.* 56, 218–226. doi: 10.1037/0003-066X.56.3.218

Goleman, D. (2001). "Emotional intelligence: issues in paradigm building" in *The Emotionally Intelligent Workplace*. eds. D. Goleman and C. Cherniss, vol. *13* (San Francisco, CA: Jossey-Bass), 26.

Gul, F. A., Wu, D., and Yang, Z. (2013). Do individual auditors affect audit quality? Evidence from archival data. *Account. Rev.* 88, 1993–2023. doi: 10.2308/accr-50536

Gundry, L. C., and Liyanarachchi, G. A. (2007). Time budget pressure, auditors' personality type, and the incidence of reduced audit quality practices. *Pac. Account. Rev.* 19, 125–152. doi: 10.1108/01140580710819898

Hayes, A. F. (2012). PROCESS: a versatile computational tool for observed variable mediation, moderation, and conditional process modeling [white paper]. Available at: www.afhayes.com/public/process 2012.pdf

Herrbach, O. (2001). Audit quality, auditor behaviour and the psychological contract. *Eur. Account. Rev.* 10, 787–802. doi: 10.1080/09638180127400

Humphrey, R. H. (2013). The benefits of emotional intelligence and empathy to entrepreneurship. *Entrep. Res. J.* 3, 287–294. doi: 10.1515/erj-2013-0057

Jamshed, S., and Majeed, N. (2019). Relationship between team culture and team performance through lens of knowledge sharing and team emotional intelligence. *J. Knowl. Manag.* 23, 90–109. doi: 10.1108/JKM-04-2018-0265

Jordan, P. J., and Troth, A. C. (2004). Managing emotions during team problem solving: emotional intelligence and conflict resolution. *Hum. Perform.* 17, 195–218. doi: 10.1207/s15327043hup1702_4

Joseph, D. L., and Newman, D. A. (2010). Emotional intelligence: an integrative meta-analysis and cascading model. *J. Appl. Psychol.* 95, 54–78. doi: 10.1037/a0017286

Kanawattanachai, P., and Yoo, Y. (2002). Dynamic nature of trust in virtual teams. *J. Strateg. Inf. Syst.* 11, 187–213. doi: 10.1016/S0963-8687(02)00019-7

Khaksar, J., Salehi, M., and Dasht Bayaz, M. L. (2021). The relationship between political connections, auditor characteristics and auditor narcissism. *J. Facil. Manag.* 20, 521–537. doi: 10.1108/JFM-03-2021-0038

Kim, T.-Y., Cable, D. M., and Kim, S.-P. (2005). Socialization tactics, employee proactivity, and person-organization fit. *J. Appl. Psychol.* 90, 232–241. doi: 10.1037/0021-9010.90.2.232

Knechel, W. R. (2013). Do auditing standards matter? *Curr. Issues Audit.* 7, A1–A16. doi: 10.2308/ciia-50499

Kusuma, S. P., and Sukirman, S. (2017). The effect of emotional intelligence and Auditorâ€™s experience on audit quality with Independence as a moderating variable. *Acc. Analy, J.* 6, 370–379. doi: 10.15294/aaj.v6i3.18218

Law, K. S., Wong, C. S., Huang, G. H., and Li, X. (2008). The effects of emotional intelligence on job performance and life satisfaction for the research and development scientists in China. *Asia Pac. J. Manag.* 25, 51–69. doi: 10.1007/s10490-007-9062-3

Lennox, C., Wang, Z. T., and Wu, X. (2018). Earnings management, audit adjustments, and the financing of corporate acquisitions: evidence from China. *J. Account. Econ.* 65, 21–40. doi: 10.1016/j.jacceco.2017.11.011

Lin, C. P. (2007). To share or not to share: modeling tacit knowledge sharing, its mediators and antecedents. *J. Bus. Ethics* 70, 411–428. doi: 10.1007/s10551-006-9119-0

Lopez, D. M., and Peters, G. F. (2012). The effect of workload compression on audit quality. *Audit. J. Pract. Theory* 31, 139–165. doi: 10.2308/ajpt-10305

Love, P., Edwards, D., and Wood, E. (2011). Loosening the Gordian knot: the role of emotional intelligence in construction. *Eng. Constr. Archit. Manag.* 18, 50–65. doi: 10.1108/09699981111098685

Mohamed, D. M., and Habib, M. H. (2013). Auditor independence, audit quality and the mandatory auditor rotation in Egypt. *Educ. Bus. Soc. Contemp. Middle East. Issues* 6, 116–144. doi: 10.1108/EBS-07-2012-0035

Momm, T., Blickle, G., Liu, Y., Wihler, A., Kholin, M., and Menges, J. I. (2014). It pays to have an eye for emotions: emotion recognition ability indirectly predicts annual income. *J. Organ. Behav.* 36, 147–163. doi: 10.1002/job.1975

Montenegro, A., Dobrota, M., Todorovic, M., Slavinski, T., and Obradovic, V. (2021). Impact of construction project managers' emotional intelligence on project success. *Sustain. For.* 13:10804. doi: 10.3390/su131910804

Naude, P., Zaefarian, G., Tavani, Z. N., Neghabi, S., and Zaefarian, R. (2014). The influence of network effects on SME performance. *Ind. Mark. Manag.* 43, 630–641. doi: 10.1016/j.indmarman.2014.02.004

Obrenovic, B., Jianguo, D., Tsoy, D., Obrenovic, S., Khan, M. A. S., and Anwar, F. (2020). The enjoyment of knowledge sharing: impact of altruism on tacit knowledge-sharing behavior. *Front. Psychol.* 11:1496. doi: 10.3389/fpsyg.2020.01496

Parmar, B. L., Freeman, R. E., Harrison, J. S., Wicks, A. C., Purnell, L., and De Colle, S. (2010). Stakeholder theory: the state of the art. *Acad. Manag. Ann.* 4, 403–445. doi: 10.5465/19416520.2010.495581

Persellin, J. S., Schmidt, J. J., Vandervelde, S. D., and Wilkins, M. S. (2019). Auditor perceptions of audit workloads, audit quality, and job satisfaction. *Account. Horiz.* 33, 95–117. doi: 10.2308/acch-52488

Saklofske, D. H., Austin, E. J., and Minski, P. S. (2003). Factor structure and validity of a trait emotional intelligence measure. *Personal. Individ. Differ.* 34, 707–721. doi: 10.1016/S0191-8869(02)00056-9

Sheldon, O. J., Dunning, D., and Ames, D. R. (2014). Emotionally unskilled, unaware, and uninterested in learning more: reactions to feedback about deficits in emotional intelligence. *J. Appl. Psychol.* 99, 125–137. doi: 10.1037/a0034138

Slaski, M., and Cartwright, S. (2002). Health, performance and emotional intelligence: an exploratory study of retail managers. *Stress Health* 18, 63–68. doi: 10.1002/smi.926

Smith, K. J., and Emerson, D. J. (2017). An analysis of the relation between resilience and reduced audit quality within the role stress paradigm. *Adv. Account.* 37, 1–14. doi: 10.1016/j.adiac.2017.04.003

Sparrowe, R. T., Liden, R. C., Wayne, S. J., and Kraimer, M. L. (2001). Social networks and the performance of individuals and groups. *Acad. Manag. J.* 44, 316–325. doi: 10.5465/3069458

Vera-Munoz, S. C., Ho, J. L., and Chow, C. W. (2006). Enhancing knowledge sharing in public accounting firms. *Account. Horiz.* 20, 133–155. doi: 10.2308/acch.2006.20.2.133

Vidyarthi, P. R., Anand, S., and Liden, R. C. (2014). Do emotionally perceptive leaders motivate higher employee performance? The moderating role of task interdependence and power distance. *Leadersh. Q.* 25, 232–244. doi: 10.1016/j.leaqua.2013.08.003

Wilderom, C. P. M., Hur, Y., Wiersma, U. J., Peter, T., and Lee, J. (2015). From manager's emotional intelligence to objective store performance: through store cohesiveness and sales-directed employee behavior. *J. Organ. Behav.* 36, 825–844. doi: 10.1002/job.2006

Williamson, O. E. (1993). Calculativeness, trust, and economic organization. *J. Law Econ.* 36, 453–486. doi: 10.1086/467284

Wong, C. S., and Law, K. S. (2002). The effects of leader and follower emotional intelligence on performance and attitude: an exploratory study. *Leadersh. Q.* 13, 243–274. doi: 10.1016/S1048-9843(02)00099-1

Yan, Z., Wang, T., Chen, Y., and Zhang, H. (2016). Knowledge sharing in online health communities: a social exchange theory perspective. *Inf. Manag.* 53, 643–653. doi: 10.1016/j.im.2016.02.001

Yang, L., Brink, A. G., and Wier, B. (2018). The impact of emotional intelligence on auditor judgment. *Int. J. Audit.* 22, 83–97. doi: 10.1111/ijau.12106

Yilmaz, C., and Hunt, S. D. (2001). Salesperson cooperation: the influence of relational, task, organizational, and personal factors. *J. Acad. Mark. Sci.* 29, 335–357. doi: 10.1177/0307945009420

Zaccaro, S. J., Green, J. P., Dubrow, S., and Kolze, M. (2018). Leader individual differences, situational parameters, and leadership outcomes: a comprehensive review and integration. *Leadersh. Q.* 29, 2–43. doi: 10.1016/j.leaqua.2017.10.003

Zhu, F., Wang, X., Wang, L., and Yu, M. (2021). Project manager's emotional intelligence and project performance: the mediating role of project commitment. *Int. J. Proj. Manag.* 39, 788–798. doi: 10.1016/j.ijproman.2021.08.002

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 December 2022
DOI 10.3389/fpsyg.2022.1071625

OPEN ACCESS

EDITED BY
Shanshan Wang,
Dhurakij Pundit University, Thailand

REVIEWED BY
Wang Molin,
East China University of Science and Technology, China
Xinqi Zhang,
Guizhou University of Finance and Economics, China
Chun-Shuo Chen,
Dhurakij Pundit University, Thailand

*CORRESPONDENCE
Jie Jin
jinjie@nufe.edu.cn
Yongsong Liu
793350453@qq.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 16 October 2022
ACCEPTED 16 November 2022
PUBLISHED 13 December 2022

CITATION
Huang R, Jin J, Sunguo T and Liu Y (2022) The moderating effect of psychological trust on knowledge spillovers and firms' open innovation. *Front. Psychol.* 13:1071625. doi: 10.3389/fpsyg.2022.1071625

The moderating effect of psychological trust on knowledge spillovers and firms' open innovation

Rui Huang[1], Jie Jin[2]*, Tianxin Sunguo[3] and Yongsong Liu[4]*

[1]International Business School, Yunnan University of Finance and Economics, Kunming, China, [2]Division of Science & Technology Administration, Yunnan University of Finance and Economics, Kunming, China, [3]Business School, Yunnan University of Finance and Economics, Kunming, China, [4]School of International Languages and Cultures, Yunnan University of Finance and Economics, Kunming, China

Psychological trust is an important link in building interpersonal relationships and has a significant impact on the attitude and behavior of knowledge subjects. Based on the characteristics of knowledge attributes, this paper analyzed the data of 180 high-tech firms in China from 2014 to 2020 to deeply explore the effects of explicit knowledge spillover and tacit knowledge spillover on firms' open innovation, and the moderating effect of psychological trust on the relationship between the two. It is found that: first, explicit knowledge spillover and tacit knowledge spillover have an inverted U-shaped relationship with firms' open innovation, i.e., the effect of open innovation increases and then decreases as the degree of knowledge spillover increases; second, psychological trust positively moderates the non-linear relationship between knowledge spillover and firms' open innovation. This paper provides a rational explanation of firms' management behavior from a psychological perspective, and enriches and expands the research related to knowledge spillover, firms' open innovation and psychological trust. It is suggested that firms should pay more attention to inter-organizational trust relationships and pay attention to the psychological growth and development of knowledge employees to improve open innovation in firms.

KEYWORDS

knowledge spillover, firms' open innovation, psychological trust, explicit knowledge spillover, tacit knowledge spillover

1 Introduction

With the explosion of information and accelerated global innovation in the knowledge economy, it is challenging for firms to hold the complete resources and technologies required for innovation (Flipse et al., 2013). What's more, firms with core knowledge in a particular domain of expertise are also at risk of being disrupted or overturned. It is urgent for firms to change their development paradigm as the "closed innovation model" that completely relies on the firm's internal resources has failed to follow on the heels of an increasingly complex market and technological

environment. Chesbrough and Crowther (2006) proposed that as an innovation model, open innovation can help firms to cross the innovation boundary and to achieve innovation goals while strengthening the flow of knowledge resources among innovation subjects. The research shows that as a central innovation strategy and innovation model for firms, open innovation plays a key role in innovation activities (Yang et al., 2021). Especially in the context of economic globalization, open innovation and activities are growing. As the world's largest emerging economy, Chinese firms are going global at an accelerating pace, and they need to be more open to the rapid updating of technological knowledge and strive to capture complementary resources in open innovation in order to gain sustainable competitive advantages and further enhance the international competitiveness of Chinese firms. Obviously, as a new innovation model, open innovation is receiving more and more attention at the theoretical and practical levels, but how to improve the effectiveness of open innovation in firms has been analyzed by academics.

Previous studies have shown that firms can acquire knowledge resources spilled outward from other knowledge subjects in direct or indirect communication and interaction (Yi et al., 2021). As a critical element of firm knowledge management, the relationship between knowledge spillover and innovation has received widespread attention from academics (Bloom et al., 2013). Aghion et al. (2014) recommend that knowledge spillovers from advanced firms provide more possibilities for others to "learn by doing," thus increasing the probability of successful innovation. In addition, firms can proactively seek potential collaborators by selectively sharing part of their knowledge (Alexy et al., 2013) to avoid the risk of core technology leakage, Hence, an effective source of innovation is provided by knowledge spillover for firms' open innovation. Conversely, instead of solely considering how the recipient firm can benefit from the knowledge spillover process (Zahra and George, 2002), recent research shows that while the recipient firm utilizes the spilled knowledge, firms on the spillover producer also have the potential to benefit (Yang and Steensma, 2014). Simultaneously, knowledge external interaction exploration in the knowledge spillover process provides valuable learning opportunities for spillover firms to enhance innovation ability (Xin Ding et al., 2010). Accordingly, systematic and comprehensive consideration of the impacts on both sides of knowledge spillover in the spillover process is also an essential premise for the exploration of the relationship between knowledge spillover and firms' open innovation.

Moreover, the effectiveness of knowledge spillover may be affected by context factors, such as the organizational atmosphere (Kim and Park, 2020). Filatotchev et al. (2011) believed that it is difficult to separate knowledge from those who possess it since the majority parts of the knowledge within firms are complicated and tacit. The skills of the knowledge subject play a key role in achieving the knowledge spillover effect (Ramadani et al., 2017). Lin et al. (2012) proposed that in a such social phenomenon, interpersonal and social relations are essential factors to promote the emergence of knowledge spillover. The psychological trust of employees can promote not only social collaboration but also close and frequent interaction between individuals. As a psychological state, psychological trust is an essential bound to establish and cultivate interpersonal and social relations (Dirks and Ferrin, 2001). By establishing proactive psychological contracts with employees, firms change employees' attitudes and behaviors, including their motivation, ability and willingness to engage in knowledge exchange (Malik and Nilakant, 2016). Consequently, psychological trust is a psychological mechanism for deepening knowledge exchanges (Colquitt et al., 2012), and its importance in the spillover of knowledge cannot be ignored. Therefore, this paper explores the role of psychological trust between knowledge spillover and firms' open innovation.

In summary, although the research related to the impact of knowledge spillovers on innovation has been around for a long time, the existing research rarely mentioned the relationship between knowledge spillover and a specific innovation model, such as open innovation; furthermore, prior research has trapped into analyzing the effects of knowledge spillover from the perspective of the recipient, while the influence on the spillover producer has been ignored. However, research has shown that in the process of knowledge spillover, the spillover producer also has an indirect impact on the innovation effect. In addition, regardless psychological change is an important factor influencing individual behavior, the existing literature provides poor evidence on whether and how psychological factors influence knowledge spillover activities and open innovation activities within firms. Based on the above analysis, this paper integrates knowledge management theory and innovation theory, focusing on the changes influenced during the process of knowledge spillover of both recipient and spillover producers, this paper explores the potential relationship between knowledge spillover and open innovation in firms from the perspective which regards knowledge spillover as an essential knowledge acquisition channel. Moreover, in order to enrich and expand research in related fields from the perspective of employee psychology, psychological trust is introduced as a specific psychological factor in this paper to observe its moderating effect on the relationship between the two mentioned above.

The rest of the paper is organized as follows: The second section explores key foundational theories. Meanwhile, research hypotheses and models are proposed. The third part is the methodology which includes the construction of the regression model, variable design, variable measurement and sample selection. The fourth section summarizes the findings of the empirical analysis, including the robustness test, statistical analysis and analysis results. Finally, the discussion and conclusion consist of research conclusions, theoretical contributions, implications, limitations and prospective direction for future research.

2 Literature review

2.1 Open innovation

Chesbrough first introduced the concept of open innovation and contended that open innovation is a new paradigm of innovation management in which firms maximize the use of resources inside and outside the organization to innovate and earn profit. Guo et al. (2019) pointed out that in a business environment, innovation resources and experience will be gained through accelerated openness once a firm is under the pressure of a competitor. Regarded as interaction, integration and synergy between elements of innovation, open innovation realizes the free flow of crucial resources to cross the organizational boundary (Ritala et al., 2017). Although scholars have reached a general consensus on the importance of open innovation while a unified standard for related concepts is still missing. Alam et al. (2022) considered that the mechanism of the role of open innovation cannot be fully explained from the single view of firms that a study in which the management theory and the resource dependency theory should be conjoined. Based on the above research, this paper analyzes the concept of open innovation from diverse perspectives by summarizing the existing literature and concludes with the following aspects: (1) From the perspective of innovation resource, resource theory regards open innovation as an asset. Vanhaverbeke et al. (2008) deem that the acquisition of productive resources such as knowledge, customers or suppliers, and infrastructure services is the main purpose of open innovation; (2) From the perspective of knowledge, Lichtenthaler (2009) mentioned that open innovation is a process of knowledge search and enrichment, in which internal and external knowledge development, integration and utilization are systematically carried out through innovation activities; (3) From the perspective of resource dependence theory, the inability of firms to fully integrate the entire resources needed for innovation by internal integration leads to the inevitable demands of production resources provided by other firms (Chesbrough, 2003).

In addition, the influencing factors of firms' open innovation are also highlighted in this paper. (1) Firm' capability. Keupp and Gassmann (2009) thought that a series of innovation obstacles, such as rising R&D costs within firms and the shortening trend of the product life cycle, make certain firms more inclined to carry out open innovation than others; (2) Organizational Environment. In the process of innovation, Chesbrough and Crowther (2006) considered that external resources and knowledge contribute to innovation performance even in firms with strong R&D and innovation capabilities; (3) Senior management characteristics. According to Salter et al. (2014), the thinking ability and innovative ideas of R&D individuals have a nonlinear relationship with the openness of external knowledge sources. Meanwhile, the knowledge-based theory shows that knowledge, as the core element of innovation, is the basis of open innovation (Hilbert and López, 2011). Ye (2022) deemed that the improvement of innovation capabilities depends not only on the firm's R&D investment but also on the diffusion or spillovers of external knowledge and R&D capital. Knowledge spillovers with no compensation or compensation less than the actual value of knowledge can acquire valuable core technologies from other firms (Cassiman and Veugelers, 2002). Through knowledge spillovers, the knowledge base and resources of other firms are used to increase firms' own R&D investment and to achieve more innovative output with less R&D cost (Dai et al., 2022). As the unique modality of knowledge acquisition makes knowledge spillover an essential factor affecting open innovation, this paper analyzes how to optimize the use of knowledge spillover to promote firms' open innovation from the perspective of knowledge spillover.

2.2 Knowledge spillover

Since the concept of knowledge spillover is introduced in the analysis of economic problems by Arrow in 1962, knowledge spillover has become an important research direction in economics and management. However, concepts related to knowledge spillover such as knowledge diffusion, knowledge transfer and knowledge flow are confused by scholars in various fields, in fact, these concepts are quite different. First, knowledge spillover and knowledge transfer belong to the same category of knowledge flow. Fallah and Ibrahim (2004) put forward that knowledge communication may occur in every interaction between knowledge subjects. "Knowledge transfer" is considered to be the knowledge exchange that occurs consciously among people or organizations while any unconscious knowledge transmission beyond such communication belongs to "knowledge spillover." Whereas, contradictory to previous studies that regard knowledge spillover as an unconscious knowledge dissemination process, Alexy et al. (2013) found that to augment the possibility of acquiring valuable knowledge in the future, firms can consciously select some internally developed knowledge to provide free use to external participants through carriers such as technical drawings, meeting minutes and contracts. pointing out that defining knowledge spillover in terms of "conscious and unconscious" is not accurate. Furthermore, Keller (2010) emphasized that as a method of knowledge diffusion, knowledge spillover mainly refers to the part of knowledge that diffused through externalities. The externality feature of knowledge spillover suggests that knowledge recipients can develop and create new knowledge by combining the acquired knowledge with their knowledge without compensating the knowledge creator or below the compensation of knowledge creation cost (Zhu and Xu, 2019). In a word, this paper states that knowledge

spillover refers to knowledge being acquired by subjects other than the knowledge creator in the form of no compensation or compensation less than the value of knowledge created.

Moreover, Angeles Montoro-Sánchez et al. (2011) contended that distinct types of knowledge spillovers lead to differences in the quantity and quality of external resources acquired by firms, which may eventually affect the effect of firms' innovation. According to the source of knowledge spillover, knowledge spillover can be classified as domestic knowledge spillover and foreign knowledge spillover (Chen et al., 2012). According to the direction of spillover, it is categorized as outward and inward knowledge spillover by Cassiman and Veugelers (2002). Gaur et al. (2019) asserted that knowledge flow depends on the attributes and context of knowledge being transferred. The characteristics of tacit and explicit are the most common factors to affect knowledge flows (Dhanaraj et al., 2004). Jensen (2007) classified knowledge into explicit and tacit knowledge based on the degree of modifiability. As formalized knowledge, explicit knowledge is easy to encode, retrieve and transfer (Hansen, 2002). Inversely, as an informal form of knowledge-based primarily on personal experience and skills, tacit knowledge is difficult to compile and communicate (Bibi and Ali, 2017; Bogers et al., 2018). The huge difference between explicit knowledge and tacit knowledge leads to distinct spillover effects. Consequently, for the purpose of launching an advanced exploration related to the distinct effects of various types of knowledge spillovers on firms' open innovation, this paper divides knowledge spillover into two dimensions: tacit knowledge spillover and explicit knowledge spillover. In specific, explicit knowledge spillover refers to new technologies or products carried by language, text or graphics that are acquired by other subjects other than knowledge creators for free or at a small cost. Tacit knowledge spillover refers to all kinds of information, experience and skills based on individuals acquired by other subjects other than knowledge creators for free or at a small cost.

2.3 Knowledge spillovers and firms' open innovation

Knowledge spillover is considered an inevitable knowledge transfer phenomenon in open innovation (Cassiman and Veugelers, 2002). Specifically, Knowledge spillover not only provides the raw materials needed for open innovation but also strengthens the communication between the firm and external knowledge, as well as the increment of value extension on spilled knowledge (Yang et al., 2010). However, open innovation is affected differently due to distinct attributes of knowledge. Seidler de Alwis and Hartmann (2008) believed that compared with explicit knowledge, tacit knowledge capable of adapting to the rapidly updating trend of innovative technologies in the knowledge economy plays a more significant role in knowledge spillovers and innovation. Based on the statement above, this paper explores the role played by tacit knowledge spillover and explicit knowledge spillover in open innovation.

2.3.1 Explicit knowledge spillover and firms' open innovation

The majority of explicit knowledge spillovers come from leasing new equipment or purchasing new products from competitors. Although those firms that adopt knowledge spillovers to create more advanced technologies by using new technologies to process and improve old technologies can avoid the risks of R&D and the entire consequences of R&D failures (Yi et al., 2021). However, new technologies that can be easily obtained induce the appearance of firms' dependence and the abandonment of risky innovation and R&D. Thus, this paper assumes that explicit knowledge spillovers have a nonlinear relationship with firms' open innovation.

First, the knowledge spillover producers can take advantage of potentially beneficial learning opportunities from the spillover process (Yang et al., 2010). With the increase of knowledge spillover, it is beneficial for the producers to observe how the recipients combine their knowledge with other new knowledge, stimulate new thinking and new ideas in the spillover firms, and then improve their innovation behaviors and achieve more innovative knowledge reorganization (Dosi, 1988; Yang and Steensma, 2014; Duan et al., 2021), providing an open exchange between innovative knowledge provides a good foundation. Second, knowledge spillover will also produce a demonstration effect (Ramadani et al., 2017), in which advanced products and services will create a sense of crisis and competition awareness for the recipients. As the degree of such spillover increases, the pressure felt by firms will also increase, which will boost their innovation enthusiasm and provide a good basis for the exchange between different knowledge subjects of open innovation; Third, firms are able to strategically promote technology replication, actively shape the cooperative behavior of the others innovation ecosystem and actively guide other players to adopt follow-through strategies thus ultimately influence the industry standard when new equipment and new products are learned and utilized by others (Alexy et al., 2013). In this case, open innovation cooperation will be promoted due to the narrowing of the technological distance between the two sides of knowledge spillovers and the assimilation of development goals. Therefore, collaboration and communication between the source of the spillover producers and the recipients expand as explicit knowledge spillover rises. Open innovation will consequently become more efficient.

However, the negative effect on open innovation appears as the degree of knowledge spillover continues to increase, as the explicit knowledge spillovers will be influenced by other factors, and the difficulty of cooperation and communication between firms' augments. First, the explicit character of knowledge leads to knowledge transfer at a negligible cost, resulting in "free-rider" behavior (Nieto and Quevedo, 2005). When knowledge recipients realize that they can survive by absorbing

external knowledge, they will relax the R&D activities of independent innovation, and excessive knowledge spillover will have a squeezing effect on independent innovation. Firms will ultimately lose their competitive advantages, fail to provide valuable information to other cooperative firms, and eventually withdraw from the market, which is not conducive to the exchange and collaboration of open innovation. The R&D activities of independent innovation will be relaxed when the knowledge recipients realize that it is possible to survive by absorbing external knowledge. This means that excessive knowledge spillover causes a squeezing effect on independent innovation. The knowledge spillover producer will not only lose their own competitive advantages but also be eliminated from the market over time as valuable information to other cooperative firms cannot be provided, which is not conducive to the exchange and cooperation of open innovation. What's more, Harabi (1995) emphasized that it is impossible for firms to acquire external knowledge for free. Only firms that have accumulated a large amount of relevant knowledge internally can be able to absorb and use such proprietary technology. The more explicit knowledge is accepted, the more the firm needs to spend on identifying, assimilating, and integrating external knowledge, which is likely to result in costs over benefits. Based on the consideration of maximizing benefits, instead of new external information acceptance or open innovation collaboration, firms tend to innovate alone. Based on the above analysis, this paper puts forward the following hypotheses:

> H1: There is an inverted U-shaped relationship between explicit knowledge spillover and firms' open innovation. In other words, explicit knowledge spillovers promote open innovation until the inflection point is reached. Once the inflection point is reached, firms' open innovation starts to decline.

2.3.2 Tacit knowledge spillover and firms' open innovation

The characteristics of mute and complexity make it more difficult for tacit knowledge to be codified or communicated. Correspondingly, the task of obtaining valuable tacit knowledge becomes challenging (Umar et al., 2021). According to Seidler de Alwis and Hartmann (2008), tacit knowledge transfer is primarily based on individual interactions and experiences. It is possible to transfer tacit knowledge more successfully through personal mobility (Song et al., 2003) and practical experience. Hence, this paper believes that the mobility and attitudes of individuals play a significant role in the impact of tacit knowledge spillover on firms' open innovation.

In the initial stage of knowledge spillover, tacit knowledge spillover positively contributes to firms' open innovation: first, employees can continuously "learn by doing" in new areas through individual mobility to dig the depth and expand the breadth of knowledge, which will eventually accelerate the value addition of individuals and the creation of new knowledge (Choudhury and Kim, 2019). In this process, the knowledge spillover producer will enhance the exploration of new knowledge in pursuit of higher value. Meanwhile, the knowledge recipients can continuously acquire new knowledge spillover, thus improving the level of innovation in the whole organization. Second, the interaction of knowledge is facilitated by the mobility of skilled professionals at various spatial scales (Almeida and Kogut, 1999). Knowledge complementarity between knowledge spillover producers and recipients can promote collaboration and knowledge recombination among knowledge subjects that may stimulate the emergence of more abundant resources (Nyberg and Wright, 2015) and the possibility of firms' open innovation; Finally, knowledge subjects have strong achievement motivation that aspires to increase higher levels of achievement in work and enhance their value (Aguinis and Glavas, 2012). Showing experience and technology to others and being learned by others meets a higher level of psychological demand for knowledge subjects such as self-fulfillment, being respected or being granted (Krausert, 2014), thus generating a higher accomplishment while the exchanges and cooperation of innovation will be stimulated.

However, the increase in the degree of tacit knowledge spillover brings a more obvious inhibitory effect on open innovation, once the threshold is exceeded. First, excessive tacit knowledge spillover will have competitive effects on open innovation (Zhang et al., 2022). In this situation, the risk of the core technical knowledge of the knowledge spillover producer being leaked increases, and competitors can quickly achieve technological catch-up and product substitution through excessive knowledge transfer and opportunism (Brockman et al., 2018; Ye, 2022), depriving the knowledge producer of their initial competitive advantages and causing the decrescence in employees' enthusiasm as spillovers for knowledge flow. Second, the technology evolution theory shows that excessive emphasis on prior knowledge would result in technological similarity and incremental evolution, thus the potential knowledge locked-in or path dependence occurs (Burmaoglu et al., 2019). Schilling and Green (2011) contended that valuable innovation often comes from diverse knowledge systems. It is possible that over-absorbing tacit knowledge spillovers from other firms lead to similar innovation paths between firms, arousing the increasement of knowledge substitutability and the reduction of firms' likelihood of seeking external collaboration. Consequently, firms' open innovation will be inhibited. Based on the above analysis, this paper puts forward the following hypotheses:

> H2: There is an inverted U-shaped relationship between tacit knowledge spillover and firms' open innovation. In other words, with an increase in tacit knowledge spillover,

> firms' open innovation is on the rise; when tacit knowledge spillover exceeds the inflection point level, firms' open innovation begins to decline.

2.4 The moderating effect of psychological trust on knowledge spillover and firms' open innovation

Scholars have not yet reached a consensus on the definition of trust, due to the characteristics of abstraction and complexity (Rutten et al., 2016). Based on psychology (Lau et al., 2007), individuals generate trust in their psychological consciousness, which is reflected in their positive expectations of other others' behavior. Jones et al. (2010) suggested that goodwill and competence are two essential components of trust, in which goodwill is typically present in interpersonal relationships and competence is an evaluation of other firms' skills. The existing literature generally regards trust as a subjective belief that plays a crucial role in facilitating and stabilizing relationships between various subjects. Accordingly, this paper defines psychological trust as a state of psychology, that is, a subject's optimistic prediction of others' behavior as well as a subject's view of the fairness and security of the organizational environment. According to Bottazzi et al. (2016), it is challenging for firms to constrain opportunistic behaviors during open innovation through formal means. Firms engaged in open innovation must simultaneously rely on other means to ease the conflict between various types of knowledge. Thus, during the process of cooperation, psychological trust helps to union different subjects together, to remove informational obstacles and to decrease opportunism. In addition, psychological trust contributes to the establishment of open knowledge environment where a variety of required resources for knowledge subjects are provided (Von Krogh et al., 2012). Inter-firm cooperation based on trust is beneficial to the establishment of an organizational environment for mutual understanding and communication. Such cooperation can motivate organizational members to share their explicit and tacit knowledge (Nonaka et al., 2016; Millar et al., 2017). In this paper, we analyzed the changes in the relationship between knowledge spillover and open innovation in firms under different psychological trust levels.

2.4.1 The moderating effect of psychological trust on explicit knowledge spillover and firms' open innovation

Explicit knowledge is generally contained in an organization's accessible artifacts and structural elements. In this regard, companies can obtain valuable explicit knowledge spillovers through convenient measures such as purchasing patents or participating in trade fairs (Lee et al., 2021; Bernal et al., 2022). However, the potential impact of knowledge gaps on spillovers means that larger knowledge gaps come with higher costs and more uncertainty (Bernal et al., 2022). Therefore, the negative knowledge spillover effect happens when a lack of a mutual knowledge foundation occurs, making it difficult for knowledge recipients to absorb and understand the spillover producers' products, equipment, etc. (Perri et al., 2013). Yuan et al. (2016) concluded that good psychological trust promotes knowledge transfer and sharing. Under the guarantee of the trusted relationship between the two sides of knowledge spillover, the knowledge spillover producers are willing to offer resources and tools required for innovation to the recipients. Under the such relationship, such relationship can shorten the technological distance between firms, accelerate the absorption of valuable innovative products by the recipients, improve the recognition of innovation strategies of both sides of knowledge spillover, and promote the development of firms toward a similar technological path, thus the generation of open innovation will be accelerated. Second, psychological trust helps alleviate the problem of knowledge information asymmetry between firms (Ho et al., 2018). Considerable information asymmetry in innovation activities leads to the possibility that recipients cannot trust the source of knowledge spillovers. The specific performance is that even if new explicit knowledge resources (such as machinery and equipment, innovative products, etc.) that are easy to absorb and understand are obtained, firms still need to spend time and cost on ongoing adaption and adjustment. On the contrary, under the condition of mutual trust, firms can shorten the learning cycle through repeated interactions, thus reducing the coordination costs between partners (Gulati and Singh, 1998). In this way, the process of innovation commercialization is shortened and the formation of open innovation outcomes is accelerated. Based on the above analysis, this paper puts forward the following hypotheses:

> H3: Psychological trust strengthens the relationship between explicit knowledge spillover and firms' open innovation; in other words, psychological trust makes the inverted U-shaped relationship between explicit knowledge spillover and firms' open innovation steeper.

2.4.2 The moderating effect of psychological trust on tacit knowledge spillover and firms' open innovation

The trusted relationship between organization members is the basic condition for creating, sharing and using tacit knowledge (Seidler de Alwis and Hartmann, 2008). The connection based on mutual trust and understanding can effectively facilitate the exchange of information and enhance the continuous flow and diffusion of knowledge, especially tacit knowledge spillover. First, a high level of psychological trust creates a cooperative atmosphere which facilitates knowledge

spillover and increases knowledge producers' willingness to spill knowledge (Bibi and Ali, 2017; Park and Kim, 2018). The spillover of tacit knowledge stored in people's minds and experiences depends on the working practices and face-to-face communication of the subject of knowledge (Nonaka, 2008). Face-to-face communication and guidance between individuals are necessary conditions for the effective spillover of individual unique knowledge (Berraies et al., 2020). Moreover, psychological trust inspires employees to engage in collaborative activities, to share and to absorb knowledge from other trusted individual. In this case, perceptions based on psychological trust not only promote social collaboration but also encourage close and frequent interactions between individuals, between which employees can feel comfortable with sharing their knowledge as their perception of the risk of opportunistic behavior is reduced (Sankowska, 2013); second, the representational gaps are one of the biggest obstacles in knowledge exchange, particularly for tacit knowledge (Cronin and Weingart, 2007). The representational gaps are the differences in perceptions of an issue among various knowledge subjects. As knowledge subjects cannot fluently master each other's domains of knowledge, diverse perceptions of issues arising from different knowledge and values among individuals in an open innovation challenge have the potential to undermine collective information processing. Sun et al. (2020) thought that building and maintaining trustworthy relationships in knowledge exchange enables firms to overcome the representational gaps that a mutual trust helps to increase the partners' understanding and appreciation. The effectiveness of knowledge spillover can be enhanced when individuals trust others and show positive attitudes to understand others (Scuotto et al., 2020). Based on the above analysis, this paper puts forward the following hypotheses:

> H4: Psychological trust strengthens the relationship between tacit knowledge spillover and firms' open innovation; in other words, psychological trust makes the inverted U-shaped relationship between tacit knowledge spillover and firms' open innovation steeper.

Based on the above analysis, our research model is shown in **Figure 1**.

3 Materials and methods

3.1 Data

Duan et al. (2022) thought that manufacturing is an important area of comprehensive national power competition and technological competition among countries in the world. According to the current industrial classification of the Chinese national economy, the high-tech manufacturing industry mainly includes firms in pharmacy, aerospace, transportation equipment manufacturing, computer and other electronic equipment manufacturing. Meanwhile, high-tech manufacturing firms are knowledge-intensive, and their production and operation status, R&D activities, new product development and sales, and patents all account for important ratios (Duan et al., 2021). Based on the above analysis, we collected the financial statements of Chinese A-share listed manufacturing firms in the CSMAR database, the sample firms were screened as follows: (1) Firms with "ST" and "*ST" marks are excluded; (2) Firms in financial industries with apparent differences in accounting standards from other industries are excluded; (3) Firms with missing information are also excluded. Since the primary data for this paper were obtained from the CSMAR database and the 2015 China General Social Survey (CGSS), where the CSMAR database is only updated to 2020 and the CGSS data were collected in 2015, we aimed to measure with the most recent sample data based on the availability and completeness of the data. As a result, the data of 180 firms from 2014 to 2020 were selected as the research sample.

3.2 Measures

3.2.1 Dependent variable

Patents are considered the primary manifestation of firms' open innovation outcomes, referring to Brockman et al. (2018), the quantity of joint patent applications is used to measure a firm's effectiveness in terms of open innovation. Joint patents are commonly used as a representative of collaborative innovation in the management and organizational literature (Arora et al., 2016), as Joint ownership of intellectual property is an effective strategy for firms to jointly develop technologies. In order to obtain the open innovation performance of the firms, the number of Joint patent applications is used to measure open innovation performance, the standard applicant names of all patents of the sample firms are downloaded from the National Intellectual Property Administration (NIPA), and the number of Joint patents with the number of applications greater than one are filtered out and summed up in this paper.

3.2.2 Independent variable

Most scholars agreed that a firm's patents are a good indicator to measure knowledge spillovers (Yamin and Otto, 2004). Seidler-de Alwis and Hartmann (2008) assumed that patents are an ideal representation of explicit knowledge in the business environment. Following their approach, this paper measured explicit knowledge spillover by calculating and analyzing the number of patent applications to represent a firm's knowledge and technological output. The more patent applications a firm has, the more knowledge creation and the more knowledge spillover it generates to the outside. In addition, Block (2012) stated that higher R&D expenditures generate abundant new knowledge, leading to a stronger knowledge spillover effect. Therefore, the level of total R&D

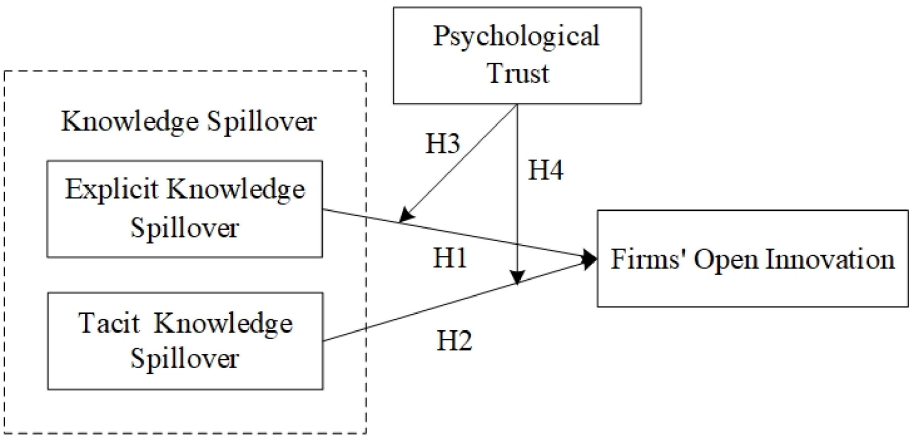


FIGURE 1
Research framework.

expenditures is used as a proxy variable for tacit knowledge spillover in this paper's empirical study on innovation and knowledge spillover.

3.2.3 Moderating variable

This paper makes use of data from the China General Social Survey (CGSS) 2015 to establish our measure of psychological trust, which is based on Zhang and Ke (2002). In response to the question "In general social interactions/contacts that do not directly involve pecuniary interests, how many strangers do you think you can trust?" The survey respondents were given the options of "Mostly untrustworthy," "Mostly untrustworthy," "50-50 between trustworthy and untrustworthy," "Mostly trustworthy," "Mostly trustworthy," and "overwhelmingly credible." We assign values 1, 2, 3, 4, and 5 to each of these five options to calculate the average value for all residents of each province and city as the trust indicator value for the simple province and city, which is adapted to assign a value to the psychological trust of employees in firms in the province to which they belong. Considering that the trust environment of a region is less likely to change in the short term (Umar et al., 2021), this paper uses the index of 2015 as a proxy for the trust situation in 2014–2020 as well.

3.2.4 Control variable

Based on the existing research results, this paper used the variables of Firm age, Firm size, financial leverage (FL), Firm profitability (ROA) and the number of R&D personnel as control variables that affect the factors of firms' open innovation and knowledge spillover.

(1) Firm age. Young firms have a larger risk of innovation (Chin et al., 2022), and they may be more willing to cooperate. Also, Chesbrough (2003) assumed that older firms have a stronger absorptive capacity, which enables them to better identify, absorb and utilize external knowledge in the knowledge spillover process.

(2) Firm size. Prior research has identified firm size as a key driver of innovation collaboration. Smaller firms may have greater resource constraints, therefore, having a greater need for open innovation and a faster reaction toward open decisions (Chesbrough and Crowther, 2006).

(3) Financial leverage (FL). A firm's financial position affects its willingness to engage in open innovation. Firms that are more financially constrained can use relationships from innovation networks to overcome resource constraints and increase productivity (Chesbrough and Crowther, 2006). We consider that the role of firms' profitability reflects the firm's financial position.

(4) Firm profitability (ROA). The behavior of investing in innovation is influenced by the financial stability and operational performance of the firms (Chin et al., 2021). Firms with high profitability are usually willing to invest more resources in innovation, while firms with weak profitability lack the resources to invest in innovative activities (Liu and Li, 2020). Therefore, profitability may have an impact on open innovation.

(5) Number of R&D personnel. Firms that are committed to R&D investment are more possible to have more co-patents (Blundell et al., 1999). Therefore, the importance of controlling a firm's overall R&D situation drives us to adopt the number of R&D personnel as a control variable.

The definition of each variable in this paper is shown in **Table 1**.

3.3 Model

We analyze the relationships between firms' open innovation, psychological trust, and knowledge spillover in high-tech manufacturing firms. To test the proposed

TABLE 1 Variables and measurements.

Variable	Variable name	Variable measurement
Dependent variable	Open innovation (OI)	Number of joint patent applications
Independent variables	Explicit knowledge spillover (EKS)	Total expenditure for R & D
	Tacit knowledge spillover (TKS)	Number of patent applications for firms
Moderating variables	Trust(TR)	Chinese General Social Survey data in 2015
Control variables	RDPerson	Number of R & D personnel
	Financial Leverage (FL)	Total liabilities/Total assets
	Firm profitability (ROA)	Net profit/Total assets
	Firm Age (Age)	The difference between the statistical cut–off year and the establishment date of the firm
	Firm Size (Size)	The natural logarithm of total assets

hypotheses H1-H4, we establish the following regression models:

$$OI_{i,t} = \alpha_0 + \alpha_1 TKS_{i,t} + \alpha_2 TKS^2{}_{i,t} + \Sigma\alpha * controls_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$OI_{i,t} = \beta_0 + \beta_1 EKS_{i,t} + \beta_2 EKS^2{}_{i,t} + \Sigma\beta * controls_{i,t} + \varepsilon_{i,t} \quad (2)$$

To test hypotheses H3,H4, based on the model (1), (2), we add the interaction terms of psychological trust, tacit knowledge spillover, and explicit knowledge spillover square to establish model (3), (4), respectively, as follows:

$$OI_{i,t} = \lambda_0 + \lambda_1 TKS_{i,t} + \lambda_2 TKS^2{}_{i,t} + \lambda_3 TKS_{i,t} * TR_{i,t} + \lambda_4 TKS^2{}_{i,t} * TR_{i,t} + \lambda_5 TR_{i,t} + \Sigma\beta * controls_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$OI_{i,t} = \gamma_0 + \gamma_1 EKS_{i,t} + \gamma_2 EKS^2{}_{i,t} + \gamma_3 EKS_{i,t} * TR_{i,t} + \gamma_4 EKS^2{}_{i,t} * TR_{i,t} + \gamma_5 TR_{i,t} + \Sigma\beta * controls_{i,t} + \varepsilon_{i,t} \quad (4)$$

4 Empirical analysis

4.1 Descriptive statistics and correlation analysis

We performed a descriptive statistical analysis of all variables and Table 2 presents the means, standard deviations, minimum and maximum values of the variables. The statistical results show that there is a large gap between the minimum and maximum values of firms' open innovation. In terms of the two dimensions of knowledge spillover, the mean value of explicit knowledge spillover in firms is higher than that of tacit knowledge spillover, indicating that most firms mainly use explicit knowledge spillover to promote innovation.

TABLE 2 Descriptive statistics of variables.

Variable	N	Mean	SD	Min	Max
OI	1246	7.181	22.140	0	296
TKS	1255	18.713	1.373	11.369	22.718
EKS	1221	53.980	114.446	0	1633
Trust	1253	38.195	2.376	32.632	42.198
RP	1256	743.281	1011.194	0	12481
Age	1257	20.486	4.138	9.920	36.330
Size	1253	22.783	1.143	19.910	33.350
Asset	1253	0.459	0.205	0.034	2.290
ROA	1249	0.039	0.076	-0.957	0.340

The matrix of correlation coefficients between the variables is displayed in Table 3. The table demonstrates a significant positive correlation between firms' open innovation and tacit knowledge spillover (TKS) and explicit knowledge spillover (EKS). Regression analysis must, however, be used to examine the relationship between the independent and dependent variables in further detail. The analysis of the data reveals a significant positive link between psychological trust (TR) and open innovation practices across businesses. The correlation coefficients between the variables were also typically lower than 0.5. However, certain correlation coefficients were higher than 0.5, thus a variance inflation factor test (VIF test) was carried out in this paper to avoid the problem of multicollinearity. Table 4 shows the VIF test results of the variables in which the maximum value of the VIF test result is 2.050 $<$ 5 and the mean value of the VIF test result is 1.59 $<$ 5, so there is no serious co-linearity problem between the variables.

4.2 Analysis of regression results

Drawing on Haans et al. (2016), this paper proposes three criteria for testing the validity of the inverted U-shaped relationship: first, the primary term coefficient is positive and the quadratic term coefficient is significantly negative; second, the slope at both ends of the definition domain should be significantly positive or negative; and third, the confidence interval at the 95% level of the turning point needs to fall within the definition domain. The test results meet the above requirements, and the details are shown in Figures 2, 3 and Table 5.

Table 5 shows that Model 1 is a regression of the relationship between the primary term of explicit knowledge spillover, the quadratic term of explicit knowledge spillover, and open innovation of firms. The results show that the

TABLE 3 Correlation coefficient matrix of variables.

	OI	TKS	EKS	Trust	RP	Age	Size	Asset	ROA
OI	1								
TKS	0.165***	1							
EKS	0.262***	0.372***	1						
Trust	0.066**	0.018	0.132***	1					
RP	0.057**	0.604***	0.374***	0.064**	1				
Age	0.089***	0.004	−0.029	−0.104***	−0.064**	1			
Size	0.179***	0.609***	0.364***	0.130***	0.508***	0.018	1		
Asset	0.017	0.176***	0.158***	0.003	0.176***	0.066**	0.381***	1.000	
ROA	0.062**	0.165***	0.029	0.098***	−0.001	−0.066**	0.060**	−0.540***	1.000

*$p < 0.1$, **$p < 0.05$, and ***$p < 0.01$.

coefficient of the primary term of explicit knowledge spillover is: 0.005($P < 0.01$),and the coefficient of the quadratic term is -0.000 ($P < 0.1$). When the minimum value of explicit knowledge spillover (0), the slope of the curve $\beta_1+2\beta_1 = EKS_{max}$ 0.005 > 0; when the maximum value of the explicit knowledge spillover (1633), the slope of the curve $\beta_1+2\alpha\beta_1 = EKS_{min}$ -0.004 < 0, and the slope of the sample boundary has the opposite sign. And, the inflection point of the curve is 1254.326, which is within the sample range. Open innovation shows an upward and then downward trend with the rise in explicit knowledge spillover of the firm. The inverted U-shaped association between explicit knowledge spillover and open innovation is supported by the data, supporting hypothesis H1. Model 2 is the regression of the relationship between the primary term of tacit knowledge spillover, the quadratic term of tacit knowledge spillover and open innovation. The results show that the coefficient of the primary term of tacit knowledge spillover is: 3.648 ($p < 0.05$) and the coefficient of the quadratic term is -0.094 ($p < 0.05$). When the tacit knowledge spillover takes the minimum value (11.36924), the slope of the curve $\alpha_1+2\alpha_1 = TKS_{min}$ 1.511 > 0;when the tacit knowledge spillover takes the maximum value (22.71756), the slope of the curve $\alpha_1+2\alpha_1 = TKS_{max}$ -0.623 < 0, and the slope of the sample boundary has the opposite sign. The curve's inflection point, which falls inside the sample range, is 15.87979. There is an inverted U-shaped correlation between tacit knowledge spillover and open innovation, which supports the hypothesis H2 that open innovation shows a tendency of growing and then declining as tacit knowledge spillover of firms grows.

TABLE 4 Variable VIF test.

Variable	VIF	1/VIF
TKS	2.050	0.487
Size	2.010	0.497
Asset	1.860	0.537
RP	1.750	0.571
ROA	1.680	0.595
EKS	1.250	0.797
Trust	1.060	0.945
Age	1.030	0.974
Mean VIF	1.590	

4.3 The analysis of moderating effect

According to Haans et al. (2016), the moderating variable can affect the inverted U-shaped relationship in two different ways: first, it can move the turning point to the left or to the right, and second, it can flatten or steepen the curve. The inflection points of the curves are as follows after including the interaction term of psychological trust in models (3) and (4) along with explicit knowledge spillover, tacit knowledge spillover, and their squared terms in the equation.

$$TKS^* = \frac{-\lambda_1-\lambda_3 \times TR}{2\lambda_2+2\lambda_4 \times TR}, EKS^* = \frac{-\gamma_1-\gamma_3 TR}{2\gamma_2+\gamma_4 \times TR} \quad (5)$$

Apparently, when psychological trust shifts, so does the positioning of the inflection point. Calculate the model (5)'s number of partial guidance:

$$\frac{\partial TKS^*}{\partial TR} = \frac{\lambda_1\lambda_4-\lambda_2\lambda_3}{2(\lambda_2+\lambda_4 \times TR)^2}, \frac{\partial EKS^*}{\partial TR} = \frac{\gamma_1\gamma_4-\gamma_2\gamma_3}{2(\gamma_2+\gamma_4 \times TR)^2} \quad (6)$$

We set the first derivative with respect to X to zero. Model (6) shifts the curve's inflection point when it is not equal to 0, $2(\lambda_2+\lambda_4 = TR)^2$ and $2(\gamma_2+\gamma_4 = TR)^2$are always greater than 0. Therefore, when $\lambda_1\lambda_4-\lambda_2\lambda_3$ 0 and $\gamma_1\gamma_4-\gamma_2\gamma_3$ 0, the inflection point shifts to the left;$\lambda_1\lambda_4-\lambda_2\lambda_3$ 0 and $\gamma_1\gamma_4-\gamma_2\gamma_3$ 0 the inflection point shifts to the right. Hypotheses H3 and H4 demonstrate that psychological trust plays a moderating role in the inverted U-shaped relationship between explicit knowledge spillover and tacit knowledge spillover and open innovation. The higher the level of psychological trust, the stronger the positive impact of explicit and tacit knowledge spillover on open innovation. By performing the same test for model (3) and calculating$\lambda_1\lambda_4-\lambda_2\lambda_3$ 0 and $\gamma_1\gamma_4-\gamma_2\gamma_3$ 0 therefore the whole curve shifts to the left. The coefficients of

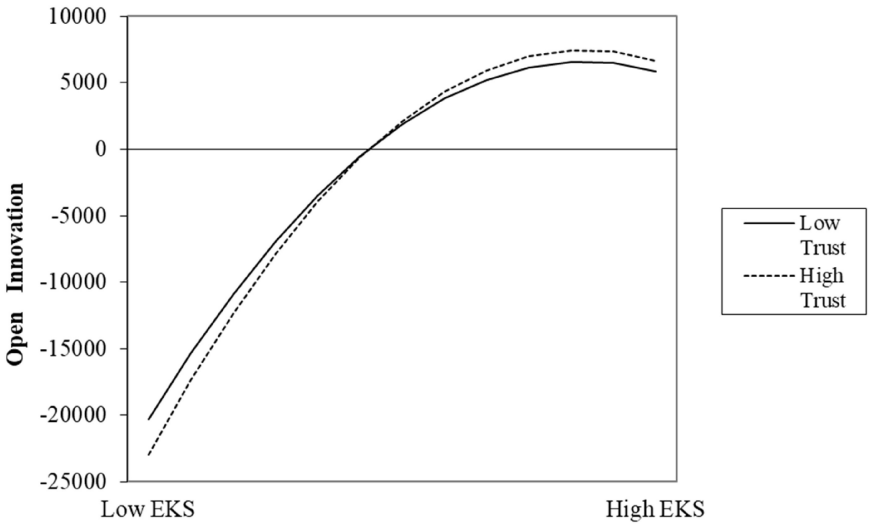


FIGURE 2
The moderating effect of psychological trust on the relationship between explicit knowledge spillover and open innovation.

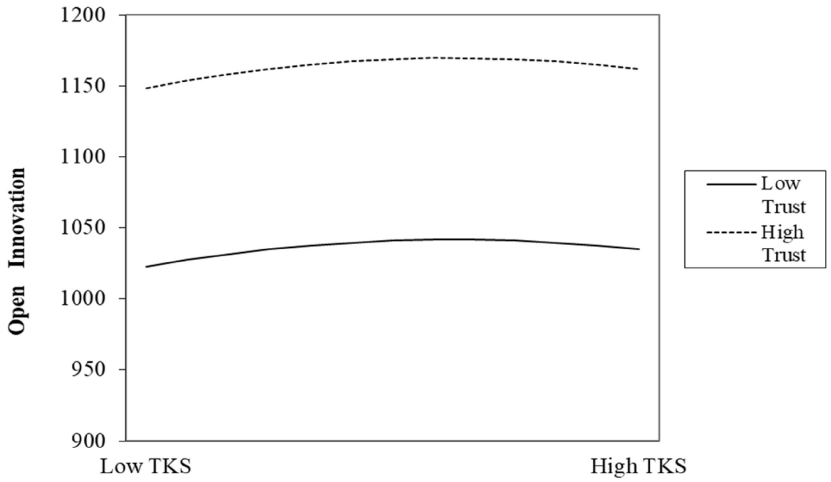


FIGURE 3
The moderating effect of psychological trust on the relationship between tacit knowledge spillover and open innovation.

the psychological trust moderating term are: -87.202 ($p < 0.1$), -248.227 ($p < 0.01$) respectively, which proves the existence of a moderating effect. Columns (3) and (4) in Table 5 show the model regression results after adding the interaction terms of explicit knowledge spillover, tacit knowledge spillover and its quadratic term with psychological trust, respectively. The interaction coefficient between psychological trust and EKS is 3.059 ($p < 0.01$), while the coefficient of the quadratic term is -0.009 ($p < 0.01$); the coefficient of the interaction term between psychological trust and TKS is 4043.868 ($p < 0.01$) and the quadratic term coefficient was -105.394 ($P < 0.01$). Therefore, the inverted U-shaped relationship between explicit knowledge spillover, tacit knowledge spillover, and open innovation remains valid after including the interaction terms. We plotted the moderating effects of psychological trust based on the results in Table 5 (Figures 2, 3).

Before taking into consideration the ease of psychological trust, Figure 2 illustrates changes in the relationship curve between explicit knowledge spillover and open innovation: (1) Before the inflection point, the curve for psychological trust with a lower level is relatively flat, and the curve for psychological trust with a higher level is steep, suggesting that firms with high psychological trust improve their open innovation performance more quickly as explicit knowledge spillover increases. (2) The inflection point's location shifts. The apex of the high psychological trust curve is higher than the inflection point of

TABLE 5 Relationships between principal variables.

	(1)	(2)	(3)	(4)
	OI	OI	OI	OI
EKS	0.005***		0.014***	
	(0.001)		(0.001)	
EKS2	−0.000*		−0.000***	
	(0.000)		(0.000)	
TKS		3.648**		10.463***
		(1.722)		(2.308)
TKS2		−0.094**		−0.268***
		(0.046)		(0.060)
Trust			−87.202*	−248.227***
			(46.655)	(66.339)
EKS* Trust			3.059***	
			(0.767)	
EKS2 * Trust			−0.009***	
			(0.001)	
TKS * Trust				4043.868***
				(901.758)
TKS2* Trust				−105.394***
				(23.276)
RP	−3.832	1.609	−0.000***	−0.000
	(5.264)	(8.723)	(0.000)	(0.000)
Age	0.063**	0.067**	0.045***	0.077***
	(0.026)	(0.027)	(0.015)	(0.023)
Size	0.166*	0.483***	0.337***	0.468***
	(0.088)	(0.113)	(0.085)	(0.116)
Asset	−0.400	−0.724*	−1.305***	−1.099**
	(0.400)	(0.409)	(0.367)	(0.459)
ROA	0.444	−0.792	−1.379	−1.846
	(1.082)	(1.063)	(0.883)	(1.200)
Cons	−2.722	−44.753**	−5.671***	−0.217***
	(2.072)	(17.700)	(1.912)	(0.071)
Inflate cons	−0.112*	−0.081	−0.146**	−0.189***
	(0.059)	(0.061)	(0.059)	(0.071)
N	1158	1189	1203	1234
Log pseudolikelihood	−8432.454	−9166.754	−7767.514	−9038.669

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

the low psychological trust curve, demonstrating that explicit information spillover is more beneficial to improving open innovation performance at higher levels of psychological trust. (3) After the inflection point, the open innovation curve of the firms has begun to decline. Although the flatness of the various psychological trust curves is comparable, the high psychological trust curve is always higher than the low psychological trust curve, showing that open innovation performance decreases with increasing explicit knowledge spillover regardless of psychological trust; even with the same explicit knowledge spillover, the high psychological trust firms still outperform low trust firms in terms of open innovation performance. The relationship between explicit knowledge spillover and open innovation cannot be considered to be positively regulated by psychological trust because this regulatory effect is dependent on the amount of explicit knowledge spillover. In the link between the two, psychological trust has a negative impact at the level of low explicit knowledge spillover. When the level of explicit knowledge spillover is high, psychological trust positively moderates the relationship between the two.

Calculating coefficient $\lambda_1\lambda_4-\lambda_2\lambda_3$ 0, results in the turning point of the curve moving to the left, as shown in Figure 3. The curve shows that regardless of psychological trust, open innovation performance declines when tacit knowledge increases; even if the same tacit knowledge overflows, high psychological trust firms do better in open innovation than low psychological trust ones. H4 is therefore confirmed.

4.4 Robustness test

To test the reliability of the regression model and empirical results, this paper uses two ways to test the robustness of the regression results: (1) changing the regression model, i.e., using Poisson regression; (2) lagging the explanatory variable firms' open innovation by one period, and the robustness results are shown in Tables 6, 7: Model 1 and Model 2 are regressions of the relationship between explicit knowledge spillover, tacit knowledge spillover quadratic term and open innovation, respectively. The results show that the primary coefficients of the explicit knowledge spillover quadratic term are both -0.000 and significant at the 1% and 10% levels, respectively. Also, primary coefficients of the tacit knowledge spillover quadratic term are -8.793 and -0.101 and significant at the 5% and 10% levels, respectively, and hypothesis H1 and hypothesis H2 are verified. Model 3 adds the interaction term of explicit knowledge spillover and psychological trust on the basis of model 1, and the results show that the coefficients of the interaction term of the secondary term of explicit knowledge spillover and psychological trust are -0.008 and -0.006, and both of them are significant at the 1% level, saying that the inverted U-shaped relationship between explicit knowledge spillover and firms' open innovation is strengthened with the increase of psychological trust; model 4 adds Model 4 adds the interaction term of tacit knowledge spillover and psychological trust on the basis of model 2, and the results show that the coefficients of the interaction term of tacit knowledge spillover and psychological trust are -15.230 and -99.530, which are significant at the 5% and 1% levels, respectively, indicating that the inverted U-shaped relationship between tacit knowledge spillover and firms' open innovation is strengthened with the increase of psychological trust. The above findings are generally consistent with the regression results and the signs of each variable are the same as the empirical results in the previous paper, proving that the conclusions are robust.

TABLE 6 Robustness test: Change regression method.

	(1)	(2)	(3)	(4)
	OI	OI	OI	OI
EKS	0.010***		0.018***	
	(0.000)		(0.001)	
EKS2	−0.000***		−0.000***	
	(0.000)		(0.000)	
TKS		52.952***		1.142**
		(20.329)		(0.505)
TKS2		−8.793**		−0.028**
		(3.534)		(0.013)
Trust			−88.616	−258.634***
			(71.704)	(77.014)
EKS* Trust			1.891***	
			(0.222)	
EKS2 * Trust			−0.008***	
			(0.001)	
TKS * Trust				606.344**
				(261.059)
TKS2* Trust				−15.230**
				(6.927)
RP	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.035***	0.103***	0.010	0.115***
	(0.008)	(0.009)	(0.008)	(0.008)
Size	0.216***	−0.677	0.171***	−0.015
	(0.051)	(1.393)	(0.051)	(0.056)
Asset	1.042***	−0.182***	0.571***	1.589***
	(0.184)	(0.019)	(0.191)	(0.185)
ROA	1.098***	0.049**	0.571*	1.987***
	(0.308)	(0.020)	(0.313)	(0.299)
Cons	−5.039***	−77.310**	−3.022***	−1.200
	(1.060)	(30.579)	(1.057)	(1.203)
N	1203	1112	1203	1234

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

5 Discussion

5.1 Conclusion

Collected from Chinese listed manufacturing firms in Shanghai and Shenzhen A-shares from 2014 to 2020 as research samples, this paper systematically expounds on the impact of knowledge spillovers on firms' open innovation. Dividing knowledge spillover into explicit knowledge spillover and tacit knowledge spillover, psychological trust, an important variable in the field of psychology, is introduced as a moderator variable to analyze the influence mechanism of these two different types of knowledge spillovers on firms' open innovation. The following findings were obtained:

First, this paper found the "double-edged sword" effect of knowledge spillovers on firms' open innovation. On the one hand, knowledge spillovers can significantly improve the innovation process by lowering R&D costs and market risks; on the other hand, knowledge spillover could hinder both the recipient firm's ability to innovate and the spillover firm's passion for innovation. This paper proposed and verified the hypothesis that an inverted U-shaped relationship exists between explicit knowledge spillovers, tacit knowledge spillovers and open innovation. The empirical results demonstrated that the promotion effect of knowledge spillover on firms' open innovation only functions at a limited level that

TABLE 7 Robustness test: Lag open innovation by one period.

	(1)	(2)	(3)	(4)
	OI	OI	OI	OI
EKS	0.005***		0.012***	
	(0.001)		(0.001)	
EKS2	−0.000*		−0.000***	
	(0.000)		(0.000)	
TKS		3.968*		9.314***
		(2.131)		(2.382)
TKS2		−0.101*		−0.235***
		(0.056)		(0.062)
Trust			−56.353	−256.281***
			(53.575)	(68.052)
EKS* Trust			2.173***	
			(0.763)	
EKS2 * Trust			−0.006***	
			(0.001)	
TKS * Trust				3837.871***
				(948.913)
TKS2* Trust				−99.530***
				(24.751)
RP	−12.202	−2.319	−0.000***	−0.000
	(10.562)	(11.538)	(0.000)	(0.000)
Age	0.052**	0.053**	0.032*	0.058**
	(0.026)	(0.027)	(0.017)	(0.025)
Size	0.114	0.393***	0.317***	0.319***
	(0.084)	(0.118)	(0.077)	(0.121)
Asset	−0.992**	−1.284***	−1.680***	−0.959**
	(0.435)	(0.435)	(0.437)	(0.381)
ROA	−0.191	−1.594	−2.615**	−0.000
	(1.332)	(1.275)	(1.258)	(0.000)
Cons	−1.097	−46.012**	−4.683***	−6.075**
	(2.050)	(21.647)	(1.752)	(2.790)
Inflate cons	−0.119*	−0.097	−0.132**	−0.212***
	(0.063)	(0.065)	(0.063)	(0.073)
N	1023	1055	1029	1060
Log pseudolikelihood	−6784.252	−7389.833	−6212.515	−7138.477

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

excessive knowledge spillover damages the promotion effect of open innovation.

Second, although we conclude that knowledge spillover and firms' open innovation are nonlinear related, different types of knowledge spillover have distinct mechanisms to influence open innovation. In contrast, tacit knowledge spillover takes individuals with knowledge as carriers to acquire valuable experience and technology, which has a subtle impact on open innovation. Meanwhile, we propose that knowledge spillover producers are not always in a disadvantageous position in the spillover process, and proper knowledge exchange is also beneficial to knowledge creators.

Third, the findings indicated that psychological trust is a crucial moderator in the relationship between information spillover and firms' open innovation. Employees will face resource loss owing to excessive emotional resource consumption when psychological trust is low (Hobfoll, 2001; Halbesleben et al., 2014). On the contrary, the increment of psychological trust can not only promote the exchange of experience and knowledge among organizational members to a large extent but also improve the willingness of organizational members to share knowledge (Yuan et al., 2016). By strengthening and fostering trust amongst knowledge subjects, firms may encourage more collaborative communication and enhance the effectiveness of open innovation.

5.2 Theoretical contributions

First, regarding the influence mechanism of knowledge spillovers, this paper breaks through the discussion of a single level that knowledge spillovers only positively or negatively affect firms' open innovation. While the inverted U-shaped relationship between explicit knowledge spillover, tacit knowledge spillover and firms' open innovation is verified, the balance of positive and negative effects of knowledge spillover in different contexts is also explored in this paper. As a further refinement of the relationship between knowledge spillovers and innovation, these findings not only help researchers understand the relationship between knowledge spillovers and firms' open innovation more comprehensively, but also improve knowledge management theory and innovation theory. Moreover, emphasis on the dynamic role of the knowledge spillover producers in the process of knowledge spillover shows that the knowledge spillover producers, as the initiator of knowledge spillover and the bearer of knowledge spillover, has a decisive role in the scale and channel selection of knowledge spillover.

Second, by integrating knowledge spillover, firms' open innovation and psychological trust into the same framework for research, this paper provided a new understanding vision for the development of open innovation in specific contexts. From the perspective of psychological trust, which effectively combines management science and psychology, we examined psychological changes in knowledge subjects between knowledge spillover and firms' open innovation. Encouraging the integration of knowledge across disciplines, the above perspective further verified the logical analysis that psychological trust can increase organizational competitiveness more thoroughly while a reasonable explanation of management behavior is provided. What's more, a rational explanation of management behavior from the perspective of psychology enriches and expands the related research on psychological trust.

5.3 Managerial implications

First, as the main subject of innovation activities, firms need to raise their awareness of open innovation and strive to break their own development boundaries. Firms actively cooperate with universities, research institutions and even competitors to obtain the complementary resources they need. Also, a comprehensive and integrated understanding of the relationship between knowledge spillovers and open innovation is necessary for market innovation activities. At the micro level, spillovers are not entirely harmful to firms on the knowledge spillover producers. Turning passive into active, the observation of innovation activities or other knowledge reorganization behaviors that happens in recipient firms can help the knowledge spillover producers to accumulate relevant innovation experience as well as reduce the uncertainty and risk in the subsequent innovation process. Accordingly, recipient firms must be cautious in their resource selection for digestion, and absorption. The reuse of the new external knowledge should be based on their development situation to optimize the benefits of the firms' knowledge spillover.

Second, firms should pay more attention to the trust relationship between organizations, including the mutual trust between individuals. Furthermore, in addition to paying attention to the trust construction of the entire organization in all aspects of human resource management, the micro-level such as the individual psychology of employees needs more attention. In particular, knowledge-based employees are strongly motivated to achieve their goals with a strong sense of self-worth. To address the needs of knowledge-based talent, firms need to create a competitive compensation and welfare system by focusing on the growth and development of knowledge-based employees.

Third, at the national macro level, market regulators must establish a favorable institutional environment for firms' innovation. The state must provide knowledge guarantee and institutional support for the transition from Made in China to Create in China, relying on policies and systems such as intellectual property protection to effectively maintain the profits of innovative firms, to limit the "speculative" behavior in innovation activities, and to motivate firms' innovation activities as well as the whole society.

5.4 Limitations and suggestions for future research

First, while this research mainly analyzes the impact of employees' psychological trust from a static perspective, recent studies indicate that psychological trust shows some fluctuation in the temporal dimension (Qin et al., 2018; Ju et al., 2019). Therefore, future research might investigate the effects of psychological trust in a dynamic temporal context. Second, focused on the positives of psychological trust, potential negatives are neglected. It is possible that psychological trust will lead to emotional tiredness or even destruction. To develop a more comprehensive and dynamic understanding of the relationship between knowledge and innovation, it is meaningful to investigate the detrimental impacts of psychological trust in terms of its function between the two in the future. Third, based on the availability of data, the data sources in this paper cannot be updated to the most recent year, and other measurement methods such as questionnaires or replacement of other databases can be used in the future to make the findings of this paper more comprehensive.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

RH contributed the central idea, analyzed most of the data, and wrote the initial draft of the manuscript. JJ, TS, and YL contributed to refining the ideas, carrying out additional analyses, and finalizing this manuscript. All authors discussed the results and revised the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aghion, P., Akcigit, U., and Howitt, P. (2014). What do we learn from schumpeterian growth theory? *Hand. Econ. Growth* 2, 515–563. doi: 10.1016/B978-0-444-53540-5.00001-X

Aguinis, H., and Glavas, A. (2012). What we know and don't know about corporate social responsibility. *J. Manag.* 38, 932–968. doi: 10.1177/0149206311436079

Alam, M. A., Rooney, D., and Taylor, M. (2022). Measuring inter-firm openness in innovation ecosystems. *J. Bus. Res.* 138, 436–456. doi: 10.1016/j.jbusres.2021.08.069

Alexy, O., George, G., and Salter, A. J. (2013). Cui bono? The selective revealing of knowledge and its implications for innovative activity. *Acad. Manag. Rev.* 38, 270–291. doi: 10.5465/amr.2011.0193

Almeida, P., and Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks. *Manag. Sci.* 45, 905–917. doi: 10.1287/mnsc.45.7.905

Arora, A., Athreye, S., and Huang, C. (2016). The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. *Res. Policy* 45, 1352–1361. doi: 10.1016/j.respol.2016.03.019

Bernal, P., Carree, M., and Lokshin, B. (2022). Knowledge spillovers. R&D partnerships and innovation performance. *Technovation* 115:102456. doi: 10.1016/j.technovation.2022.102456

Berraies, S., Hamza, K. A., and Chtioui, R. (2020). Distributed leadership and exploratory and exploitative innovations: Mediating roles of tacit and explicit knowledge sharing and organizational trust. *J. Knowl. Manag.* 25, 1287–1318. doi: 10.1108/JKM-04-2020-0311

Bibi, S., and Ali, A. (2017). Knowledge sharing behavior of academics in higher education. *J. Appl. Res. High. Educ.* 9, 550–564. doi: 10.1108/JARHE-11-2016-0077

Block, J. H. (2012). R&D investments in family and founder firms: An agency perspective. *J. Bus. Ventur.* 27, 248–265. doi: 10.1016/j.jbusvent.2010.09.003

Bloom, N., Schankerman, M., and Van Reenen, J. (2013). Identifying technology spillovers and product market rivalry. *Econometrica* 81, 1347–1393. doi: 10.3982/ECTA9466

Blundell, R., Dearden, L., Meghir, C., and Sianesi, B. (1999). Human capital investment: The returns from education and training to the individual, the firm and the economy. *Fisc. Stud.* 20, 1–23. doi: 10.1111/j.1475-5890.1999.tb00001.x

Bogers, M., Foss, N. J., and Lyngsie, J. (2018). The "human side" of open innovation: The role of employee diversity in firm-level openness. *Res. Policy* 47, 218–231. doi: 10.1016/j.respol.2017.10.012

Bottazzi, L., Da Rin, M., and Hellmann, T. (2016). The importance of trust for investment: Evidence from venture capital. *Rev. Financ. Stud.* 29, 2283–2318. doi: 10.1093/rfs/hhw023

Brockman, P., Khurana, I. K., and Zhong, R. I. (2018). Societal trust and open innovation. *Res. Policy* 47, 2048–2065. doi: 10.1016/j.respol.2018.07.010

Burmaoglu, S., Sartenaer, O., Porter, A., and Li, M. (2019). Analysing the theoretical roots of technology emergence: An evolutionary perspective. *Scientometrics* 119, 97–118. doi: 10.1007/s11192-019-03033-y

Cassiman, B., and Veugelers, R. (2002). R&D cooperation and spillovers: Some empirical evidence from Belgium. *Am. Econ. Rev.* 92, 1169–1184. doi: 10.1257/00028280260344704

Chen, V. Z., Li, J., and Shapiro, D. M. (2012). International reverse spillover effects on parent firms: Evidences from emerging-market MNEs in developed markets. *Eur. Manag. J.* 30, 204–218. doi: 10.1016/j.emj.2012.03.005

Chesbrough, H., and Crowther, A. K. (2006). Beyond high tech: Early adopters of open innovation in other industries. *R D Manag.* 36, 229–236. doi: 10.1111/j.1467-9310.2006.00428

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business Press.

Chin, T., Shi, Y., Singh, S. K., Agbanyo, G. K., and Ferraris, A. (2022). Leveraging blockchain technology for green innovation in ecosystem-based business models: A dynamic capability of values appropriation. *Technol. Forecast. Soc*. 183:121908. doi: 10.1016/j.techfore.2022.121908

Chin, T., Wang, W., Yang, M., Duan, Y., and Chen, Y. (2021). The moderating effect of managerial discretion on blockchain technology and the firms' innovation quality: Evidence from Chinese manufacturing firms. *Int. J. Prod. Econ*. 240:108219. doi: 10.1016/j.ijpe.2021.108219

Choudhury, P., and Kim, D. Y. (2019). The ethnic migrant inventor effect: Codification and recombination of knowledge across borders. *Strateg. Manag. J.* 40, 203–229. doi: 10.1002/smj.2977

Colquitt, J. A., LePine, J. A., Piccolo, R. F., Zapata, C. P., and Rich, B. L. (2012). Explaining the justice–performance relationship: Trust as exchange deepener or trust as uncertainty reducer? *J. Appl. Psychol.* 97, 1–15. doi: 10.1037/a0025208

Cronin, M. A., and Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. *Acad. Manag. Rev*. 32, 761–773. doi: 10.5465/amr.2007.25275511

Dai, L., Zhang, J., and Luo, S. (2022). Effective R&D capital and total factor productivity: Evidence using spatial panel data models. *Technol. Forecast. Soc.* 183:121886. doi: 10.1016/j.techfore.2022.121886

Dhanaraj, C., Lyles, M. A., Steensma, H. K., and Tihanyi, L. (2004). Managing tacit and explicit knowledge transfer in IJVs: The role of relational embeddedness and the impact on performance. *J. Int. Bus. Stud.* 35, 428–442. doi: 10.1057/palgrave.jibs.8400098

Dirks, K. T., and Ferrin, D. L. (2001). The role of trust in organizational settings. *Organ. Sci.* 12, 450–467. doi: 10.1287/orsc.12.4.450.10640

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *J. Econ. Lit.* 26, 1120–1171. doi: 10.2307/2726526

Duan, Y., Deng, Z., Liu, H., Yang, M., Liu, M., and Wang, X. (2022). Exploring the mediating effect of managerial ability on knowledge diversity and innovation performance in reverse cross-border M&As: Evidence from Chinese manufacturing corporations. *Int. J. Prod. Econ.* 247:108434. doi: 10.1016/j.ijpe.2022.108434

Duan, Y., Huang, L., Luo, X., Cheng, T., and Liu, H. (2021). The moderating effect of absorptive capacity on the technology search and innovation quality relationship in high-tech manufacturing firms. *J. Eng. Technol. Manag.* 62:101656. doi: 10.1016/j.jengtecman.2021.101656

Fallah, M. H., and Ibrahim, S. (2004). "Knowledge spillover and innovation in technological clusters," in *Proceedings, IAMOT 2004 conference*, Washington, DC, 1–16. doi: 10.3389/fdata.2021.689310

Filatotchev, I., Liu, X., Lu, J., and Wright, M. (2011). Knowledge spillovers through human mobility across national borders: Evidence from Zhongguancun science park in China. *Res. Policy* 40, 453–462. doi: 10.1016/j.respol.2011.01.003

Flipse, S., van der Sanden, M., van der Velden, T., Fortuin, F., Onno Omta, S., and Osseweijer, P. (2013). Identifying key performance indicators in food technology contract R&D. *J. Eng. Technol. Manage.* 30, 72–94. doi: 10.1016/j.jengtecman.2012.11.003

Gaur, A. S., Ma, H., and Ge, B. (2019). MNC strategy, knowledge transfer context, and knowledge flow in MNEs. *J. Knowl. Manag.* 23, 1885–1900. doi: 10.1108/JKM-08-2018-0476

Gulati, R., and Singh, H. (1998). The architecture of cooperation: Managing coordination costs and appropriation concerns in strategic alliances. *Admin. Sci. Q.* 43, 781–814. doi: 10.2307/2393616

Guo, B., Pérez-Castrillo, D., and Toldrà-Simats, A. (2019). Firms' innovation strategy under the shadow of analyst coverage. *J. Financ. Econ.* 131, 456–483. doi: 10.1016/j.jfineco.2018.08.005

Haans, R. F. J., Pieters, C., and He, Z.-L. (2016). Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. *Strateg. Manag. J.* 37, 1177–1195. doi: 10.1002/smj.2399

Halbesleben, J. R., Neveu, J. P., Paustian-Underdahl, S. C., and Westman, M. (2014). Getting to the "COR" understanding the role of resources in conservation of resources theory. *J. Manag.* 40, 1334–1364. doi: 10.1177/0149206314527130

Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organ. Sci.* 13, 232–248. doi: 10.1287/orsc.13.3.232.2771

Harabi, N. (1995). *Channels of R&D spillovers: An empirical investigation*. Schönberggasse: Institute of Economics at the University of Zurich, 37.

Hilbert, M., and López, P. (2011). The world's technological capacity to store, communicate, and compute information. *Science* 332, 60–65. doi: 10.1126/science.1200970

Ho, M. H., Ghauri, P. N., and Larimo, J. A. (2018). Institutional distance and knowledge acquisition in international buyer-supplier relationships: The moderating role of trust. *Asia Pac. J. Manag.* 35, 427–447. doi: 10.1007/s10490-017-9523-2

Hobfoll, S. E. (2001). The influence of culture, community, and the nested-self in the stress process: Advancing conservation of resources theory. *Appl. Psychol.* 50, 337–421. doi: 10.1111/1464-0597.00062

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. *Q. J. Econ.* 122, 879–924. doi: 10.1162/qjec.122.3.879

Jones, S. L., Fawcett, S. E., Fawcett, A. M., and Wallin, C. (2010). Benchmarking trust signals in supply chain alliances: Moving toward a robust measure of trust. *Benchmarking Int. J.* 17, 705–727. doi: 10.1108/14635771011076452

Ju, D., Huang, M., Liu, D., Qin, X., Hu, Q., and Chen, C. (2019). Supervisory consequences of abusive supervision: An investigation of sense of power, managerial self-efficacy, and task-oriented leadership behavior. *Organ. Behav. Hum. Dec.* 154, 80–95. doi: 10.1016/j.obhdp.2019.09.003

Keller, W. (2010). International trade, foreign direct investment, and technology spillovers. *Hand. Econ. Innov.* 2, 793–829. doi: 10.1016/S0169-7218(10)02003-4

Keupp, M. M., and Gassmann, O. (2009). Determinants and archetype users of open innovation. *R D Manag.* 39, 331–341. doi: 10.1111/j.1467-9310.2009.00563.x

Kim, E. J., and Park, S. (2020). Transformational leadership, knowledge sharing, organizational climate and learning: An empirical study. *Leadersh. Organ. Dev. J.* 41, 761–775. doi: 10.1108/LODJ-12-2018-0455

Krausert, A. (2014). HRM systems for knowledge workers: Differences among top managers, middle managers, and professional employees. *Hum. Resour. Manag.* 53, 67–87. doi: 10.1002/hrm.21554

Lau, D. C., Liu, J., and Fu, P. P. (2007). Feeling trusted by business leaders in China: Antecedents and the mediating role of value congruence. *Asia Pac. J. Manag.* 24, 321–340. doi: 10.1007/s10490-006-9026-z

Lee, J. Y., Xiao, S. S., and Choi, B. (2021). Unpacking the drivers of emerging market firms' international joint venture formation: The interplay between technological innovation strategies and home- and host-institutional pressures. *J. Bus. Res.* 134, 378–392. doi: 10.1016/j.jbusres.2021.05.049

Lichtenthaler, U. (2009). Outbound open innovation and its effect on firm performance: Examining environmental influences. *R D Manag.* 39, 317–330. doi: 10.1111/j.1467-9310.2009.00561.x

Lin, T. C., Wu, S., and Lu, C. T. (2012). Exploring the affect factors of knowledge sharing behavior: The relations model theory perspective. *Expert Syst. Appl.* 39, 751–764. doi: 10.1016/j.eswa.2011.07.068

Liu, P., and Li, H. (2020). Does bank competition spur firm innovation? *J. Appl. Econ.* 23, 519–538. doi: 10.1080/15140326.2020.1806001

Malik, A., and Nilakant, V. (2016). Knowledge integration mechanisms in high-technology business-to-business services vendors. *Knowl. Man Res. Pract.* 14, 565–574. doi: 10.1057/kmrp.2015.9

Millar, C. C., Chen, S., and Waller, L. (2017). Leadership, knowledge and people in knowledge-intensive organisations: Implications for HRM theory and practice. *Int. J. Hum. Res. Manag.* 28, 261–275. doi: 10.1080/09585192.2016.1244919

Montoro-Sánchez, A., Ortiz-de-Urbina-Criado, M., and Mora-Valentín, E. M. (2011). Effects of knowledge spillovers on innovation and collaboration in science and technology parks. *J. Knowl. Manag.* 15, 948–970. doi: 10.1108/13673271111179307

Nieto, M., and Quevedo, P. (2005). Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort. *Technovation* 25, 1141–1157. doi: 10.1016/j.technovation.2004.05.001

Nonaka, I. (2008). *The knowledge-creating company*. Boston: Harvard Business Review Press.

Nonaka, I., Hirose, A., and Takeda, Y. (2016). 'Meso'-foundations of dynamic capabilities: Team-level synthesis and distributed leadership as the source of dynamic creativity. *Glob. Strateg. J.* 6, 168–182. doi: 10.1002/gsj.1125

Nyberg, A. J., and Wright, P. M. (2015). 50 years of human capital research: Assessing what we know, exploring where we go. *Acad. Manag. Perspect*. 29, 287–295. doi: 10.5465/amp.2014.0113

Park, S., and Kim, E. J. (2018). Fostering organizational learning through leadership and knowledge sharing". *J. Knowl. Manag.* 22, 1408–1423. doi: 10.1108/JKM-10-2017-0467

Perri, A., Andersson, U., Nell, P. C., and Santangelo, G. D. (2013). Balancing the trade-off between learning prospects and spillover risks: MNC subsidiaries' vertical linkage patterns in developed countries. *J. World Bus*. 48, 503–514. doi: 10.1016/j.jwb.2012.09.006

Qin, X., Huang, M., Hu, Q., Schminke, M., and Ju, D. (2018). Ethical leadership, but toward whom? How moral identity congruence shapes the ethical treatment of employees. *Hum. Relat*. 71, 1120–1149. doi: 10.1177/0018726717734905

Ramadani, V., Abazi-Alili, H., Dana, L., Rexhepi, G., and Ibraimi, S. (2017). The impact of knowledge spillovers and innovation on firm-performance: Findings from the Balkans countries. *Int. Entrep. Manag. J*. 13, 299–325. doi: 10.1007/s11365-016-0393-8

Ritala, P., Huizingh, E., Almpanopoulou, A., and Wijbenga, P. (2017). Tensions in R&D networks: Implications for knowledge search and integration. *Technol. Forecast. Soc*. 120, 311–322. doi: 10.1016/j.techfore.2016.12.020

Rutten, W., Blaas-Franken, J., and Martin, H. (2016). The impact of (low) trust on knowledge sharing. *J. Knowl. Manag.* 20, 199–214. doi: 10.1108/JKM-10-2015-0391

Salter, A., Criscuolo, P., and Ter Wal, A. L. (2014). Coping with open innovation: responding to the challenges of external engagement in R&D. *Calif. Manag. Rev*. 56, 77–94. doi: 10.1525/cmr.2014.56.2.77

Sankowska, A. (2013). Relationships between organizational trust, knowledge transfer, knowledge creation, and firm's innovativeness. *Learn. Organiz*. 20, 85–100. doi: 10.1108/09696471311288546

Schilling, M. A., and Green, E. (2011). Recombinant search and breakthrough idea generation: An analysis of high impact papers in the social sciences. *Res. Policy* 40, 1321–1331. doi: 10.1016/j.respol.2011.06.009

Scuotto, V., Beatrice, O., Valentina, C., Nicotra, M., Di Gioia, L., and Briamontef, M. F. (2020). Uncovering the micro-foundations of knowledge sharing in open innovation partnerships: An intention-based perspective of technology transfer. *Technol. Forecast Soc*. 152:119906. doi: 10.1016/j.techfore.2019.119906

Seidler de Alwis, R., and Hartmann, E. (2008). The use of tacit knowledge within innovative companies: Knowledge management in innovative enterprises. *J. Knowl. Manag*. 12, 133–147. doi: 10.1108/13673270810852449

Song, J., Almeida, P., and Wu, G. (2003). Learning–by–hiring: When is mobility more likely to facilitate interfirm knowledge transfer? *Manag. Sci*. 49, 351–365. doi: 10.1287/mnsc.49.4.351.14429

Sun, W., Ding, Z., Xu, X., and Cui, K. (2020). Internationalization and firm default risk: The roles of environmental dynamism and marketing capability. *J. Bus. Res*. 121, 142–153. doi: 10.1016/j.jbusres.2020.08.027

Umar, M., Sial, M. H., Ali, S. A., Bari, M. W., and Ahmad, M. (2021). Trust and social network to boost tacit knowledge sharing with mediation of commitment: Does culture moderate? *VINE J. Inf. Knowl. Manag. Syst.* ahead-of-print (ahead-of-print). doi: 10.1108/VJIKMS-01-2021-0012

Vanhaverbeke, W., Van de Vrande, V., and Chesbrough, H. (2008). Understanding the advantages of open innovation practices in corporate venturing in terms of real options. *Creat. Innov. Manag.* 17, 251–258. doi: 10.1111/j.1467-8691.2008.00499.x

Von Krogh, G., Nonaka, I., and Rechsteiner, L. (2012). Leadership in organizational knowledge creation: A review and framework. *J. Manage. Stud*. 49, 240–277. doi: 10.1111/j.1467-6486.2010.00978.x

Xin Ding, D., Hu, P. J. H., Verma, R., and Wardell, D. G. (2010). The impact of service system design and flow experience on customer satisfaction in online financial services. *J. Serv. Res.* 13, 96–110. doi: 10.1177/1094670509350674

Yamin, M., and Otto, J. (2004). Patterns of knowledge flows and MNE innovative performance. *Int Manag*. 10, 239–258. doi: 10.1016/j.intman.2004.02.001

Yang, H., and Steensma, H. K. (2014). When do firms rely on their knowledge spillover recipients for guidance in exploring unfamiliar knowledge? *Res. Policy.* 43, 1496–1507. doi: 10.1016/j.respol.2014.04.016

Yang, H., Phelps, C., and Steensma, H. K. (2010). Learning from what others have learned from you: The effects of knowledge spillovers on originating firms. *Acad. Manage. J.* 53, 371–389. doi: 10.5465/amj.2010.49389018

Yang, M., Wang, J., and Zhang, X. (2021). Boundary-spanning search and sustainable competitive advantage: The mediating roles of exploratory and exploitative innovations. *J. Bus. Res*. 127, 290–299. doi: 10.1016/j.jbusres.2021.01.032

Ye, H. (2022). the impact of knowledge spillovers on regional innovation performance: From the perspective of patent cooperation. *World Sci. Res. J*. 8, 102–115.

Yi, L., Wang, Y., Upadhaya, B., Zhao, S., and Yin, Y. (2021). Knowledge spillover, knowledge management capabilities, and innovation among returnee entrepreneurial firms in emerging markets: Does entrepreneurial ecosystem matter? *J. Bus. Res.* 130, 283–294. doi: 10.1016/j.jbusres.2021.03.024

Yuan, X., Olfman, L., and Yi, J. (2016). How do institution-based trust and interpersonal trust affect interdepartmental knowledge sharing? *Inf. Resour. Manag. J*. 29, 15–38. doi: 10.4018/IRMJ.2016010102

Zahra, S. A., and George, G. (2002). The net-enabled business innovation cycle and the evolution of dynamic capabilities. *Inform. Syst. Res.* 13, 147–150. doi: 10.1287/isre.13.2.147.90

Zhang, J., Yu, J., and Qu, X. (2022). *Spatial dynamic panel data models with high-order time-varying endogenous weights matrices*. Available at SSRN 4163612. doi: 10.2139/ssrn.4163612

Zhang, W., and Ke, R. (2002). Trust in China: A cross-regional analysis. *Econ. Res. J*. 10, 59–65.

Zhu, X., and Xu, J. (2019). Impact of knowledge spillover on the knowledge transfer performance in China's manufacturing industry. *Technol. Anal. Strateg.* 31, 1199–1212. doi: 10.1080/09537325.2019.1599853

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 15 December 2022
DOI 10.3389/fpsyg.2022.1041767

OPEN ACCESS

EDITED BY
Yunlong Duan,
Yunnan University of Finance And Economics, China

REVIEWED BY
Xinqi Zhang,
GuiZhou University of Finance and Economics, China
Fan Chao,
Renmin University of China, China

*CORRESPONDENCE
Jianbin Chen
jianbin.chen@buu.edu.cn

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 11 September 2022
ACCEPTED 24 November 2022
PUBLISHED 15 December 2022

CITATION
Jiao Z, Li C and Chen J (2022) Knowledge platform affordances and knowledge collaboration performance: The mediating effect of user engagement. *Front. Psychol.* 13:1041767. doi: 10.3389/fpsyg.2022.1041767

Knowledge platform affordances and knowledge collaboration performance: The mediating effect of user engagement

Zeyu Jiao, Chang Li and Jianbin Chen*

Business College, Beijing Union University, Beijing, China

Knowledge collaboration is the result of knowledge transfer and social interaction among users on knowledge platforms, and its formation mechanism has attracted much attention. Based on the affordance theory, this paper introduces user engagement as a mediating variable to study the relationship between knowledge platform affordances and knowledge collaboration performance. Data collected from 361 valid questionnaires from the Zhihu platform were analyzed by using SPSS 26.0 and Amos 24.0. The results show that knowledge platform affordances have a direct and positive influence on knowledge collaboration performance as well as an indirect influence through user engagement. Expressly, user engagement undertakes three intermediary paths between knowledge platform affordances and knowledge collaboration performance: knowledge affordances-conscious participation-knowledge collaboration performance, knowledge affordances-enthusiasm-knowledge collaboration performance, and social affordances-social interaction-knowledge collaboration performance. This paper explores the formation process of knowledge collaboration performance by synthesizing affordance and user engagement theories. It clarifies the fundamental role of knowledge affordances in stimulating users' conscious participation and enthusiasm, and the critical role of social affordances in stimulating social interaction. Therefore, this paper further enriches theories of knowledge collaboration and knowledge platform affordances and provides a practical reference for the strategic optimization and development of knowledge platforms.

KEYWORDS

knowledge collaboration, social interaction, knowledge platforms, user engagement, knowledge platform affordances, knowledge collaboration performance

Introduction

Online knowledge communities integrate the functions of knowledge information loading, consulting, retrieval, system management, and instant messaging, which have become essential platforms for knowledge communication and social interactions. At the same time, with the continuous development of knowledge platforms, the role of users has

transferred from traditionally passive knowledge receivers to knowledge co-creators. Knowledge platforms such as Quora, Stack Overflow, and Zhihu have all achieved success in knowledge services (Goes et al., 2016). However, some knowledge platforms, such as Baidu Xinzhi and Wukong Q&A, have limited their development due to incomplete functions and low knowledge quality, which eventually lead to the loss of users and the disintegration of the community (Chen, 2021). As an online knowledge platform, the key to survival and development is to increase user traffic and maintain user stickiness. Therefore, attracting potential user groups to join the platform and maintaining active user engagement has become crucial for the sustained development of knowledge platforms.

Knowledge collaboration is the primary operating mechanism of knowledge platforms (Arazy et al., 2013; Kane and Ransbotham, 2016). Based on different needs of knowledge exploration and knowledge contribution, community users interact with each other and promote knowledge innovation to realize the appreciation of knowledge capital and social capital (Chen et al., 2014; Matei et al., 2018). According to Jiao et al. (2021), knowledge collaboration is influenced by knowledge platform affordances in two ways. One is that knowledge affordances provide a resource base for knowledge collaboration and directly affect the knowledge collaboration process. The other is that social affordances provide basic support and public services for knowledge collaboration. Thus, the realization mechanism of knowledge collaboration is not only directly affected by factors such as users' needs, cognitive conflict, group size, and content quality (Liu F. J. et al., 2020) but also closely related to platform affordances.

How to realize the influencing mechanism of knowledge collaboration performance has become a new challenge.

Enhancing user engagement is a crucial way to expand community traffic. In a large number of studies focusing on platform ecology and value co-creation (Parker and Alstyne, 2005; Zhong et al., 2020), user engagement has received extensive attention as an essential source of value co-creation. It is defined as "a quality of user experience characterized by the depth of an actor's cognitive, temporal, affective, and behavioral investment when interacting with a digital system" (O'Brien and Cairns, 2016). Meanwhile, from a socio-technical perspective, a knowledge platform is a collection of possibilities and needs of user behaviors of knowledge collaboration in social media and organizational environments (Rice et al., 2017). Platform positioning and organizational characteristics determine its affordances and social resource search and aggregation method (Su et al., 2020). Those affordances could directly determine the user engagement effect. Although there is a complex causal relationship between knowledge platform affordances and user engagement, this paper mainly focuses on the impact of support capabilities on user engagement.

This paper makes a contribution to the literature and practice in lots of ways. In the theoretical aspect, this paper goes deep into the interaction between the platform and users to discuss how to realize the way to improve knowledge collaboration performance and expand the depth of research on affordances and user engagement in the context of knowledge platforms. Existing research has studied the impact of gamification on user engagement in the environment of mobile apps (Ho and Chung, 2020; Bitrián et al., 2021). There is also a study about the relationship between customer engagement and the value creation of company social networks (Zhang et al., 2017). With the improvement of business models, user engagement has become almost a fundamental role of the platform economy. However, most platforms focus heavily on network traffic and user attention, there are still many uncertainties from user access to the platform to forming user engagement. Therefore, the formation mechanism of user engagement has received little attention in current research. In particular, studying user engagement in combination with platform features is a gap in platform user research. Existing research explored the formation mechanism of user engagement in multiple dimensions, focusing on perceived benefits (Wang and Jiang, 2018), trust atmosphere (Yang and Tu, 2018), user value (Ning et al., 2019), and digital touchpoint (Lemon and Verhoef, 2016). Because of the heterogeneity of the platform, the engagement between the platform and the user is bidirectional and it is not enough to study the user engagement without the platform characteristics. The research on this topic is conducive to realizing the integration of platform affordances and user engagement, further enriching the theoretical system of knowledge collaboration mechanism, and realizing theoretical innovation.

In the practical aspect, this paper can provide a decision-making reference for companies to promote user engagement by building platform affordances. The research on this topic can guide more platforms to provide effective affordances and improve user engagement under the premise of unifying user needs and organizational characteristics. In this way, it could help avoid wasting social resources and improve Internet innovation's success rate.

Literature review

Knowledge platform affordances

Affordances

Affordance originally refers to the support that objective things can provide for a certain behavior, that is, the possibility of things providing a certain behavior (Gibson, 1986). It refers to the general characteristics of an object which enable it to fulfill the specific needs of individuals. In a certain context, the affordance of something is determined by its actual properties and perceived properties (Norman, 1988). The concept of affordance is emphasized differently in different subject areas. In recent years, it has grown in popularity in organizational research to better understand the impact of a combination of new technologies and organizational characteristics on organizational innovation and functioning (Majchrzak and Faraj, 2013). Especially for social

media affordances, they have attracted a lot of attention from researchers as their significant impact on users' behavior and psychology, and organizations' communication process. According to Rice et al. (2017), social media affordances refer to the relationship between action possibilities and users' perceived needs aggregated in social media and the corporate environment under the constraints of the potential features or functions of social media platforms. Based on social media affordances, Majchrzak and Faraj (2013) investigated different ways for employees to engage with the platform and facilitate knowledge sharing. Postigo (2016) analyzed how YouTube can guide users to conduct behaviors that benefit the platform's commercial interests through the design of its platform architecture. Sun et al. (2019) did research about the influences of corporate social work platforms on employees' improvisation ability.

Concerning dimensions of affordances, Treem and Leonardi (2012) suggested four dimensions of social media affordances: visibility, associating, editability, and persistence, which have been widely accepted (Fayard and Weeks, 2014; Sun et al., 2019; Zhang, 2020). Affordances of meta-voicing, trigger attending, network-informed associating, and generative role-taking were proposed by Majchrzak and Faraj (2013). Additionally, Rice et al. (2017) proposed six dimensions of functional media affordances. Fox and McEwan (2017) mentioned ten dimensions of communication affordances. Pan and Liu (2017) suggested mobile affordances, which include portability, availability, locatability, and multimediality. The most integrated literature suggested by Karahanna et al. (2018) divided social media affordances into egocentric affordances (self-presentation, content sharing, and interactivity) and allocentric affordances (presence signaling, relationship formation, group management, browsing other's content, meta-voicing, communication, collaboration, competition, and sourcing). Based on this dimension, the relationship among users' psychological needs, platform affordances, and platform features is established in the context of social media.

Knowledge platform affordances

Knowledge platforms are not only intermediaries in the multilateral market but also heterogeneous production organizations with different value propositions, market orientations, and different resource endowments. It is "productive" (converges and empowers socialized producers) and "knowledgeable" (provides industry-specific knowledge and proprietary resources), and is unique and decisive in the influencing mechanism of knowledge collaboration performance (Chen et al., 2014). Based on the socio-technical perspective, the affordance theory can better demonstrate the interaction between Internet technology, user needs, and organizational characteristics, and better understand the innovation operations under the guidance of affordances. Different from data ability, the value of knowledge platform affordances is not merely created by digital technology. More importantly, it is co-created by the interaction between users, technology, and purposes of use (Ghazawneh and Henfridsson, 2015). By studying the micro-mechanism of the interaction between users and the platform, we can reveal the key elements and institutional arrangements necessary to engage users through the affordances of knowledge platforms, and provide helpful theoretical guidance for the realization of platform value.

The knowledge platform accumulates two types of knowledge resources in the process of supporting the communication between knowledge seekers and contributors: "knowledge about users" and "knowledge produced by users." The former refers to the knowledge about users' attributes, social networks, and behaviors accumulated on the platform through digital interaction. It can promote the evolution of collaboration tools, user portraits, and accurate recommendations and is ultimately reflected in platform functions. In this way, it forms the social affordances of the platform (Karahanna et al., 2018; Sun et al., 2019). The latter is the knowledge production results contributed by users and jointly completed, which become the platform's strategic resources, manifested as the platform's knowledge affordances (Shi et al., 2020). Based on the social media affordances suggested by Karahanna et al. (2018) and knowledge attributes suggested by Shi et al. (2020), the author suggested 10 affordances of online knowledge platforms by taking Zhihu as an example (Jiao et al., 2021). The result shows that knowledge platforms consist of social affordances and knowledge affordances, which constitute the theoretical basis of knowledge collaboration mechanism in this paper (see Table 1).

User engagement

The concept of engagement has attracted widespread academic attention since Kahn (1900) initial study of the work environment. Therefore, many scholars have conducted related research in various fields. The research includes work by sociologists on social engagement, psychologists on civil engagement, educators on student engagement, and organizational behavior scholars on employee engagement and occupational engagement (Ilic, 2008; Hollebeek, 2011). In recent years, with the development of digital technology, the concept of user engagement in the digital environment has gradually received attention. User engagement is a user experience with aesthetic appeal, interactivity, perceived control, etc. (O'Brien and Toms, 2010), which is more manifested as non-transactional behavior beyond purchase (information sharing, word-of-mouth communication, and value co-creation). It helps companies build valuable connections (Mauda and Kalman, 2016). Some researchers have focused on the user-system properties that provide an engaging experience, which allows researchers to provide guidelines on how to enhance users' experiences and facilitates the operationalization of user engagement (Jacques, 1996; O'Brien, 2018). In recent decades, the human-computer interaction (HCI) research has increasingly focused on understanding, designing, and measuring user engagement with computers in the health, education, gaming, and news media sectors. Collectively, this research has

TABLE 1 Knowledge platform affordances.

Affordances	Definitions	Example features
Social affordances		
Self-presentation	Users can display and present information related to themselves. This includes sharing information that somehow portrays users and shows who they are, their values and preferences, their expertise, etc. Updating descriptive information about themselves, such as gender, occupation and location; and posting content involving pictures and videos related to themselves (Davis et al., 2009; Nardon and Aten, 2012; Halpern and Gibbs, 2013; Junglas et al., 2013)	Posting my own content on Zhihu; updating my profile on Zhihu; writing personal opinions on Zhihu
Content Sharing	Users can share and distribute content unrelated to them to others. (for example, sharing posts, videos, etc.; Kietzmann et al., 2011; Majchrzak and Faraj, 2013; Treem and Leonardi, 2012)	Sharing links of other people's articles on Zhihu; sharing others' videos and photos on Zhihu
Relationship Formation	Users can establish relationships with others, including joining groups or online communities (Kietzmann et al., 2011; Treem and Leonardi, 2012)	Following other users on Zhihu; joining an online community (e.g., "Quanzi" on Zhihu)
Browsing Other's Content	Users can view others' content and receive alerts to pay attention to others' content (Davis et al., 2009; Kietzmann et al., 2011; Halpern and Gibbs, 2013)	Browsing others' content on Zhihu; receiving notifications on Zhihu
Meta-voicing	Users can participate in online conversations by responding to other people's status, profile, content, and activities online, and viewing other people's responses to their status, profile, content, and activities. In meta-voice, the user "not only has to express his or her opinion, but also add meta-knowledge to content already online." (Faraj et al., 2011; Majchrzak et al., 2013)	Voting on a post on Zhihu; commenting on other's posts on Zhihu; liking what others post on Zhihu
Sourcing	Users are able to ask for resources or funds, including meeting others' requests for funds or resources (Karahanna et al., 2018)	Asking or answering questions on Zhihu
Knowledge affordances		
Reliability	It refers to the extent to which the answers on social Q & A websites make users feel trustworthy and reliable (Zhu et al., 2009). Users think that the answer is of high quality only when they believe that the source and content of the answer are reliable (Kim and Oh, 2009)	The reliability of Zhihu content is reflected in its questions, answers, articles, videos, pictures, etc.
Selectivity	Users can subscribe to specific content or sources of information (Gibbs et al., 2013)	Zhihu involves varied content in multiple sections, and the content within each section is highly subdivided (Cai et al., 2019)
Economies	It means that the subject obtains relatively maximum benefits with relatively minimum investment, so as to obtain benefits most economically and meet the needs of survival and development (Cai, 2008)	Zhihu provides users with a free Q&A community (Zou and Luo, 2017). Users can spend less money asking questions to experts in related fields
Uniqueness	It is defined as individuals pursuing unique characteristics different from others by acquiring, using and disposing of consumer goods (Tian et al., 2001). Novelty is a concept closely related to uniqueness. Novelty refers to the extent to which the answers on social Q & A websites make users feel innovative. Innovative answers will bring new ideas to users and will also be regarded as high-quality answers by users (Zhu et al., 2009; Shah and Pomerantz, 2010)	In-depth content production on Zhihu is different from the knowledge provided by other Q&A platforms. Zhihu online and offline knowledge products are carried out at the same time (Hou and Xiao, 2017)

demonstrated that user engagement is highly context-dependent. Each digital environment has its own set of technological affordances that interact with the motivations of users in order to achieve a particular goal (O'Brien and Cairns, 2016). In 2018, O'Brien et al. define user engagement as "a quality of user experience characterized by the depth of an actor's cognitive, temporal, affective, and behavioral investment when interacting with a digital system."

In the marketing domain, Bowden (2009) claimed that customer engagement is a psychological process by which new customers build loyalty and old customers maintain their loyalty to a brand. Similar to user engagement, Van Doorn et al. (2010) put forward that customer engagement is a non-transactional behavior when a customer shows interest in a business or brand for some reasons. Brodie et al. (2013) pointed out that engagement is a multi-dimensional concept that includes cognitive, affective, and behavioral factors, and customers may have different forms of engagement with different stakeholders in different contexts.

Based on the above literature, although it has not reached an agreement about the dimensions of user engagement, it can be seen that most of the explanations emphasize that the relationship between customers or users and enterprises or digital environment contains users' emotional, cognitive, and behavioral involvement. In the context of online knowledge platforms, users' experiences are digitally mediated (e.g., online search). Thus, it is timely and vital to understand how individuals interact with these

digital environments (O'Brien and Cairns, 2016; O'Brien, 2018). Digital knowledge platforms like Zhihu have two main features. The first one is that Zhihu has social networking functions. Using the sharing function of the platform and the social interactions of users, the platform can promote knowledge sharing and value co-creation. This process needs to rely on interpersonal interaction and knowledge exchange among users, thereby promoting the flow of information on the knowledge platform. Additionally, as a public knowledge question-and-answer platform, Zhihu users may not be brand admirers. Many researchers believe that highly engaged users determine their sustainability on the Zhihu platform. Highly engaged users with a strong passion can provide a vibrant online environment for knowledge platforms. Therefore, this paper will use enthusiasm (emotional element), conscious participation (cognitive element), and social interaction (behavioral element) suggested by Vivek (2009) to measure the user engagement of knowledge platforms.

Knowledge collaboration performance

Knowledge collaboration was first proposed by Karlenzig et al. (2002) and has been continuously enriched since then. For example, it emphasizes the purpose of integrating complementary knowledge to solve problems (Leijen and Baets, 2002). It also suggests the synergistic effect that the overall benefit is greater than the sum of the individual parts (Leijen and Baets, 2002). In addition, it mentions the transfer of the right information to the right people at the right time, and organizes effective ways to convert knowledge into value (Fan et al., 2007). Tong (2012) comprehensively pointed out that knowledge collaboration is a dynamic process of transferring appropriate information and knowledge to the appropriate target or object at the appropriate time and space, thus realizing knowledge innovation. This is an advanced stage of knowledge management. Chen et al. (2014) further summed up the "appropriateness" of knowledge collaboration at the micro level and the "value-added" effect at the macro level, and proposed two crucial dimensions to measure the performance of knowledge collaboration: knowledge capital appreciation and social capital appreciation. This is also the research basis of this paper.

The knowledge collaboration performance of the knowledge platform is the ultimate value realization method of knowledge (Chen et al., 2014). At present, there is no unified definition in the academic community. However, the conclusion that it includes two dimensions of knowledge capital appreciation and social capital appreciation has been recognized by many scholars (Chen et al., 2014; Strickland, 2014; Bharati et al., 2015; Seo, 2020; Zhou et al., 2022). Social capital in a virtual community represents the connection between people and the personal wealth accumulated through the connection, which is the trust cooperation, and collective behavior established in the interpersonal network of the community (Chang and Chuang, 2011). The social capital theory believes that the network of relationships embodied by individuals has an impact on interpersonal knowledge-sharing behavior (Nahapiet and Ghoshal, 1998). In its simplest form, social capital is what an individual knows about someone that extends what you have (economic capital) or know (human capital). A basic assumption about social capital is that social systems have immediate or expected value. The success of viral marketing, open-source communities, and social media makes the purpose of social capital very attractive (Han et al., 2020). Therefore, gaining social capital appreciation has also become one of the main purposes for users to participate in knowledge collaboration. Social capital includes three dimensions: structural dimension, relationship dimension, and cognitive dimension (Seo, 2020). The structural dimension measures the social connection status, that is, the relationship between members of the knowledge platform. The relationship dimension is the strength of the relationship between members, which is reflected in the individual's sense of trust, identity, and reciprocity with other users in the knowledge platform. That is, when an individual gets help from others, he will give each other in return (Chow and Chan, 2008). The cognitive dimension is mainly reflected in the shared vision of the members of the knowledge platform, that is, the members' common interests, viewpoints, and values (Zhao et al. Hair et al., 2010).

Compared with the appreciation of social capital, the appreciation of knowledge capital is more direct (Chen et al., 2014), which is directly reflected in the acquisition of knowledge by users. Due to the sharing and non-attrition of knowledge capital, the appreciation of knowledge capital is not only manifested in the increase of explicit knowledge (such as experience summary, process documentation, and knowledge base) or the final explicit knowledge product delivered to customers. The implicit knowledge achievements also become the value-added part of knowledge capital, manifested as the improvement of individual and team capabilities, the accumulation of experience, and the improvement of processes (*ibid*). The value-added of explicit knowledge capital mainly measures the knowledge achievements ultimately formed by knowledge collaboration and jointly owned by organizations or teams, such as patents, processes, and regulations, as well as the increase of knowledge units such as program library, rule base, knowledge base, and case base. The appreciation of implicit knowledge capital mainly measures the increase of individual experience and skills, the improvement of team ability, and the improvement of organizational culture and practice (Hedlund and Nonaka, 1993).

Research models and hypotheses

Knowledge platform affordances and knowledge collaboration performance

Previous research has shown that users' psychological needs drive them to participate in the use of knowledge platforms, and the affordances provided by the organizational features of

knowledge platforms can be used to meet such psychological needs (Karahanna et al., 2018; Jiao et al., 2021). Therefore, platform affordances comprehensively reflect organizational features and customer needs. Among them, social affordances are the product of the interaction between users' psychological needs and platform organizational features, while knowledge affordances are the interaction product of platform knowledge resources and users' psychological needs (Shi et al., 2020). It is easy to conclude that knowledge platform affordances offer two possibilities for user behavior. On the one hand, knowledge affordances allow users to increase new knowledge by providing a resource base for knowledge collaboration, so as to facilitate knowledge capital appreciation. On the other hand, social affordances can encourage users to socialize through its social functions, so as to influence social capital appreciation. Thus, H1 and H2 are suggested.

> *H1:* Knowledge affordances have a positive influence on knowledge collaboration performance.
>
> *H2:* Social affordances have a positive influence on knowledge collaboration performance.

The mediating effect of user engagement

Knowledge platform affordances and user engagement

Based on the above analysis, knowledge platform affordances are divided into social affordances and knowledge affordances. Social affordances include self-presentation, content sharing, relationship formation, browsing other's content, sourcing and meta-voicing， and knowledge affordances refer to knowledge attributes. The psychological needs of users promote the use of knowledge platforms to a certain extent. At the same time, knowledge platforms also provide affordances to meet user needs. From a socio-technical perspective, a knowledge platform is a collection of relationships that aggregate user behavior possibilities and needs in social media and organizational environments (Rice et al., 2017). Its value is not only created by digital technology but co-created by the interaction between users, technology, and purpose of use (Ghazawneh and Henfridsson, 2015). Ongus and Nyamboga (2019) also mentioned that the quality and relevance of technical resources and information content are closely related to user needs. Therefore, the platform characteristics formed under the support of technology and resources enable the realization of knowledge platform affordances. Over the past two decades, the Human-Computer Interaction (HCI) community has become gradually interested in understanding, designing, and measuring user engagement in numerous computer-mediated health, education, gaming, social and news media, and search applications (O'Brien and Cairns, 2016). Overall, this work shows that user engagement is highly context-dependent: each digital environment has unique technological and social affordances that interact with users' motivations to achieve some desired purpose.

Vivek (2009) proposed three dimensions of user engagement: enthusiasm, conscious participation, and social interaction. In this scale, conscious participation is the reflection of the cognitive element in user engagement. Enthusiasm is the emotional factor, and social interaction is the behavioral factor. From users' perspectives, user engagement may come from the fact that their needs are met during the process of their engagement or use of digital platforms (Gummerus et al., 2012). According to the existing literature, conscious participation means users' intentional participation in activities and they have some cognition with the activities (Vivek, 2009). In marketing activities, reason-oriented customers desire quick and easy access to information about the use of services and products (Zhang et al., 2017). It is common for society-oriented customers to engage in conversation and interaction with others who share similar interests or needs when shopping (Babin et al., 1994). A meaningful connection between people can be created by user engagement (Luthans and Peterson, 2002). Enthusiasm refers to users' engagement with intense excitement or passion (Vivek, 2009). In the literature of work engagement and customer engagement, enthusiasm is considered to be a positive emotion. It is characterized by a high level of excitement, which is an active and lasting emotion (Bloch, 1986). Vivek (2009) also stressed the importance of enthusiasm for capturing users' strong excitement and focus. In terms of social interaction, it means the interaction and communication of ideas, feelings, and opinions among users (Vivek, 2009). Through social interaction, consumers can quickly and easily obtain information about relevant products, thereby building intimacy with like-minded people (Muniz and O'guinn, 2001). In the context of knowledge platforms, knowledge platforms with different affordances could facilitate user engagement in different ways. For example, in the context of Zhihu, people who use knowledge platforms with knowledge affordances may often browse content on Zhihu (conscious participation), spend much time on Zhihu to learn knowledge (enthusiasm), and exchange ideas in Zhihu communities (social interaction). Thus, the following hypotheses are proposed:

> *H3:* Knowledge affordances have a positive influence on conscious participation.
>
> *H4:* Knowledge affordances have a positive influence on enthusiasm.
>
> *H5:* Knowledge affordances have a positive influence on social interaction.

Additionally, people who use platforms with social affordances are likely to pay lots of attention to Zhihu communities (conscious participation), be passionate about Zhihu (enthusiasm), and enjoy interacting with other users (social interaction). Therefore, digital environments attract users for different reasons (e.g., to learn

knowledge, to socialize with people) with different affordances (knowledge affordances and social affordances) to promote engagement. Therefore, hypotheses are suggested as follows:

> *H6:* Social affordances have a positive influence on conscious participation.
>
> *H7:* Social affordances have a positive influence on enthusiasm.
>
> *H8:* Social affordances have a positive influence on social interaction.

User engagement and knowledge collaboration performance

Knowledge collaboration is an effective way to convert knowledge into value and is the core business process of the platform system (Chen et al., 2014). The impact of user engagement on knowledge collaboration could be manifested in conscious participation, enthusiasm, and social interaction. In terms of conscious participation, users' cognitive and conscious participation in knowledge platforms may enhance knowledge collaboration performance. Because in knowledge platforms, some users who are reason-oriented may want to have a quick and comprehensive understanding of useful content (such as searching answers for their questions). Some society-oriented users would like to communicate with those who possess the same interests, goals, or needs (Babin et al., 1994). Thus, individuals with different cognition participating in knowledge platforms may obtain such values as acquiring knowledge or skills (knowledge capital appreciation), as well as building their social circles (social capital appreciation; Jaakkola and Alexander, 2014).

With regard to enthusiasm, Glassman and McAfee (1990) suggest that users with enthusiasm are more likely to take risks, which allows them to be willing to take the initiative to reduce misunderstandings and avoid uncertainty. In the context of knowledge platforms, enthusiastic users are more likely to alleviate anxiety and uncertainty, so they could increase trust in the content of knowledge platforms. On the basis of this, interactions allow users to get the needed knowledge and information (Lanier and Hampton, 2008), which could improve knowledge capital appreciation. In addition, this enables the users to present and express themselves in a way they like, so as to increase social capital appreciation (Kaplan and Haenlein, 2010; Gummerus et al., 2012).

It is well-documented that social interaction has a significant impact on value co-creation (Zhang et al., 2017). This kind of value is created by forming mutual trust (Stewart and Pavlou, 2002). Knowledge platforms like Zhihu, with a higher level of interactivity, can attract users to discuss content and respond to questions quickly (Teeni, 2001). For example, the function of the online community enables people who have similar interests to discuss topics they are interested in together. As a result, users can get information and learn knowledge in a quick and easy way, thereby facilitating individuals to know each other and become friends (Muniz and O'guinn, 2001). Building closer relationship can improve both knowledge and social capital appreciation. Therefore, we propose:

> *H9:* Conscious participation has a positive influence on knowledge collaboration performance.
>
> *H10:* Enthusiasm has a positive influence on knowledge collaboration performance.
>
> *H11:* Social interaction has a positive influence on knowledge collaboration performance.

The mediating effect of user engagement

Based on the former research, it could be seen that platform provides function affordances and resource affordances according to mission and positioning. It helps users realize the aggregation of psychological needs with technology and products, while user engagement is from the fact that users' needs are met during the process of using platforms (O'Brien and Cairns, 2016). As a result, it is more likely that knowledge platform affordances can promote user engagement of conscious participation, enthusiasm, and social interaction. Therefore, knowledge platform affordances constitute a prerequisite for user engagement.

From a social-technical perspective, online knowledge platforms are composed of the behavioral possibilities and needs of users in social media and organizational settings (Rice et al., 2017). Based on the literature, the purpose of social media affordances is to trigger user engagement, such as sharing of information and interaction, through social media sites (Majchrzak et al., 2013; Cabiddu et al., 2014). In this way, users are enabled to acquire resources and create values (Lin and Kishore, 2021). In the context of knowledge platforms, social affordances facilitate users to use the social functions of Zhihu. People who have a demand for socializing will be highly engaged in Zhihu. Highly engaged users are more willing to expand their social networks and share knowledge on Zhihu to find those who share the same interests, goals, or needs and then communicate with them, which will facilitate users' social interaction on Zhihu. From this process, it could bring knowledge capital increase and social capital increase. It is the same reasoning that can be applied to knowledge affordances. Therefore, the following hypotheses are suggested.

> *H12:* User engagement plays the mediating role between knowledge platform affordances and knowledge collaboration performance.

The sub-hypotheses of this hypothesis are as follows:

> *H12a:* Conscious participation mediates the relation between knowledge affordances and knowledge collaboration performance.

H12b: Enthusiasm meditates the relation between knowledge affordances and knowledge collaboration performance.

H12c: Social interaction mediates the relation between knowledge affordances and knowledge collaboration performance.

H12d: Conscious participation mediates the relation between social affordances and knowledge collaboration performance.

H12e: Enthusiasm meditates the relation between social affordances and knowledge collaboration performance.

H12f: Social interaction mediates the relation between social affordances and knowledge collaboration performance.

A conceptual framework is established based on the theoretical analysis above, as shown in Figure 1. This model has illustrated the influence mechanism of different dimensions of user engagement on knowledge collaboration performance. That is, knowledge platform affordances not only have a direct influence on knowledge collaboration performance, but also exert an indirect influence through user engagement.

Research methods

Research process

On the basis of existing research and related theoretical viewpoints, this paper has established an overall theoretical framework in the previous chapter and clearly stated the relationship between each variable. However, establishing the theoretical framework also requires relatively scientific and reasonable empirical research methods to test it to clarify further the relationship between the variables in the framework, which inevitably involves the design of the entire research process.

This paper selects the Zhihu application as the representative of knowledge platforms for research. As one of the earliest socialized knowledge communities in China, Zhihu has grown steadily since its launch in January 2011, and the knowledge payment system has gradually matured. In 2018, Zhihu's official data showed that the number of users exceeded 220 million. According to data from iResearch, from August 2019 to July 2020, the monthly independent numbers of Zhihu mobile terminals were stable between 46 million and 56 million (Guo, 2020). Due to Zhihu's rich experience in operating knowledge communities, it has always maintained strong competitiveness. Since this paper focuses on the impact of knowledge platform affordances and user engagement on knowledge collaboration performance, which makes it challenging to measure related variables through open data from Zhihu, this paper adopts the questionnaire survey method to collect relevant data. Furthermore, the overall data type of this paper belongs to cross-sectional data, and all variable data are obtained through questionnaires. The scales in the questionnaire refer to the mature scales of existing research, and the questionnaire is designed in combination with the Zhihu platform. Then, a professional data collection company is used to issue questionnaires. Then, data collection, input, and analysis are carried out to empirically test the relationship between knowledge platform affordances, user engagement, and knowledge collaboration performance.

Questionnaire design

The design of the questionnaire directly affects whether the obtained data fit the research needs. It is a prerequisite for obtaining valid and reliable data. Therefore, the questionnaire

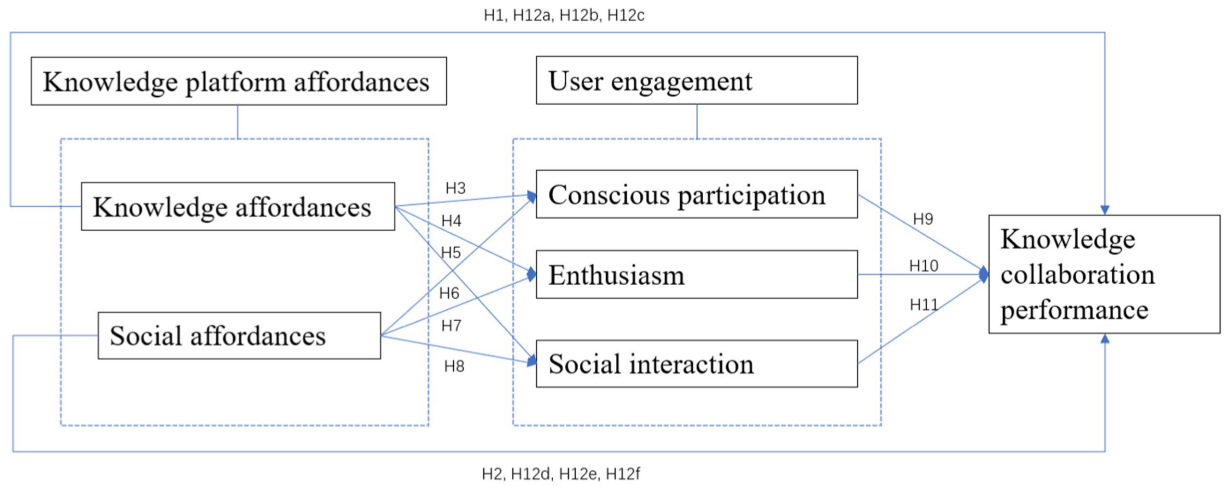


FIGURE 1
The conceptual model.

design is the first work to be done before the start of the questionnaire survey. On the basis of existing research, this paper adopts the following steps to design the questionnaire. First, studying relevant literature. Second, engaging in the dialog and discussion with academic experts, and communicating with some Zhihu users on the question design in the questionnaire. Finally, conducting a pre-test and completing the final draft of the questionnaire on this basis (see questionnaires in Appendix 1). Based on the literature, the primary measurement scales of each variable are shown in Table 2.

Data collection

According to the report, Zhihu users are mainly from developed cities, and the proportion of users in first-and second-tier cities is as high as 75.4% (Guo, 2020). Therefore, the questionnaire sample mainly selects users from first-and second-tier cities in China. Considering that our research objects need to meet certain conditions,

for example, they must be people who have used Zhihu and have a certain understanding of its functions, we hired a professional questionnaire survey company to distribute 500 online questionnaires to long-term users of Zhihu. Additionally, the survey company gave small gifts as rewards to users who responded to the questionnaire, so as to improve the recovery rate and effectiveness of the questionnaire. In order to ensure the authenticity of the questionnaire as much as possible, it is emphasized that the purpose of this answer is to collect relevant data for scientific research, and there are no other commercial considerations. It also shows that there is no problem of revealing key information, so users are required to fill in the answer according to the actual situation. Moreover, the questionnaires are filled out anonymously, and the relevant information of the respondents will not be disclosed. Our investigation started in April of 2022 and ended in May of the same year. Three hundred sixty-one valid questionnaires were obtained in the final.

It should be noted that since each questionnaire used in this paper is completed by the same person, it is necessary to pay attention to the problem of common method variance (MacKenzie and Podsakoff, 2012). For this problem, this paper adopts two methods of program control and statistical method control to solve it. First of all, from the above, in the research process, the author thoroughly emphasized that there is no right or wrong answer information, and it is used for research rather than commercial purposes. In addition, for the respondents, they answered the questions anonymously to reduce the bias of answering tendency. Secondly, the author also performed the Harman single-factor test on the recovered data and put all the items together for exploratory factor analysis. The results showed that the factor loading of the first principal component was 27.216%, and it can be seen that the common method variance is not obvious. Therefore, this paper believes that the sample data used does not have serious common method variance problems.

TABLE 2 Main measurement scales in the research model.

Variable	Measurement scales	Sources
Knowledge platform affordances	Social affordances Knowledge affordances	Postigo (2016), Rice et al. (2017), Dong (2018), Karahanna et al. (2018), Shi et al. (2020)
User engagement	Conscious participation Enthusiasm Social interaction	Vivek (2009), O'Brien and Cairns (2016), and O'Brien (2018)
Knowledge collaboration performance	Knowledge capital appreciation Social capital appreciation	Chow and Chan (2008), Zhao et al. (2010), Chang and Chuang (2011), Chen et al. (2014)

Results and analysis

This study used SPSS 26.0 and Amos 24.0 statistical software to analyze the research samples. Among them, the analysis methods involved in SPSS 26.0 in this study include descriptive statistics, reliability analysis, and exploratory factor analysis, while methods involved in AMOS 24.0 include confirmatory factor analysis and structural equation model analysis.

Descriptive statistics analysis of samples

The survey finally collected 361 valid questionnaires. The basic information about the samples is shown in Table 3.

Exploratory factor analysis

In this paper, SPSS 26.0 software was used to conduct exploratory factor analysis to test the construct validity of the scale. First, through the Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphere test to see if the data can be subjected to factor analysis. According to Kaiser (1974), KMO above 0.90 indicates that the scale is very suitable for factor analysis. If the KMO is between 0.8 and 0.9, it is suitable for factor analysis. If the KMO is below 0.5, it is very unsuitable for factor analysis. In addition, factor analysis can be done when the statistical significance probability of Bartlett's Test of Sphericity is less than or equal to the significance level.

Through repeated exploratory factor analysis, PA4 and UE2 have cross-loadings, and UE12 factor loading is lower than 0.4. After excluding items that do not meet the requirements, 24 items are finally retained.

The Bartlett sphericity test shows that Bartlett $\chi^2 = 3679.161$ and $p < 0.001$, which are obtained by performing the test of the correlation matrix on the questionnaire. It indicates that there are

TABLE 3 Descriptive statistics.

Variable	Types	FREQ	PCT
The number of days of using Zhihu in the last month	5–10 days	57	15.8
	10–15 days	188	52.1
	15–20 days	71	19.7
	More than 20 days	45	12.5
Gender	Male	244	67.6
	Female	117	32.4
Age	Under 20 years old	27	7.5
	20–30 years old	140	38.8
	30–40 years old	79	21.9
	40–50 years old	69	19.1
	Over 50 years old	46	12.7
Education level	Colleges	67	18.6
	Bachelor	167	46.3
	Master	65	18
	Doctor	62	17.2
Occupation	Students	47	13
	Researchers	51	14.1
	Managers	47	13
	Technical (or R&D) personnel	63	17.5
	Business people	50	13.9
	Freelancers	58	16.1
	Other	45	12.5
The number of years you have used Zhihu	Within 1 year	25	6.9
	1–3 years	59	16.3
	3–5 years	150	41.6
	5–7 years	72	19.9
	7 years and above	55	15.2

common factors among the 24 items of the questionnaire, and it is necessary to carry out the factor analysis on this correlation matrix. At the same time, the KMO measure of sampling adequacy is calculated, and the result shows KMO = 0.862, indicating that it is suitable for factor analysis.

It can be seen from the table below that the factor is intercepted based on the characteristic root >1. After factor extraction is performed on 24 items, six factors are finally extracted, and the six factors cumulatively explain 65.786% of the total variation, which can explain most of the variance. The first factor represents SA (Social affordances) with factor loadings ranging from 0.782 to 0.727; the second factor represents KCP (Knowledge collaboration performance) with factor loadings ranging from 0.782 to 0.664; the third factor represents EN (Enthusiasm) with factor loadings ranging from 0.848 to 0.685; the fourth factor represents SI (Social interaction) with factor loadings ranging from 0.851 to 0.776; the fifth factor represents CP (Conscious participation), with factor loadings ranging from 0.796 to 0.771; the sixth factor represents KA (Knowledge affordances), and factor loadings ranged from 0.799 to 0.767. The loadings of the six factors are all >0.5, and the item distribution after factor rotation is consistent with the theoretical hypotheses of the questionnaire structure, so the revised questionnaire has good construct validity (Table 4).

Confirmatory factor analysis

This paper used AMOS 24.0 software to conduct confirmatory factor analysis on the samples. Confirmatory factor analysis is a statistical analysis of social survey data. Confirmatory factor analysis explores whether the factor structure model of the scale fits the actual data collected, and whether the indicator variables can be effectively used as the procedures for measuring latent variables. In this study, the maximum likelihood method was used to estimate the model, and the fit of the model was verified by the following indicators: (1) Chi-square (χ^2) test. The χ^2 index is the most basic test index for model fitting, and the χ^2/df value is generally used to test. The smaller the value, the higher the simulation fit. Usually, when $\chi^2/df < 3$, it means that the model has a good fit (Huang, 2004). (2) The root mean square error of approximation (RMSEA). It is

TABLE 4 Factor analysis results.

	1	2	3	4	5	6
PA6	**0.782**	0.110	−0.059	0.016	0.074	0.056
PA10	**0.779**	0.117	0.089	0.093	0.005	−0.015
PA5	**0.774**	0.091	−0.025	0.028	0.033	0.178
PA7	**0.768**	0.107	−0.031	0.103	−0.033	−0.002
PA9	**0.733**	0.064	0.103	0.107	−0.030	0.134
PA8	**0.727**	0.147	0.089	0.117	0.052	0.066
KCP5	0.191	**0.782**	0.172	0.119	0.106	0.094
KCP4	0.129	**0.765**	0.201	0.129	0.128	0.115
KCP3	0.156	**0.744**	0.180	0.085	0.126	0.086
KCP2	0.071	**0.677**	0.259	0.022	0.211	0.060
KCP1	0.161	**0.664**	0.147	0.203	0.124	0.189
UE8	0.057	0.181	**0.848**	0.095	0.075	0.000
UE6	0.048	0.241	**0.818**	0.083	0.109	0.001
UE7	0.001	0.256	**0.712**	0.046	0.098	0.113
UE5	0.023	0.147	**0.685**	0.139	0.199	0.156
UE10	0.139	0.128	0.121	**0.851**	0.046	−0.079
UE11	0.085	0.082	0.151	**0.798**	0.066	0.057
UE9	0.161	0.192	0.035	**0.776**	0.062	−0.001
UE4	−0.008	0.170	0.170	0.122	**0.796**	0.113
UE3	0.006	0.112	0.173	0.071	**0.784**	0.035
UE1	0.065	0.251	0.072	−0.011	**0.771**	0.096
PA1	0.158	0.152	0.089	−0.061	−0.010	**0.799**
PA3	0.177	0.107	0.106	0.003	0.130	**0.795**
PA2	0.004	0.121	0.028	0.036	0.109	**0.767**
Characteristic root	3.700	3.111	2.711	2.149	2.064	2.053
% of Variance	15.417	12.964	11.297	8.955	8.599	8.554
Cumulative %	15.417	28.380	39.677	48.632	57.232	65.786

PA, knowledge platform affordances; KCP, knowledge collaboration performance; UE, user engagement. The bold values represent factor loadings greater than 0.5.

sensitive to the wrong model and is an ideal fitting indicator. The closer the value of RMSEA is to 0, the better the model fit. Usually when RMSEA <0.08, the model has a good degree of fit (Browne and Cudeck, 1993). (3) Standardized root mean square residual (SRMR). Its value ranges from 0 to 1. When SRMR <0.08, it indicates that the model fits well (Hu and Bentler, 1999). (4) Comparative fit index (CFI), Tucker-Lewis index (TLl), and incremental fit index (IFI). Usually, CFI > 0.9, TLI > 0.9, and IFI > 0.9 indicate a good model fit (Wu, 2013). Table 5 shows that the ideal value is reached, thus indicating that the confirmatory factor analysis model fits well.

From Table 6, it can be seen that the factor loadings of KA, SA, CP, EN, SI, and KCP are all above 0.5. The CR values are all above 0.7, and the AVE values are all above 0.5. According to Hair et al., (2010)'s suggestion in validity evaluation, the absolute value of factor loading should be at least 0.5, and the best index value should be above 0.7. The average variance extraction (AVE) index value should be above 0.5, and the reliability index value should be higher than 0.7. Therefore, this questionnaire has good convergent validity.

The statistics in Table 7 show the correlation coefficient between each variable and the square root of AVE. According to the method proposed by Fornell and Larcker (1981), whether the square root of AVE is higher than the correlation coefficient between two variables is used to judge the discriminant validity. Based on the data, the questionnaire shows good discriminant validity.

TABLE 5 Confirmatory factor analysis.

Measure	χ^2	*df*	χ^2/df	RMSEA	SRMR	CFI	TLI	IFI
Threshold			<3.00	<0.08	<0.08	>0.9	>0.9	>0.9
Results	388.828	237	1.641	0.042	0.043	0.957	0.949	0.957

TABLE 6 Convergent validity.

Constructs	Items	Factor loading	*t*-value	CR	AVE
KA	PA1	0.737	–	0.752	0.505
	PA2	0.603	9.533		
	PA3	0.780	10.569		
SA	PA5	0.746	–	0.868	0.524
	PA6	0.738	13.412		
	PA7	0.718	13.037		
	PA8	0.705	12.810		
	PA9	0.695	12.610		
	PA10	0.737	13.397		
CP	UE1	0.703	–	0.768	0.527
	UE3	0.660	10.375		
	UE4	0.807	11.202		
EN	UE5	0.652	–	0.836	0.564
	UE6	0.825	12.524		
	UE7	0.686	10.963		
	UE8	0.823	12.508		
SI	UE9	0.709	–	0.799	0.573
	UE10	0.865	12.144		
	UE11	0.684	11.363		
KCP	KCP1	0.676	–	0.855	0.543
	KCP2	0.662	11.134		
	KCP3	0.721	11.998		
	KCP4	0.800	13.078		
	KCP5	0.812	13.217		

KA, knowledge affordances; SA, social affordances; CP, conscious participation; EN, enthusiasm; SI, social interaction; KCP, knowledge collaboration performance.

Reliability analysis

Reliability refers to the consistency or stability of measurement results obtained according to measurement tools. In this paper, Cronbach's Alpha is used to test the internal consistency reliability of the questionnaire. Devellis (1991) put forward that the value of the α coefficient between 0.65 and 0.70 is the minimum acceptable value.

In this paper, the reliability coefficient value of every variable is above 0.7, so the reliability of the questionnaire is good (see Table 8).

Structural equation modeling for the main effects

Table 9 shows that the model fit statistics have reached the ideal value, which means that the main effects model is well-fitted. From Table 10, it can be seen that KA has a significant positive effect on KCP ($\beta = 0.308$, $p < 0.001$), and SA has a

TABLE 7 Discriminant validity.

Constructs	KA	SA	CP	EN	SI	KCP
KA	**0.711**					
SA	0.322***	**0.724**				
CP	0.309***	0.112	**0.726**			
EN	0.246***	0.148*	0.432***	**0.751**		
SI	0.032	0.310***	0.237***	0.320***	**0.757**	
KCP	0.405***	0.393***	0.510***	0.582***	0.394***	**0.737**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. The diagonal elements represent the square root of the AVE. The bold values represent the square root of the AVE.

TABLE 8 Reliability analysis.

Constructs	Cronbach's alpha	Number of items
KA	0.746	3
SA	0.868	6
CP	0.763	3
EN	0.832	4
SI	0.791	3
KCP	0.854	5

significant positive effect on KCP ($\beta = 0.293$, $p < 0.001$), so H1 and H2 are supported (Figure 2).

Structural equation modeling for the mediating effects

Table 11 presents that the mediating effects model is well-fitted. In addition, the mediating effects path analysis shows that KA has a significant positive effect on CP ($\beta = 0.327$, $p < 0.001$); KA has a significant positive effect on EN ($\beta = 0.245$, $p < 0.001$); KA has no significant effect on SI ($\beta = -0.036$, $p > 0.05$). SA has no significant effect on CP ($\beta = 0.023$, $p > 0.05$); SA has no significant effect on EN ($\beta = 0.083$, $p > 0.05$); SA has a significant positive effect on SI ($\beta = 0.325$, $p < 0.001$); CP has a significant positive effect on KCP ($\beta = 0.273$, $p < 0.001$); EN has a significant positive effect on KCP ($\beta = 0.382$, $p < 0.001$); SI has a significant positive effect on KCP ($\beta = 0.175$, $p < 0.01$); KA has a significant positive effect on KCP ($\beta = 0.165$, $p < 0.01$); and SA has a significant positive effect on KCP ($\beta = 0.212$, $p < 0.001$). Therefore, except for KA to SI, SA to EN, and SA to CP, the hypotheses are all valid.

Previous studies (MacKinnon et al., 2004; Williams and MacKinnon, 2008) pointed out that the Bootstrap method is more statistically accurate than the causal steps approach and product of coefficient for testing indirect effects. One of the most significant advantages of the Bootstrap method is that the estimation of the indirect effect does not require the indirect effect to follow a normal distribution. Therefore, the Bootstrap method in this paper is used to test the mediating effect.

From Table 12, we know that in the path of KA → CP → KCP, the confidence interval does not contain 0 (0.040, 0.164), so it shows that CP has a mediating effect between KA and KCP, and the size of the mediating effect is 0.089. In the path of KA → EN → KCP, the confidence interval does not contain 0 (0.039, 0.162), so it means that EN has a mediating effect between KA and KCP, and the size of the mediating effect is 0.094. In the path of KA → SI → KCP, the confidence interval contains 0 (−0.043, 0.023), thus indicating that SI does not have a mediating effect between KA and KCP. In the path of SA → CP → KCP, the confidence interval contains 0(−0.035, 0.047), so it means that there is no mediating effect of CP between SA and KCP. In the path of SA → EN → KCP, the confidence interval contains 0(−0.019, 0.093), thus indicating that EN does not have a mediating effect between SA and KCP. In the path of SA → SI → KCP, the confidence interval does not contain 0 (0.021, 0.117), thus indicating that SI plays a mediating role between SA and KCP, and the size of the mediating effect is 0.057 (Figure 3).

TABLE 9 The test for the main effects.

Measure	χ^2	*df*	χ^2/df	RMSEA	SRMR	CFI	TLI	IFI
Threshold			<3.00	<0.08	<0.08	>0.9	>0.9	>0.9
Results	194.876	74	2.633	0.067	0.044	0.941	0.928	0.942

TABLE 10 Main effects path analysis.

Path	Standardized coefficient	SE	*t*-value	Value of *p*
KA → KCP	0.308	0.063	4.503	***
SA → KCP	0.293	0.062	4.597	***

***$p < 0.001$.

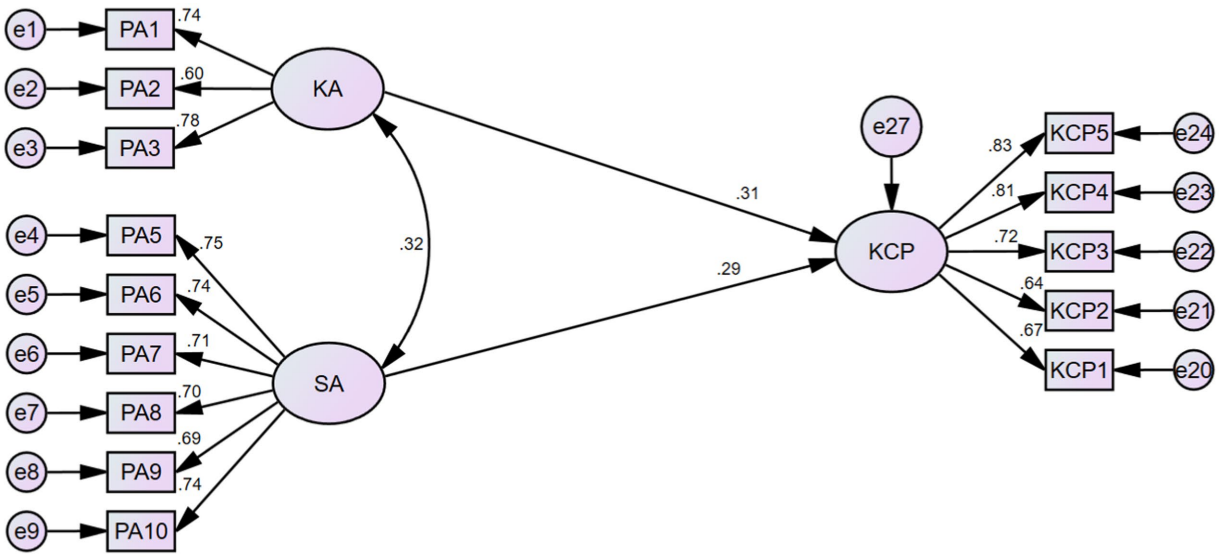


FIGURE 2
Structural equation modeling for the main effects.

Empirical results

According to the above empirical test results, most of the hypotheses in this paper are supported. Specifically, knowledge platform affordances influence knowledge collaboration performance positively, so H1 and H2 are supported. As a mediating role, user engagement also positively influences knowledge collaboration performance, so H9, H10, and H11 are supported. In terms of the relationship between knowledge platform affordances and user engagement, we can see that knowledge affordances have a positive effect on conscious participation and enthusiasm. However, they do not influence social interaction positively. Thus, H3 and H4 are supported, but H5 is rejected. Although social affordances have a positive effect on social interaction, neither conscious participation nor enthusiasm is positively related to social affordances. Thus, H6 and H7 are rejected but H8 is supported. From the mediating effect analysis, the results show that conscious participation and enthusiasm mediate the relation between knowledge affordances and knowledge collaboration performance. Additionally, social interaction mediates the relation between social affordances and knowledge collaboration performance. However, the paths of KA → SI → KCP, SA → CP → KCP, SA → EN → KCP are not proved. Therefore, H12a, H12b, and H12f are supported, but H12c, H12d, and H12e are rejected.

TABLE 11 The test for the mediating effects.

Measure	χ^2	*df*	χ^2/df	RMSEA	SRMR	CFI	TLI	IFI
Threshold			<3.00	<0.08	<0.08	>0.9	>0.9	>0.9
Results	453.754	240	1.891	0.050	0.076	0.939	0.930	0.939

TABLE 12 Mediating effect analysis.

Path	Mediating effect	Bias-corrected 95% CI	
		Lower	Upper
KA → CP → KCP	0.089	0.040	0.164
KA → EN → KCP	0.094	0.039	0.162
KA → SI → KCP	−0.006	−0.043	0.023
SA → CP → KCP	0.006	−0.035	0.047
SA → EN → KCP	0.032	−0.019	0.093
SA → SI → KCP	0.057	0.021	0.117

Bootstrap = 5,000.

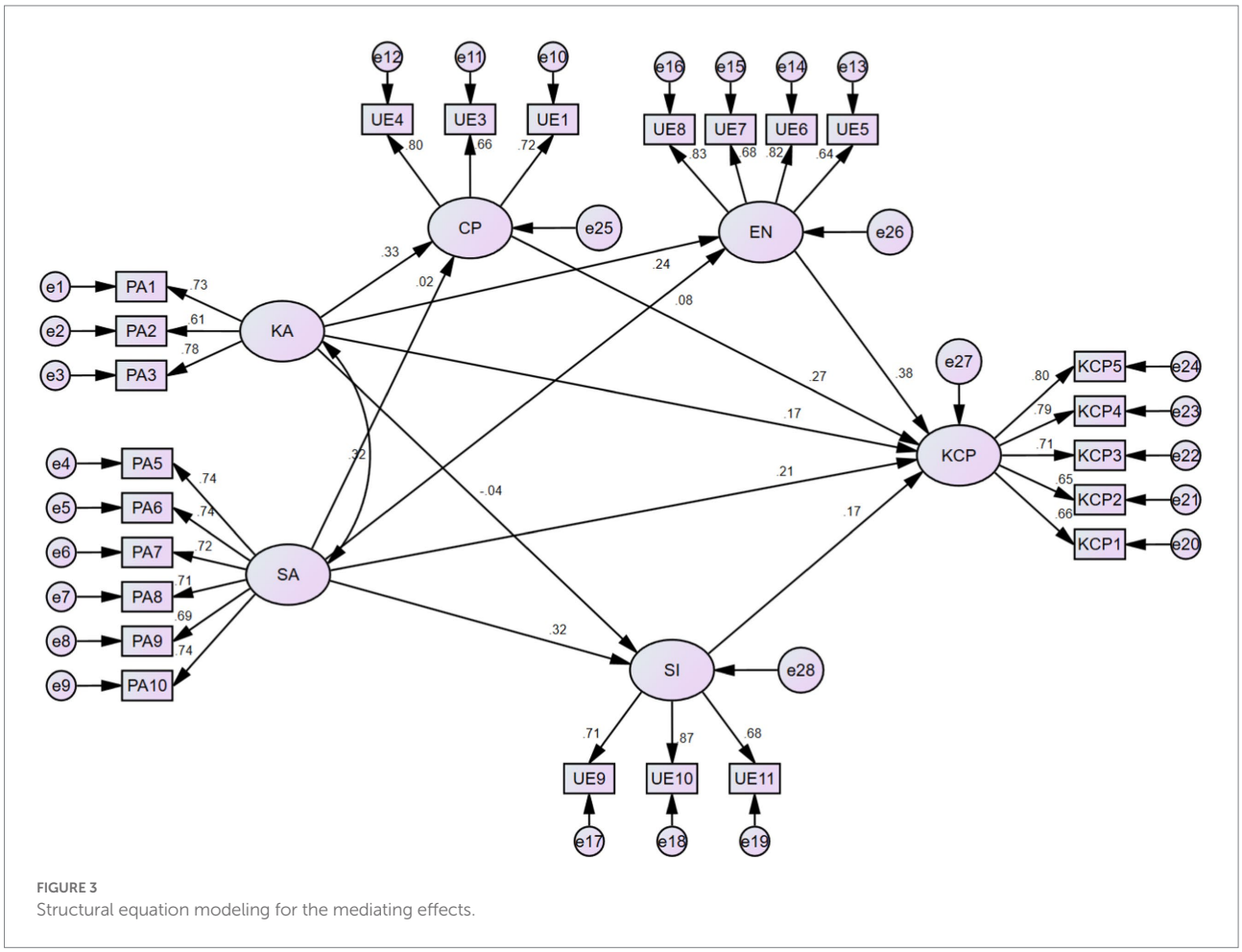


FIGURE 3
Structural equation modeling for the mediating effects.

Discussions

First, knowledge platform affordances have a direct and positive influence on knowledge collaboration performance. Knowledge affordances and social affordances can facilitate the realization of knowledge collaboration performance. This conclusion clarifies the relationship between affordances and knowledge collaboration performance and provides a basis for the research on the realization mechanism of knowledge collaboration performance.

Second, user engagement partially mediates the relation between knowledge platform affordances and knowledge collaboration performance. The results show that conscious participation and enthusiasm play a mediating role between knowledge affordances and knowledge collaboration performance, and social interaction mediates the relation between social affordances and knowledge collaboration performance. This complements the influencing factors of improving knowledge collaboration performance, focusing on the bi-directionality of user engagement from the perspective of user and platform interaction. Additionally, the application of the composition of user engagement proposed by Vivek (2009) in the knowledge platform is added. However, the paths of knowledge affordances-social interaction-knowledge collaboration performance, social affordances-conscious participation-knowledge collaboration performance, and social affordances-enthusiasm-knowledge collaboration performance are not supported. It can be seen that the two kinds of affordances of the knowledge platform can provide targeted promotion for user engagement. On the one hand, knowledge affordances enhance users' enthusiasm and conscious participation. On the other hand, social affordances ensure the satisfaction of social psychological needs, thus forming a high degree of user stickiness. The reason of the result could be that users' conscious participation and enthusiasm for engaging in the platform mainly come from the demand for knowledge resources themselves. Whereas the interactive needs of users to participate in the platform are motivated by the social functions provided by the platform. From the literature, we know that knowledge affordances reflect the user's pursuit of knowledge resources from the knowledge platform, which is the interaction result between the user's demand for certain knowledge and the platform's knowledge resources (Shi et al., 2020). Since we decompose social interactions separately in both knowledge platform affordances and user engagement, this may cause the absence of cross effects between the two variables. This has also become a limitation of the research, and the configuration analysis may be the focus of the next research to determine whether there is a more complex causal relationship between knowledge platform affordances and user engagement.

Third, user engagement has a direct and positive influence on knowledge platform collaboration. Different from other studies that focus on the relationship between user engagement and behavioral outcomes like word of mouth and app rating (Wu et al., 2018; Bitrián et al., 2021), this paper puts the application scenario on the knowledge platform and focuses on how user engagement affects knowledge collaboration performance.

Conclusions and implications

Conclusion

In the context of the "sinking" of the Internet innovation market, how to accurately grasp the diverse psychological needs of a large number of non-traditional users and improve knowledge collaboration performance timely and effectively have become a core issue that knowledge platforms must face. Based on surveying users of Zhihu as objects, this paper uses the affordance theory to study the formation process of knowledge collaboration performance, revealing the mediating role of user engagement in the formation of performance, thus providing a theoretical basis for the operational decisions of digital content platforms.

By sorting and analyzing existing literature and related theories, this paper proposes a theoretical framework for the relationship among knowledge platform affordances, user engagement, and knowledge collaboration performance. In a nutshell, knowledge platform affordances can directly affect knowledge collaboration performance and act on it through user engagement. According to affordance theory, knowledge platform affordances are the set of possibilities for platform users to take behaviors using platform technology in a demand-oriented manner (Leonardi and Barley, 2010; Robey et al., 2012), which can be used to better understand the impact of a combination of new technologies and organizational characteristics on user behavior (Majchrzak and Faraj, 2013). It can be seen that the formation of platform knowledge collaboration performance is the result of the interaction of factors such as platform characteristics, user needs, and platform technology, which also means that platform decision-making must consider these three important factors at the same time, so as to avoid pure "traffic thinking." Meanwhile, user engagement is an important dependency for the formation of platform performance, and the source of user engagement is also rooted in the high interaction of the above three elements. On top of this, it is necessary to pay attention to the interaction of the three to gain important user trust, user participation, and user stickiness.

Since the knowledge platform has the dual functions of seeking knowledge and socializing, the behavior of platform users naturally contains the needs of both aspects, thus forming two kinds of affordances of the platform: knowledge affordances and social affordances. The research in this paper finds that the conscious participation and enthusiasm of user engagement mainly come from the user's pursuit of knowledge resources, while social interaction comes from social needs. This also shows that the knowledge platform is fundamental and critical in constructing high-quality knowledge resources, and the strengthening and improvement of the platform's social function has an important synergistic and complementary role.

Moreover, it is manifested from the paper that user engagement of conscious participation, enthusiasm, and social interaction could enhance knowledge collaboration performance. Therefore, individuals who use knowledge platforms with intention, are passionate about knowledge platforms, or enjoy social interactions on knowledge platforms could contribute to the appreciation of knowledge capital and social capital.

Implications

Theoretical implication

Open innovation with user engagement is an essential feature of digital platforms (Yu et al., 2018). Current research focuses on several aspects of user needs, user behavior, and platform performance. However, the formation mechanism of user engagement and performance is rarely explored from the perspective of the integration of the three. In the digital age, users have become common participants in the development of platforms (Zhang et al., 2021), while each platform has its unique affordances, which are the integrated products of users' needs and platform features. As a result, it is important to understand the mechanism of knowledge collaboration performances based on platform affordances and user engagement.

Our study has enriched the existing studies by exploring deeper into the relationship among knowledge platform affordances, user engagement, and knowledge collaboration performance. It has verified the mediating value of user engagement between knowledge platform affordances and knowledge collaboration performance. Affordances provide a theoretical basis for revealing the underlying interaction mechanism of user engagement at the social-technical level. This topic firstly explores knowledge platform affordances and user engagement in the context of popular knowledge production and profoundly understands the matching of platform systems and users. Secondly, the realization of platform value can be explained by analyzing the relation between user engagement and knowledge collaboration performance.

Practical implication

In the fierce market competition, it is not easy to encourage users to engage in value co-creation (Wang and Jiang, 2018). User engagement is an effective way to enhance platform performance (Xia et al., 2021). In the context of this paper, the establishment of user engagement with knowledge platforms is an effective way of making knowledge platforms into a new generation of competitive marketing channels. Management of enterprises should be fully aware that knowledge platform affordances and user engagement play an important role in promoting platform value. It should be noticed that if the design of platforms could fully facilitate users to engage in platforms. Enterprises should pay attention to the differences in organizational characteristics determined by value positioning and resource endowments, and design more scientific and effective user engagement mechanisms at the socio-technical level, thereby promoting the high-quality development of the knowledge platforms. The research results of this topic have broad application prospects in knowledge platform enterprises and platform economy.

The current social production system is highly developed, with abundant commodities and diverse services. Each user has different consumption motivations and needs in different situations. For each platform, it is no longer simple "traffic thinking," but it is necessary to match platform features with user needs and use digital technology to achieve this connection. The conclusions of this paper fully reveal that platforms in the digital economy era must pay attention to the matching of user needs and their own characteristics. Furthermore, it is necessary to carry out a more in-depth motivation and demand portrait of the platform user group, and conduct a comprehensive analysis of the platform positioning, value proposition, and core capabilities, so as to formulate the correct operation strategy.

Limitations and future research

Due to the limitations of the author's ability, research time, and the cost of questionnaires, this paper has certain limitations. The specific examples are shown as follows.

First, since this paper uses questionnaires to obtain data for empirical research, the type of data is cross-sectional data, which will cause the explanatory power of causal relationship inference between knowledge platform affordances, user engagement, and knowledge collaboration performance to be relatively decreased, so it cannot be completely determined that there is a clear causal relationship between these variables. Relevant studies recommend using different variables to obtain data at different time points for empirical testing. Therefore, it is necessary to further improve the data measurement procedures in the future and use time-series or longitudinal data to clarify the causal relationship between variables (Chen and Wu, 2011). In addition, research samples with a certain time span can better observe the impact of affordances and user engagement.

Second, the sample size of this paper is limited due to the author's ability and time and cost constraints. The proportion of Zhihu users in first-and second-tier cities is relatively high. However, with the "sinking" of the Zhihu market, third-and fourth-tier users are gradually increasing, and female users have increased significantly. Therefore, the sample may lack certain universality, and a relatively large number of cities and populations should be further tested in the future.

Third, there may be joint complementary effects between the multiple affordances of the knowledge platform and the engagement ways, and configuration analysis of these variables should be carried out in the future. Through this analysis method, it is possible to reveal different affordance paths and engagement paths for obtaining high performance, not only to discover the differences in the effects of different affordances and engaging ways and their combinations, but also to discover the differences in the psychological needs of users. In this way, it could promote customer segmentation and user profiling and provide decision-making references for the efficient and healthy development of the platform.

In addition, although Zhihu is a successful enterprise, other knowledge platforms are worth studying. In the future, two or three knowledge platforms, such as Quora and Wukong Q&A, can be selected for comparative research. These platforms have different organizational characteristics (value positioning, resource endowment, and competitive strategy), but they are all question-and-answer knowledge platforms. There are both successful cases and failure cases, which is convenient for comparative research. In recent years, with the rapid development of the Internet knowledge industry, practical cases such as knowledge payment and free reading have emerged, and cases of value co-creation and co-destruction have emerged. Designing an effective user engagement mechanism for non-traditional partners still lacks mature theoretical guidance. The case study approach is also helpful for building theory and discovering new theoretical insights (Eisenhardt and Graebner, 2007).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZJ is responsible for the main structure and writing of the paper. JC is responsible for data collection and analysis. CL is responsible for the final changes and corrections. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Arazy, O., Yeo, L., and Nov, O. (2013). Stay on the Wikipedia task: when task-related disagreements slip into personal and procedural conflicts. *J. Am. Soc. Inf. Sci. Technol.* 64, 1634–1648. doi: 10.1002/asi.22869

Babin, B. J., Darden, W. R., and Griffin, M. (1994). Work and/or fun: measuring hedonic and utilitarian shopping value. *J. Consum. Res.* 20, 644–656.

Bharati, P., Zhang, W., and Chaudhury, A. (2015). Better knowledge with social media? Exploring the roles of social capital and organizational knowledge management. *J. Knowl. Manag.* 19, 456–475. doi: 10.1108/JKM-11-2014-0467

Bitrián, P., Buil, I., and Catalán, S. (2021). Enhancing user engagement: the role of gamification in mobile apps. *J. Bus. Res.* 132, 170–185. doi: 10.1016/j.jbusres.2021.04.028

Bloch, P. H. (1986). Product enthusiasm: many questions, a few answers. *Adv. Consum. Res.* 13, 539–543.

Bowden, J. L. H. (2009). The process of customer engagement: a conceptual framework. *J. Marketing Theory Pract.* 17, 63–74. doi: 10.2753/MTP1069-6679170105

Brodie, R. J., Ilic, A., Juric, B., and Hollebeek, L. (2013). Consumer engagement in a virtual brand community: an exploratory analysis. *J. Bus. Res.* 66, 105–114. doi: 10.1016/j.jbusres.2011.07.029

Browne, M. W., and Cudeck, R. (1993). "Alternative ways of assessing model fit", in *Test. Struct. Equation Models.* eds. K. A. Bollen and J. S. Long (Newbury Park, CA: Sage), 136–162.

Cabiddu, F., De Carlo, M., and Piccoli, G. (2014). Social media affordances: enabling customer engagement. *Ann. Tourism Res.* 48, 175–192. doi: 10.1016/j.annals.2014.06.003

Cai, H. S. (2008). Examining economic law from the perspective of interests. *Soc. Sci.* 2008, 70–73. doi: 10.3969/j.issn.1002-3240.2008.07.019

Cai, S., Shi, H. R., Fu, X., and Chen, X. (2019). Research on the factors influencing the sales of paid knowledge products: taking Zhihu live as an example. *J. Manage. Eng.* 33, 71–83. doi: 10.13587/j.cnki.jieem.2019.03.009

Chang, H. H., and Chuang, S. S. (2011). Social capital and individual motivations on knowledge sharing: participant involvement as a moderator. *Inf. Manag.* 48, 9–18. doi: 10.1016/j.im.2010.11.001

Chen, W. (2021). ByteDance to shut down Q&a app Wukong Wenda | KrASIA. Available at: https://kr-asia.com/bytedance-to-shut-down-qa-app-wukong-wenda (Retrieved April 24, 2022).

Chen, J. B., Guo, Y. L., and Xu, K. B. (2014). Performance of knowledge collaboration based on capital appreciation. *Sci. Sci. Manage. S.& T.* 35, 35–43.

Chen, J. D., and Wu, A. Q. (2011). A review of foreign innovation research. *Foreign Econ. Manage.* 33, 58–65. doi: 10.16538/j.cnki.fem.2011.02.006

Chow, W. S., and Chan, L. S. (2008). Social network, social trust and shared goals in organizational knowledge sharing. *Inf. Manag.* 45, 458–465. doi: 10.1016/j.im.2008.06.007

Davis, A., Murphy, J., Owens, D., Khazanchi, D., and Zigurs, I. (2009). Avatars, people, and virtual worlds: foundations for research in Metaverses. *J. Assoc. Inf. Syst.* 10, 91–117. doi: 10.17705/1jais.00183

Devellis, R. F. (1991). *Scale Development Theory and Applications* London SAGE.

Dong, X. Y. (2018). *The Impact of IT Affordance and Social Ties on Social Commerce Purchase Intention*. Doctoral dissertation Harbin Institute of Technology.

Eisenhardt, K. M., and Graebner, M. E. (2007). Theory building from cases: opportunities and challenges. *Acad. Manag. J.* 50, 25–32. doi: 10.5465/amj.2007.24160888

Fan, Z., Zhuang, Y., and Pan, Q. (2007). The research of the backup and restore of the SQL server database. *Database Inf. Manage.* 6, 304–307.

Faraj, S., Jarvenpaa, S. L., and Majchrzak, A. (2011). Knowledge collaboration in online communities. *Organization Sci.* 22, 1224–1239. doi: 10.1287/orsc.1100.0614

Fayard, A. L., and Weeks, J. (2014). Affordances for practice. *Inf. Organ.* 24, 236–249. doi: 10.1016/j.infoandorg.2014.10.001

Fornell, C., and Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *J. Mark. Res.* 18, 39–50. doi: 10.1177/002224378101800104

Fox, J., and McEwan, B. (2017). Distinguishing technologies for social interaction: the perceived social affordances of communication channels scale. *Commun. Monogr.* 84, 298–318. doi: 10.1080/03637751.2017.1332418

Ghazawneh, A., and Henfridsson, O. A. (2015). Paradigmatic analysis of digital application market places. *J. Inf. Technol.* 30, 198–208. doi: 10.1057/jit.2015.16

Gibbs, J., Rozaidi, N., and Eisenberg, J. (2013). Overcoming the "ideology of openness,": probing the affordances of social media for organizational knowledge sharing. *J. Comput.-Mediated Commun.* 19, 102–120. doi: 10.1111/jcc4.12034

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Lawrence Erlbaum Associates, Florence, Kentucky, 227–235.

Glassman, M., and McAfee, R. B. (1990). Enthusiasm: the missing link in leadership. *SAM Adv. Manag. J.* 55, 4–6.

Goes, P. B., Guo, C., and Lin, M. (2016). Do incentive hierarchies induce user effort? Evidence from an online knowledge exchange. *Inf. Syst. Res.* 27, 497–516. doi: 10.1287/isre.2016.0635

Gummerus, J., Liljander, V., Weman, E., and Pihlström, M. (2012). Customer engagement in a Facebook brand community. *Manag. Res. Rev.* 35, 857–877. doi: 10.1108/01409171211256578

Guo, H. (2020). Zhihu Product Analysis Report: Epitome of the Status Quo Industry in China_Online. Available at: https://www.sohu.com/a/418464953_11481918 (Retrieved April 11, 2022).

Hair, J. F., Black, W. C, Babin, B. J., and Anderson, R. E. (2010).*Multivariate Date Analysis: A Global Perspective* Upper Sadder River, NJ:Prentice-Hall.

Halpern, D., and Gibbs, J. (2013). Social media as a catalyst for online deliberation? Exploring the affordances of Facebook and YouTube for political expression. *Comput. Hum. Behav.* 29, 1159–1168. doi: 10.1016/j.chb.2012.10.008

Han, S. H., Yoon, S. W., and Chae, C. (2020). Building social capital and learning relationships through knowledge sharing: a social network approach of management students' cases. *J. Knowl. Manag.* 24, 921–939. doi: 10.1108/JKM-11-2019-0641

Hedlund, G., and Nonaka, I. (1993). *Models of Knowledge Management in the West and Japan // Lorange B. Implementing Strategic Processes, Change, and Cooperation*. London: Macmillian.

Ho, M. H. W., and Chung, H. F. (2020). Customer engagement, customer equity and repurchase intention in mobile apps. *J. Bus. Res.* 121, 13–21. doi: 10.1016/j.jbusres.2020.07.046

Hollebeek, L. (2011). Exploring customer brand engagement: definition and themes. *J. Strateg. Mark.* 19, 555–573. doi: 10.1080/0965254X.2011.599493

Hou, Y. Q., and Xiao, M. (2017). The development of socialized question-and-answer community and its communication characteristics: taking Zhihu as an example. *Northern Media Res.* 2017, 37–41. doi: 10.19544/j.cnki.bmyj.2017.0057

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance. *Struct. Equ. Model.* 6, 1–55.

Huang, F. M. (2004). *Structural Equation Modeling Theory and Applications*. Taipei: Wunan.

Ilic, A. (2008). *Towards a Conceptualisation of Consumer Engagement in Online Communities: a Netnographic Study of Vibration Training Online Community. Unpublished master's thesis*. Auckland: University of Auckland (Department of Marketing).

Jaakkola, E., and Alexander, M. (2014). The role of customer engagement behavior in value co-creation a service system perspective. *J. Serv. Res.* 17, 247–261. doi: 10.1177/1094670514529187

Jacques, R. (1996). *The Nature of Engagement and its Role in Hypermedia Evaluation and Design* London South Bank University Available at: https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.336369.

Jiao, Z., Chen, J., and Kim, E. (2021). Modeling the use of online knowledge community: a perspective of needs-affordances-features. *Comput. Intell. Neurosci.*, 1–16. doi: 10.1155/2021/3496807

Junglas, I., Goel, L., Abraham, C., and Ives, B. (2013). The social component of information systems—how sociability contributes to technology acceptance. *J. Assoc. Inf. Syst.* 14, 585–616. doi: 10.17705/1jais.00344

Kahn, W. (1900). Psychological Conditions of Personal Engagement and Disengagement at Work. *Acad. Manage. J.* 33, 692–724.

Kaiser, H. F. (1974). Little jiffy, mark IV. *Educ. Psychol. Meas.* 34, 111–117.

Kane, G. C., and Ransbotham, S. (2016). Research note-content and collaboration: an affiliation network approach to information quality in online peer production communities. *Inf. Syst. Res.* 27, 424–439. doi: 10.1287/isre.2016.0622

Kaplan, A. M., and Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Bus. Horiz.* 53, 59–68. doi: 10.1016/j.bushor.2009.09.003

Karahanna, E., Xu, S. X., Xu, Y., and Zhang, N. (2018). The needs-affordances-features perspective for the use of social media. *MIS Q.* 42, 737–756. doi: 10.25300/MISQ/2018/11492

Karlenzig, W., Markovich, M., Borromeo, J. J., and Chilcott, M. (2002). Knowledge collaboration. Dimension Data. Available at: http://www.didata.com

Kietzmann, J. H., Hermkens, K., McCarthy, I. P., and Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Bus. Horiz.* 54, 241–251. doi: 10.1016/j.bushor.2011.01.005

Kim, S., and Oh, S. (2009). Users' relevance criteria for evaluating answers in asocial Q&a site. *J. Am. Soc. Inf. Sci. Technol.* 60, 716–727. doi: 10.1002/asi.21026

Lanier, C., and Hampton, R. (2008). Consumer participation and experiential marketing: understanding the relationship between co-creation and the fantasy life cycle. *Adv. Consum. Res.* 35, 44–48.

Leijen, H. V., and Baets, W. R. J. (2002). "A cognitive framework for reengineering knowledge–intensive processes," in *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03)*, Hawaii, USA.

Lemon, K. N., and Verhoef, P. C. (2016). Understanding customer experience throughout the customer journey. *J. Mark.* 80, 69–96. doi: 10.1509/jm.15.0420

Leonardi, P. M., and Barley, S. R. (2010). What's under construction here? Social action, materiality, and power in constructivist studies of technology and organizing. *Acad. Manag. Ann.* 4, 1–51. doi: 10.5465/19416521003654160

Lin, X., and Kishore, R. (2021). Social media-enabled healthcare: a conceptual model of social media affordances, online social support, and health behaviors and outcomes. *Technol. Forecast. Soc. Chang.* 166:120574. doi: 10.1016/j.techfore.2021.120574

Liu, F. J., Lin, X. F., Lin, Z. K., and Qiu, Y. (2020). Model construction and empirical study of knowledge collaboration in online encyclopedias from the perspective of interaction. *J. Modern Inf.* 40, 64–73. doi: 10.3969/j.issn.1672-884x.2020.07.015

Liu, J., Zhang, X., Meng, F., and Lai, K. H. (2020). Deploying gamification to engage physicians in an online health community: an operational paradox. *Int. J. Prod. Econ.* 228:107847. doi: 10.1016/j.ijpe.2020.107847

Luthans, F., and Peterson, S. J. (2002). Employee engagement and manager self-efficacy. *J. Manag. Dev.* 21, 376–387. doi: 10.1108/02621710210426864

MacKenzie, , and Podsakoff, P. M. (2012). Common method bias in marketing: causes, mechanisms, and procedural remedies. *J. Retail.* 88, 542–555. doi: 10.1016/j.jretai.2012.08.001

MacKinnon, D. P., Lockwood, C. M., and Williams, J. (2004). Confidence limits for the indirect effect: distribution of the product and resampling methods. *Multivariate Behav. Res.* 39, 99–128. doi: 10.1207/s15327906mbr3901_4

Majchrzak, A., and Faraj, S. (2013). The contradictory influence of social media affordances on online communal knowledge sharing. *J. Comput.-Mediat. Commun.* 19, 38–55. doi: 10.1111/jcc4.12030

Majchrzak, A., Faraj, S., Kane, G. C., and Azad, B. (2013). The contradictory influence of social media affordances on online communal knowledge sharing. *J. Comput. Mediated Commun.* 19, 38–55. doi: 10.1111/jcc4.12030

Matei, S. A., Jabal, A. A., and Bertino, E. (2018). Social-collaborative determinants of content quality in online knowledge production systems: comparing Wikipedia and stack overflow. *Soc. Netw. Anal. Min.* 8, 36–51. doi: 10.1007/s13278-018-0512-3

Mauda, L., and Kalman, Y. M. (2016). "Characterizing quantitative measures of user engagement on organizational facebook pages," in *2016 49th Hawaii International Conference on System sciences (HICSS)*. IEEE. 3526–3535.

Muniz, A. M. Jr., and O'guinn, T. C. (2001). Brand community. *J. Consum. Res.* 27, 412–432. doi: 10.1086/319618

Nahapiet, J., and Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Acad. Manag. Rev.* 23, 242–266. doi: 10.2307/259373

Nardon, L., and Aten, K. (2012). Valuing virtual worlds: the role of categorization in technology assessment. *J. Assoc. Inf. Syst.* 13, 772–796. doi: 10.17705/1jais.00311

Ning, L. J., Sun, Z. Y., and Xiao, S. C. (2019). Research on the forming and driving mechanisms of user value system in platform ecosystem——from the perspective of user engagement. *J. Northeastern Univ. (Social Sci.)* 21:470. doi: 10.15936/j.cnki.1008-3758.2019.05.005

Norman, D. A. (1988). *The Psychology of Everyday Things*. New York: Basic Books.

O'Brien, H. L. (2018). "A holistic approach to measuring user engagement," in *New Directions in Third Wave Human-Computer Interaction*, vol. *2* Methodologies (Cham: Springer), 81–102.

O'Brien, H., and Cairns, P. (2016). *Why Engagement Matters: Cross-Disciplinary Perspectives of User Engagement in Digital Media*. Cham: Springer.

O'Brien, H. L., and Toms, E. G. (2010). The development and evaluation of a survey to measure user engagement. *J. Am. Soc. Inf. Sci. Technol.* 61, 50–69. doi: 10.1002/asi.21229

Ongus, R. W., and Nyamboga, C. M. (2019). Collecting development practices in using information technology: a comparative study, journal of logistics. *Inf. Serv. Sci.* 6, 1–22.

Pan, Z. D., and Liu, Y. S. (2017). What's "New"? Power Entrapment and Theoretical Reflection in "New Media" Discourse. *News Commun. Rev.* 2017, 2–19.

Parker, G. G., and Alstyne, M. W. V. (2005). Two-sided network effects: a theory of information product design. *Manag. Sci.* 51, 1494–1504. doi: 10.1287/mnsc.1050.0400

Postigo, H. (2016). The socio-technical architecture of digital labor: converting play into YouTube money. *New Media Soc.* 18, 332–349. doi: 10.1177/1461444814541527

Rice, R. E., Evans, S. K., Pearce, K. E., and Sivunen, A. (2017). Organizational Media Affordances: Operationalization and Associations with Media Use. *J. Commun.* 67, 106–130. doi: 10.1111/jcom.12273

Robey, D., Raymond, B., and Anderson, C. (2012). "Theorizing information technology as a material artifact in information systems research," in *Materiality and organizing: Social Interaction in a Technological World*. eds. P. M. Leonardi, B. A. Nardi and J. Kallinikos (Oxford: Oxford University Press), 217-236.

Seo, R. (2020). Interorganizational learning for R&D consortium performance: a social capital perspective. *J. Knowl. Manag.* 24, 395–414. doi: 10.1108/JKM-06-2019-0265

Shah, C., and Pomerantz, J. (2010). "Evaluating and predicting answer quality in community QA," in *Proceedings of the 33rd International ACM SIGIR Conference on Research and Development in Information Retrieval*.

Shi, S. P., He, X. Y., Zhang, J., Hong, J., and Wu, Y. (2020). Value realization of internet start-ups from the perspective of affordance: a case study based on Zhong you bang. *Manage. Case Stud. J.* 13, 315–330. doi: 11.7511/JMCS20200305

Stewart, D. W., and Pavlou, P. A. (2002). From consumer response to active consumer: measuring the effectiveness of interactive media. *J. Acad. Mark. Sci.* 30, 376–396. doi: 10.1177/009207002236912

Strickland, V. (2014). *A correlational Study on the Absence of Incentives to Share Knowledge in a Virtual Community*. Ann Arbor, Michigan, U.S.: ProQuest LLC.

Su, W., Li, Y. C., Wang, T. D., and Hao, S. S. (2020). The impact of user empowerment and service innovation on app performance. *Sci. Res. Manage. J.* 41, 193–201. doi: 10.19571/j.cnki.1000-2995.2020.08.020

Sun, Y., He, S. J., Shang, R. A., and Fu, J. D. (2019). Research on the mechanism of corporate social work platforms affecting Employees' improvisation ability—based on the perspective of online social networks. *Manage. World* 35, 157–168.

Teeni, D. (2001). Review: a cognitive-affective model of organizational communication for designing IT. *MIS Q.* 25, 251–312. doi: 10.2307/3250931

Tian, K. T., Bearden, W., and Hunter, G. L. (2001). Consumer need for uniqueness: scale development and validation. *J. Consum. Res.* 28, 50–67. doi: 10.1086/321947

Tong, Z. (2012). Knowledge collaboration (KC) and the relationship between KC and some related concepts. *Lib. Inf. Serv.* 56, 107–112.

Treem, J. W., and Leonardi, P. M. (2012). Social media use in organizations: exploring the affordances of visibility, editability, persistence, and association. *Commun. Yearbook* 36, 143–189. doi: 10.2139/ssrn.2129853

Van Doorn, J., Lemon, K. N., Mittal, V., Nass, S., Pick, D., Pirner, P., et al. (2010). Customer engagement behavior: theoretical foundations and research directions. *J. Serv. Res.* 13, 253–266. doi: 10.1177/1094670510375599

Vivek, S. D. (2009). *A Scale of Consumer Engagement. doctoral dissertation*. Tuscaloosa, AL: The University of Alabama TUSCALOOSA.

Wang, W., and Jiang, Y. W. (2018). Engagement V.S. dependence: investigating the perceived benefits on Users' continuance intention in Social Q&a Community. *Jinan J. Philos. Social Sci.* 137, 96–114. doi: 10.3969/j.issn.1000-5072.2018.10.009

Williams, J., and MacKinnon, D. P. (2008). Resampling and distribution of the product methods for testing indirect effects in complex models. *Struct. Equ. Model.* 15, 23–51. doi: 10.1080/10705510701758166

Wu, M. L. (2013). *Structural Equation Modeling—Advanced AMOS Practice*. Chongqing: Chongqing University Press.

Wu, J., Fan, S., and Zhao, J. L. (2018). Community engagement and online word of mouth: an empirical investigation. *Inf. Manag.* 55, 258–270. doi: 10.1016/j.im.2017.07.002

Xia, S. D., Deng, S. L., and Li, Y. J. (2021). Research on the evaluation of Experts' contribution in knowledge sharing community from the perspective of user engagement. *Inf. Doc. Serv.* 42, 74–81. doi: 10.12154/j.qbzlgz.2021.06.008

Yang, X. C., and Tu, L. (2018). The influence of trust climate to user engagement——based on the perspective of the value co-creation theory in the sharing economy mode. *Manag. Rev.* 30, 164–174.

Yu, J., Meng, Q. S., Zhang, Y., and Jin, J. (2018). Digital entrepreneurship: the future directions of entrepreneurship theory and practice in the digital era. *Stud. Sci. Sci.* 36, 1801–1808. doi: 10.3969/j.issn.1003-2053.2018.10.010

Zhang, M. (2020). *Research on the Influence of Function Affordance on the Traffic Import from Social Media to E-commerce*, vol. *2020* Master dissertation. Harbin Institute of Technology.

Zhang, M., Guo, L., Hu, M., and Liu, W. (2017). Influence of customer engagement with company social networks on stickiness: mediating effect of customer value creation. *Int. J. Inf. Manag.* 37, 229–240. doi: 10.1016/j.ijinfomgt.2016.04.010

Zhang, H. J., Hu, L. Y., and Gu, Y. Z. (2021). User experience, entrepreneurship traits and corporate opportunity identification. *Manag. Rev.* 33, 337–352.

Zhao, Y. M., Li, M. J., and Chen, H. P. (2010). An empirical study on Consumer's information sharing behavior in virtual community. *Chin. J. Manage.* 7, 1490–1494.

Zhong, Q., Yang, X. F., and Wu, Z. Q. (2020). Review of value co-creation in platform ecosystems. *Syst. Eng.—Theory Pract.* 11, 1–16. doi: 10.12011/SETP2020-1568

Zhou, Y., Chen, J., and Cheng, B. (2022). The incentive configuration path of user knowledge collaboration performance in online knowledge community – spiritual incentives or material incentives? *China Bus. Market.*

Zhu, Z. M., Delphine, B., and Iryna, G. (2009). A Multi-Dimensional Model for Assessing the Quality of Answers in Social Q&a Sites. Diss.

Zou, B. H., and Luo, H. (2017). Knowledge payment-a knowledge dissemination model Centered on openness, sharing and payment. *New Media Res.* 3, 110–112. +132. doi: 10.16604/j.cnki.issn2096-0360.2017.11.048

10.3389/fpsyg.2022.1041767

Appendix 1 Questionnaire

Answers "1–7" express your opinion on the topic, and the score indicates a gradual progression from "strongly disagree" to "strongly agree." Please select "√" according to your actual situation.

Knowledge platform affordances	**Strongly disagree → strongly agree**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1. I think the content on Zhihu is more accurate, detailed and convincing.							
2. I can Q&A for free or ask an expert for a low cost on Zhihu.							
3. I think Zhihu has rich content and many forms of content (videos, pictures, links to related knowledge points).							
4. I think there are many new ideas/concepts in Zhihu content.							
5. I can upload my own content on my personal homepage of Zhihu.							
6. I can share the content I am interested in with my friends on Zhihu.							
7. I can join online communities on Zhihu.							
8. I can comment on other's posts on Zhihu.							
9. I can ask or answer questions on Zhihu.							
10. I can browse other people's content on Zhihu.							
User engagement							
1. Anything related to Zhihu grabs my attention.							
2. I pay a lot of attention on Zhihu.							
3. I often browse content on Zhihu.							
4. When I encounter problems, I use Zhihu intentionally.							
5. I spend a lot of my discretionary time using Zhihu.							
6. My days would not be the same without using Zhihu.							
7. I am passionate about Zhihu.							
8. I am heavily into using Zhihu.							
9. I love discussing topics with users who have similar interests to me on Zhihu.							
10. I enjoy interacting with other Zhihu users.							
11. Using Zhihu is more fun when other people around me do it too.							
12. I often liking and commenting other Zhihu users' content.							
Knowledge collaboration performance							
1. I learned new knowledge and skills from Zhihu.							
2. I can apply the knowledge I learned from Zhihu to solve practical problems.							
3. Interacting with other users on Zhihu broadens my horizons.							
4. I often share views or ideas with friends on Zhihu.							
5. I made new friends on Zhihu.							

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 23 December 2022
DOI 10.3389/fpsyg.2022.1091613

OPEN ACCESS

EDITED BY
Wei Zhou,
Yunnan University of Finance And Economics, China

REVIEWED BY
Na Lu,
Qujing Normal University, China
Danxue Luo,
Yunnan University of Finance And Economics, China
Xingqi Zou,
Kunming University of Science and Technology, China

*CORRESPONDENCE
Jiayun Chai
✉jiayunchai@163.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 07 November 2022
ACCEPTED 02 December 2022
PUBLISHED 23 December 2022

CITATION
Ding C, Deng L, Yang J and Chai J (2022) How do idiosyncratic deals influence innovation performance? From the perspective of coworker.
Front. Psychol. 13:1091613.
doi: 10.3389/fpsyg.2022.1091613

How do idiosyncratic deals influence innovation performance? From the perspective of coworker

Chen Ding[1], Lingxiao Deng[2], Jing Yang[3] and Jiayun Chai[4]*

[1]School of Business, Nanjing University, Nanjing, China, [2]AIEN Institute, Shanghai Ocean University, Shanghai, China, [3]School of Public Administration and Policy, South China University of Technology, Guangzhou, China, [4]School of Business, Jiangxi Normal University, Nanchang, China

In the hypercompetitive marketplace, contemporary organizations incorporate the diversity of talents into job design (i.e., offering idiosyncratic deals), in order to meet the unique needs of talented employees and achieve the purpose of attracting, motivating, and retaining them. Based on the cognitive-affective processing system framework, this study aims to explore the effect of coworkers' perceptions of employees' idiosyncratic deals (CPEID) on coworker innovation performance, the mediating role of thriving at work, and the moderating role of humility. Two-wave data were obtained from 248 employees of 15 China firms. The findings suggest that (a) CPEID increase coworker innovation performance by fostering coworker learning; (b) CPEID decrease coworker innovation performance by undermining coworker vitality; (c) Coworker humility not only positively moderates the relationship between CPEID and coworker learning, but also positively moderates the indirect effect of coworker learning between CPEID and coworker innovation performance; and (d) the moderating role of coworker humility is not significant in the relationship between CPEID and coworker vitality. This study provides a theoretical explanation for whether CPEID have both positive and negative effects on coworker innovation performance, and extends boundary conditions of idiosyncratic deals (i-deals). Besides, the findings inspire managers to make reasonable use of the positive role of i-deals.

KEYWORDS

idiosyncratic deals, thriving at work, learning, vitality, innovation performance, employee humility

1. Introduction

In the hypercompetitive marketplace, talented employees have changed their weak position in employment relationships, due to their high bargaining power (Rousseau, 2001). To rebalance employment relationships, contemporary organizations incorporate the diversity of talents into job design, namely offering idiosyncratic deals (i-deals), e.g., flexible work schedules, special training opportunities, and greater advancement

opportunities. In doing so, organizations not only meet the unique needs of talented employees but also achieve the purpose of attracting, motivating, and retaining them (Vidyarthi et al., 2016).

I-deals refer to "voluntary, personalized agreements of a nonstandard nature negotiated between individual employees and their employers regarding terms that benefit each party" (Rousseau et al., 2006). Specifically, their negotiations include promotion opportunities, flextime, flex place, job security, and material incentives (Huo et al., 2014; Ng and Lucianetti, 2016). Coworkers' perceptions of employees' i-deals (CPEID) refer to coworkers' active perceptions of whether and to what extent employees obtain i-deals (Hornung et al., 2008; Ng and Feldman, 2010). By carefully observing or gathering information to know the movements of i-dealers, coworkers will obtain various active perceptions used to evaluate their own organizational status, which in turn influences their attitudes and behaviors (Vidyarthi et al., 2016). Coworkers, as the majority of the organization members, whose attitudes and behaviors will affect the ultimate implementation effectiveness of i-deals (Rousseau et al., 2006). Therefore, the key to whether organizations can treat employees fairly and differently lies in whether the implementation of i-ideals can achieve the effectiveness that all three parties (i-dealers, managers, and coworkers) view them as win-win-win or at least win-win-no lose (Lai et al., 2009).

Compared to ample research from the receiver's perspective (i-dealers), the research from the bystander's perspective (i-dealers' coworkers) is less. On the one hand, CPEID increase their own expectations of obtaining similar i-deals in the future, which in turn motivates coworkers to engage in organizational citizenship behavior (Huo et al., 2014). On the other hand, CPEID cause coworkers to have negative emotions, which leads to malicious competition and ostracism among employees (Ng, 2017). Prior research had focused on behavioral outcome variables about employees, e.g., voice (Marescaux et al., 2019), helping (Guerrero and Challiol-Jeanblanc, 2016), and work withdrawal (Xiong et al., 2018). However, typical outcome variables about employees were neglected, e.g., innovation performance, and task performance. Given that in-service employees need to make special contributions to the organization in order to get i-deals (Liao et al., 2016), innovation performance not only is a critical work result for employees but also helps employees to make special contributions to the organization, which increases the possibility of obtaining i-deals in the future; in addition, innovation performance is also the best proof of whether the implementation of i-deals can achieve win-win-win or at least win-win-no lose. Based on this, we view coworker innovation performance as the dependent variable to explore the effect of CPEID on coworker innovation performance.

Based on social comparison theory, conservation of resources theory, and equity theory, although prior research explored negative cognition mechanisms, i.e., psychological contract violation (Xiong et al., 2018) and distributive injustice (Marescaux et al., 2019), the promoting effect of CPEID on positive cognition was neglected; though a handful of research explored the mediating role of negative emotions, i.e., envy (Ng, 2017; Wang et al., 2021a) and emotional exhaustion (Kong et al., 2020), they lacked an in-depth discussion on whether CPEID can have both positive and negative effects. Since the events (i.e., i-dealers have received many organizational resources such as i-deals, attention from leaders or organizations, special training opportunities, and job security; Ng and Feldman, 2010) are important to coworkers, coworkers will interpret and evaluate these events. Doing so will directly motivate coworkers' cognition and affection (Mischel and Shoda, 1995), and ultimately affect their distal outcomes (i.e., attitude, behavior, and performance). Considering this, we subdivide thriving at work into two dimensions of learning and vitality, exploring the double-edged effect of CPEID on coworker innovation performance, based on the cognitive-affective processing system framework. On the one hand, granting i-deals shows that organizations are willing to invest in employees, which will encourage coworkers to regard i-dealers as role models in order to improve their innovation performance through observational learning and advice-seeking. On the other hand, i-dealers occupy important resources of the organization, which reflects that coworkers' organizational status is impaired; furthermore, this will make coworkers feel nervous, ultimately damaging their innovation performance. Therefore, this study represents learning as the cognitive unit, and vitality as the affective unit.

Owing to CPEID with a double-edge effect, how to strengthen its positive effect and weaken its negative effect are also the focus of this study. Based on individual differences (e.g., individual characteristics, life experiences), when different individuals are confronted with the same event, the idiosyncratic responses of cognition, affection, and behavior will be output, namely individual differences regulate the individual's encoding process (Mischel and Shoda, 1995). Therefore, coworkers' individual characteristics explain this process (event—cognition/affection). Considering the cultural differences between China and western countries regarding the understanding of CPEID (Huo et al., 2014), Chinese employees influenced by Chinese traditional culture may have the following humble characteristics: clear self-awareness, appreciation of others' strengths, and willingness to seek advice with an open mind (Exline et al., 2004; Owens and Hekman, 2012). Therefore, we seek to explore the boundary effect of coworker humility, by representing coworker humility as an individual characteristic. Specifically, coworkers with a high level of humility are comfortable expressing appreciation for i-dealers, and can interpret i-deals as an organizational investment in employees based on competence, which is likely to enhance the positive effect of CPEID; coworkers with a low level of humility, due to unclear self-cognition, believe that i-deals come from managers' partiality (Wang et al., 2021b), which are likely to increase the negative effect of CPEID.

In conclusion, based on the cognitive-affective processing system framework, we explore the effect of CPEID on coworker innovation performance *via* cognition (learning) or affection (vitality), and examine the moderating role of coworker humility.

This study makes managers aware of the double-edged effect of CPEID on coworker innovation performance, and inspires managers reasonably to use the positive role of i-deals.

2. Theory and hypothesis

The cognitive-affective processing system framework shows that individuals will activate different cognitive and affective units in the process of evaluating an event (Mischel and Shoda, 1995). Therefore, when coworkers carefully observe and gather information to know the movements of idealers and form a perception used to evaluate their organizational status (Vidyarthi et al., 2016), coworkers will activate different cognitions and affections. Thriving at work is characterized by the joint experience of learning (cognition) and vitality (affection; Spreitzer et al., 2005). A handful of research suggests that the two components (learning and vitality) of thriving at work have differential effects (Prem et al., 2017), and combining the two-wave structures of learning and vitality into a single test of thriving at work can cause bias in the estimation (Guo and Hu, 2022). Therefore, this study subdivides thriving at work into two dimensions of learning and vitality, exploring the effect of CPEID on coworker innovation performance *via* cognition (learning) or affection (vitality), i.e., the positive effect of inspiring coworkers to learn and the negative effect of undermining coworkers' vitality.

2.1. The mediating role of learning

The cognitive-affective processing system framework shows that events affecting an individual's resources will activate a corresponding cognitive response (Mischel and Shoda, 1995). Therefore, coworkers' perception that others get i-deals will activate a positive cognitive unit (learning). Learning refers to the cognitive experience that an individual is acquiring, and can apply knowledge and skills (Spreitzer et al., 2005). Specifically, i-dealers obtain many organizational resources (e.g., attention from leaders, special training opportunities, and job security), and can fully utilize their knowledge and skills in the workplace, which shows that organizations are willing to invest in employees (Ng and Lucianetti, 2016). By interpreting this event, coworkers truly feel the approbation of organizations on i-dealers' competence (Ho and Kong, 2015), and also increase coworkers' confidence in obtaining similar i-deals in the future, such that they will be willing to improve their competence by learning (Huo et al., 2014). Coworkers regard i-dealers as role models to learn through observation and interaction. In doing so, coworkers gradually recognize i-dealers' strengths and their own weaknesses, and get effective information on how to improve themselves (Ma et al., 2022), e.g., i-dealers' workflows, and risky negative behaviors (Lee and Duffy, 2019). Besides observation and imitation, coworkers can also directly interact with i-dealers, e.g., by seeking advice, and asking for feedback (Pan et al., 2021). Considering that i-dealers give coworkers more careful, accurate, and targeted feedback through interaction (Lee and Duffy, 2019), coworkers can receive more direct information input (De Stobbeleir et al., 2011) to gradually close the gap with i-dealers (Wang et al., 2021a).

Learning can enhance coworker innovation performance. On the one hand, the learning process effectively activates the individual's self-perfection motivation which encourages individuals to actively pursue more achievements and approbations (Pierce and Gardner, 2004), e.g., coworkers will proactively solve organizational problems to gain support from leaders. On the other hand, coworkers willing to learn can positively view their surroundings, and are more willing to engage in interpersonal interactions. Specifically, the coworkers not only will proactively learn or seek help from i-dealers to improve their own knowledge and skill deficiencies, but also expand their own attention span and increase their own activity of thinking in order to enable them to adopt flexible, appropriate work strategies; in addition, interpersonal interaction enhances the relationship between coworkers and i-dealers, which facilitates the rapid dissemination of resources (e.g., knowledge) within the organization, and creates a favorable climate for knowledge sharing (Lee and Duffy, 2019). Therefore, coworkers can improve their own innovation performance by obtaining overflow resources of i-dealers in the cooperative network (Grigoriou and Rothaermel, 2014).

In summary, granting i-deals shows that organizations are willing to invest in their own employees, and set role models for coworkers, which motivates coworkers to learn, and ultimately improves coworker innovation performance. Accordingly, the following hypothesis is proposed.

> *Hypothesis* 1: Coworker learning mediates the positive relationship between CPEID and coworker innovation performance.

2.2. The mediating role of vitality

According to the cognitive-affective processing system framework (Mischel and Shoda, 1995), besides the positive cognitive unit represented by learning, coworkers' affective unit represented by vitality will also be activated by the event that others obtain i-deals. Vitality refers to the positive experience of having energy available, reflecting feelings of aliveness (Spreitzer et al., 2005). In order to evaluate their own organizational status, coworkers will proactively collect and covertly observe the movement of i-dealers (Vidyarthi et al., 2016). I-dealers obtained many organizational resources, e.g., attention from leaders, special training opportunities, and job security (Rousseau et al., 2016). Considering that organizational resources are scarce (Wang et al., 2021a) and coworkers are highly sensitive to their own interests (e.g., salary, promotion), i-dealers occupying a large number of organizational resources increase work stress and perceptions of resource threat on coworkers (Ma et al., 2022), which shows that coworkers' organizational status has been compromised

(Liao et al., 2016). Coworkers find themselves in a disadvantageous position by interpreting i-dealers' movement, which adds to the psychological pressure on coworkers about how to get i-deals. On the one hand, this can lead to negative emotions toward coworkers (e.g., relative deprivation, anxiety, and dissatisfaction). On the other hand, this reduces coworkers' aspirations for the future and induces them to perceive the uncertainty of obtaining i-deals in the future, which will activate basic anxiety-related neurological processes, arousing negative emotions such as anxiety and depression (Jonas et al., 2014), and in severe cases even triggering depressive reactions (Cohen-Charash, 2009).

Low vitality can decrease coworker innovation performance. On the one hand, coworkers with low vitality will carefully assess their surroundings in order to reduce decision risk and uncertainty, which leads coworkers to do a series of behaviors resulting in lower innovation performance (e.g., adhere to work habits, strive to maintain the status quo, and to avoid or abandon innovative behaviors that may expose their flaws and bring negative consequences). On the other hand, the negative emotion of tension and anxiety reduce coworkers' ability to control their environment and their confidence in solving work problems (Bakker et al., 2008); specifically, coworkers with insufficient control are more likely to make mistakes at work, and coworkers with emotional exhaustion will fall into a vicious cycle (i.e., neither being willing to seek help nor taking the initiative to change the status quo), which further undermines their thinking and creativity. Campbell et al. (2017) findings suggest that antisocial behaviors are common retaliatory responses to threats. Specifically, faced with a sense of work stress and resource threat caused by i-dealers, coworkers with low vitality tend to vent their emotions through aggressive behaviors (e.g., bullying, intimidating, and slamming). Considering the negative effect of adopting this behavior in the workplace on coworkers' reputation and status, coworkers have to spend extra time and vigor to adjust their emotions, which will lead to negative effects on their innovation performance.

In conclusion, i-dealers occupying significant organizational resources send a signal that coworkers' organizational status is compromised. This undermines coworker vitality by making coworkers into negative emotions of anxiety and dissatisfaction, which ultimately decreases their innovation performance. Accordingly, the following hypothesis is proposed.

> *Hypothesis* 2: Coworker vitality mediates the negative relationship between CPEID and coworker innovation performance.

2.3. CPEID and innovation performance

The cognitive-affective processing system framework shows that the events can activate both cognitive and affective units (Mischel and Shoda, 1995). Therefore, according to H1, H2, and this framework, CPEID can simultaneously activate coworkers learning (cognition) and coworker vitality (affection). A recent study shows that there are many differences between learning and vitality in terms of their effect on innovation performance, i.e., learning is a stronger contributor to innovation than vitality (Guo and Hu, 2022). Specifically, compared to individuals' emotional responses which are short-lasting and unstable, individuals' cognitive responses are longer-lasting and more rational (Mischel and Shoda, 1995). Therefore, although CPEID undermine coworker vitality in the short term, it stimulates coworker learning in the long term (Prem et al., 2017). Additionally, given that innovation requires knowledge input, the growth in knowledge from learning is more important than vitality from positive emotions(Guo and Hu, 2022). Taken together, this study speculates that CPEID have a positive total indirect effect on coworker innovation performance. Accordingly, the following hypothesis is proposed.

> *Hypothesis* 3: CPEID have a positive total indirect effect on coworker innovation performance via simultaneously motivating coworker learning and vitality.

2.4. The moderating role of employee humility

Humility consists of three main dimensions, i.e., accurate self-awareness, appreciation of others' strengths, and teachability (Owens et al., 2013). Specifically, humble employees (a) have accurate and clear self-awareness and can openly admit their own shortcomings; (b) appreciate the strengths of their coworkers and their contributions to the organization; and (c) are willing to humbly learn new knowledge from coworkers and leaders (Exline et al., 2004; Owens and Hekman, 2012). Based on the cognitive-affective processing system framework, a study shows that there are individual differences in the interpretation and assessment of events, i.e., personality traits affect the process (the activation of cognitive and affective units by events), which in turn influences individuals' behavioral choices (Mischel and Shoda, 1995). Therefore, this study hypothesized that coworker humility would explain the "event-cognition/affection" process.

When the level of humility is high, coworkers (a) can openly express appreciation for i-dealers; (b) are clearly aware of areas where they are inferior to i-dealers (e.g., knowledge, competence, and experience); (c) are aware of that the organization invests in employees base on employee abilities (Ng and Lucianetti, 2016); and (d) tend to view i-deals as a reasonable measure to improve management efficiency. Based on the above behaviors, coworkers believe a fact that by improving their abilities, they will be able to get i-deals in the future. On the one hand, this increases coworkers' internal motivation (Prem et al., 2017); specifically, this inspires coworkers to focus on their self-growth and development, and motivates coworkers to take the initiatives to improve their capabilities optimistically. On the other hand, this also encourages coworkers to humbly learn from i-dealers in order

to achieve the ability level of obtaining i-deals in the future, e.g., using indirect or direct learning methods (e.g., observing, imitating, and seeking advice; Lee and Duffy, 2019; Pan et al., 2021). Taken together, high levels of humility reinforce the positive effect of CPEID on coworker learning.

When the level of humility is low, coworkers' self-perceptions are unclear and self-serving, which leads coworkers to selfishly interpret their own and i-dealers' achievements in order to boast about themselves and devalue i-dealers (Ma et al., 2022). Specifically, when i-dealers have not yet brought clear benefits to the organization, coworkers argue that the allocation of i-deals is most likely the result of managerial bias (Wang et al., 2021a), i.e., i-dealers have interpersonal advantages with leaders rather than objective advantages (e.g., knowledge, skills). Coworkers' negative interpretation ultimately influences coworker learning and vitality. Specifically, this not only undermines coworker vitality by inducing negative emotions (e.g., anger, self-worth denial, and anxiety; Schmitt et al., 2010), but also inhibits coworker learning by exacerbating coworkers' negative perceptions of potential harm or loss and reducing coworkers' motivation to observe, seek advice and imitate. Accordingly, the following hypothesis is proposed.

> *Hypothesis* 4: Coworker humility positively moderates the relationship between CPEID and coworker learning/vitality: compared to the low level of coworker humility, the high level of coworker humility can strengthen the positive relationship between CPEID and coworker learning (4a), and weaken the negative relationship between CPEID and coworker vitality (4b).

Based on the above hypotheses, this study suggests that coworker humility, respectively, moderates the indirect effect of learning and vitality between CPEID and innovation performance. When the level of humility is high, coworkers can recognize the initiatives of i-deals and believe that the gap between themselves and i-dealers can be closed through learning, which not only reduces coworkers' anxiety about the future, but also allows coworkers to be positive and optimistic in their risk assessment (Marescaux et al., 2021). In addition, owing to the expectation of receiving similar treatment in the future, coworkers are willing to improve their efficiency by taking initiatives to ameliorate the existing technology, which ultimately increases innovation performance. However, the low level of humility not only weakens the positive effect of CPEID on coworker learning, but also induces coworker's low vitality feelings (e.g., hostility, anxiety, resentment, and anger). Therefore, coworkers are likely to choose negative behavioral responses to reduce decision risk and uncertainty (e.g., by avoiding or abandoning innovation), which ultimately undermines coworker innovation performance. Accordingly, the following hypothesis is proposed.

> *Hypothesis* 5: Coworker humility moderates the mediating effect of coworker learning/vitality between CPEID and coworker innovation performance: compared to the low level of coworker humility, the high level of coworker humility can strengthen the mediating effect of coworker learning between CPEID and coworker innovation performance (5a), and weaken the mediating effect of coworker vitality between CPEID and coworker innovation performance (5b).

In summary, the conceptual model used in this study is shown in Figure 1.

3. Materials and methods

3.1. Participants and procedure

Considering that knowledge employees have better chances to get i-deals (Wang et al., 2021a), our data were collected from questionnaire surveys on knowledge employees in product development departments of 15 high-tech enterprises from

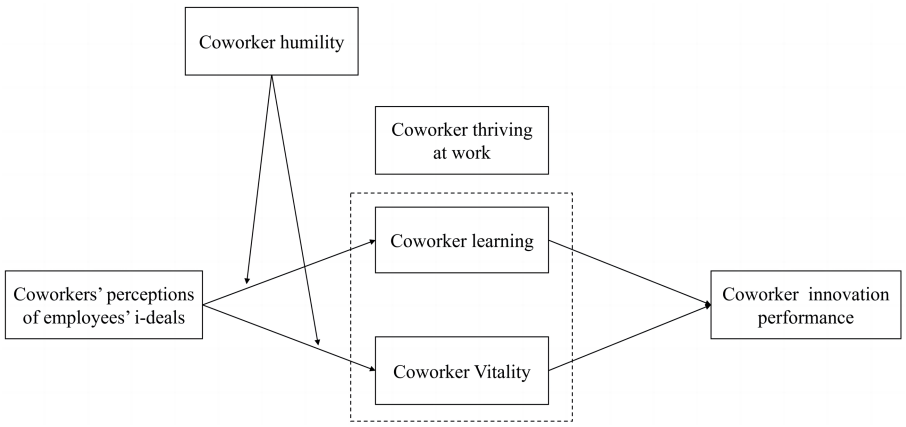


FIGURE 1
Theoretical model.

four cities (i.e., Wuhan, Hangzhou, Nanjing, and Guangzhou). Given that whether employees' own have i-deals is an important boundary condition for CPEID to influence coworkers' behavior (Ng, 2017), this study investigated the employees who did not obtain i-deals. With the assistance of alumni, we verified with corporate managers that the company had i-deals management policies, and obtained the assistance of HRM departments. In order to ensure the accuracy of questionnaire matching across time tags and that each group of employees was from the same team which only have one i-dealer, HRM departments assigned numbers to the employees who volunteered to participate in the survey. To ease employees' concerns for the survey, we thoroughly explained the goal and guide of the questionnaire, and highlighted that the survey data used for scientific research is completely confidential.

This study adopted a two-wave survey distributed and collected on-site. At Time 1, the total of 300 employees provided information (i.e., perceptions to i-dealer, humility, and demographic characteristics); after eliminating missing data, our final sample consisted of 277 employees (response rate = 92.33%). At Time 2, a second-wave on-site survey was conducted, namely required employees to report information (i.e., thriving at work, innovation performance, and demographic characteristics). after eliminating missing data, our final sample consisted of 248 employees (response rate = 89.53%). Among them, 44.35% of participants were female; 55.65% of participants were male; 86.69% of participants were between 26 and 35 years old; 83.06% of participants' tenure were under 5 years; 88.71% of participants had a bachelor's degree or higher; and 72.98% of participants had an income between CNY 5,000 and CNY 9,000.

3.2. Measures

Survey items back-translated following Brislin (1970) procedure were completed on a seven-point Likert scale ranging from 1 (not at all) to 7 (to a great extent), and validated repeatedly in the Chinese context.

Coworkers' perceptions of employees' i-deals (*Time 1*). Drawing on Wang et al. (2021a)' approach and the 6-item scale developed by Ng and Feldman (2010), we explored the extent to which coworkers perceive i-dealers (referred to as Peter below) in six dimensions (a level of pay, advancement opportunities, skill training, career development opportunities, a level of job security, support for personal problems). A sample item was "The organization promises Peter a level of job security that most employees in the department do not enjoy" ($\alpha = 0.918$).

Thriving at work (Time 2). Drawing on the scale developed by Porath et al. (2012), the scale consists of five questions on each of the two dimensions of learning and vitality. A sample item of learning was "As time goes on, I learn more and more at work" ($\alpha = 0.831$); A sample item of vitality was "I feel alive and vital at work" ($\alpha = 0.952$).

Innovation performance (Time 2). Drawing on the scale developed by Janssen (2001), the scale consists of nine questions in three dimensions (idea generation, idea promotion, and idea realization). Sample items were "I always search out new working methods, techniques, or instruments; I always make important organizational members enthusiastic for innovative ideas; I try my best to introduce innovative ideas into the work environment in a systemic way" ($\alpha = 0.915$).

Employee humility (Time 1). Drawing on the scale developed by Owens et al. (2013), the scale consists of nine questions in three dimensions (self-awareness, appreciation of employees' strengths, and teachability). Sample items were "I acknowledge Peter has more knowledge and skills than me; I show appreciation for the unique contributions of Peter; I am willing to learn from Peter and employees" ($\alpha = 0.910$).

Control Variables (Time 1). Consistent with the extant studies (Kong et al., 2020; Wang et al., 2021a), this study controlled demographic variables (gender, age, education, tenure, and monthly income).

4. Results

4.1. Common method biases test

This study adopted process control and statistical control to ensure the validity of the study results. The former was achieved by four means (i.e., questionnaire instructions, reverse question set, cross-formatting of items, and anonymous survey), while the latter was achieved by using the "Harman single-factor test" method of SPSS 26.0, which yielded an explained variance of the first factor was 26.469%; since it did not account for 50% of the total variance (Fuller et al., 2016), the common method bias was within acceptable limits.

4.2. Confirmatory factor analysis

To examine the discriminant validity of the variables, this study conducted a confirmatory factor analysis by using Mplus 7.4 software. Since the sample size was relatively small compared with the number of items, this study performs three-factor parceling for the five variables. Specifically, in order to reduce the parameter estimation bias (Bandalos, 2008), we (a) parceled the item with the largest and smallest factor loading as the first factor; (b) parceled the item with the second largest and second smallest loading as the second factor; and (c) parceled the remaining item as the third factor. The results of confirmatory factor analyses (see Table 1) showed that the five-factor model ($\chi^2_{[80]} = 115.224$, RMSEA = 0.042, CFI = 0.987, TLI = 0.983, SRMR = 0.034) fit the data better than any of alternative models, and this model met the ideal standard.

4.3. Descriptive statistics and correlations

Descriptive statistics and correlations of scales are displayed in Table 2. CPEID were positively related to coworker learning and coworker innovation performance ($r = 0.206$, 0.167, $p < 0.01$), and were negatively related to coworker vitality ($r = -0.171$, $p < 0.01$); Both coworker learning and coworker vitality were positively related to coworker innovation performance ($r = 0.340$, 0.185, $p < 0.01$); Coworker humility was positively related to both coworker learning and coworker vitality ($r = 0.185$, $p < 0.01$; 0.126, $p < 0.05$). Taken together, the hypothesized relationships between the variables were initially verified.

4.4. Test of hypotheses

By using Mplus 7.4 software for hypothesis testing, this study used Bootstrapping to replicate samples 5,000 times. The path coefficients of the mediator analysis are shown in Table 3. On the one hand, the results reported in Table 3 showed CPEID (a) positively predicted coworker learning ($\beta = 0.192$, $p < 0.01$); (b) negatively predicted coworker vitality ($\beta = -0.222$, $p < 0.05$); and (c) had a non-significant direct effect on coworker innovation performance ($\beta = 0.044$, $p > 0.05$). On the other hand, the results reported in Table 3 showed that both coworker learning and coworker vitality positively predicted coworker innovation performance. Therefore, both hypothesis 1 and hypothesis 2 were initially supported (i.e., both coworker learning and coworker

TABLE 1 Results of confirmatory factor analysis.

Measurement Model	$\chi 2$	*df*	$\chi 2/df$	RMSEA	CFI	TLI	SRMR
5-Factor model	115.224	80	1.440	0.042	0.987	0.983	0.034
4-Factor model	425.434	84	5.065	0.128	0.876	0.845	0.117
3-Factor model	928.920	87	10.677	0.198	0.695	0.631	0.179
2-Factor model	1688.566	89	18.973	0.269	0.420	0.315	0.215
1-Factor model	2237.508	90	24.861	0.310	0.221	0.091	0.245

5-Factor model (hypothesized model), 4-Factor model (CPEID and learning merged), 3-Factor model (CPEID and learning merged, vitality and innovation performance merged), 2-Factor model (CPEID, learning merged, vitality and innovation performance merged), 1-Factor model (CPEID, learning merged, vitality, innovation performance and humility merged). RMSEA, Root Mean Square Error of Approximation, CFI, Comparative Fit Index, TLI, Tucker-Lewis Index, SRMR, Standardized Root Mean Square Residual; and Source: Mplus 7.4 software analysis.

TABLE 2 Descriptive statistics and correlations.

Variable	*Mean*	*SD*	1	2	3	4	5	6	7	8	9
1.Gender	1.557	0.498									
2.Age	2.008	1.211	−0.249**								
3.Education	3.198	0.707	0.101	−0.248**							
4.Tenure	1.673	0.987	−0.230**	0.880**	−0.261**						
5.Monthly income	5.953	0.737	0.055	0.381**	0.001	0.368**					
6.CPEID	4.763	1.294	0.026	0.122	0.054	0.098	0.084				
7.Learning	4.984	1.202	−0.042	0.126*	−0.066	−0.008	0.084	0.206**			
8.Vitality	4.279	1.671	−0.001	0.067	−0.057	0.015	0.047	−0.171**	−0.148*		
9.Innovation performance	5.206	0.996	−0.131*	0.323**	−0.088	0.093	0.322**	0.167**	0.340**	0.185**	
10.Humility	4.821	1.117	−0.150*	0.182**	−0.059	0.150*	0.177**	0.006	0.185**	0.126*	0.259**

$n = 248$; *$p < 0.05$, **$p < 0.01$.

TABLE 3 Path analysis of mediators.

Path	Coefficient	*SE*	Boot 95% CI
CPEID → Innovation performance	0.044	0.059	[−0.073, 0.165]
CPEID → Coworker learning	0.192**	0.069	[0.064, 0.334]
Coworker learning → innovation performance	0.526***	0.083	[0.360, 0.685]
CPEID → Coworker vitality	−0.222*	0.086	[−0.383, 0.041]
Coworker Vitality → Innovation performance	0.116**	0.039	[0.042, 0.195]

$n = 248$; SE: standard error; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; and CI: confidence interval.

vitality fully mediate the relationship between CPEID and coworker performance innovation).

The results of the indirect effect analyses are shown in Table 4, which demonstrates the robustness of the study. The results showed that (a) the indirect effect value of CPEID affecting coworker innovation performance through coworker learning was 0.101 and the 95% confidence interval was [0.035, 0.189] (not including 0, significant); (b) the indirect effect value of CPEID affecting coworker innovation performance through coworker vitality was −0.026 and the 95% confidence interval was [−0.063, −0.005] (not including 0, significant); and (c) the total indirect effect value of CPEID affecting coworker innovation performance was 0.075 and the 95% confidence interval was [0.008, 0.164] (not including 0, significant). Therefore, hypothesis 1, hypothesis 2, and hypothesis 3 were initially supported.

The path coefficients of the moderator analysis are shown in Table 5. The interaction term of CPEID and coworker humility positively predicted coworker learning ($\beta = 0.208$, $p < 0.01$), which supported Hypothesis 4a; the interaction term of CPEID and coworker humility had a non-significant effect on coworker vitality ($\beta = -0.069$, $p = 0.411 > 0.05$), which rejected hypothesis 4b (i.e., the moderating effect of Coworker humility between CPEID and coworker vitality was not significant).

By adding and subtracting, respectively, one standard deviation from the mean of coworker humility, this study divided the sample into high and low groups to plot the moderating effect (see Figure 2). The results reported in Figure 2 showed that (a) at a low level of humility, the negative relationship between CPEID and coworker learning was not significant ($\gamma = -0.119$, $p = 0.294 > 0.05$); and (b) at a high-level humility, there was a significant positive relationship between CPEID and coworker learning ($\gamma = 0.346$, $p < 0.001$). Therefore, hypothesis 4a was further verified.

The results of the indirect effects of coworker learning at different levels of humility are shown in Table 6, which demonstrates the robustness of the study. When the level of humility is high, the indirect effect of CPEID on coworker innovation performance through coworker learning was 0.077, and the 95% confidence interval was [0.086, 0.291] (not including 0, significant); When the level of humility is low, the indirect effect of CPEID on coworker innovation performance through coworker learning was −0.027, and the 95% confidence interval was [−0.180, 0.053] (not including 0, significant); and the difference between the two was 0.104, and 95% confidence interval was [0.081, 0.422] (not including 0, significant). Taken together, the indirect effect of coworker learning was strengthened with increasing values of coworker humility, which supported hypothesis 5a.

5. Discussion

5.1. Conclusion

Based on the cognitive-affective processing system framework, this study examined the double-edged effect of CPEID on coworker innovation performance through (a) using coworker learning or coworker vitality as mediators, and (b) using coworker humility as a moderator. Based on a sample of 248 knowledge workers, this study had the following findings.

(1) In terms of cognition, granting i-deals showed that organizations are willing to invest in their employees, which inspires coworkers actively to learn and emulate i-dealers in order to improve coworker innovation performance. In terms of affection, owing to i-dealers occupying important organizational resources, coworkers' organizational status is compromised, which will reduce coworker innovation performance by inhibiting coworker vitality. Integrating cognition and affection, the implementation of i-deals achieves a "win-win-win" management effect because CPEID have a positive total indirect effect on coworker innovation performance through coworker thriving at work.

(2) Coworker humility not only positively moderates the relationship between CPEID and coworker learning, but also reinforces the mediating role of coworker learning in the relationship between CPEID and coworker innovation performance. However, the moderating effect of coworker humility is not significant in the relationship between CPEID and

TABLE 4 Results of mediating path analysis.

Path	Stage		Effect	
	First	Second	Indirect	Total
CPEID → Coworker learning → Innovation performance	0.192*** [0.064, 0.334]	0.526*** [0.360, 0.685]	0.101* [0.035, 0.189]	0.075* [0.008, 0.164]
CPEID → Coworker vitality → Innovation performance	−0.222* [−0.383, 0.041]	0.116** [0.042, 0.195]	−0.026* [−0.063, −0.005]	

$n = 248$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; CI confidence interval.

TABLE 5 Path analysis of moderator.

Path	Coefficient	*SE*	Boot 95% CI
CPEID*Coworker humility → Coworker learning	0.208**	0.067	[0.072, 0.335]
CPEID*Coworker humility → Coworker vitality	−0.069	0.084	[−0.234, 0.091]

$n = 248$; **$p < 0.01$; SE: standard error; CI: confidence interval.

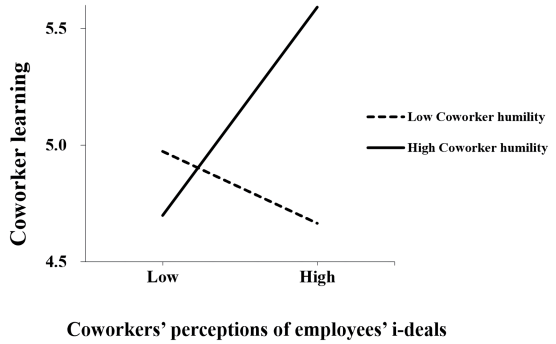


FIGURE 2
Moderating effect of coworker humility.

TABLE 6 Results of indirect effect of moderated mediation.

Moderator	Indirect effect	*SE*	95% CI
Coworker humility	CPEID → Coworker learning → Innovation performance		
High (Mean + SD)	0.171**	0.052	[0.086, 0.291]
Low (Mean − SD)	−0.059	0.058	[−0.180, 0.053]
differences	0.230**	0.086	[0.081, 0.422]

$n = 248$; SE standard error; $^{**}p < 0.01$; CI confidence interval.

coworker vitality. The reason may be that although coworkers with different levels of humility may differently interpret and evaluate the event of employees obtaining i-deals, CPEID undermine coworker vitality. Specifically, On the one hand, since coworkers with a high level of humility have a clear perception of the gap between themselves and i-dealers, they may believe that they have not obtained i-deals because of their lack of effort, which can lead to feelings of inferiority and thus unhappiness, anxiety, and depression (Smith et al., 1994); furthermore, when coworkers predict that they will not reach i-dealers' ability level by doing their best, coworkers' intrinsic motivation will be suppressed (Lockwood and Kunda, 1999), which further undermines their vitality. On the other hand, since coworkers with a low level of humility have a self-serving bias (Ma et al., 2022), they may believe that they do not receive i-deals because of managers' bias (Wang et al., 2021b), which will lead to negative emotion (e.g., resentment, anger, self-worth denial). Accordingly, coworker humility does not significantly moderate the relationship between CPEID and vitality.

5.2. Theoretical implications

The theoretical implications of this study are the following:

Firstly, this study extends the theoretical perspective of i-deals from a bystander perspective. Most previous studies had focused on binary interaction scenarios (i.e., sender and receiver), neglecting the reactions of third parties (i.e., bystanders) to i-deals (Liao et al., 2016). Drawing upon the cognitive-affective processing system framework, we examine the mechanism of CPEID on coworker innovation performance. On the one hand, we integrate the positive and negative effects of i-deals implementation in order to provide a new theoretical perspective for i-deals research (Wang et al., 2021b); on the other hand, we provide empirical support for the hypothesis that the implementation of i-deals can achieve a "win-win-win" management effect (Lai et al., 2009).

Second, this study distinguishes the difference in the role of learning and vitality, and reveals the double-edged effect of CPEID in terms of cognitive and affective. We consider the fact that coworkers interpret and evaluate this event (employees get i-deals), which directly motivates their cognition and affection (Mischel and Shoda, 1995), and ultimately affects their distal outcomes (e.g., attitude, behavior, and performance). Therefore, we subdivide thriving at work into two dimensions: learning and vitality (Prem et al., 2017). The cognitive pathway extends the positive effects of i-deals. Specifically, unlike the mediating role of negative cognition (e.g., psychological contract violation, distributive injustice; Xiong et al., 2018; Marescaux et al., 2019), this study extends the positive effect of CPEID on coworker cognition to innovation performance by constructing a "CPEID-coworker learning-coworker innovation performance" action chain. The affective pathway is consistent with previous research (Ng, 2017; Kong et al., 2020; Wang et al., 2021a); namely, CPEID undermine coworker vitality by making them feel negative emotions, which in turn reduces their innovation performance.

In the end, this study examines the moderating role of employee humility, expanding the boundary conditions of i-deals. Considering that Chinese employees are deeply influenced by Chinese traditional culture of humility, this study focused on the different applicability of i-deals to differentiated individuals, exploring the moderating effect of employee humility on their cognitive units (Mischel and Shoda, 1995), i.e., whether the direct effect of CPEID on coworker learning and the indirect effect of CPEID on coworker innovation performance varies depending on their level of humility. This study (a) responds to Liao et al. (2016)'s call to focus on the role of individual characteristics of leaders and employees, (b) extends the boundary conditions for the positive role of CPEID in the Chinese context (Rousseau et al., 2009), and (c) provides new insights into the differential role of i-deals results based on cultural differences (Huo et al., 2014).

5.3. Practical implications

The practical implications of this study are as follows:

First, owing to the implementation of i-deals achieves a "win-win-win" management effect (e.g., coworkers will take initiatives—*via* viewing i-dealers as role models—to improve their innovation performance in order to obtain similar i-deals in the

future), managers should take advantage of the positive effects of i-deals. Specifically, managers should (a) establish high-quality social and economic exchange relationships with employees (Lai et al., 2009), (b) convey the information to employees that organizations are willing to invest in talented employees, (c) encourage employees to improve their knowledge and skill levels, (d) increase the likelihood that employees obtain similar i-deals in the future (Ng and Lucianetti, 2016), (e) create a fair and equitable atmosphere as much as possible, and (f) motivate employees to correctly interpret organizational policies by increasing the openness and transparency of talent management policies.

Second, managers should pay attention to the psychological state of employees without i-deals and try to avoid the negative effects caused by the implementation of i-deals. As a differentiated HRM practice, CPEID will reduce coworker innovation performance by undermining coworker vitality. Therefore, managers should pay attention to the emotional reactions of coworkers. Specifically, when coworkers fall into negative emotions at work, managers should enhance the self-regulation ability and subfertility of coworkers through communication, positive feedback, and emotion regulation (Marescaux et al., 2021), which will mitigate the decrease in vitality and reduce the chances of subsequent negative behaviors.

In the end, managers should pay attention to differences in employees' humility and take appropriate measures to impose positive and effective interventions on employees. This study showed that when coworker humility levels are high, CPEID increase coworker innovation performance by strengthening their learning. Since managers expressing humility can enhance employees' humility to some extent (Zhong et al., 2019), managers can shape humble leadership through co-development behavior with employees. Managers should (a) actively communicate and interact with employees to help them establish correct self-perceptions, (b) create a good organizational learning atmosphere in order to dispel employees' worries about exposing their own shortcomings, and (c) encourage employees to humbly and actively learn and seek advice.

5.4. Limitations and directions for future research

Although this study has some theoretical and practical significance, there are still aspects that need to be improved. Firstly, although this study used multiple time points to collect data in order to control endogenous, all data were obtained from the subjective reports of the employees who participated in the test, which resulted in the inability to verify causality. Therefore, future research could use experimental manipulation to further enhance the explanatory power of the model. Secondly, based on this study examining the double-edged effect of CPEID from a bystander perspective, future research could further explore other mechanisms of i-deals (e.g., developmental, task mechanisms). Thirdly, considering that this study examined the mediating role of coworker learning and coworker vitality based on the cognitive-affective processing system framework, future research could seek other cognitive and affective mechanisms based on other theories (e.g., transactional theory of stress and coping, and affective event theory). Finally, given that this study focused on the moderating effect of the personality trait (employee humility), future research could focus on the moderating effect of situational factors (e.g., transformational leadership, competitive climate) to dig deeper into the boundary conditions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Nanjing University, China. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CD: study conception and design, data collection, analysis of results, and manuscript preparation. LD: study design, manuscript preparation, and revision. JY: study conception and manuscript preparation. JC: manuscript finalization. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Bakker, A. B., Van Emmerik, H., and Van Riet, P. (2008). How job demands, resources, and burnout predict objective performance: a constructive replication. *Anxiety. Stress. Copin.* 21, 309–324. doi: 10.1080/10615800801958637

Bandalos, D. L. (2008). Is parceling really necessary? A comparison of results from item parceling and categorical variable methodology. *Struct. Equ. Modeling* 15, 211–240. doi: 10.1080/10705510801922340

Brislin, R. W. (1970). Back-translation for cross-cultural research. *J. Cross-Cult. Psychol.* 1, 185–216. doi: 10.1177/135910457000100301

Campbell, E. M., Liao, H., Chuang, A., Zhou, J., and Dong, Y. (2017). Hot shots and cool reception? An expanded view of social consequences for high performers. *J. Appl. Psychol.* 102, 845–866. doi: 10.1037/apl0000183

Cohen-Charash, Y. (2009). Episodic envy. *J. Appl. Soc. Psychol.* 39, 2128–2173. doi: 10.1111/j.1559-1816.2009.00519.x

De Stobbeleir, K. E. M., Ashford, S. J., and Buyens, D. (2011). Self-regulation of creativity at work: the role of feedback-seeking behavior in creative performance. *Acad. Manag. J.* 54, 811–831. doi: 10.5465/amj.2011.64870144

Exline, J. J., Baumeister, R. F., Bushman, B. J., Campbell, W. K., and Finkel, E. J. (2004). Too proud to let go: narcissistic entitlement as a barrier to forgiveness. *J. Pers. Soc. Psychol.* 87, 894–912. doi: 10.1037/0022-3514.87.6.894

Fuller, C. M., Simmering, M. J., Atinc, G., Atinc, Y., and Babin, B. J. (2016). Common methods variance detection in business research. *J. Bus. Res.* 69, 3192–3198. doi: 10.1016/j.jbusres.2015.12.008

Grigoriou, K., and Rothaermel, F. T. (2014). Structural micro-foundations of innovation: the role of relational stars. *J. Manage.* 40, 586–615. doi: 10.1177/0149206313513612

Guerrero, S., and Challiol-Jeanblanc, H. (2016). Idiosyncratic deals and helping behavior: the moderating role of i-deal opportunity for co-workers. *J. Bus. Psychol.* 31, 433–443. doi: 10.1007/s10869-015-9421-x

Guo, S. H., and Hu, Q. Q. (2022). Energetic learning: the effect of organizational identification and thriving at work on innovation performance. *Manag. Rev.* 34, 205–217. doi: 10.14120/j.cnki.cn11-5057/f.2022.01.011

Ho, V. T., and Kong, D. T. (2015). Exploring the signaling function of idiosyncratic deals and their interaction. *Organ. Behav. Hum. Dec.* 131, 149–161. doi: 10.1016/j.obhdp.2015.08.002

Hornung, S., Rousseau, D. M., and Glaser, J. (2008). Creating flexible work arrangements through idiosyncratic deals. *J. Appl. Psychol.* 93, 655–664. doi: 10.1037/0021-9010.93.3.655

Huo, W., Luo, J., and Tam, K. L. (2014). Idiosyncratic deals and good citizens in China: the role of traditionality for recipients and their coworkers. *Int. J. Hum. Resour. Manag.* 25, 3157–3177. doi: 10.1080/09585192.2014.919949

Janssen, O. (2001). Fairness perceptions as a moderator in the curvilinear relationships between job demands, and job performance and job satisfaction. *Acad. Manag. J.* 44, 1039–1050. doi: 10.2307/3069447

Jonas, E., Mcgregor, I., Klackl, J., et al (2014). *Threat and defense: From anxiety to approach*. United States: Academic Press.

Kong, D. T., Ho, V. T., and Garg, S. (2020). Employee and coworker idiosyncratic deals: implications for emotional exhaustion and deviant behaviors. *J. Bus. Ethics* 164, 593–609. doi: 10.1007/s10551-018-4033-9

Lai, L., Rousseau, D. M., and Chang, K. T. T. (2009). Idiosyncratic deals: coworkers as interested third parties. *J. Appl. Psychol.* 94, 547–556. doi: 10.1037/a0013506

Lee, K., and Duffy, M. K. (2019). A functional model of workplace envy and job performance: when do employees capitalize on envy by learning from envied targets? *Acad. Manag. J.* 62, 1085–1110. doi: 10.5465/amj.2016.1202

Liao, C., Wayne, S. J., and Rousseau, D. M. (2016). Idiosyncratic deals in contemporary organizations: a qualitative and meta-analytical review. *J. Organ. Behav.* 37, S9–S29. doi: 10.1002/job.1959

Lockwood, P., and Kunda, Z. (1999). Increasing the salience of one's best selves can undermine inspiration by outstanding role models. *J. Pers. Soc. Psychol.* 76, 214–228. doi: 10.1037/0022-3514.76.2.214

Ma, J., Wang, H. P., and Yan, Y. (2022). A jump is possible: when does envy of star employees make colleagues resentful and when does it inspire them to improve? *J. Ind. Eng. Eng. Man.* 36, 40–50. doi: 10.13587/j.cnki.jieem.2022.03.004

Marescaux, E., De Winne, S., and Rofcanin, Y. (2021). Co-worker reactions to i-deals through the lens of social comparison: the role of fairness and emotions. *Hum. Relat.* 74, 329–353. doi: 10.1177/0018726719884103

Marescaux, E., De Winne, S., and Sels, L. (2019). Idiosyncratic deals from a distributive justice perspective: examining co-workers' voice behavior. *J. Bus. Ethics* 154, 263–281. doi: 10.1007/s10551-016-3400-7

Mischel, W., and Shoda, Y. (1995). A cognitive-affective system theory of personality: Reconceptualizing situations, dispositions, dynamics, and invariance in personality structure. *Psychol. Rev.* 102, 246–268. doi: 10.1037/0033-295X.102.2.246

Ng, T. W. H. (2017). Can idiosyncratic deals promote perceptions of competitive climate, felt ostracism, and turnover? *J. Vocat. Behav.* 99, 118–131. doi: 10.1016/j.jvb.2017.01.004

Ng, T. W. H., and Feldman, D. C. (2010). Idiosyncratic deals and organizational commitment. *J. Vocat. Behav.* 76, 419–427. doi: 10.1016/j.jvb.2009.10.006

Ng, T. W. H., and Lucianetti, L. (2016). Goal striving, idiosyncratic deals, and job behavior: goal striving and idiosyncratic deals. *J. Organ. Behav.* 37, 41–60. doi: 10.1002/job.2023

Owens, B. P., and Hekman, D. R. (2012). Modeling how to grow: an inductive examination of humble leader behaviors, contingencies, and outcomes. *Acad. Manag. J.* 55, 787–818. doi: 10.5465/amj.2010.0441

Owens, B. P., Johnson, M. D., and Mitchell, T. R. (2013). Expressed humility in organizations: implications for performance, teams, and leadership. *Organ. Sci.* 24, 1517–1538. doi: 10.1287/orsc.1120.0795

Pan, J., Zheng, X. (. J.)., Xu, H. (. H.)., Li, J. (. K.)., and Lam, C. K. (2021). What if my coworker builds a better LMX? The roles of envy and coworker pride for the relationships of LMX social comparison with learning and undermining. *J. Organ. Behav.* 42, 1144–1167. doi: 10.1002/job.2549

Pierce, J. L., and Gardner, D. G. (2004). Self-esteem within the work and organizational context: a review of the organization-based self-esteem literature. *J. Manage.* 30, 591–622. doi: 10.1016/j.jm.2003.10.001

Porath, C., Spreitzer, G., Gibson, C., and Garnett, F. G. (2012). Thriving at work: toward its measurement, construct validation, and theoretical refinement. *J. Organiz. Behav.* 33, 250–275. doi: 10.1002/job.756

Prem, R., Ohly, S., Kubicek, B., and Korunka, C. (2017). Thriving on challenge stressors? Exploring time pressure and learning demands as antecedents of thriving at work. *J. Organiz. Behav.* 38, 108–123. doi: 10.1002/job.2115

Rousseau, D. M. (2001). Flexibility versus fairness? *Organ. Dyn.* 29, 260–273. doi: 10.1016/S0090-2616(01)00032-8

Rousseau, D. M., Ho, V. T., and Greenberg, J. (2006). I-deals: idiosyncratic terms in employment relationships. *Acad. Manag. Rev.* 31, 977–994. doi: 10.5465/amr.2006.22527470

Rousseau, D. M., Hornung, S., and Kim, T. G. (2009). Idiosyncratic deals: testing propositions on timing, content, and the employment relationship. *J. Vocat. Behav.* 74, 338–348. doi: 10.1016/j.jvb.2009.02.004

Rousseau, D. M., Tomprou, M., and Simosi, M. (2016). Negotiating flexible and fair idiosyncratic deals (i-deals). *Organ. Dyn.* 45, 185–196. doi: 10.1016/j.orgdyn.2016.07.004

Schmitt, M., Baumert, A., Gollwitzer, M., and Maes, J. (2010). The justice sensitivity inventory: factorial validity, location in the personality facet space, demographic pattern, and normative data. *Soc. Just. Res.* 23, 211–238. doi: 10.1007/s11211-010-0115-2

Smith, R. H., Parrott, W. G., Ozer, D., and Moniz, A. (1994). Subjective injustice and inferiority as predictors of hostile and depressive feelings in envy. *Pers. Soc. Psychol. B.* 20, 705–711. doi: 10.1177/0146167294206008

Spreitzer, G., Sutcliffe, K., Dutton, J., Sonenshein, S., and Grant, A. M. (2005). A socially embedded model of thriving at work. *Organ. Sci.* 16, 537–549. doi: 10.1287/orsc.1050.0153

Vidyarthi, P. R., Singh, S., Erdogan, B., Chaudhry, A., Posthuma, R., and Anand, S. (2016). Individual deals within teams: investigating the role of relative i-deals for employee performance. *J. Appl. Psychol.* 101, 1536–1552. doi: 10.1037/apl0000145

Wang, L. L., Long, L. R., and Zhang, Y. (2021b). The relationship between newcomers' l-deals and coworkers' ostracism and self-improvement: the mediating role of envy and the moderating role of organizational overall justice. *Manag. Rev.* 33, 234–244. doi: 10.14120/j.cnki.cn11-5057/f.2021.08.020

Wang, L. L., Zhang, F. Y., Tu, Y., and Zhang, X. (2021a). The double-edged sword effect of idiosyncratic deals on bystanders. *Hum. Resour. Dev. China.* 38, 63–75. doi: 10.16471/j.cnki.11-2822/c.2021.9.005

Xiong, J., Ye, M. L., and Chen, Y. S. (2018). Exploring the effect of coworkers' idiosyncratic deals on employees work withdrawal behavior: based on the perspective of equity theory. *J. Psychol. Sci.* 41, 929–935. doi: 10.16719/j.cnki.1671-6981.20180425

Zhong, J., Zhang, L., Li, P., and Zhang, D. Z. (2019). Can leader humility enhance employee wellbeing? The mediating role of employee humility. *Leadership. Org. Dev. J.* 41, 19–36. doi: 10.1108/LODJ-03-2019-0124

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 January 2023
DOI 10.3389/fpsyg.2022.1082981

OPEN ACCESS

EDITED BY
Shanshan Wang,
Dhurakij Pundit University,
Thailand

REVIEWED BY
Xi Xi,
Harbin University of Commerce, China
Hongpeng Wang,
Lanzhou University,
China
Chun-Shuo Chen,
Dhurakij Pundit University, Thailand

*CORRESPONDENCE
Xueyan Dong
✉ xueyandong@nwpu.edu.cn
Xuan Xiao
✉ xiaoxuan@gzhu.edu.cn
Xu Liu
✉ liu-xu@mail.nwpu.edu.cn

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 October 2022
ACCEPTED 28 November 2022
PUBLISHED 13 January 2023

CITATION
Dong X, Liu X and Xiao X (2023) Understanding the influencing mechanism of users' participation in live streaming shopping: A socio-technical perspective. *Front. Psychol.* 13:1082981. doi: 10.3389/fpsyg.2022.1082981

Understanding the influencing mechanism of users' participation in live streaming shopping: A socio-technical perspective

Xueyan Dong[1]*, Xu Liu[1]* and Xuan Xiao[2]*

[1]School of Management, Northwestern Polytechnical University, Xi'an, China, [2]School of Management, Guangzhou University, Guangzhou, China

Introduction: In live streaming shopping, exploring the influencing mechanism of consumers' participation is an important prerequi site for understanding consumer behavior in social commerce activities. The purpose of this study is to explore the relationship betw een technological and social factors (visibility, media richness, guidance shopping and real-time interactivity) in live streaming shop ping and consumers' purchase intention. The mediating roles of attraction and cognitive assimilation were also examined.

Methods: This study collected 425 pieces of data through questionnaire survey. The structural equation model is established based on S-O-R frame. The hypothesis is tested by structural equation model.

Results: Our study found that that real-time interactive and media richness positively affect attraction; visibility, guidance shopping and media richness positive affect cognitive assimilation; cognitive assimilation and attraction positive affect consumers' purchase intention; cognitive assimilation and attraction play a partial mediating role in the influence of technology and social factors on cons umers' purchase intention of live streaming shopping.

Discussion: From the perspective of socio-technical, this study explores the influence mechanism of different influencing factors on consumers' purchase intention in live streaming shopping. This study expands the application of IT affordance theory in the context of live streaming shopping, and reveals the mediating role of attraction and cognitive assimilation between social, technological factors and consumers' purchase intention.

KEYWORDS

live streaming, socio-technical perspective, IT afordance, attraction, cognitive assimilation, live streaming participation

1. Introduction

Live streaming shopping provides consumers with a more intuitive shopping experience based on its forceful interaction, which demonstrates a strong potential as a new form of social business (Sun et al., 2019). According to the survey data of China Internet

Investigation Report, until December 2020, the number of online shopping users in China has reached 782 million. In 2020, the sales of live streaming shopping reached $6 billion, which is two times the number of sales in the same period of 2019 [China Internet Network Information Center (CNNIC), 2021]. Especially, due to the impact of COVID-19, many real industries have been greatly hit; however, live streaming shopping has grown against the trend, indicating that live streaming shopping has become a new force to boost economic development. Different from traditional e-commerce, live streaming shopping creates a scene of real-time display and instant two-way interaction, which greatly meets the user's multidimensional needs of the shopping experience (Xu et al., 2020). Research shows that the visual presence in live streaming shopping helps consumers feel real and makes purchase decisions easier (Wongkitrungrueng and Assarut, 2020). Therefore, live streaming has become an important marketing tool for online platforms (e.g., social networking sites, virtual communities, and short video platforms), integrated with different industries to form "live +" embedded in consumers' daily lives, and it has become the dominant scenario actions in the digital transformation of enterprises.

Compared with traditional e-commerce, live streaming shopping has developed into a unique business model with its own distinct features. First, real-time interaction between buyers and sellers can greatly enhance information transparency. Customers can interact with the streamer in real time through barrage questioning during any live streaming shopping period, it not only can shorten the perceived distance between buyers and sellers but also can effectively reduce customers' uncertainty about products, as well as greatly eliminate customers' perceived risks caused by online virtual context. As a result, it can increase the trust extent between buyers and sellers (Wongkitrungrueng, 2018). Second, as a new way of social networking, live streaming has a more abundant and diversified means of communication than traditional social networking does. Thereby, it can not only meet customers' consumption needs but also can expand their entertainment needs (Busalim and Hussin, 2016). Finally, in the process of live streaming shopping, consumers can express their opinions and understand others through the interactive screenplay, praise, and comments. Accordingly, consumers' purchase decisions-making is rather reasonable.

The practice of live streaming shopping is increasingly popular; however, research on this streaming is still in its early stage. Previous studies paid limited attention to exploring the impact mechanism of live streaming on users' purchase intention (Chen and Lin, 2018). Wongkitrungrueng and Assarut's study shows that live streaming can help promote consumer engagement (Wongkitrungrueng, 2018). Furthermore, most of the existing studies follow the research paradigm (e.g., driven factors) of traditional e-commerce to social commerce (Xu et al., 2020; Zhang et al., 2020). Xu et al. (2020) research shows that the interaction between streamers and consumers in the live streaming environment can stimulate consumers to produce different consumption behaviors. From the perspective of IT affordance, Sun et al. (2019) found that the technological features in live streaming shopping have a positive impact on consumers' purchase intention. Existing research has shown that the building of strong and weak ties between buyers and sellers can help consumers to make purchase decisions (Dong and Wang, 2018), but we still know little about how the relationship works in the live streaming shopping context. In addition, the existing research mainly focused on a single point of view to explore the factors that affect users' live streaming participation (e.g., trust issues, technical aspects, and online reviews; Ou et al., 2014; Li et al., 2020; Stsiampkouskaya et al., 2021); however, these studies cannot provide an integrated framework for understanding the reality of live streaming from a whole contextualized view. Thus, it has greatly hindered the academic innovative exploration of this novel phenomenon (Dong and Wang, 2018), since live streaming shopping is significantly different from other commerce in terms of technical functions, audience groups, and interactive ways (Floh and Madlberger, 2013).

Against the backdrop of these issues, we argue that there is a need to understand the contextualized factors driving consumers to make a purchase in live streaming and explore the specific impact mechanism that how these factors affect users' purchase intention. To achieve this goal, we draw literature on social commerce and IT affordance and adopt a sociotechnical perspective to construct a contextualized model for the following three reasons. First, live streaming shopping is under the scope of social commerce, which is a prevalent socio-technical phenomenon, and the socio-technical perspective provides us with the opportunity to capture both social and technical elements simultaneously in framing and investigating technology-related societal issues (Li et al., 2021). Second, the socio-technical perspective, integrating the technical design with the social environment to cause goal-oriented behavior, is particularly well consistent with this study's investigation of user's intention to use live steaming to further make sure the goals of IT function to social purchases (Wong et al., 2021). In addition, the context of live steaming shopping merits new interaction insights regarding how the IT functionalities enable consumers to achieve social and shopping goals by shaping their cognition state, and this fits well our theoretical investigation.

The rest of this study is structured as follows. First, we review the related literature and provide a theoretical foundation. Then, based on the Stimulus-Organism-Response (S-O-R) framework, we build our research model from three levels: live streaming as a technology platform, live streaming as an online social context, and interplay of the technological functions and the social situation of live streaming. Next, we describe our research design and results. Finally, we discuss the study's contributions, implications, and limitations, as well as future research. Our work is expected to shed light on theory development in this emerging live streaming research area and help practitioners understand how the desirable socio-technical system shapes consumers' live streaming purchase intention.

2. Theoretical development

2.1. Live streaming shopping

Live streaming shopping represents the completion of mobile payment and online trading activities, while e-commerce activities perform trading through the network of live streaming platforms (Sun et al., 2019). It mainly includes a real-time live streaming platform, which provides a live environment for customers. Through live streaming technology and live streaming infrastructure, customers' needs for interaction, entertainment, and shopping are met (Xu et al., 2020; Liu et al., 2022). From the point of view of information technology, live streaming is a way of releasing information by producing and releasing information on the spot. Through live streaming, the information publisher (streamer) can immediately send images and sounds to other locations, and users can receive information in real time (Chen and Lin, 2018). With the development in the vertical field, tourism, education, entertainment, games, and other industries have begun to adopt live streaming technology as a new development method. Compared to other live streaming industries, live streaming shopping has become an emerging representative industry with its speed and scale of development (Wang, 2019). With the emergence of a large number of streamers, the phenomenon of live streaming delivery quickly caught on the Internet and attracted widespread attention (Gong et al., 2022). Live streaming shopping is a new way of shopping; this new way allows consumers and sellers to interact in real time (Yang et al., 2022). Consumers can not only gain product information directly through the streamer's introduction but also gain a better understanding of other users' attitudes through the barrage and comments (Lu and Chen, 2021). At the same time, consumers can obtain shopping coupons or special goods by playing games and interactive lottery in the process of watching live streaming. This form of more entertaining shopping enables consumers to meet the enjoyment demand beyond the actual demand and stimulates the users to have purchase intention (Lim and Ayyagari, 2018). In traditional e-commerce activities, buyers and sellers do not know each other enough, which greatly affects the establishment of the trust relationship between buyers and sellers. On the contrary, in live streaming shopping, buyers and sellers interact between themselves to build strong emotional ties, which can help consumers eliminate the uncertainty generated by online shopping (Guo et al., 2021). To understand the particularity of live streaming shopping, this study summarizes the differences between live streaming shopping and other traditional shopping models, as shown in Table 1. The business model of live streaming shopping is fragmented, diversified, and fun-seeking. In the era of the digital economy, the emergence of live streaming shopping meets people's online shopping needs more effectively.

2.2. Stimulus-organism-response model

The Stimulus-Organism-Response model (S-O-R) includes three parts: stimuli from the internal and external environment, the state of the organism, and their behavioral responses (Mehrabian and Russell, 1974). There are three key elements in this framework, namely stimulus, organism, and response. Stimuli can trigger individual emotional and cognitive processes that lead to the response of individual behavior (Donovan, 1994). The S-O-R model reveals the whole process of individual behavior, which is widely used in research studies of consumer behavior and online purchase (Chan et al., 2017; Xu et al. 2020). Zhang et al. (2014) applied the S-O-R model to the research on social commerce and explored the influence of technical characteristics (stimulus) in social commerce on customers' virtual experience (organism) and customers' participation intention (response); customers' experience determines their final participation intention and is also influenced by the characteristics of social commerce. The stimulus represents the factors that attract the attention of the consumer, the organism represents the internal state of the consumer, and the reaction is the result of the response to the stimulus and the change in the internal state (Chan et al., 2017).

In the research on live streaming shopping, researchers apply the S-O-R model to explore the relationship between stimuli in the live streaming environment, consumers' cognitive and emotional states, and resulting behaviors. For example, Xu et al. (2020) found that stimuli in the live streaming environment have

TABLE 1 Comparison between live streaming shopping and other shopping models.

Shopping way	Content presenting	Feature	Example
Live streaming shopping	Real-time explanation + interaction + purchase	Bullet interaction, Instant comments, Convenient information consultation, Strong entertainment	Taobao live streaming, Douyin live streaming
Short video ecommerce	Browse + purchase	Interactive admiration, Instant comment, Strong entertainment, Concise video content, Concentrated commodity information	Micro video, Watermelon video, Volcano video
Traditional platform e-commerce	Browse + purchase	Rich commodity information, Information update lag, Communication inconvenience	Tian Mao mall, JD Mall, Amazon
Traditional offline shopping guide	Real-time explanation + accompany + purchase	Experience, Time consuming, Product information collection difficult	Wal-Mart, Carrefour and Hualian

a direct impact on the internal state of consumers and then affect consumer behavior. In the context of live streaming shopping, the S-O-R model well meets the needs of our study. First, this model can well summarize the environmental stimuli (such as technical features and social features of live streaming) in live streaming shopping in this study, thus researchers can summarize relevant influencing factors from a richer and more comprehensive perspective (Donovan 1994; Chan et al., 2017). Second, the model can help us observe the impact of environmental stimuli in live shopping on the internal states (cognitive and emotional states) of consumers, and how they ultimately influence consumer behavior. The core content of the S-O-R model is that environmental stimuli have an impact on the internal states and behaviors of individuals. Therefore, we believe that the adoption of this model can help us more clearly understand the impact of environmental stimuli in live streaming shopping on the internal state and behavior of consumers.

2.3. IT affordance

The affordance theory originated from the field of ecological psychology. It describes the phenomenon that the subject produces a certain behavior based on the perception of environmental characteristics (Gibson, 1978; Leonardi, 2011). This theory has gradually been widely used in the field of information systems and social psychology. In terms of the affordance definition, it means that the environment has different attributes, which could affect the way users achieve their goals in a specific context (Markus and Silver, 2008). Strong et al. (2014) believes that affordance is provided by technology or environment and focuses more on the possibility provided by the environment for individuals, which requires the interaction between the environment and individuals. Since Gibson (1978) proposed the idea of affordance, it has been improved and developed by many scholars in the field of ecological psychology and information systems, and many categories have been derived, such as perceived affordance, true affordance (Norman, 2002), and technological affordance (Markus and Silver, 2008). In reference to IT functionalities, IT affordance presents the possibility that the technology subject could provide a specific user group with specific technical features to achieve their goals (Treem and Leonardi, 2013). For years, IT affordance has been increasingly used in explaining how users and IT artifacts relate to each other. The notion of IT affordance has slightly different nuanced meanings and its attributes can afford different possibilities for action across users and contexts (Dong and Wang, 2018). For example, scholars have classified social media affordances into four categories: visibility, persistence, editability, and relevance (Lin et al., 2013). Based on the new insights into social commerce, Dong and Wang (2018) divided IT affordance into six dimensions, namely visibility, guidance shopping, social connecting, trading, triggered attending, and metavoicing, to explore how these IT features make users achieve their social shopping goals.

Over the recent few years, the affordance term has been widely used in the study of social commerce. Some scholars have studied the relationship building between buyers and sellers from the perspective of IT affordance, and the research results show that the functions of social media greatly affect the formation of strong and weak relationships between buyers and sellers (Shao et al., 2020). Different from traditional e-commerce, social commerce often has a large number of information presentation methods, and the media richness of social commerce can often affect consumers' viewing intentions (Shao and Pan 2019). In recent years, how to combine the theory of affordances with emerging social business models, such as live streaming shopping, has also attracted much attention of many scholars to explore its underlying causal relationship. For example, Shao et al. (2020) constructed a theoretical model to explore how live streaming influences users' shopping intention by introducing three specific living streaming features (visibility, metavoicing, and guidance shopping) from the view of IT affordance. Based on the technology provided by the live streaming platform, users can watch the display of goods and interact with sellers, the interaction between buyers and sellers has also become an important aspect affecting consumers' behavior (Xu et al., 2020). Furthermore, Shao et al. (2020) explored the influence mechanism of user satisfaction and user stickiness in social networks from the perspective of technology affordance and revealed the moderating role of users' experience in this research model. By providing users with functions that meet their purchase needs, user satisfaction can be greatly improved. On the contrary, the absence of shopping platform functions will reduce users' participation, which could inhibit the potential for users' participation. Studies have shown that the IT affordances theory helps explain the technology use effects (Dong and Wang, 2020). The possibility of IT is providing users with a variety of possible purchase goals through specific technology affordances in a certain environment. That is, the more powerful live streaming shopping affordances are, the more active they will stimulate and enable users to engage in social commerce actions. Based on this, combined with the characteristics of live streaming shopping situations, this study explores the impact of visibility, real-time interaction, and guidance shopping on consumers' purchase intention from the perspective of the IT affordances theory. It also introduces the concept of media richness into the theory of availability; taking live streaming as a social environment, this study explores the impact of affordance in live streaming on consumers' purchase intention.

2.4. Socio-technical interaction perspective

In order to study the influence of technical and environmental characteristics on consumers' purchasing behavior in live streaming shopping, we introduce a

social-technology interaction perspective. Socio-technical interaction perspective holds that the system consists of two parts: social environment and technical characteristics (Wong et al., 2021). Social environment and technical characteristics are often known as mutual support and influence. First of all, from the perspective of technical characteristics, in the process of live streaming shopping, everything about shopping is supported by information technology (Leonardi, 2015). In other words, the live streaming shopping platform is a technology platform (Kong et al., 2019). Specifically, live streaming shopping is carried out with the support of information technology. The development of live streaming shopping business model is inseparable from the support of information technology (Gao et al., 2018). When people do live streaming shopping, the display of the product needs the support of visualization technology, consumer information acquisition needs big data and other technologies to achieve, and user feedback needs comments and other functions to achieve (Cherns, 1976). Second, from the perspective of the social environment, it represents the environment where the system users use and interact. In the context of live streaming shopping, the interaction between users and streamers constitutes the overall social environment. Users can also communicate with each other through bullet screens or comments. In measurement, generally through the degree of interaction, user satisfaction represents the user's perception of the environment (Chai and Kim, 2012). Some scholars have found that a person's perception of the social environment can greatly affect the type of behavior, including the adaptation or escape environment (Mehrabian and Russell, 1974). In the process of participating in live streaming, good interaction and communication can encourage users to continue watching. On the contrary, the lack of communication environment is often difficult to establish links between the streamers and users. In the context of live streaming shopping, the influence of the social environment on consumer behavior is significant. The interaction between consumers and the streamer in the process of live streaming shopping, as well as the atmosphere and environment of live streaming, will have an impact on consumers' purchase behavior (Adelaar et al., 2003). Finally, technology and social environment are interrelated and mutually influenced. In social business activities, technical support provides users with more choices of consumption patterns. The social environment also affects consumers' purchasing behavior. Technological factors are the antecedent variables that affect consumers to make purchase decisions. Social factors also affect consumers' behavior. The interaction of the two factors affects consumers' purchase behavior (Hu and Zhang, 2017). In the context of social commerce, users' behavior is affected by both social environment and technological characteristics. Most of the existing studies are from a single perspective and lack research on the interaction between technology and social factors. This study is conducted from a socio-technical perspective, choosing guidance shopping, visibility, and media richness to represent the technical factors of live streaming shopping. From the perspective of live streaming technology and social environment interaction, the concept of real-time interaction is introduced. This study hopes to supplement and improve the research on user behavior in live streaming shopping by analyzing the environmental and technical characteristics of live streaming shopping.

3. Theoretical model and hypothesis development

3.1. Interaction between live streaming technology functions and social situation

Live streaming shopping has changed the way of information exchange in online shopping. The application of live streaming technology combines social media functions with online shopping, and streamers and audiences can exchange information through real-time interaction (Wong et al., 2021). The audience can learn more about the product information. Meanwhile, this kind of chat-like interaction also brings consumers more fun and increases their love for the online shopping mode of live streaming shopping. In this study, we choose real-time interaction as the representative of live streaming technology and social situation interaction.

3.1.1. Real-time interaction, attraction, and cognitive assimilation

Real-time interaction refers to the possibility of timely information exchange between buyers and sellers (Sun et al., 2019). This kind of information exchange can largely eliminate consumers' uncertainty about live streaming shopping. It can also strengthen the construction of social relations between the two parties. Dong and Wang (2018) believes that interactivity has a significant moderating effect on the formation of strong and weak relationships between buyers and sellers in social purchase activities. Good interaction between buyers and sellers can enhance the strength of the relationship. In the live streaming environment, interaction is an important way of emotional connection between the audience and the streamer. When viewers interact with streamers and other viewers, they have a better impression of the live streaming (Chen and Lin, 2018). Real-time interaction is reflected in the instant communication between consumers and streamers through the barrage and comments. Interaction in social business activities can increase consumers' perception of the products. Some researchers divide the interaction in social commerce into two types. One type is product reputation and the other is to observe the purchase behavior of other consumers (Lv et al., 2018). Observation of other users' behaviors enables users to deepen their understanding of the product, and conformity often affects consumers' purchase choices. Live streaming provides support for these two forms of interaction. Consumers can answer their doubts by asking

questions to the streamer. The streamer can also understand customers' needs through friendly communication and interaction with the audience. Through real-time communication, the streamer can narrow the distance between the audience and provide customers with more shopping guidance (Yim et al., 2017). In the process of live streaming shopping, positive interaction can improve consumers' interest and recognition of live streaming shopping. Therefore, exploring the impact of real-time interaction on users' cognition and emotion can help us better understand consumer behavior in live streaming shopping activities. Based on the above viewpoints, we thus propose the following hypotheses:

> *H1a*: Real-time interactivity has a positive impact on attraction.
>
> *H1b*: Real-time interactivity has a positive impact on cognitive assimilation.

3.2. Live streaming as a technical platform

The mode of live broadcast shopping is realized with certain technical support. First, without the technology of information production and dissemination, such as live streaming, the audience would not be able to interact with the streamers or obtain product information through live streaming. Second, the streamers provide opinions on product selection through live streaming. The audience raises their questions and purchase demands through bullet screens, and the streamers provide answers and professional opinions through live streaming. Finally, live streaming shopping incorporates text, pictures, voice, video, and other social media information. Live streaming shopping not only realizes the function of online shopping but also realizes the function of social media. This study chooses visibility, guidance shopping, and media richness as the technical characteristics of live streaming shopping.

3.2.1. Guidance shopping and attraction, cognitive assimilation

Guidance shopping refers to the possibility of providing consumers with appropriate product choices or services based on their needs and preferences (Dong and Wang, 2018). In live streaming shopping, streamers can provide customers with personalized recommendations based on their actual needs and personal preferences, which helps to enhance the customer's cognitive experience and allows customers to immerse themselves in the consumption situation (Wang and Yu, 2017). Guidance shopping in live streaming shopping is mainly achieved through two ways: one is to provide product and service recommendations according to customers' consumption habits. Recommendation information provided in this way often lags behind in time and is increasingly unable to meet consumers' shopping needs. The other way is to provide consumers with shopping choices based on demand and interest through the introduction. The streamer understands the needs of consumers through real-time interaction with consumers. Guidance to consumers can increase consumers' perception of product information by recommending appropriate products to consumers, thereby increasing the social existence of consumers in live streaming shopping (Ou et al., 2014). By providing customers with shopping guidance to enhance consumers' stickiness in using live streaming shopping, consumers will be attracted by the product information in which they are interested. Guidance shopping is a comprehensive display of information exchange in live streaming shopping, which meets consumers' shopping needs through guidance shopping. Based on the above viewpoints, we thus propose the following hypotheses:

> *H2a*: Guidance shopping has a positive impact on attraction.
>
> *H2b*: Guidance shopping has a positive impact on cognitive assimilation.

3.2.2. Visibility and attraction, cognitive assimilation

Visibility is defined as the degree of information display about products, including text, pictures, videos, and other information visible to consumers (Dong and Wang, 2018). Consumers can get timely updated product information when they are in live streaming shopping. Consumers get information about products visually. Live streaming shopping is an all-round display of products based on the visualization of product information. Consumers can understand the use of products and see the use of the effect of products according to the presentation of the streamer. Visual information stimulation greatly reduces the uncertainty of consumers on products (Yim et al., 2017). Live streaming shopping focuses on providing consumers with a sense of reality in the product information display. In live streaming, the consumer can see the streamer throughout the whole process. As a real individual, the streamer enhances the social existence perceived by the consumer (Li, 2019). In the live streaming shopping process, consumers get a full display of product information, the two-dimensional information became a three-dimensional perception of the product (Sun et al., 2019). Based on the above viewpoints, we thus propose the following hypotheses:

> *H3a*: Visibility has a positive impact on attraction.
>
> *H3b*: Visibility has a positive impact on cognitive assimilation.

3.2.3. Media richness and attraction, cognitive assimilation

The concept of media richness originates from the theory of information richness theory, which is defined as the ability of information to change users' understanding and

communication through media communication (Daft and Lengel, 1986). Information is transmitted through media to provide users with perceptual cues. For example, in the live streaming shopping situation, consumers can get information through text, pictures, videos, live screens, and other ways to enrich their cognition. From the perspective of information dissemination, different media have different impacts on the dissemination ability of information. It is generally believed that face-to-face information dissemination is the most effective means of information dissemination because it allows rapid mutual feedback (Song et al., 2004). Shao et al. (2019) believes that in a social media interaction, social media richness will affect users' access to information and perception. Specifically, the media richness provides users with a richer social media experience, which will affect users' participation behavior. From the perspective of network media and information technology, the continuous updating of network media and the rapid development of information technology provides the possibility for multi-form media communication. The higher degree of media richness, the more information perception and media experience can be given to users. On the contrary, the low degree of media richness may not only produce the rapid dissemination of information but also affect the media experience of users (Tseng and Wei, 2020). Through the diversified media dissemination of the live streaming platform, users are given rich information perception from various aspects such as vision and hearing. Diversified information presentation will increase consumers' experience, reduce users' uncertainty due to insufficient information acquisition, and improve the attractiveness of rich media communication paths to consumers. According to the theory of media richness, people tend to choose media with higher media richness, which will also lead to more active social interaction and other participation behaviors (Anandarajan et al., 2010). Based on the above viewpoints, we thus propose the following hypotheses:

> *H4a*: Media richness has a positive impact on attraction.
>
> *H4b*: Media richness has a positive impact on cognitive assimilation.

3.3. Attraction, cognitive assimilation, and purchase intention

In the application of the socio-technical perspective, users' cognition, emotion, and behavior are the main research directions. Users' emotional tendencies and cognitive attitudes are the two main aspects affecting users' behavior (Leonardi, 2015). Users' perception of technology and social environment affects their own emotions and cognition, which is ultimately reflected in the guidance of users' behavior. In the live streaming shopping scene, attraction represents that the audience is willing to continue to watch the live streaming. Attraction can predict people's future attitudes and behaviors while making people have emotional tendencies (Shen et al., 2019). As an expression of emotional tendency, the attraction has been widely used in existing studies to represent emotional tendency (Wang and Han, 2021). In this study, attractiveness is taken as a variable representing consumers' emotional tendencies, which reflect the important influence of the attractiveness of live streaming shopping on consumers' purchasing behavior. Cognitive assimilation is used as the expression of cognitive attitude (Wang and Yu, 2017). Emotional tendency represents the user's emotional response; cognitive attitude is the embodiment of the user's self-perception (Adelaar et al., 2003). In live streaming shopping, cognitive assimilation represents the consumers' knowledge and understanding of products, which is another aspect that affects consumers' purchasing decisions. Therefore, this study chooses cognitive assimilation to represent consumers' cognitive attitudes. Based on the S-O-R model, stimulus to response is affected by the body state. This study argues that attraction and cognitive assimilation as internal organic states stimulate the generation of consumers' purchase intention.

Some scholars defined consumers' activities from three aspects: cognition, emotion, and behavior (Lv et al., 2018). Consumers access product information through a variety of media (Adelaar et al., 2003). In the context of live streaming shopping, consumers can access product and service information through text descriptions, pictures, and live streaming by streamers (Xu et al., 2020). In the context of live streaming shopping, consumers' purchase decisions are affected by technical factors and social factors. For example, when the audience is attracted by a live advertisement (text, picture) to start a live streaming shopping, the live audience becomes a potential consumer. After watching the live streaming, the live audience may purchase the live commodity for reasons such as actual demand or impulse consumption. In the whole process, the audience's subjective cognition will be affected by various media information, streamers, or other comments. At the same time, emotional tendencies affect consumers' subjective perception of goods, and positive emotional tendencies can make consumers more willing to accept product recommendations. Based on the above viewpoints, we thus propose the following hypotheses:

> *H5*: Attraction has a positive impact on purchase intention.
>
> *H6*: Cognitive assimilation has a positive impact on purchase intention.

3.4. Mediating effect of attraction and cognitive assimilation

Previous studies have found that technology and social factors have an impact on consumers' purchase intention, and this impact

is realized by attraction and cognitive assimilation (Xu et al., 2020). Attraction is the most critical factor to encourage consumers to buy. Attracting consumers' interest and curiosity in products through various ways is the basis to guide consumers to further understand products (Adelaar et al., 2003). Consumers' cognition of products is also a way to influence consumers' purchase intention. Cognitive assimilation changes consumers' attitudes toward products by influencing their perceptions of products (Lv et al., 2018).

In the context of live streaming shopping, the influence of technological factors and social factors on consumers' purchasing behavior is usually realized through attraction and cognitive assimilation (Xu et al., 2020). Attractiveness is the starting point of establishing the connection between buyers and sellers. In the process of live streaming shopping, the streamer attracts consumers' attention through technological and social factors and thus increasing the possibility of purchase. The process of users watching live streaming shopping is more about the formation of their cognition of the product. Through the introduction of streamers in live streaming, consumers will have a more profound and comprehensive cognition of the product. Influencing consumers' cognition of products through technological means and social interaction is also a way to influence consumers' purchase intention. Based on the above viewpoints, we thus propose the following hypotheses:

> *H7*: Attraction mediates the relationship between real-time interaction, guidance shopping, visibility, media richness, and purchase intention.
>
> *H8*: Cognitive assimilation mediates the relationship between real-time interaction, guidance shopping, visibility, media richness, and purchase intention.

In order to test the structural model and reduce the influence of non-study variables on the data analysis, our study included eight control variables. The control variables were gender, age, education background, monthly income, whether they knew about live streaming shopping, the time they used live streaming shopping, the number of times they used live streaming shopping, and the live streaming software they used.

In the context of live streaming shopping, technical factors have an impact on live streaming shopping behavior through information technology. Based on the stimulus-organism-response (S-O-R) framework, from the perspective of socio-technology interaction, we construct a theoretical model from three levels: live streaming as a technical platform, the interaction between live streaming technical function and social context, and live streaming as an online social environment. The technical factors mainly include visibility, guidance shopping, and media richness, and the social-technology interaction factors mainly include real-time interaction. The user's perceived attraction and cognitive assimilation are the internal organism state, and the purchase intention of live streaming is the response. Figure 1. shows the relationship between the variables involved in this study.

4. Research methodology and date analysis

4.1. Research method

This study mainly adopts a survey for data collection. In order to ensure the content validity and measurement validity of constructs, the measurement items of this study are all adapted from the existing literature. By combining the situation of live streaming shopping, we designed a questionnaire that fits our study. In this study, we use a seven-point Likert Scale to measure the focus constructs. This study involved seven constructs. The measurement items of real-time interaction (RI), visibility (VI), purchase intention (PI), and guidance shopping (GS) were adapted from Dong and Wang (2018). The item of media richness (MR) was adapted from Shao and Pan (2019). Attraction (AT) and Cognitive assimilation (CA) were measured by items adapted from Xu et al. (2020). In order to get valid questionnaires, our study designed reverse items to ensure the effectiveness of the questionnaire. In order to ensure the accuracy of the questionnaire items, we did a pre-test experiment. We randomly invited 20 survey subjects who had participated in live streaming shopping for a test and modified the scale according to the test results to ensure the accuracy of the questionnaire scale. The measurement items involved in the questionnaire scale are shown in Appendix A.

When collecting survey data, we published the questionnaire on China's largest questionnaire platform "Sojump" and spread the link through the social platforms WeChat and QQ. We prepared random lucky money for the respondents to encourage them to engage. A total of 425 questionnaires were collected from 9 April 2021 to 25 May 2021. In addition, we set the screening question "Have you ever had a live streaming shopping experience" to screen the survey subjects. A total number of 223 valid questionnaires were obtained after excluding invalid questionnaires. The descriptive statistics of the sample are shown in Table 2. It can be seen from Table 2 that most of the respondents are female users (68.6%). Most respondents were in their 20 and 30 s. Most of them have known about live streaming shopping (88.8%). The commonly used platforms for live streaming shopping are Tao bao live streaming (68.6%) and Dou Yin live streaming (54.3%). Characteristics of users are consistent with the research situation of live streaming shopping.

4.2. Data analysis method

The selection of data analysis methods has an important impact on the reliability of research results. Because the measurement items used in this study are mostly from the

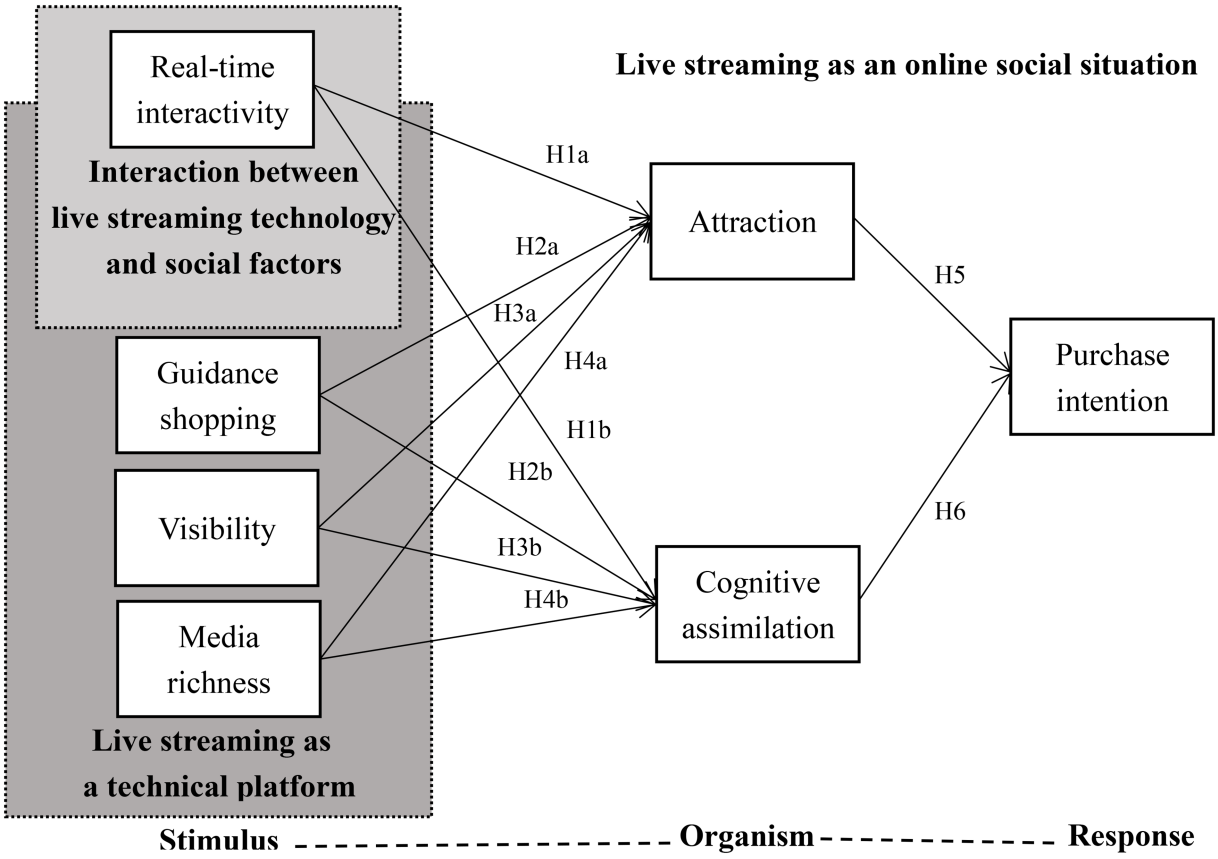


FIGURE 1
Research model.

existing literature. Due to the different research situations, it is necessary to ensure the effectiveness of the measurement items used in the live streaming situation concerned in our study. Therefore, this study first used SPSS25.0 software for exploratory factor analysis, deleted invalid load factor items (including error factor load and double factor load), and finally got the formal scale used in this study (see Appendix A; Chin, 1998). In the part of the structural model test, our study uses Amos25.0 software for confirmatory factor analysis. Through confirmatory factor analysis, the reliability and effectiveness of the structural model and the path coefficient between relevant factor variables can be effectively tested (Gefen et al., 2000a,b).

4.2.1. Measurement model

In order to ensure that the measurement model can properly reflect the observed variables in this study, exploratory factor analysis was used to evaluate the validity and reliability. The main parameters include Cronbach's α and composite reliability (CR; Bagozzi and Yi, 1988). The values of Cronbach's α and CR of all variables should be >0.7, which indicates that the construct has good reliability. All the variables measured in our study are greater than the threshold of 0.7. This shows that our research data have good reliability. The results are shown in Table 3.

The convergent validity of variables is evaluated by testing factor loading and average variance extracted (AVE; Chin et al., 2003). The factor loading values of all variables were higher than 0.7, and all AVE values were higher than 0.5, which indicates that the measurement model had good aggregation validity. The factor loading values of all variables involved in the measurement model were higher than 0.5, and the AVE values were about 0.5. In the evaluation of the discriminant validity of each variable in the measurement model, our study uses the cross-load coefficient of the measurement index Fornell Larcker criterion to compare and analyze whether the square root of each variable AVE is greater than the correlation coefficient between the variable and other variables (Hair et al., 2014). Through testing, the factor-load coefficients of all the measurement indicators used in our study and their corresponding variables are significantly higher than those of the indicators and other variables. At the same time, the square root of the AVE value of each variable is greater than the correlation coefficient between the variable and other variables. The results are shown in Tables 4, 5.

TABLE 2 Sample characteristics description.

Demographic variable	Category	Frequency	Percentage (%)
Sexuality	Man	70	31.4%
	Women	153	68.6%
Age	<20	47	21.2%
	20–30	131	58.7%
	30–40	33	14.8%
	40–50	11	4.9%
	>50	1	0.4%
Education	Senior high school	17	7.6%
	Junior college	19	8.5%
	Bachelor	145	65.0%
	Masters	33	14.8%
	PhD	9	4.0%
Live streaming shopping experience	3 months or less	81	36.3%
	4–6 months	35	15.7%
	7–12 months	15	6.7%
	1–2 years	68	30.5%
	2 years or more	24	10.8%
Monthly income (¥)	<2,000	107	48.0%
	2,000–5,000	53	23.8%
	5,000–8,000	33	14.8%
	>8,000	30	13.5%
Number of live streaming shopping per month	0	72	32.3%
	1–3	82	36.8%
	3–5	24	10.8%
	5–7	29	13.0%
	>7	16	7.2%
Used live streaming shopping software	Taobao	153	68.6%
	WeChat	30	13.5%
	Tik Tok	121	54.3%
	Kwai	60	26.9%
	Others	37	16.6%

4.2.2. Common method bias

Common method bias refers to the artificial covariation between predictor and outcome variables caused by the same data source or raters, the same measurement environment, the context of the survey variable, and the variable itself (Podsakoff et al., 2003). This study reduces the generation of common method bias from two aspects: program control and statistical test. First, from the aspect of program control, at the beginning of the questionnaire design, it is necessary to consider reducing the common method deviation. In the process of a questionnaire survey, anonymous evaluation is adopted. The length of the problem and the order of the problem are set reasonably. Second, our study tests the common method bias in the measurement model from the perspective of statistics. Our study first uses the Harman single factor test method to evaluate the influence of common method bias by calculating the maximum variance interpretation rate of a single factor in the model (Podsakoff et al., 2003). The results show that the maximum variance interpretation rate of the single factor in the model is 31.33%, which does not account for the majority of the total variance. Therefore, the common method bias has no significant influence on the measurement model of this study. Finally, this study examines whether there is a common method bias in the model by confirmatory factor analysis (Wen and Dandan, 2018). A latent variable with common method deviation was added to the structural equation model, and the adaptation index of the original model and the structural model with the latent variable was compared. The test results showed that the change of RMSEA did not exceed 0.05, and the change of CFI and IFI did not exceed 0.1. The results are shown in Table 6, indicating that there was no obvious common method deviation in the measurement model of this study.

4.2.3. Structural model

In our study, Amos25.0 software was used to analyze the structural model. The data were analyzed to test the significance of the relationship between measurement variables and the fitting index of the model. The specific analysis results are shown in Table 7. According to the fitness index of the model, it can be seen that the value of the variable correlation index used in our study is within the recommended value range, so the model in this study has a good fitting degree. The explicitness of the relationship between variables is shown in Figure 2. R^2 represents the extent to which structural models account for variations in variables (Gefen et al., 2000a). It can be seen from the values in the figure that the R^2 value of the entire model is 0.3, indicating that this model explains 30% of the variation in consumers' purchase intention. The R^2 value of attraction is 0.34, and the R^2 value of cognitive assimilation is 0.36, indicating that the four variables of visibility, real-time interaction, guidance shopping, and media richness have strong explanatory power for attraction and cognitive assimilation.

From the above analysis, it can be seen that the path coefficient of real-time interaction on attraction is 0.188 ($p < 0.1$), indicating that real-time interaction has a positive impact on attraction. The hypothesis of H1a is supported. The path influence coefficient of real-time interaction on cognitive assimilation is −0.015 ($p > 0.1$), indicating that the influence of real-time interaction on cognitive assimilation is not significant, and that hypothesis of H1b is not supported. The path coefficients of guidance shopping on attraction and cognitive assimilation were 0.061 ($p > 0.1$) and 0.121

10.3389/fpsyg.2022.1082981

TABLE 3 Reliability and validity analysis of construct.

Construct	Indicator	Substantive factor loading	Cronbach's α	CR	AVE
Real-time interaction	RI1	0.554	0.785	0.784	0.500
	RI2	0.739			
	RI3	0.718			
	RI4	0.739			
Guidance shopping	GS1	0.684	0.816	0.828	0.547
	GS2	0.738			
	GS3	0.762			
	GS4	0.772			
Visibility	VI1	0.729	0.795	0.815	0.527
	VI2	0.786			
	VI3	0.790			
	VI4	0.580			
Media richness	MR1	0.710	0.711	0.742	0.500
	MR2	0.781			
	MR3	0.603			
Attraction	AT1	0.683	0.809	0.805	0.514
	AT2	0.775			
	AT3	0.830			
	AT4	0.548			
Cognitive assimilation	CA1	0.724	0.800	0.807	0.514
	CA2	0.775			
	CA3	0.780			
	CA4	0.568			
Purchase intention	PI1	0.677	0.824	0.817	0.599
	PI2	0.843			
	PI3	0.793			

($p < 0.05$), respectively. The results indicate that guidance shopping had no significant effect on attraction, and the conclusion did not support the hypothesis of H2a. It also shows that guidance shopping has a significant effect on cognitive assimilation, which supports the hypothesis of H2b. The effect of visibility on attraction was not significant ($\beta = 0.101$, $p > 0.1$). Visibility had a significant effect on cognitive assimilation ($\beta = 0.189$, $p < 0.05$). It can be seen that visibility has no positive effect on attraction, hypothesis H3a is not supported. Visibility has a positive effect on cognitive assimilation, hypothesis H3b is supported. The path influence coefficients of media richness on attractiveness and cognitive assimilation are 0.401 ($p < 0.05$) and 0.373 ($p < 0.05$), indicating that media richness has a significantly positive impact on the attractiveness and cognitive assimilation. Hypotheses H4a and H4b are supported.

In the relationship between attraction and consumers' purchase intention, the path coefficient of attraction to consumers' purchase intention is 0.648 ($p < 0.001$), which indicates that attraction has a significant positive impact on consumers' purchase intention, and hypothesis H5 is supported. The path coefficient of cognitive assimilation on consumers' purchase intention was 0.301 ($p < 0.05$), which indicated that cognitive assimilation had a positive effect on consumers' purchase intention, hypothesis H6 is supported. The influence of attraction and cognitive assimilation on purchase intention is significant, and the results of statistical analysis are shown in Table 8. By comparing the effects of attraction and cognitive assimilation on purchase intention, we found that attraction has a more significant impact on consumers' purchase intention.

In this study, process plug-in in SPSS was used to test the mediating effect of the structural equation model within a 95% confidence interval as shown in Table 9.

The indirect effects of real-time interaction, guidance shopping, visibility, and media richness on consumers' purchase intention through attraction and cognitive assimilation are not

TABLE 4 Cross-factor loading analysis.

Construct	RI	GS	VI	MR	AT	CA	PI
RI1	0.751	0.423	0.271	0.247	0.372	0.195	0.366
RI2	0.802	0.371	0.401	0.372	0.362	0.321	0.349
RI3	0.806	0.450	0.394	0.410	0.282	0.226	0.272
RI4	0.767	0.444	0.298	0.288	0.275	0.218	0.251
GS1	0.476	0.794	0.203	0.328	0.282	0.222	0.234
GS2	0.429	0.769	0.330	0.373	0.267	0.334	0.300
GS3	0.381	0.806	0.307	0.356	0.240	0.340	0.288
GS4	0.449	0.851	0.346	0.418	0.308	0.297	0.291
VI1	0.272	0.258	0.782	0.364	0.267	0.383	0.213
VI2	0.332	0.313	0.823	0.405	0.340	0.317	0.281
VI3	0.342	0.220	0.815	0.307	0.225	0.264	0.218
VI4	0.424	0.351	0.733	0.278	0.247	0.306	0.329
MR1	0.378	0.391	0.453	0.832	0.319	0.367	0.320
MR2	0.334	0.353	0.310	0.842	0.287	0.215	0.333
MR3	0.285	0.350	0.262	0.710	0.351	0.373	0.224
AT1	0.314	0.182	0.266	0.283	0.763	0.390	0.381
AT2	0.367	0.327	0.305	0.402	0.832	0.365	0.393
AT3	0.319	0.313	0.280	0.319	0.867	0.420	0.343
AT4	0.325	0.261	0.240	0.249	0.725	0.387	0.375
CA1	0.264	0.299	0.348	0.362	0.458	0.812	0.277
CA2	0.131	0.241	0.268	0.280	0.351	0.806	0.211
CA3	0.240	0.229	0.301	0.266	0.357	0.802	0.247
CA4	0.342	0.386	0.364	0.326	0.382	0.742	0.306
PI1	0.394	0.322	0.362	0.337	0.437	0.362	0.828
PI2	0.325	0.261	0.308	0.293	0.379	0.237	0.898
PI3	0.323	0.309	0.194	0.336	0.402	0.264	0.857

RI, Real-time interaction; GS, Guidance shopping; VI, Visibility; MR, Media richness; AT, Attraction; CA, Cognitive assimilation; PI, Purchase intention.

included in the 95% confidence interval, which indicates that there is a significant mediating effect in the structural model. Hypotheses H7 and H8 are supported.

In order to test whether attraction and cognitive assimilation play a partial mediation effect or a complete mediation effect, our study uses Baron and Kenny (1986) method to test the relationship between independent variables and dependent variables in the presence of intermediary variables. First, by examining the relationship between independent variables and mediating variables, we found that real-time interaction, guidance shopping, visibility, and media richness have significant effects on attraction and cognitive assimilation. Second, when there is no intermediary variable, the effect value of the independent variable on the intermediary variable, the effect between the real-time interaction, guidance shopping, visibility, media richness, and purchase intention are significant. Finally, with the addition of the mediating variables, attraction and cognitive assimilation, the effect values of real-time interaction, guidance shopping, visibility, and media richness on purchase intention are significantly reduced, indicating that attraction and cognitive assimilation play a partial mediating role between real-time interaction, guidance shopping, visibility, media richness, and consumers' purchase intention. The test results are shown in Table 10.

TABLE 5 Correlation coefficients between variables.

	RI	GS	VI	MR	AT	CA	PI
RI	0.692						
GS	0.540	0.740					
VI	0.435	0.363	0.726				
MR	0.418	0.456	0.430	0.702			
AT	0.416	0.341	0.342	0.395	0.717		
CA	0.307	0.365	0.404	0.390	0.489	0.717	
PI	0.399	0.342	0.331	0.371	0.168	0.328	0.774

Diagonal bold value is the square root of the AVE value of each variable.

TABLE 6 Common method deviation test.

	GFI	AGFI	RMSEA	IFI	CFI
Original model	0.863	0.831	0.055	0.919	0.917
Model after adding common method factor	0.891	0.850	0.045	0.951	0.949

TABLE 7 Structural model adaptation index.

Adaptation indicators	Recommended values	Fitting values
λ^2	The smaller the better	474.883
λ^2/df	<3.000	1.678
GFI	>0.800	0.863
AGFI	>0.800	0.835
RMSEA	<0.080	0.055
NNFI	>0.800	0.820
IFI	>0.900	0.919
CFI	>0.900	0.917

5. Discussion

5.1. Research conclusions

From the perspective of socio-technical, this study establishes a theoretical model and conducts empirical tests to explore the influence of social and technological factors on consumers'

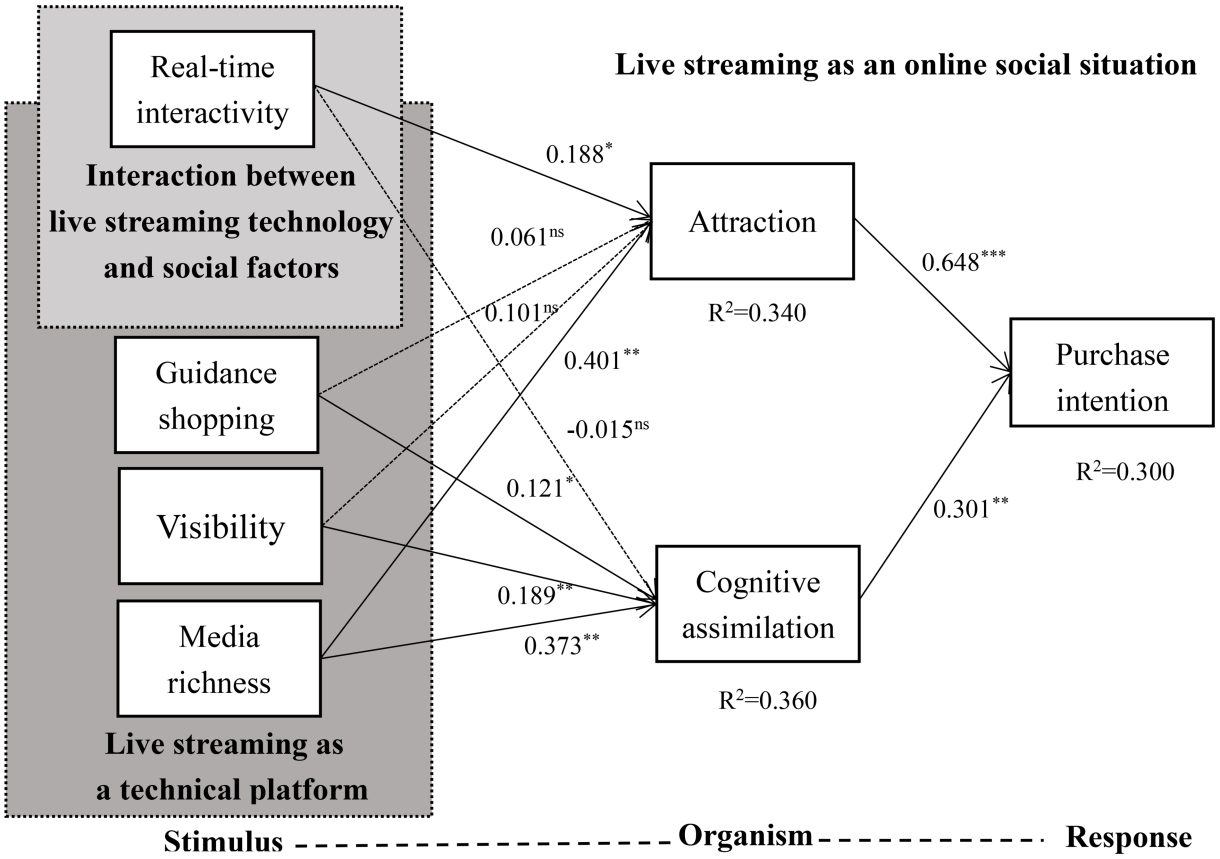


FIGURE 2
Model test results. ***p<0.001; **p<0.05; *p<0.1; ns p>0.1; Solid arrows represent significant influence; dotted arrows represent insignificant influence.

TABLE 8 Significance test of mediating variable to the dependent variable.

	PI		
	β	t	Value of p
AF	0.520	5.958***	0.000
CA	0.186	1.932***	0.000
F		33.183***	

AT, Attraction; CA, Cognitive assimilation; PI, Purchase intention.
*** means the t-value is significant.

purchase intention in live streaming shopping. Through testing the research hypothesis, we got a relevant conclusion.

First, real-time interaction has a positive impact on attractiveness but has no significant impact on cognitive assimilation. Real-time interaction is an effective way to establish an emotional connection between buyers and sellers. At the same time, real-time interaction can strength the relationship between buyers and sellers. In the live streaming situation, the good interaction between the streamer and the audience is an effective way to enhance the attraction of live streaming shopping to consumers. The streamer reduces the consumers' strangeness through self-introduction and product display; it can also close the psychological distance between them. The social connection between buyers and sellers through real-time interaction is a kind of emotional connection between the two sides, which is more stable and reliable than an ordinary business relationship. This study analyzes the particularity of live streaming shopping mode. Our research finds that the product information presented in the form of live streaming can attract consumers' attention. In live streaming shopping, the impact of real-time interaction on cognitive assimilation is not significant. We believed that there are several possible reasons for this. First, in live streaming shopping, consumers will interact with other viewers while interacting with streamers, and information from different sources may produce conflict; the amount of information available in a short period of time can create cognitive difficulties for consumers, which will confuse consumers' cognition (Xu et al., 2020). Second, in live streaming shopping, streamers often introduce multiple products in a short time, and the product information provided by streamers varies for different goods. When the product information introduced by streamers to consumers is not comprehensive enough and the streamers fail to solve the wonders of consumers through

interaction, it is not easy for consumers to have cognitive assimilation, but it needs time.

Second, guidance shopping has a positive effect on cognitive assimilation but has no significant effect on attractiveness. Guidance shopping is an important factor in the theory of IT affordance. From the perspective of IT affordance, guidance shopping is to provide consumers with personalized product recommendations according to consumers' needs and preferences for products. The two sides solve the problems generated by consumers in the shopping process through further exchanges, so as to better meet their needs. In the process of providing shopping guidance to consumers, the relationship between streamer and audience is more closely. From the perspective of products, the reason why consumers choose live streaming shopping is largely due to their own needs. Before making shopping choices, consumers often have a subjective judgment on whether the product is suitable for them. The director's shopping guidance only makes consumers clear about their shopping choices, which explains the reason why guidance shopping has no obvious influence on attraction.

Third, visibility has a significant positive impact on cognitive assimilation but has no significant impact on attraction. Visibility is one of the relevant technical characteristics in the field of social commerce. From the perspective of social commerce, visual perception is the most direct way for consumers to obtain goods or service information. Consumers produce direct impressions of the product through the information they see. The product information provided by visibility for consumers can effectively reduce consumers' perceived risk and uncertainty of products (Dong and Wang, 2018). In the live streaming environment, consumers can obtain a lot of product information through live streaming. For example, consumers can only see the effect of products through pictures and videos before. However, in live streaming shopping, the streamer can provide consumers with a live display of product effects according to the specific situation of consumers. Consumers will process and organize the contents they see so as to deepen their own cognition or correct their previous perception. Compared with the positive effect of visibility on cognitive assimilation, the impact of visibility on attractiveness is not significant in the live streaming shopping context (Sun et al. 2019). In the previous online shopping process, consumers can only understand the product information through pictures, text introductions, and other ways. Whether it is from the perspective of the seller or the perspective of the buyer, due to the limitations of information dissemination, the content and volume of information are very limited, and consumers can quickly complete the acquisition and processing of commodity information. In the network of live streaming, due to the change in the way of information dissemination, the main content to the audience is often the display of dynamic effects. The audience needs to spend a certain amount of time and energy to collect information about commodities, which undoubtedly increases the difficulty of consumers in obtaining commodity information, resulting in the dispersion of consumer attention. It is difficult to attract consumers' attention the first time.

Fourth, media richness has a significantly positive impact on attractiveness and cognitive assimilation. In the live streaming situation, both businesses and consumers have rich media information expression. The streamer can introduce product information through text, pictures, and live streaming videos. The audience can also express their ideas through rich media (Shao et al., 2020). Media richness is a technical feature that online live streaming shopping is more characteristic of other e-commerce models. Live streaming integrates all media information expressions, providing consumers with richer sources of information and facilitating communication between streamers and customers. Diversified media information expression can satisfy consumers' curiosity, eliminate uncertainty, and increase the attraction of live streaming shopping to consumers. More

TABLE 9 Mediating effect test results.

	Effect size	Boot SE	Boot LLcl	Boot ULcl
RI → AF → PI	0.198	0.047	0.120	0.307
RI → CA → PI	0.091	0.046	0.023	0.208
GS → AF → PI	0.172	0.042	0.102	0.266
GS → CA → PI	0.109	0.049	0.035	0.228
VI → AF → PI	0.175	0.045	0.097	0.270
VI → CA → PI	0.120	0.048	0.040	0.237
MR → AF → PI	0.201	0.049	0.120	0.308
MR → CA → PI	0.113	0.046	0.034	0.217

TABLE 10 Partial mediation effect and complete mediation effect test results.

	AF effect	CA effect	PI (no mediation) effect	PI (mediation) effect	*t*
RI	0.421	0.282	0.307	0.214	3.691***
GS	0.336	0.326	0.239	0.195	0.959**
VI	0.338	0.363	0.256	0.202	2.658**
MR	0.411	0.369	0.271	0.226	3.111**

*** means the *t*-value is significant.

information acquisition means that consumers can form their own cognition of products more quickly and comprehensively, which also helps to increase consumers' understanding of products.

Fifth, attraction and cognitive assimilation have a positive impact on consumers' purchase intention. Attraction is the highlight of live streaming shopping compared with other social business models. Due to its more entertaining nature, live streaming shopping meets consumers' shopping needs and their own entertainment needs, which will bring more satisfaction to consumers. Meanwhile, the emotional connection based on interaction is often more solid than the single communication based on text, which can provide consumers with a sense of social existence. Online live streaming eliminates consumers' uncertainty in the shopping process through more abundant product information displays. It also urges consumers' cognition of products more comprehensive. This cognition is produced after consumers watch live streaming shopping. In terms of time, it is subjective cognition that can most affect consumers' purchase intention. The survey results show that consumers' own cognitive assimilation is an important prerequisite for influencing consumers' behavior. Cognitive assimilation based on information acquisition will affect consumers' subsequent social sharing and have an important impact on their willingness to consume.

Finally, attraction and cognitive assimilation mediate the relationship between visibility, media richness, guidance shopping, real-time interaction, and consumer purchase intention. Attraction and cognitive assimilation can affect the impact of social and technical factors on consumer purchase intention. Technical factors and social factors in live streaming shopping are the direct factors affecting consumers' purchase intention, which are realized by attraction and cognitive assimilation. Live streaming shopping mode attracts the attention of consumers with its own characteristics. Consumers form their own cognition through the acquisition of live streaming shopping information. This cognition is largely affected by technical factors and social factors in live streaming shopping mode. Attraction and cognitive assimilation change the influence of social and technical factors on consumers' purchase intention to some extent.

5.2. Theoretical implications

The theoretical contributions of this research mainly focus on the following aspects.

First, from the perspective of socio-technical interaction, this study discusses the factors that affect consumers' purchase intention in live streaming shopping. Although there have been studies from a technical point of view to explore the technical characteristics of live streaming shopping on the impact of consumer purchase intention, there has been a lack of research on the social characteristics of live streaming shopping (Li et al., 2021). Most of the research focuses on social characteristics the impact of trust, and perceived risk on consumer purchase behavior (Xu et al., 2020). There is a lack of theoretical integration between technical and social perspectives. Based on the practice of live streaming situations, this study explores the interactive logic of socio-technical interaction from three levels: live streaming as a technical platform, the interaction between live streaming technical functions and social situations, and live streaming as an online social situation. It further details and reveals the impact of social and technical factors on purchase decisions in the process of live streaming shopping. The technical factors and social factors of live streaming shopping are equally important. They influence and support each other and together constitute the environment of live streaming shopping. The discussion on the application of the socio-technical perspective in this study enriches the related research on consumer behavior, providing a theoretical reference for the subsequent research on consumer purchase behavior in live streaming shopping.

Second, this study introduces consumer emotion into the study of consumer behavior and confirms that the emotional attitude of consumers in the process of live streaming shopping will greatly affect their final purchase decision. Although there have been studies on the factors affecting consumers' behavior from many aspects, there is a lack of discussion on the influence of emotional tendencies on consumer decision-making (Kong et al., 2019). In the new e-commerce format, consumers are increasingly inclined to choose the emotional connection established by the buyers and sellers as the basis for their shopping choices. In the live streaming situation, the emotional connection between the streamer and the audience will directly affect the emotional tendency of consumers.

Third, this study expands the theoretical application of technology affordance theory in live streaming shopping situations. Although previous studies have researched the impact of IT affordance theory on consumer purchase behavior, with the support of information network technology, the new social commerce model has solved many problems that cannot be solved before (Sun et al. 2019). In the scene of live streaming shopping, the introduction of IT affordance theory can well explain the influence of technology factors on consumer behavior. Meanwhile, our study also introduces the concept of media richness into the IT affordance theory, reflecting the rich application of information technology means in the live streaming scene, and enriches the research of IT affordance theory in the scene of live streaming shopping.

At the same time, based on the theory of IT affordance, this study also discusses the interaction between technical functions and social emotions in the live streaming scene and further refines the theoretical research on live streaming shopping.

5.3. Practical implications

Through the discussion of the research results, the practical implications of this study mainly concentrate on the following aspects. First, this study helps enterprises to understand the relationship between social and technical characteristics in live streaming shopping scenes. For example, in terms of consumer perception, the richer product information is expressed, the more consumer uncertainty is eliminated (Gefen and Straub, 2004). When displaying commodities, the live streaming shopping platform should fully display commodity information as much as possible, which includes various attributes of commodities, use effect, and related after-sales service. Only sufficient details can meet consumers' demand for product understanding. Live streaming shopping is a hot spot in current mobile social commerce. In order to attract consumers' attention, interesting things must be displayed in the live scene. How to fully display the production to consumers is a little inspiration that this study wants to bring to relevant enterprises.

Second, the research results help enterprises to better apply live streaming technology and expand the channels of product promotion. The great enrichment of material living standards has changed people's purely demand-oriented shopping style. In social business activities, people pay more attention to the experience in specific scenarios. Enterprises involved in online shopping should shift their focus from "traffic" to "context" to meet the needs of consumers and create a more diversified live streaming shopping scene. As one of the marketing scenarios, live streaming can quickly attract consumers' attention. How to create content product information around consumers' psychology, fully connect with consumers' values and create live streaming content according to consumers' value needs is very important for product marketing of enterprises.

5.4. Limitations and future research

The research of this study has the following limitations: First, the respondents in this study are people with the live streaming shopping experience and there is a lack of surveys on users who use other online shopping models. Whether the survey conclusion is applicable to consumers of other new online business models needs further demonstration. Second, due to the complexity of the live streaming shopping environment and the diversity of participants, consumers' purchase intention cannot completely represent their final purchase behavior. Therefore, longitudinal studies on consumer behavior at different time periods can be added to future research, in order to have a clearer understanding of consumer behavior. Finally, streamers are also important factors affecting consumers' purchasing behaviors in live streaming shopping. Their professional and trustworthy characteristics may affect consumers' final purchasing decisions. Future studies can start with various subjects participating in live streaming shopping to study the influence of the characteristics of different subjects on consumers' purchasing behaviors.

6. Conclusion

From the perspective of socio-technical interaction, this study explores the technical and social factors that affect consumers' purchase intention in live streaming shopping scenes. Through the study, we found that technical factors and social factors do not affect consumer purchase intention alone. Under the interaction of technical and social factors, the characteristic factors in live streaming shopping will affect consumers' shopping choices. This study not only expands the theoretical research on consumer behavior in the context of live streaming shopping but also provides practical guidance for enterprises to better apply live streaming technology for product marketing.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

XD: conceptualization, theoretical foundation, and investigation. XL: methodology and writing. XX: writing. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by the grants from the National Natural Science Foundation of China 71902158, 72272122, 71972061, and 72172043. This work was supported in part by the Guangdong Basic and Applied Basic Research Foundation under grant 2019A1515110992.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adelaar, T., Chang, S., Lancendorfer, K. M., Lee, B., and Morimoto, M. (2003). Effects of media formats on emotions and impulse buying intent. *J. Inf. Technol.* 18, 247–266. doi: 10.1080/0268396032000150799

Anandarajan, M., Zaman, M., Dai, Q., and Arinze, B. (2010). Generation Y adoption of instant messaging: an examination of the impact of social usefulness and media richness on use richness. *IEEE Trans. Prof. Commun.* 53, 132–143. doi: 10.1109/TPC.2010.2046082

Bagozzi, R. P., and Yi, Y. (1988). On the evaluation of structural equation models. *J. Acad. Mark. Sci.* 16, 74–94.

Baron, R. M., and Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* 51, 1173–1182. doi: 10.1037/0022-3514.51.6.1173

Busalim, A. H., and Hussin, A. R. C. (2016). Understanding social commerce: a systematic literature review and directions for further research. *Int. J. Inf. Manag.* 36, 1075–1088. doi: 10.1016/j.ijinfomgt.2016.06.005

Chai, S., and Kim, M. (2012). A socio-technical approach to knowledge contribution behavior: an empirical investigation of social networking sites users. *Int. J. Inf. Manag.* 32, 118–126. doi: 10.1016/j.ijinfomgt.2011.07.004

Chan, T., Cheung, C., and Lee, Z. (2017). The state of online impulse-buying research: a literature analysis. *Inf. Manag.* 54, 204–217. doi: 10.1016/j.im.2016.06.001

Chen, C.-C., and Lin, Y.-C. (2018). What drives live-stream usage intention? The perspectives of flow, entertainment, social interaction, and endorsement. *Telematics Inform.* 35, 293–303. doi: 10.1016/j.tele.2017.12.003

Cherns, A. (1976). The principles of sociotechnical design. *Hum. Relat.* 29, 783–792. doi: 10.1177/001872677602900806

Chin, W. W. (1998). Commentary issues and opinion on structural equation Modeling. *MIS Q.* 22, 522–526.

Chin, W. W., Barbara Marcolin, L., and Peter Newsted, R. (2003). A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Inf. Syst. Res.* 14, 189–217. doi: 10.1287/isre.14.2.189.16018

China Internet Network Information Center (CNNIC) (2021). The 47th Statistical Report on Internet Development in China.

Daft, R. L., and Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Manage. Sci.* 32, 554–571.

Dong, X., and Wang, T. (2018). Social tie formation in Chinese online social commerce: the role of IT affordances. *Int. J. Inf. Manag.* 42, 49–64. doi: 10.1016/j.ijinfomgt.2018.06.002

Dong, X., and Wang, T. (2020). Technical feature, social tie structure and social commerce purchase behavior. *J. Manage. Sci.* 23, 94–115. (in Chinese)

Donovan, R. (1994). Store atmosphere and purchasing behavior. *J. Retail.* 70, 283–294. doi: 10.1016/0022-4359(94)90037-X

Floh, A., and Madlberger, M. (2013). The role of atmospheric cues in online impulse-buying behavior. *Electron. Commer. Res. Appl.* 12, 425–439. doi: 10.1016/j.elerap.2013.06.001

Gao, W., Liu, Y., Liu, Z., and Li, J. (2018). How does presence influence purchase intention in online shopping markets? An explanation based on self-determination theory. *Behav. Inf. Technol.* 37, 786–799. doi: 10.1080/0144929X.2018.1484514

Gefen, D., and Straub, D. W. (2004). Consumer trust in B2C e-commerce and the importance of social presence: experiments in e-products and e-services. *Omega* 32, 407–424. doi: 10.1016/j.omega.2004.01.006

Gefen, D., Straub, D., and Boudreau, M. C. (2000b). Structural equation modeling and regression: guidelines for research practice. *Commun. Assoc. Inf. Syst.* 4:7. doi: 10.17705/1CAIS.00407

Gefen, D., Straub, D. W., Boudreau, M.-C., Gefen, D., Straub, D. W., and Boudreau, M. (2000a). Structural equation Modeling and regression: guidelines for research practice. *Commun. AIS* 4:7. doi: 10.17705/1CAIS.00407

Gibson, J. J. (1978). The ecological approach to the visual perception of pictures. *Leonardo* 11, 227–235. doi: 10.2307/1574154

Gong, H., Zhao, M., Ren, J., and Hao, Z. (2022). Live streaming strategy under multi-channel sales of the online retailer. *Electron. Commer. Res. Appl.* 55:101184. doi: 10.1016/j.elerap.2022.101184

Guo, L., Hu, X., Lu, J., and Ma, L. (2021). Effects of customer trust on engagement in live streaming commerce: mediating role of swift guanxi. *Internet Res.* 31, 1718–1744.

Hair Jr, F. J., Sarstedt, M., Hopkins, L., and Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM). *Eur. Bus. Rev.* 26, 106–121. doi: 10.1108/EBR-10-2013-0128

Hu, M., and Zhang, M. (2017). Why do audiences choose to keep watching on live video streaming platforms? An explanation of dual identification framework. *Comput. Hum. Behav.* 75, 594–606. doi: 10.1016/j.chb.2017.06.006

Kong, Y., Wang, Y., Hajli, S., and Featherman, M. (2019). In sharing economy we trust: examining the effect of social and technical enablers on millennials' Trust in Sharing Commerce. *Comput. Hum. Behav.* 17:105993

Leonardi, P. M. (2011). When flexible routines meet flexible technologies: affordance, constraint, and the imbrication of human and material agencies. *MIS Q.* 35, 147–167. doi: 10.2307/23043493

Leonardi, P. M. (2015). Ambient awareness and knowledge acquisition: using social media to learn "who knows what" and "who knows whom". *MIS Q.* 39, 747–762. doi: 10.25300/MISQ/2015/39.4.1

Li, C. Y. (2019). How social commerce constructs influence customers' social shopping intention? An empirical study of a social commerce website. *Technol. Forecast. Soc. Chang.* 144, 282–294. doi: 10.1016/j.techfore.2017.11.026

Li, Y., Li, X., and Cai, J. (2021). How attachment affects user stickiness on live streaming platforms: a socio-technical approach perspective. *J. Retail. Consum. Serv.* 60:102478. doi: 10.1016/j.jretconser.2021.102478

Li, X., Liao, Q., Luo, X., and Wang, Y. (2020). Juxtaposing impacts of social media interaction experiences on E-commerce reputation. *J. Electron. Commer. Res.* 21, 75–95.

Lim, J., and Ayyagari, R. (2018). Investigating the determinants of telepresence in the e-commerce setting. *Comput. Hum. Behav.* 85, 360–371. doi: 10.1016/j.chb.2018.04.024

Lin, T.-C., Shih-Chieh Hsu, J., and Chen, H.-C. (2013). Customer willingness to pay for online music: the role of free mentality. *J. Electron. Commer. Res.* 14, 315–333.

Liu, F., Liu, S., and Jiang, G. (2021). Consumers' decision-making process in redeeming and sharing behaviors toward app-based mobile coupons in social commerce. *Int. J. Inf. Manag.* 67:102550. doi: 10.1016/j.ijinfomgt.2022.102550

Lu, B., and Chen, Z. (2021). Live streaming commerce and consumers' purchase intention: an uncertainty reduction perspective. *Inf. Manag.* 58:103509. doi: 10.1016/j.im.2021.103509

Lv, Z., Yue, J., and Jinghua, H. (2018). How do sellers use live chat to influence consumer purchase decision in China? *Electron. Commer. Res. Appl.* 28, 102–113.

Markus, M. L., and Silver, M. (2008). A Foundation for the Study of IT effects: a new look at DeSanctis and Poole's concepts of structural features and Spirit. *J. Assoc. Inf. Syst.* 9, 609–632. doi: 10.17705/1jais.00176

Mehrabian, A., and Russell, J. A. (1974). An Approach to Environmental Psychology.

Norman, D. A. (2002). *The Design of Everyday Things. 2nd ed.* New York: Basic Books, 9.

Ou, C. X., Pavlou, P. A., and Davison, R. M. (2014). Swift guanxi in online marketplaces: the role of computer-mediated communication technologies. *MIS Q.* 38, 209–230. doi: 10.25300/MISQ/2014/38.1.10

Podsakoff, P. M., Mac Kenzie, S. B., Lee, J. Y., and Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J. Appl. Psychol.* 88, 879–903. doi: 10.1037/0021-9010.88.5.879

Shao, Z., and Pan, Z. (2019). Building guanxi network in the mobile social platform: a social capital perspective. *Int. J. Inf. Manag.* 44, 109–120. doi: 10.1016/j.ijinfomgt.2018.10.002

Shao, Z., Zhang, L., Chen, K., and Zhang, C. (2020). Examining user satisfaction and stickiness in social networking sites from a technology affordance lens: uncovering the moderating effect of user experience. *Ind. Manag. Data Syst.* 120, 1331–1360. doi: 10.1108/IMDS-11-2019-0614

Shao, Z., Zhang, L., Li, X., and Guo, Y. (2019). Antecedents of trust and continuance intention in mobile payment platforms: the moderating effect of gender. *Electron. Commer. Res. Appl.* 33:100823

Shen, X.-L., Li, Y.-J., Sun, Y., Chen, Z., and Wang, F. (2019). Understanding the role of technology attractiveness in promoting social commerce engagement: moderating effect of personal interest. *Inf. Manag.* 56, 294–305. doi: 10.1016/j.im.2018.09.006

Song, S.-I., Hee Lee, S., So, J., and Sun Lee, J. (2004). An efficient concurrency control algorithm for high-dimensional index structures 15, 104–120.

Strong, D. M., Volkoff, O., Johnson, S. A., Pelletier, L. R., Tulu, B., Bar-On, I., et al. (2014). A theory of organization-EHR affordance actualization. *J. Assoc. Inf. Syst.* 15, 53–85. doi: 10.17705/1jais.00353

Stsiampkouskaya, K., Joinson, A., Piwek, L., and Ahlbom, C. P. (2021). Emotional responses to likes and comments regulate posting frequency and content change behaviour on social media: an experimental study and mediation model. *Comput. Hum. Behav.* 124:106940. doi: 10.1016/j.chb.2021.106940

Sun, Y., Shao, X., Li, X., Guo, Y., and Nie, K. (2019). How live streaming influences purchase intentions in social commerce: an IT affordance perspective. *Electron. Commer. Res. Appl.* 37:100886. doi: 10.1016/j.elerap.2019.100886

Treem, J. W., and Leonardi, P. M. (2013). Social media use in organizations: exploring the affordances of visibility, editability, persistence, and association. *Ann. Int. Commun. Assoc.* 36, 143–189. doi: 10.1080/23808985.2013.11679130

Tseng, C. H., and Wei, L. F. (2020). The efficiency of mobile media richness across different stages of online consumer behavior. *Int. J. Inf. Manag.* 50, 353–364. doi: 10.1016/j.ijinfomgt.2019.08.010

Wang, Y.-S. (2019). User experiences in live video streaming: a netnography analysis. *Internet Res.* 29, 638–658.

Wang, Y., and Han, X. (2021). Attractive community detection in academic social network. *J. Comput. Sci.* 51 (prepublish:101331. doi: 10.1016/j.jocs.2021.101331

Wang, Y., and Yu, C. (2017). Social interaction-based consumer decision-making model in social commerce: the role of word of mouth and observational learning. *Int. J. Inf. Manag.* 37, 179–189. doi: 10.1016/j.ijinfomgt.2015.11.005

Wen, Z., and Dandan, H. B. T. (2018). Prequel to questionnaire data modeling. *Psychol. Sci.* 41, 204–210.

Wong, R. Y. M., Cheung, C. M. K., Xiao, B., and Thatcher, J. B. (2021). Standing up or standing by: understanding bystanders' proactive reporting responses to social media harassment. *Inf. Syst. Res.* 32, 561–581. doi: 10.1287/isre.2020.0983

Wongkitrungrueng, A. (2018). Exploring how and why consumers create unintended uses of products. *Int. J. Bus. Innovation Res.* 16, 453–470. doi: 10.1504/IJBIR.2018.093521

Wongkitrungrueng, A., and Assarut, N. (2020). The role of live streaming in building consumer trust and engagement with social commerce sellers. *J. Bus. Res.* 117, 543–556. doi: 10.1016/j.jbusres.2018.08.032

Xu, X., Wu, J.-H., and Li, Q. (2020). What drives consumer shopping behavior in live streaming commerce? *J. Electron. Commer. Res.* 21, 144–167.

Yang, J., Zeng, Y., Liu, X., and Li, Z. (2022). Nudging interactive cocreation behaviors in live-streaming travel commerce: the visualization of real-time danmaku. *J. Hosp. Tour. Manag.* 52, 184–197. doi: 10.1016/j.jhtm.2022.06.015

Yim, M. Y. C., Chu, S. C., and Sauer, P. L. (2017). Is augmented reality technology an effective tool for E-commerce? An interactivity and vividness perspective. *J. Interact. Mark.* 39, 89–103. doi: 10.1016/j.intmar.2017.04.001

Zhang, H., Lu, Y., Gupta, S., and Zhao, L. (2014). What motivates customers to participate in social commerce? The impact of technological environments and virtual customer experiences. *Inf. Manag.* 51, 1017–1030. doi: 10.1016/j.im.2014.07.005

Zhang, L., Shao, Z., Li, X., and Feng, Y. (2020). Gamification and online impulse buying: the moderating effect of gender and age. *Int. J. Inf. Manag.* 61:102267.

10.3389/fpsyg.2022.1082981

Appendix A

Constructs and measurement items.

Real-time interaction (Dong and Wang, 2018)	1. During live streaming shopping, I can communicate well with streamers
	2. During live streaming shopping, when I communicate with streamers, I can choose to watch the information of the products I am interested in
	3. During live streaming shopping, streamers facilitate two-way communication between me and him/her
	4. During live streaming shopping, the streamer allows me to question his or her remarks
Guidance shopping (Dong and Wang, 2018)	5. During live streaming shopping, streamers can provide me with information about other alternatives to the product I want to buy
	6. During live streaming shopping, streamers can help me define my needs for the products I buy
	7. During live streaming shopping, streamers can help me determine which products are best for my needs
	8. During live streaming shopping, streamers can provide personalized product customization for me according to my needs
Visibility (Dong and Wang, 2018)	9. During live streaming shopping, I can see detailed pictures of the product
	10. During live streaming shopping, I can see the attributes of the product
	11. During live streaming shopping, I can see a demonstration of how the product is used
	12. During live streaming shopping, I was able to see the products more visually displayed, just as we would in real life shopping
Media richness (Shao et al., 2020)	13. I can use a variety of media (text, pictures, video) to share the information I get from live streaming shopping
	14. I can use small videos to share the information I get from live streaming shopping
	15. I can use a variety of emojis to express my views on live streaming shopping
Attraction (Xu et al., 2020)	16. I think the streamers in live streaming shopping are very talented
	17. I think streamers have a pleasant live streaming style in live streaming shopping
	18. I think the personality of streamers in live streaming shopping is very interesting
	19. I think the image of streamers in live streaming shopping is very attractive to me
Cognitive assimilation (Xu et al., 2020)	20. During live streaming shopping, my existing understanding of the product/service may be affected by the streamer
	21. During live streaming shopping, my current perception of the product/brand may be affected by the streamer
	22. During live streaming shopping, my perception of product value may be affected by the live streaming environment
	23. During live streaming shopping, through communication and interaction with streamers, my preference for products may be affected
Purchase intention (Dong and Wang, 2018)	24. I will use live streaming shopping in the future
	25. I will definitely use live streaming shopping in the next 3 months
	26. I will continue to buy the same goods on the live streaming shopping platform as last time

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 16 January 2023
DOI 10.3389/fpsyg.2022.1084090

OPEN ACCESS

EDITED BY
Yunlong Duan,
Yunnan University of Finance and Economics, China

REVIEWED BY
Jana Matošková,
Tomas Bata University in Zlín, Czechia
Xueli Li,
Dalian Minzu University, China

*CORRESPONDENCE
Jianbin Chen
✉ jianbin.chen@buu.edu.cn

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 30 October 2022
ACCEPTED 12 December 2022
PUBLISHED 16 January 2023

CITATION
Liu Y, Chen J and Han X (2023) Research on the influence of employee psychological capital and knowledge sharing on breakthrough innovation performance.
Front. Psychol. 13:1084090.
doi: 10.3389/fpsyg.2022.1084090

Research on the influence of employee psychological capital and knowledge sharing on breakthrough innovation performance

Yuhan Liu[1], Jianbin Chen[1]* and Xiaolei Han[2]

[1]Business College of Beijing Union University, Beijing, China, [2]CRRC Industrial Academy Co., Ltd., Beijing, China

Breakthrough innovation is the focus of the society in the era of knowledge economy. Employee innovation of the enterprises is the starting point of enterprise innovation behavior, and it is the result of the combination of complex psychological capital. Meanwhile, breakthrough innovation often comes from the result of knowledge sharing brought by teamwork. At present, existing studies mainly reveal the influence of knowledge and knowledge structure on the performance of radical innovation. However, the relationship between psychological capital, knowledge sharing and the breakthrough innovation performance needs to be systematically studied. Therefore, this study adopted a research approach, that is, statistical analyses were performed by using SPSS Version 18 and AMOS version 26 (Statistical analyses performed by using SPSS Version 18 and AMOS version 26).This study collected data on employees of 345 different new high-tech enterprises to explore the mechanism by which psychological capital and knowledge sharing affects the breakthrough innovation performance. The research results respond to a positive correlation between psychological capital and knowledge sharing affects the breakthrough innovation performance. Moreover, knowledge sharing has a mediating effect on the effect of psychological capital on breakthrough innovation performance, and the effect is weakened. which is of great theoretical significance for exploring the relationship between psychological capital and knowledge sharing affects the breakthrough innovation performance.

KEYWORDS

employee psychological capital, knowledge sharing, breakthrough innovation performance, self-efficacy, emotional stability

1. Introduction

In an era of knowledge-based economy, innovation is the focus topic in recent years, especially the breakthrough innovation, the research of which has increased greatly in recent years. Tu Youyou is the first top scientific researcher in China to win the Nobel Prize

in Physiology or Medicine. She has made breakthrough innovation and outstanding contributions to the development of the world's medical and health undertakings. Breakthrough innovation exists in line with incremental innovation and is usually accompanied by technological leapfrogging and substitution. Due to the progress of science and technology, and the short cycle of R&D in terms of technology and products, the competitive advantages brought by breakthrough innovation for enterprises have feature more prominently. Ke and Kunji (2013) successfully link breakthrough innovation with core competitiveness from the perspective of resources. Charles and Rothaermel (2003) focus on the management model and operation mechanism of breakthrough innovation enterprises. A large number of studies have shown that improving the performance of breakthrough innovation is the only way for countries, organizations and groups to win competitive advantages. However, there is little empirical analysis on the performance of breakthrough innovation. The existing research mainly focuses on alliance, network, resources and other fronts. For example, the research of Taishan and Yulin (2016) find that close alliance network relationship is an important means to promote breakthrough innovation. Research and development cooperation can significantly enhance the breakthrough innovation of enterprises, and knowledge pool is positively affecting the breakthrough innovation performance of alliance enterprises. Jun et al. (2014) construct a model from the perspective of "network capability-organization tacit knowledge acquisition-breakthrough innovation performance." The research found that network capability has a significant positive impact on breakthrough innovation performance, and organization tacit knowledge acquisition mediates the relationship between the two. Jian et al. (2010) integrate the resource-based theory and the resource allocation theory to study the driving mechanism of key resources on the breakthrough innovation performance of international companies in China.

Only by constantly enhancing the enterprise's breakthrough innovation vitality can the global enterprises get better development and have a positive impact on the global development. Breakthrough innovation can be regarded as a process of "knowledge acquisition-knowledge flow-knowledge creation." The main source of breakthrough innovation in an enterprise is employees. To improve the performance of breakthrough innovation of employees, one cannot only consider one factor, but also need to be specific to each stage of breakthrough innovation. Psychological capital is considered to be the key determinant of the competitive advantage of the future organization and a truly valuable asset of the enterprise. The main purpose of knowledge sharing is to increase the mobility of creativity. At present, the research on knowledge and breakthrough innovation mainly focuses on knowledge foundation, knowledge conflict, knowledge strategy and other aspects. For example, Beiling et al. (2012) study the impact of intellectual capital on the performance of enterprise breakthrough innovation from the perspective of knowledge; Zhiming (2016) conducts an empirical study on the relationship among corporate knowledge base, open innovation and breakthrough innovation performance; Huibin and Daming (2014) conduct an empirical study on the relationship among team knowledge conflict, organizational learning and breakthrough innovation performance; Xiaofen and Qiang (2017) conduct an empirical analysis on the impact of external knowledge sourcing strategy, actual and potential absorptive capacity on the performance of breakthrough innovation. To a certain extent, these studies reveal the impact of knowledge and knowledge structure on the performance of breakthrough innovation. However, the relationship among psychological capital, knowledge sharing and the performance of breakthrough innovation still needs to be studied systematically.

In summary, combining the realistic background and theoretical background mentioned above, we can find that despite the strong link between psychological capital, knowledge sharing and breakthrough innovation performance, existing research has not paid enough attention on this domain. Base on the existing research, this study conducts a theoretical discussion and empirical analysis on the impact of psychological capital and knowledge sharing on the breakthrough innovation performance. Moreover, in order to enrich and develop the research on the intermediary role of knowledge sharing between psychological capital and breakthrough innovation performance, knowledge sharing was introduced as a mediator variable to study the intermediary role of knowledge sharing between psychological capital and breakthrough innovation performance. This study mainly focuses on the following two questions: RQ1: As a kind of highly subversive and uncertain innovation, is its performance affected by psychological capital as well as innovation performance? Namely, the relationship between psychological capital and breakthrough innovation performance. RQ2: Does knowledge sharing play an intermediary role in the impact of psychological capital on breakthrough innovation performance, and what is the magnitude and direction of the intermediary effect? I.e. the exploration of the intermediary role of knowledge sharing.

2. Theoretical background and hypotheses development

2.1. Research on the breakthrough innovation performance

According to the research on the performance of breakthrough innovation, Abemathy and Utterback (1978) first proposed the concept of breakthrough innovation. Different from continuous innovation, breakthrough innovation takes the potential market as a breakthrough. Its technological development path is not to improve on the original technological track but to find a new way. It breaks the competitive basis of the original technology and thus becomes an important way for enterprises to realize technological leapfrogging and obtain continuous competitive advantages. Breakthrough innovation is the result of a systematic study, which

focuses on the reorganization and creation of knowledge (McDermott and O'Connor, 2002) and is characterized by discontinuity and nonlinearity (Linton, 2009).

From the research on the knowledge management, Huibin and Daming (2014) study the relationship among team knowledge conflict, organizational learning and breakthrough innovation performance, and found that team conflict can have an effect on breakthrough innovation performance, while organizational learning plays an intermediary role in the relationship between them. Similarly, from the perspective of knowledge, Ling et al. (2012) find that human, social and relational capital in intellectual capital can positively affect the breakthrough innovation performance of the company. In conclusion, it can be seen that team knowledge learning has an impact on the company's breakthrough innovation performance.

From the measurement research of breakthrough innovation performance, Daming and Beiling (2014) measure breakthrough innovation performance from two aspects: process and product. Yim and Tse (2005) think that breakthrough needs have the functions of brand-new product performance and exploring potential customer demand and increasing customer value according to the characteristics of breakthrough innovation. Therefore, the performance of breakthrough innovation is measured by two measurement items: product quality and customer value realization. Similarly, Ke and Kunji (2013) point out that the measurement of breakthrough innovation performance should not simply focus on the external observable final results, where the most direct embodiment of the final results is the new products, technologies or services produced. This measurement method ignores the new way of thinking, pioneering innovative ideas and the new discovery and use of scarce resources. Furthermore, the research of Junjie et al. (2017) and Yang et al. (2014) measure the items from three aspects: the development of new technology, products and services, and the impact on existing knowledge and experience. In conclusion, there are mainly three aspacts about the measurement research of breakthrough innovation performance, such as product, process and knowledge.

2.2. Research on the psychological capital

Psychological capital refers to an individual's psychological state in the process of growth and development. It is a core psychological element beyond human capital and social capital and a psychological resource to promote personal growth and performance improvement (Xudong, 2017). It is a combination of individuals' beliefs about themselves, social relationships, career development, morality, life goals, and life (Goldsmith et al., 1997). Similarly, Seligman (2002) believes that psychology focuses on the individual's advantages, health, vitality and other aspects. Furthermore, Luthans et al. (2004) believes that psychological capital is a kind of psychological ability, which includes confidence, hope, optimism and resilience. In conclusion, psychological capital is a core psychological element, a psychological resource, and psychological ability.

On the measurement of psychological capital, Goldsmith et al., 1997 divides psychological capital into two aspects: control and self-esteem. Furthermore, Luthans et al. (2008) classifies psychological capital into four levels: self-confidence/self-efficacy (having the confidence to make the necessary efforts to achieve success in the face of challenging work), hope (persevering in the pursuit of goals and adjusting the way to achieve them when necessary), optimism (maintaining a positive attitude towards the present and the future), and resilience (being firm, energetic and successful when troubled by difficulties and adversities).Similarly, Letcher (2003) divides psychological capital into five dimensions: extroversion, emotional stability, agreeableness, openness and responsibility. Similarly, Cole (2006) believes that psychological capital is self-esteem, self-efficacy, control points and emotional stability. Therefore, this study defines psychological capital as a state of mind in which an individual has a relatively stable emotional state and has the ability to recognize himself and believe in the knowledge and skills one has. It is divided into self-efficacy and emotional stability. Among this research conclusion, Goldsmith et al. (1997) divided psychological capital into two aspects: control and self-esteem. Subsequently, some scholars divided psychological capital into three, four or five dimensions. Among them, the most mainstream is the theory proposed by Luthans (2005), who divides it into self-efficacy, hope, resilience and optimism. However, some scholars believe that there are dimensionality and similarity in psychological capital. Hope, resilience and optimism belong to three items of emotional stability. Therefore, our study divides psychological capital into self-efficacy and emotional stability.

2.3. Research on the knowledge sharing

From the perspective of the concept of knowledge sharing, Bartol and Srivastava (2002) believe that knowledge sharing is a process of information transmission, in which individuals in an organization put forward their own views and suggestions to others, or share their experience and skills to others. Knowledge sharing is the transfer or flow of knowledge between different individuals and organizations (Lee, 2001). Knowledge sharing aims at knowledge appreciation. Members of an organization share the information obtained from various channels.

Judging from the measurement of knowledge sharing, different scholars divide knowledge sharing differently. One-dimensional partitioning, such as Chowdhury's (2005) complex knowledge sharing, emphasizes the process of knowledge sharing. Two-dimensional division, for example, Zarraga and Bonache (2003) divide knowledge sharing into knowledge transfer and knowledge creation, which includes both the flow of knowledge and the generation of new knowledge. Furthermore, Hooff and Bidder (2004) put forward what is two-dimensional

division, including knowledge contribution (giving knowledge to others) and knowledge collection (searching, learning, integrating knowledge), implicit and explicit knowledge sharing, and internal and external knowledge sharing of the organization; efforts and frequency of knowledge sharing (Bock et al., 2005; Mooradian et al., 2006; King, 2008). The research on the influencing factors of knowledge contribution is mainly divided into individual factors (Wansong et al., 2014) and organizational factors (Pee et al., 2010).

Therefore, knowledge sharing is a complicated process, the first is to collect and accumulate knowledge and have a certain knowledge reserve. The second is to share and exchange one's own views, skills and ideas with others. The purpose of knowledge sharing is to increase the flow of ideas. At the same time, individual factors (personal image, personal motivation, etc.) and organizational factors (organizational culture, interpersonal relationships between organizations, etc.) will affect knowledge sharing behavior.

2.4. Analysis of the influence of psychological capital, knowledge sharing on breakthrough innovation performance

2.4.1. Employee's psychological capital and knowledge sharing

Cabrera et al. (2006) find that self-efficacy is a variable that can promote knowledge exchange. People with self-confidence are more willing to speak out their own opinions. Avey et al. (2011) believe that there may be some connection between psychological capital and knowledge sharing. Threshold (2011) finds that psychological capital can positively predict knowledge sharing behavior. Abella and Zapata (2011) find that employees who are full of hope, optimistic about life and strong willpower are more likely to share knowledge. On the other hand, Bansemir et al. (2012) believe that employees' individual will has a key impact on knowledge sharing behavior. Combs et al. (2017) believe that employees' psychological capital can influence their willingness to share knowledge, and employees with higher psychological capital are more willing to share knowledge. Qian and Minggui (2014) find a positive correlation between positive psychological capital and knowledge sharing. There are barriers to knowledge sharing, and employees with a positive attitude can put themselves into work in a positive and full state and break the barriers. Goldsmith et al. (1997) divided psychological capital into two aspects: control and self-esteem. Subsequently, some scholars divided psychological capital into three, four or five dimensions. Among them, the most mainstream is the theory proposed by Luthans (2005), who divides it into self-efficacy, hope, resilience and optimism. However, some scholars believe that there are dimensionality and similarity in psychological capital. Hope, resilience and optimism belong to three items of emotional stability. Therefore, our study divides psychological capital into self-efficacy and emotional stability. Zhengde (2018) finds that employees with high self-efficacy can continuously strengthen their study, actively seek new shortcuts, and prefer to share new knowledge. Emotional stability can stabilize the innovative spirit of the employees, and make the innovative spirit of the employees play the most effective role in the process of improving the breakthrough innovation performance. From the perspective of the relationship between emotional stability and leadership, Hui et al. (2019) think that emotional stability can ensure the knowledge creation and knowledge sharing of employees. The degree of knowledge sharing increases with the increase of emotional stability (Hui et al., 2019). Therefore, the following assumptions are made:

> *H1:* The self-efficacy of employees' psychological capital has a significant positive impact on knowledge sharing.

> *H2:* The emotional stability of employees' psychological capital has a significant positive impact on knowledge sharing.

2.4.2. Employee's psychological capital and breakthrough innovation performance

The performance of enterprise's breakthrough technological innovation is closely related to the employee's psychological capital level. Employee with high psychological capital level can actively accept knowledge, define the technological innovation goal, and put the expectation of the future into action, which reflects higher motivation (Qingsong et al., 2018). Larson et al. (2008) believe that employees who have hope are better able to achieve their goals because they are able to develop more practical action plans, thus it seems that employees who have hope are better able to achieve breakthrough innovation. Carr (2008) finds that employee psychological capital can better explain the performance of breakthrough innovation than human capital and social capital, and psychological capital is a variable that can explain the performance of breakthrough innovation. Qingsong and Daming (2010) find that a healthy, positive and sunny attitude of employees can help to generate breakthrough technological innovation performance for enterprises. In addition, breakthrough innovation is risky, and people with optimism and strong willpower are more likely to achieve innovation. Carr (2008) finds that optimistic employees are more receptive to new ideas and showed more breakthrough creativity. Luthans et al. (2008) also points out that employees with strong will are better able to meet the challenges at work and achieve breakthrough success. Yuan and Jun (2016) find that psychological capital has a positive effect on employees' initiative of breakthrough innovation. Linying (2017) finds that the six dimensions of team psychological capital, namely, self-confidence, hope, optimism, resilience, cooperation and responsibility, can all promote breakthrough innovation performance. Leadership trait theory holds that in an organization, leaders' attention to subordinates can enhance employees' sense of self-efficacy and thus enhance employees' innovative behavior

(Qing et al., 2022). People's creativity stems from self-efficacy. Emotional stability has a significant impact on employees' breakthrough innovation performance. Employees show a relatively stable emotional response after receiving external stimuli, and can recover to normal emotional level more quickly to improve their breakthrough innovation performance (Xiaoxia and Rui, 2012). In the spirit of innovation, the more stable the employee's mood and the more accurate the judgment on the market, the more significant the breakthrough innovation performance improvement will be. Therefore, the following assumptions are made:

> *H3:* The self-efficacy of employees' psychological capital has a significant positive impact on breakthrough innovation performance.

> *H4:* The emotional stability of employees' psychological capital has a significant positive impact on breakthrough innovation performance.

2.4.3. Knowledge sharing and breakthrough innovation performance

Liebowitz (2002) believes that knowledge sharing behavior can promote the improvement of breakthrough innovation ability, and improve the breakthrough innovation ability and performance of organizations. Syed-Ikhsan (2004) et al. believe that knowledge sharing is the key factor to improve the enterprise's ability, that is, knowledge sharing helps to improve the ability of breakthrough innovation. CameloOrdaz et al. (2011) indicates a positive relationship between knowledge sharing and innovation performance. Qianjun (2013) find that knowledge sharing behavior is the key condition to achieve breakthrough innovation performance. Zifen and Yue (2013) believe that knowledge sharing has a direct positive impact on employees' breakthrough innovation behavior. Han and Chen (2016) find that the exploratory knowledge sharing behavior significantly promoted the performance of breakthrough innovation, and the transmission of knowledge could improve the performance of breakthrough innovation. Therefore, the following assumptions are made:

> *H5:* Knowledge sharing has a significant positive impact on employees' breakthrough innovation performance.

2.4.4. Employee's psychological capital, knowledge sharing and breakthrough innovation performance

Fenglian (2014) finds that employees with a positive attitude are more likely to share and exchange knowledge with others, and ultimately promote the breakthrough innovation of employees. Wei (2015) believes that attaching importance to employees' psychological capital and cultivating employees' ability to acquire knowledge can bring better breakthrough innovation performance. In addition, knowledge sharing often appears as an intermediate variable in relevant research (Figure 1). For example, knowledge sharing is mediated between organizational trust and performance of new products (Vanguard et al., 2010). Between internal social capital and employee's breakthrough innovation behavior (Zifen and Yue, 2013). The relationship between team psychological security and employees' breakthrough innovation behavior (Keyan, 2015). Between positive emotions and team creativity, emotions will affect team members' tacit knowledge sharing behavior, thus affecting breakthrough creativity (Chaoying et al., 2011). Therefore, the following assumptions are made:

> *H6:* Knowledge sharing plays an intermediary role in the relationship between self-efficacy of psychological capital and breakthrough innovation performance.

3. Materials and methods

3.1. Sample and data

The questionnaire for this study was distributed from January 2022 to April 2022, and lasted for 4 months. This item defines the measurement of breakthrough innovation performance as the performance generated when middle and senior managers of high-tech enterprises and grassroots employees committed to R&D participate in enterprise innovation. The respondents of the questionnaire are high-tech enterprises, including the middle and senior managers of the enterprises and the grass-roots employees who are committed to R&D. The focus on high-tech enterprises is determined by the research issues in this study. The purpose of this research is to study the relationship among psychological capital, knowledge sharing and breakthrough innovation performance, which requires the selected samples to have breakthrough innovation behavior and truly reflect breakthrough innovation performance. High-tech enterprises, on the other hand, are based on major technological breakthroughs and major development needs, thus ensuring the emergence of breakthrough innovations. Of course, not all enterprises have achieved breakthrough innovation success, and there are also failed enterprises. The breakthrough innovation of these enterprises can also reflect the research model of this paper. As the decision-maker of the enterprise, the middle and senior managers of the enterprise have a comprehensive grasp and control of the enterprise, can better understand the development status and the environment of the enterprise, and fill in the questionnaire with higher authenticity and representativeness. The grass-roots staff cannot know enough information about the firm level, it has certain limitations. However, because the grass-roots staff in deep production or research and development also have a profound understanding of the firm's breakthrough innovation, it still has a certain reference. Enterprises pay great attention to the

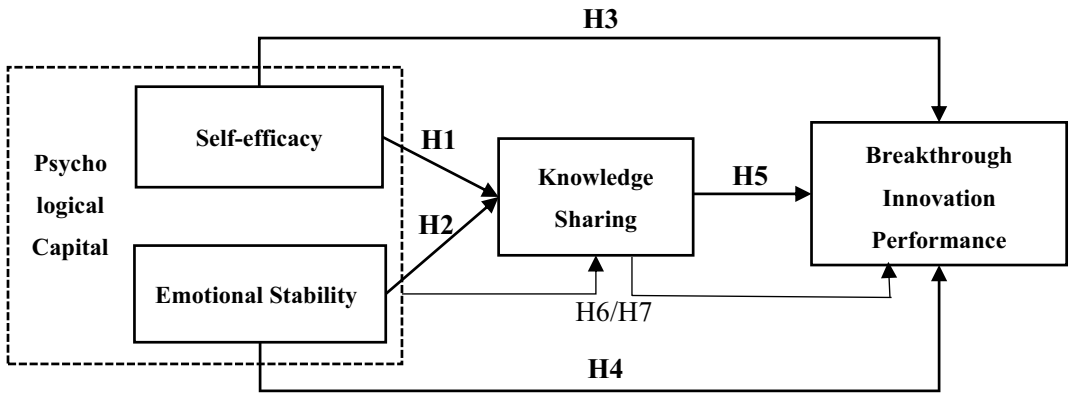


FIGURE 1
Research framework.

breakthrough innovation performance, and there are many shortcomings in this aspect, so we could tell the managers or R&D employees of enterprises when handing out questionnaires that we would provide suggestions for the improvement of breakthrough innovation performance based on the conclusions of this study, so as to encourage enterprises to be willing to participate in this study and ensure the quality of questionnaire filling. This questionnaire is mainly distributed to high-tech enterprises in the Beijing-Tianjin-Hebei region. In principle, each enterprise is required to fill in only one questionnaire as a sample. According to the availability and operability of the questionnaire, the electronic questionnaire is the main one, and the paper questionnaire is the supplementary one. The returned questionnaire was selected manually to further ensure its authenticity and representativeness. Among them, the paper-based questionnaire is mainly to eliminate the questionnaires with missing values, abnormal values and one option selected throughout or intermittently. The electronic version of the questionnaire mainly eliminates outliers, selects an option throughout or intermittently, and answers the questionnaire within 30 s. After the above-mentioned data collection and simple processing, the result is that 400 questionnaires are issued and 367 questionnaires are recovered, among which 345 were valid questionnaires, with a total effective recovery rate of 86.25%.

By calculating the descriptive statistical analysis of the questionnaires, this study draws the following analysis based on the valid questionnaires returned: There are 235 men, accounting for about 60.1%, which is mainly because the survey object of this sample is mainly managers, and managers in high-tech enterprises, especially middle and senior managers, are mostly men. The positions of the employee are distributed throughout the ordinary employee, grass-roots management, middle-level management and senior management, accounting for 12%, 25.3%, 36.1%, and 26.6% respectively, among which the middle-level and senior management are the leading ones, ensuring the authenticity of the sample and reflecting the real situation of the enterprise to a greater extent. Private enterprises and joint ventures are the main forms of ownership, and some state-owned enterprises and wholly foreign-owned enterprises are in line with the current development layout of high-tech industries. The establishment period is divided into stages with intervals of 10 years, and each stage is evenly distributed. The number of employees is divided into stages with an interval of 100, among which 200–300 are the majority, and the overall distribution is normal. The industry types are mainly high-tech enterprises, and each industry is evenly distributed. In general, the sample data of this study has a wide research scope and reasonable structure, which is highly associate to the research design requirements. Table 1 shows the descriptive statistical analysis results of samples' basic characteristics.

3.2. Measures

In this study, the five-point Likert scale was used to measure the multi-index variables involved in the questionnaire. More precisely, the respondents of the questionnaire make subjective scores according to the items measured in the questionnaire. The higher the score, the greater the tendency to agree. A score of one means strongly disagree while a score of five means strongly agree. The overall Cronbach's value of the scale is 0.932.

3.2.1. Dependent variable

The Breakthrough Innovation Performance (BIP) is measured by the Innovation Performance Scale compiled by Janssen (2000), Junjie et al. (2017), and Yang et al. (2014), which includes three dimensions, i.e., the generation, promotion and realization of innovation ideas, with a total of four items. The Likert's 5-level scale is adopted in this study to measure and conducts the analysis with several adjustment according to the research situation. A Total of four items were used in the measurement of breakthrough innovation performance. Typical topics are "your company often introduces new ideas in product development," "your company often creates products with new performance," "your company develops and introduces new production technologies in the

TABLE 1 Descriptive statistical analysis of basic characteristics of samples.

Demographic variables		Frequency	Percentage%	Cumulative percentages
Gender	Female	110	31.9	31.9
	Male	235	68.1	100.0
Marital status	Married	215	62.3	62.3
	Unmarried	130	37.7	100.0
Culture level	Below Bachelor	97	28.1	28.1
	Bachelor	192	55.7	83.8
	Master	52	15.1	98.8
	Doctor	4	1.2	100.0
Working years	Below 1 year	80	23.2	23.2
	2–4 years	129	37.4	60.4
	5–7 years	29	5.8	66.2
	8–10 years	20	23.2	89.3
	Above 10 years	87	25.2	100.0
Age	18–25	153	44.4	44.4
	26–30	95	27.5	71.9
	31–40	42	12.2	84.1
	41–50	33	9.6	93.7
	51–60	22	6.3	100.0
Position	Ordinary staff	47	12.0	12.0
	junior managers	99	25.3	37.3
	Middle Manager	141	36.1	73.4
	Senior Managers	104	26.6	100.0
Forms of ownership	State-owned enterprise	83	21.2	21.2
	Private enterprise	124	31.7	52.9
	Ioint venture enterprise	117	29.9	82.9
	Foreign-owned enterprise	67	17.1	100.0
Establishment time	0–10 years	60	15.3	15.3
	11–20 years	89	22.8	38.1
	21–30 years	81	20.7	58.8
	31–40 years	91	23.3	82.1
	Above 40 years	70	17.9	100.0
Number of employees	Below 100	56	14.3	14.3
	101–200	95	24.3	38.6
	201–300	105	26.9	65.5
	301–400	73	18.7	84.1
	Above 400	62	15.9	100.0
Industry type	Information technology industry	76	19.4	19.4
	Bioindustry	136	34.8	54.2
	New material industry	77	19.7	73.9
	New energy industry	56	14.3	88.2
	Other	46	11.8	100.0

industry," "your company creates new technological processes." The scale Cronbach's value is 0.951.

3.2.2. Independent variable

Psychological Capital (PC) mainly includes two dimensions, which are self-efficacy and emotional stability. The specific measurement methods are as follows:

1. Self-efficacy (SE) lies in the degree of confidence in one's own abilities and future expectations, while those who have received higher education and have a good educational background can endow themselves with the courage to face problems and the confidence to solve them when they are in trouble. Self-efficacy was measured by the self-efficacy Scale compiled by Jianguo (2006), Zhui and Qian (2016), and Qing et al. (2022), with six items in total. The Likert's 5-level scale is adopted in this study to measure and conducts the analysis with several adjustment according to the research situation. A Total of six items were used in the measurement of self-efficiency. Typical topics are "I can confidently express my opinions on company planning," "I can get out of work difficulties," "I can confidently analyze and solve problems," "I can do my best to achieve my work goals," "I can keep energetic in my work" and "all problems have solutions." The scale Cronbach's value is 0.876.
2. Emotional stability (ES) will affect employees' job satisfaction, which will lead them to identify with and trust leaders and organizations, and pay attention to their own responsibilities. The emotional stability is measured by the emotional stability scale prepared by Hui et al. (2019) and Xiaoxia and Rui (2012), with 5 items in total. The Likert's 5-level scale is adopted in this study to measure and conducts the analysis with several adjustment according to the research situation. Typical topics are "I can face the work pressure calmly," "I can stand firm when facing the work difficulty," "I can deal with many things at the same time," "I am optimistic about the uncertain things," "I am optimistic about the future," "I think there are two sides to everything and there is no need to be pessimistic." The scale Cronbach's value is 0.882.

3.2.3. Intermediate variable

The measurement of Knowledge Sharing (KS) is based on a scale of 10 items compiled by Ardichvil et al. (2003), Hooff and Bidder (2004) and Weggeman (2004). The Likert's 5-level scale is adopted in this study to measure and conducts the analysis with several adjustment according to the research situation. Typical topics are "when I learn something new, my colleagues in the department can also learn it," "I share the information I have with my colleagues in the department," "I share my skills with my colleagues in the department," "When I learn something new, my colleagues outside the department can also learn it," "I share the information I have with my colleagues outside the department," "I share my skills with my colleagues outside the department," "when I ask my colleagues inside the department, they will tell me what they know," "when I ask my colleagues inside the department, they will tell me about their skills," "when I ask my colleagues outside the department, they will tell me what they know," "when I ask my colleagues outside the department, they will tell me about their skills." The scale Cronbach's value is 0.919.

3.3. Data quality test

3.3.1. Confirmatory factor analysis

In order to verify the convergent validity of the model and the discriminant validity of key variables, this study adopted AMOS 26.0 software for confirmatory factor analysis. As listed in Table 2, confirmatory factor analysis was applied to analyze the factor structure of self-efficacy, emotional stability, knowledge sharing, breakthrough innovation performance, indicates that the 4-factor model has a good fit that $\chi^2/df = 2.617$, $CFI = 0.858$, $RMSEA = 0.066$, $AGFI = 0.853$, $GFI = 0.840$, $NFI = 0.973$.

3.3.2. Reliability and validity tests

The reliability emphasizes the reliability, credibility and stability of the measurement results. The collected data are processed by SPSS18.0, and the Cronbach's alpha is used to test the reliability of the above scales. According to the judgment principle of internal consistency coefficient, that is, when the coefficient of the whole scale detected by the data is above 0.5, the set of scales can be used, and when the coefficient is above 0.5 and below 0.7, the reliability of the set of scales is ideal. The coefficient above 0.8 is ideal. According to the reliability analysis results in Table 3, Cronbach's alpha of the two dimensions of

TABLE 2 Results of the confirmatory factor analysis.

Models	x^2/df	CFI	RMSEA	AGFI	GFI	NFI
(Benchmark model) 4-Factor	2.617	0.858	0.066	0.853	0.840	0.973
3-Factor model	1.73	0.931	0.059	0.890	0.967	0.933
2-Factor model	4.375	0.837	1.022	0.842	0.889	0.886
1-Factor model	1.922	0.899	0.059	0.891	0.923	0.916

$N = 345$.
4-factor model: Self-efficacy, Emotional Stability, Knowledge Sharing, Breakthrough Innovation Performance.
3-factor model: combines Self-efficacy and Emotional Stability into one factor based on the benchmark model.
2-factor model: combines Self-efficacy, Emotional Stability and Breakthrough Innovation Performance based on the benchmark model.
Single-factor model: combines Self-efficacy, Emotional Stability, Breakthrough Innovation Performance and Knowledge Sharing into one factor based on the benchmark model.

psychological capital, namely self-efficacy and emotional stability, is 0.897 and 0.905 respectively, among which Cronbach's alpha of emotional stability is >0.9, indicating that its reliability is very good. The Cronbach's alpha of self-efficacy is above 0.8, indicating its reliability is very good. The CR of each dimension is >0.7, with good internal consistency. The Cronbach's alpha of knowledge sharing is 0.912, which is >0.9, indicating that its reliability is very good, and CR is >0.7, which has good internal consistency. The Cronbach's alpha of the breakthrough innovation performance is 0.905, which is >0.9, indicating that its reliability is very good, and the CR is >0.7, which has good internal consistency.

As the scales selected in this study all come from the mature research results of scholars in relevant fields, and experts and teachers in this field are invited to check the contents of the measurement items, pass the pre-test and modify the problems, the questionnaire has good content validity. Secondly, KMO and Battlett tests are performed on the scale. First of all, the psychological capital scale is tested for the sphericity of KMO and Battlett, and KMO = 0.965 (>0.9), indicating that this variable is very suitable for factor analysis. The observed value of the Battlett sphericity test is 5733.221, and the p-value = 0.0007, which is less than the given significant level of 0.01, indicating that there is correlation between the variables. Secondly, the knowledge sharing scale is tested by KMO and Barflett sphericity, and KMO = 0.886 (close to 0.9), indicating that this variable is very suitable for factor analysis. The observed value of the Battlett sphericity test is 3005.682, and the p-value = 0.0003, which is less than the given significant level of 0.01, indicating that there is correlation between the variables. Thirdly, KMO and Bartlett's sphericity test are carried out on the Breakthrough Innovation Performance Scale, and KMO = 0.982 (>0.9), indicating that this variable is suitable for factor analysis. The observed value of Barmlets sphericity test is 2780.953, and the p-value = 0.0002, which is less than the given significant level of 0.01, indicating that there is correlation between the variables.

TABLE 3 Reliability analysis table of the questionnaire.

Variable	Dimension	Item	CITC	Cronbach's alpha if item deleted	Cronbach's alpha based on standardized items	Composite reliability
Psychological capital	Self-efficacy	Q1-1	0.669	0.883	0.897	0.898
		Q1-2	0.789	0.865		
		Q1-3	0.684	0.882		
		Q1-4	0.742	0.872		
		Q1-5	0.729	0.873		
		Q1-6	0.692	0.879		
	Emotional stability	Q2-1	0.695	0.857	0.905	0.915
		Q2-2	0.672	0.860		
		Q2-3	0.634	0.869		
		Q2-4	0.647	0.864		
		Q2-5	0.795	0.839		
Knowledge sharing		Q3-1	0.682	0.520	0.912	0.866
		Q3-2	0.746	0.713		
		Q3-3	0.769	0.578		
		Q3-4	0.715	0.739		
		Q3-5	0.794	0.682		
		Q3-6	0.807	0.697		
		Q3-7	0.802	0.731		
		Q3-8	0.821	0.786		
		Q3-9	0.825	0.775		
		Q3-10	0.864	0.824		
Breakthrough innovation performance		Q4-1	0.797	0.818	0.905	0.906
		Q4-2	0.772	0.852		
		Q4-3	0.769	0.863		
		Q4-4	0.814	0.851		

3.3.3. Descriptive statistics and correlation analysis of the research variable

The purpose of this study is to explore the relationship between various variables. Before using the structural equation model for hypothesis testing, the correlation between various variables is tested. In this paper, Pearson correlation analysis method is used to test the relationship between various variables (Table 4). Table 4 gives Pearson correlation coefficient between each variable. The results shows that the two dimensions of psychological capital (self-efficacy and emotional stability) are significantly positively correlated with knowledge sharing ($r = 0.755$, $p < 0.01$; $r = 0.672$, $p < 0.01$). The two dimensions of psychological capital (self-efficacy and emotional stability) are significantly positively correlated with breakthrough innovation performance ($r = 0.783$, $p < 0.01$; $r = 0.739$, $p < 0.01$). In addition, knowledge sharing is significantly positively correlated with breakthrough innovation performance ($r = 0.623$; $p < 0.01$). The correlation coefficient of each variable is <0.8, and there is no serious collinearity problem between each variable. All dimensions of the four variables are significantly correlated.

4. Structural equation model and regression analysis

4.1. Data calculation and processing

This study will use AMOS26.0 software to analyze the structural equation model. In the structural equation model, using the sum or average of items in each dimension instead of each item as the indicator of the latent variable can reduce the number of parameters, improve the reliability of measurement indicators and enhance the stability of parameters. In this study, the above method will be used to calculate the average value of each latent variable and then analyze it. The final result is shown in Figure 2. The right part includes 4 items of breakthrough innovation performance and error items. The left part is two dimensions of psychological capital (self-efficacy and emotional stability) with 11 items and error items, and the upper part is 10 items and error items of intermediary knowledge sharing.

TABLE 4 Variable mean, standard deviation, correlation coefficient and mean extraction variance (N =345).

	SE	ES	KS	BIP
SE	(0.65)			
ES	0.755**	(0.72)		
KS	0.517**	0.672*	(0.78)	
BIP	0.783**	0.739**	0.623*	(0.61)
Mean	3.35	4.21	3.29	2.01
SD	0.631	0.451	0.373	0.312

*$p < 0.05$; **$p < 0.01$.
The value in brackets is the average variance extracted (AVE) of each factor. The corresponding dimension factor standard accords with the average value of the sum of squares.

4.2. Hypothesis tests

Main effect test

That is to say, the relationship between independent variables and dependent variables is tested under the condition that the intermediate variables are not added into the model. The results show that employees' self-efficacy can promote breakthrough innovation performance. Hypothesis 3 is verified (Table 5). Employee emotional stability can promote breakthrough innovation performance. Hypothesis 4 is verified (Table 6).

Intermediary effect test

The intermediate variables are added to the research model for overall model test (Figure 3). The regression coefficients of the whole model path are shown in Table 5. The results show that the two dimensions of psychological capital have significant positive impact on knowledge sharing ($\beta = 0.881$, $p < 0.001$; $\beta = 0.877$, $p < 0.001$), hypothesis 1 and hypothesis 2 are verified. Knowledge sharing has a significant positive impact on breakthrough innovation performance ($\beta = 0.203$, $p < 0.01$), hypothesis 5 is verified. In this model, the principal effect is still significant, but the coefficient has decreased, indicating that knowledge sharing acts as a partial mediator. Hypothesis 6 and 7 are verified

4.3. Testing intermediary effect with regression

Control variables were further added, and the variables were regressed by SPSS18.0 software. The regression results are shown in Tables 7, 8. Regression analysis was applied to test the relationship among the four variables (Tables 7, 8). In Table 7, Model 1 is a study on the impact of control variables on breakthrough innovation performance. The VIF (1.307. 3.111, 1.121, 4.325, 3.810) of the control variables are all <10, indicating that there is no serious collinearity problem in the model and the results are acceptable. The second model is the research on the influence of self-efficacy on the performance of breakthrough innovation, in which the β of self-efficacy is 0.717 ($p < 0.001$), indicating that employees' self-efficacy can significantly promote the performance of breakthrough innovation. Model 3 introduces the variables of self-efficacy and knowledge sharing at the same time. The β value of self-efficacy is 0.566 ($p < 0.001$) and the β value of knowledge sharing is 0.363 ($p < 0.001$). both self-efficacy and knowledge sharing have significant impact on the performance of breakthrough innovation. At the same time, the β value of self-efficacy (0.556) is less than the β value before knowledge sharing (0.717), which shows that the influence of knowledge sharing on self-efficacy and breakthrough innovation performance is weakened, and knowledge sharing plays a part of intermediary role between self-efficacy and breakthrough innovation performance. These results again partially support H6.

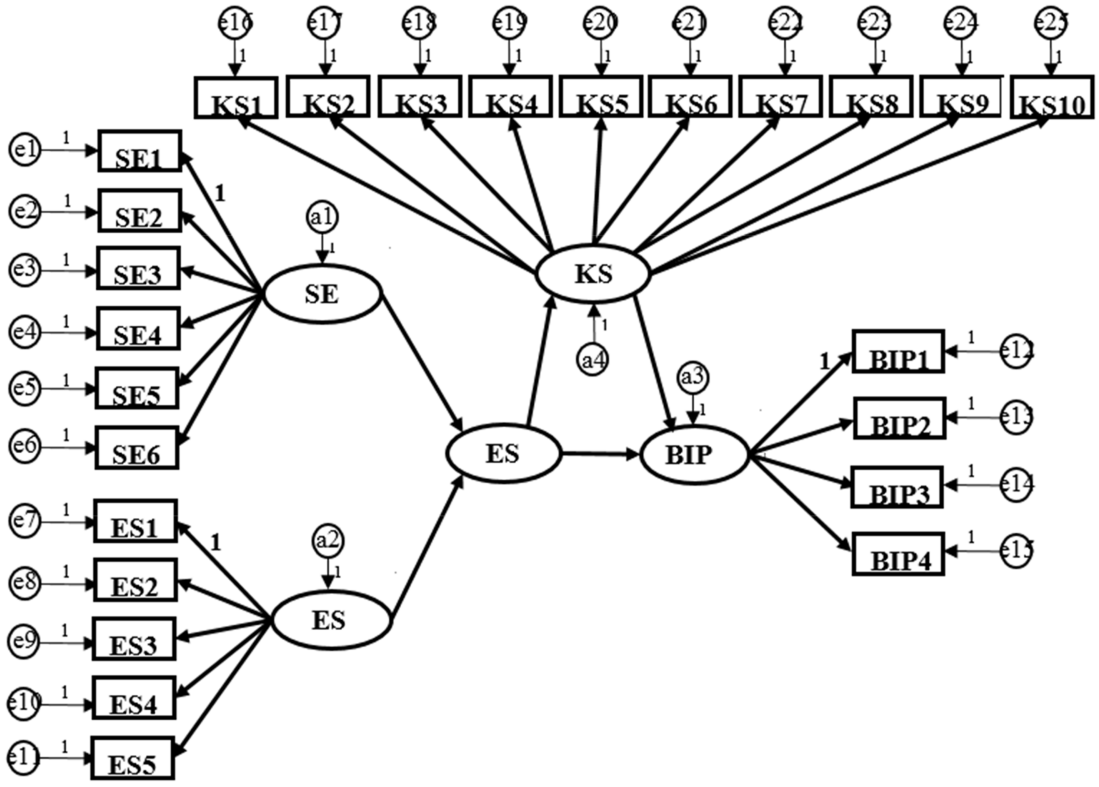


FIGURE 2
Analysis results of research model. e represents variance; a represents residual. SE, Self-Efficacy; ES, Emotional Stability; PC, Psychological Capital; KS, Knowledge Sharing; BIP, Breakthrough Innovation Performance.

TABLE 5 Path regression coefficients of research model.

Variable relation	Estimate	SE	C.R.	*p*-Value
Breakthrough innovation performance ← Self-efficacy	0.833	0.79	10.491	***
Knowledge sharing ← Self-efficacy	0.881	0.57	15.383	***
Breakthrough innovation performance ← Emotional stability	0.862	0.74	10.826	***
Knowledge sharing ← Emotional stability	0.877	0.53	15.294	***
Breakthrough innovation performance ← Knowledge sharing	0.203	0.71	2.831	**

$^{**}p < 0.01$, $^{***}p < 0.001$.

In Table 8, Model 1 is a study on the impact of control variables on breakthrough innovation performance. The VIF of the control variables (1.314. 3.173, 1.142, 4.317, 3.715) are all <10, indicating that there is no serious collinearity problem in the model and the results are acceptable. The second model is the research on the influence of emotional stability on the performance of breakthrough innovation, in which the β of emotional stability is 0.726 ($p < 0.001$), indicating that employees' emotional stability can significantly promote the performance of breakthrough innovation. Model 3 introduces the variables of emotional stability and knowledge sharing at the same time. The β value of emotional stability is 0.582 ($p < 0.001$) and the β value of knowledge sharing is 0.372 ($p < 0.001$), indicating that both emotional stability and knowledge sharing have significant impact on the performance of breakthrough innovation. At the same time, the β value of emotional stability (0.582) is less than the β value before knowledge sharing (0.726), which shows that the influence of knowledge sharing on emotional stability and breakthrough innovation performance is weakened, and knowledge sharing plays a part of intermediary role between emotional stability and breakthrough innovation performance. These results again partially support H7.

5. Discussion

5.1. Conclusion

Firstly, employees' psychological capital has a significant positive impact on breakthrough innovation performance. And

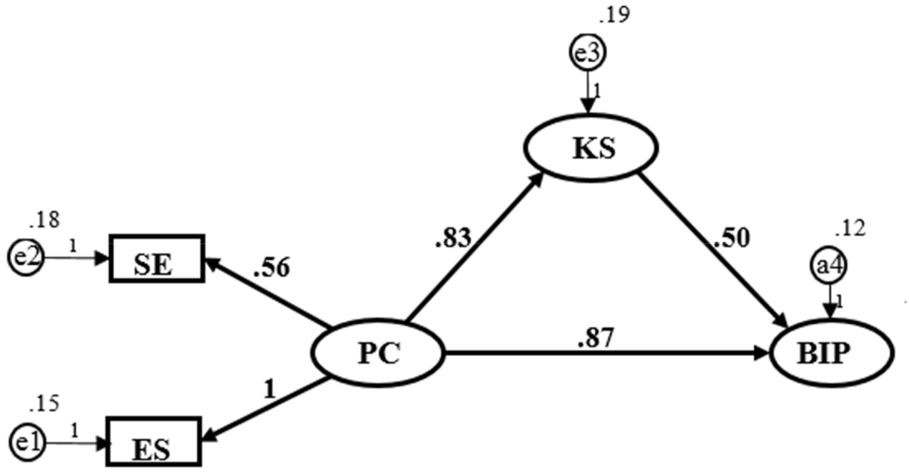


FIGURE 3
Research model path. SE, Self-Efficacy; ES, Emotional Stability; PC, Psychological Capital; KS, Knowledge Sharing; BIP, Breakthrough Innovation Performance.

TABLE 6 Regression coefficient of main effect path.

Variable relation	Estimate	SE	C.R.	*p*-Value
Breakthrough innovation performance ← Self-efficacy	1.044	0.56	19.227	***
Breakthrough innovation performance ← Emotional stability	1.045	0.55	19.381	***

***$p < 0.001$.

TABLE 7 Regression analysis of self-efficacy and knowledge sharing on breakthrough innovation performance.

	Model one	Model two	Model three
Constant	12.279	1.029	0.558
Control variable			
Gender	−0.847	−0.413	−0.506
Marital status	−0.25	−0.083	−0.186
Culture	0.057	0.120	0.144
Working years	0.161	−0.003	−0.003
Age	−0.039	−0.098	−0.037
Independent variable			
Self-efficacy		0.717***	0.566***
Knowledge sharing			0.363***
R^2	0.038	0.704	0.731
Adjustment r^2	0.018	0.697	0.724
F	1.885	99.901	101.200
ΔR^2	0.038	0.666	0.027
ΔF	1.885	756.443	33.733

Dependent variable: Breakthrough Innovation Performance ***$p < 0.001$.
Model 1 is a study on the impact of control variables on breakthrough innovation performance; Model 2 is the research on the influence of self-efficacy on the performance of breakthrough innovation; Model 3 introduces the variables of self-efficacy and knowledge sharing at the same time.

psychological capital is a positive state, including self-efficacy and emotional stability. Self-efficacy is to believe in oneself and affirm one's own ability, and emotional stability is related to individual recovery and growth. It refers to effective response and adaptation in the face of loss, difficulty or adversity. At the same time, it emphasizes individual growth after setbacks. The employees are engaged in deep-level work, and the respondents of this questionnaire are all employees engaged in IT, testing, R&D, management and other positions. If they do not have a positive mental state, they will not be able to better face challenges and setbacks at work, nor will they be able to promote breakthrough innovation performance. The positive mentality and psychological ability of employees can promote the formation of breakthrough innovation ability and the realization of breakthrough innovation idea.

Secondly, employees' psychological capital has a significant positive impact on knowledge sharing behavior. Employees with higher psychological capital are more willing to communicate and transfer information with colleagues, which is beneficial to knowledge sharing. Setbacks are inevitable in the process of knowledge sharing. Optimistic employees can smile and face setbacks. Hopeful employees are willing to participate in the knowledge sharing process to achieve their goals and employees with self-confidence are full of confidence in their work goals. They believe that they have the ability to face setbacks in the process of achieving the goals and boldly express their thoughts. Employees with good emotional stability can correctly handle the difficulties in the information transmission process, and

TABLE 8 Regression analysis of emotional stability and knowledge sharing on breakthrough innovation performance.

	Model one	Model two	Model three
Constant	12.914	1.024	0.542
Control variable			
Gender	−0.832	−0.452	−0.514
Marital status	−0.25	−0.081	−0.142
Culture	0.052	0.121	0.157
Working years	0.198	−0.002	−0.001
Age	−0.031	−0.096	−0.044
Independent variable			
Emotional stability		0.726***	0.582***
Knowledge sharing			0.372***
R^2	0.038	0.704	0.713
Adjustment R^2	0.011	0.615	0.741
F	1.825	99.915	102.210
ΔR^2	0.031	0.431	0.026
ΔF	1.817	755.521	33.915

Dependent Variable: Breakthrough Innovation Performance ***$p < 0.001$.
Model 1 is a study on the impact of control variables on breakthrough innovation performance; Model 2 is the research on the influence of emotional stability on the performance of breakthrough innovation; Model 3 introduces the variables of emotional stability and knowledge sharing at the same time.

actively adjust themselves after the setbacks, and quickly return to work. Employees with strong psychological capital are more likely to get along well with others. They dare to communicate, so that they can gain more knowledge and experience and improve their ability.

Thirdly, employee's knowledge sharing behavior has significant positive impact on breakthrough innovation performance. Knowledge sharing not only emphasizes the sharing of knowledge and skills with members within the organization, but also encourages employees to communicate and learn with members outside the organization. With the arrival of big data era, data processing begins to be completed through cloud computing. We need to find the information we need from big data and turn it into knowledge. The foundation of breakthrough innovation is knowledge, and the subject of breakthrough innovation is employees. Knowledge sharing becomes an indispensable condition in the process of breakthrough innovation. Breakthrough innovation mainly comes from the team. Without the communication and learning of team members, it is difficult to achieve breakthrough innovation.

Fourthly, knowledge sharing plays an intermediary role in psychological capital and breakthrough innovation performance. Psychological capital can not only directly affect employees' breakthrough innovation performance, but also indirectly affect breakthrough innovation performance through knowledge sharing. Psychological capital is a kind of positive mentality of employees. It is not enough to have a positive mentality. It should be reflected in actions in the end. Only "I can do it" can "I really do it." The process of knowledge sharing is not simple. We need the recognition and trust of others in order to give full play to the power of knowledge sharing.

Comparison with other studies (Larson and Luthans, 2008; Carr, 2008; Qingsong and Daming, 2010; Yuan and Jun, 2016; Qing et al., 2022), reflection on the results are as follows: this paper studies the relationship among psychological capital, knowledge sharing and breakthrough innovation performance, but the impact of breakthrough innovation performance is complex and diverse in reality. For example, personal perspective (employee well-being, job satisfaction, emotional intelligence, personal expectations and personality, etc.) and situational perspective (organizational incentive mechanism, organizational atmosphere, organizational leadership style, organizational learning ability and corporate culture, etc.) will affect the performance of breakthrough innovation. In addition, the related factors that affect psychological capital and knowledge sharing, as well as the interaction between the various influencing factors are not considered. The follow-up research needs to further enrich the research model and consider more variables that affect employees' psychological capital, knowledge sharing and breakthrough innovation performance and the interaction between these variables. In addition, due to different research objects, the dimensions of relevant variables are different and need to be further enriched and improved.

5.2. Theoretical contributions

Firstly, in terms of factors affecting employees' breakthrough innovation performance, more attentions are paid to individuals (employee well-being, emotional intelligence and work involvement, etc.) and organizational aspects (organizational atmosphere, learning ability, corporate tasks, etc.) in the past. This study focuses on the middle-level and senior-level management of high-tech enterprises and grass-roots employees who are committed to research and development. It also focuses on employees' psychological capital and knowledge sharing. In addition, it explores its impact on breakthrough innovation performance from both psychological and action levels. It enriches the research field of innovation management.

Secondly, this study constructs and verifies the model of psychological capital, employee breakthrough innovation performance and the relationship between them, and fully explores employees' breakthrough innovation potential from the psychological aspect of employees in order to improve the breakthrough innovation performance of the whole company. At the same time, this study also introduces knowledge sharing, which is beneficial to high-tech enterprises to create a strong learning atmosphere and lay a solid foundation for employee's breakthrough innovation. In addition, it also pays attention to the

psychological level and the action level of employees, which provides management enlightenment for high-tech enterprises to cultivate breakthrough innovation of employees. It should be pointed out that 1/3 of the survey objects in this study are grassroots employees committed to research and development. These samples cannot obtain enough information of the firms level, thus this study also has certain limitations.

5.3. Managerial implications

Firstly, consider paying attention to the improvement of employees' psychological capital. On the one hand, improve self-efficacy. For example, it can improve employees' ability to express their opinions about the company's plan with confidence, to get rid of work difficulties, to analyze and solve problems with confidence, and so on. On the other hand, keep emotional stability. This requires identifying one's own position and setting an expected goal at each stage. Only after reaching the goal can we enjoy the pleasure of life and remain optimistic.

Secondly, consider improve the knowledge sharing conditions of employees. On the one hand, improve the "hardware" factors of knowledge sharing. "Hardware" can be divided into two categories, one is the necessary facilities to enhance employees' knowledge reserve, the other is a communication tool to enrich employee communication. The premise of knowledge sharing is to have "a certain knowledge reserve." Set courses they are interested in according to employees' wishes, so as to increase the "class attendance rate" of employees. The improvement of communication tools and technology can also improve the quality of knowledge sharing among employees. For example, communication tools such as employees' internal email, internal telephone, internal QQ and internal forum can overcome the obstacles of time and space, receive information from employees at any time, and provide conditions for employees to "speak out." However, it is not enough to only receive internal information. Employees also need to participate in external communication. Information technology enables us to better communicate with the outside world. More and more employees with the same interests, such as "video conference," "online studio" and "online classroom," are connected and communicate with each other. On the other hand, improve the "software" factor of knowledge sharing to motivate employees to share knowledge. Companies need to select employee with strong knowledge acquisition ability and carry out a series of activities to cultivate employee's awareness of knowledge sharing. Establishing a learning organization is a way to speed up the flow of knowledge.

5.4. Limitations and suggestions for future research

Firstly, the sample is taken from the employees engaged in IT, testing and certification, R&D, management and other positions from Beijing-Tianjin-Hebei region. Therefore, the sample coverage has certain limitations. In addition, the influence of the size and nature of the company is not considered. The follow-up research needs to enrich the source and quantity of samples and consider more regions, positions and companies to make the research more universal.

Secondly, this paper studies the relationship among psychological capital, knowledge sharing and breakthrough innovation performance, but the impact of breakthrough innovation performance is complex and diverse in reality. For example, personal perspective (employee well-being, job satisfaction, emotional intelligence, personal expectations and personality, etc.) and situational perspective (organizational incentive mechanism, organizational atmosphere, organizational leadership style, organizational learning ability and corporate culture, etc.) will affect the performance of breakthrough innovation. In addition, the related factors that affect psychological capital and knowledge sharing, as well as the interaction between the various influencing factors are not considered. The follow-up research needs to further enrich the research model and consider more variables that affect employees' psychological capital, knowledge sharing and breakthrough innovation performance and the interaction between these variables. In addition, due to different research objects, the dimensions of relevant variables are different and need to be further enriched and improved.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YL contributed the central idea, analyzed most of the data, and wrote the initial draft of the paper. JC contributed to refining the ideas, carrying out additional analyses, and finalizing this paper. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by Beijing Municipal Natural Science Foundation Project of China (grant no. 9222012). The authors thank it wholeheartedly for funding our research.

Conflict of interest

XH was employed by CRRC Industrial Academy Co., Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abella, L. E. D., and Zapata, D. I. C. (2011). Relationship between psychological capital and knowledge sharing behavior in the context of organizational learning. *Acta Colornbiana De Psicologa* 14, 61–70.

Abemathy, W., and Utterback, J. (1978). Patterns of innovation in technology. *Technol. Rev.* 80, 40–47.

Ardichvil, et al. (2003). Employees' goalorientations, the quality of leader-member exchange, and of job performance and job satisfaction. *Acad. Manage. J.* 47, 368–384.

Avey, J. B., Avolio, B. J., and Lulhans, F. (2011). Experimentally analyzing the impact of leader positivity on follower positivity and performance. *Leadersh. Q.* 22, 282–294. doi: 10.1016/j.leaqua.2011.02.004

Bansemir, B., Neyer, A., and Mtislein, K. M. (2012). Knowledge exchange in intra-organizational innovation communities: the role of cognitive and affective states. *Bus. Res.* 5, 43–58. doi: 10.1007/BF03342731

Bartol, K. M., and Srivastava, A. (2002). Encouraging knowledge sharing: the role of organizational reward systems. *J. Leadersh. Organ. Stud.* 9, 64–76. doi: 10.1177/107179190200900105

Beiling, M., Daming, Y., and Xiaoqing, H. (2012). Research on the impact of intellectual capital on the performance of Enterprise's breakthrough technological innovation. *Sci. Technol. Progress Policy* 29, 79–83.

Bock, G. W., Zmud, R. W., and Kim, Y. C. (2005). Behavioral in-tendon formation in knowledge sharing examining the roles of extrinsic rriotivators, social-psychological forces, and organisational climate. *MIA Q.* 29, 87–111. doi: 10.2307/25148669

Cabrera, et al. (2006). Parental interactions with Latino infants: variation by country of origin and English proficiency. *Child Dev.* 74, 1190–1207.

CameloOrdaz, C., GarciaCruz, J., SousaGinel, E., and Valle-Cabrera, R. (2011). The influence of human resource management on knowledge sharing and innovation in Spain: the mediating role of affective commitment. *Int. Louznal Hum. Resour. Manage.* 22, 1442–1463. doi: 10.1080/09585192.2011.561960

Carr, H. (2008). *Positive Psychology: The Science of Happiness and Human Strengths*. New York: Brunner-Routledge. *Vol. 35*. 114–125.

Chaoying, T., Shu, A., and Zengliang, G. (2011). Social function of positive emotions and its influence on team creativity: mediating role of tacit knowledge sharing. *Nankai Bus. Rev.* 14, 129–137.

Charles, W. L., and Rothaermel, F. T. (2003). he performance of incumbent firms in the face of radical technological innovation. *Acad. Manag. Rev.* 28, 257–274.

Chowdhury, S. (2005). The role of affect- and cognition-based Trust in Complex Knowledge Sharing. *J. Manag. Issues* 17, 310–326. doi: 10.2307/40604504

Cole, K. (2006). "Wellbeing, psychological capital, and unemployment: an integrated a theory," in *Joint Conference of the International Association for Research in Psychology (IAREP) and the Society for The Advancement of Behavioral Economics (SABE), Purism*.

Combs, G., Smith, R. M., and Sardeshmukh, S. (2017). Willingness to share knowledge: psychological safety. *Psychol. Capital Acad. Manage. Ann. Meet. Proc.* 3:14. doi: 10.5465/AMBPP.2017.14062

Daming, Y., and Beiling, M. (2014). Research on the impact of relationship fit on knowledge transfer and breakthrough innovation performance. *Syst. Eng.-Theory Pract.* 34, 3103–3112.

Fenglian, (2014). Employee engagement,human resource management practices and competitive advantage:an integrated approach. *J. Organ. Eff.:People and Perform.* 2, 7–35.

Goldsmith, A. H., Veum, J. R., and Darity, W. (1997). The impact of psychological and human capital on wages. *Econ. Inq.* 35, 815–829. doi: 10.1111/j.1465-7295.1997.tb01966.x

Han, Y., and Chen, G. (2016). Research on the relationship between network power and innovation performance of cluster enterprises-based on the mediating role of dual knowledge sharing behavior. *Chin. J. Manag.* 13, 855–862. doi: 10.7498/aps.64.017303

Hooff, B. V. D., and Bidder, J. A. D. (2004). Knowledge sharing in context: the influence of organizational commitment, communication climate and CMC use on knowledge. *J. Knowl. Manage.* 8, 117–130. doi: 10.1108/13673270410567675

Hui, J., Liu, C., and Zhou, Q. (2019). The relationship between cadre's emotional stability and responsible leadership. *Digest Manag. Sci.* 2, 87–58.

Huibin, Y., and Daming, Y. (2014). An empirical study on the impact of R&D team knowledge conflict on Enterprise's breakthrough innovation performance. *Chin. J. Manag.* 11, 383–389.

Janssen, (2000). Job demands, perceptions of effort-reward fairness and innovative work behavior. *J. Occup. Organ. Psychol.* 73, 287–302. doi: 10.1348/096317900167038

Jian, Q., Yingjun, W., and Lianguang, C. (2010). Research on driving resources and the breakthrough innovation performance of multinational corporations in China. *Manage. Sci. Res.* 23, 28–37.

Jianguo, (2006). Individual-level cultural values as moderators of perceived organizational support-employee outcome relationships in China: comparing the effects of power distance and traditionality. *Acad. Manage. J.* 50, 715–729.

Jun, F., Liqiang, G., and Jinjun, N. (2014). Network capability, tacit knowledge acquisition and breakthrough innovation performance. *Manage. Sci. Res.* 35, 16–24.

Junjie, Y., Simeng, W., and Yunfei, S. (2017). Research on Alliance portfolio management capability, key resources acquisition and breakthrough technology innovation performance. *J. Univ. Electron. Sci. Technol. (Social Sci. Ed.)* 19, 8–14.

Ke, Z., and Kunji, G. (2013). Research the construction of Enterprise's Core competence based on breakthrough technological innovation. *Manage World* 6, 180–181.

Keyan, C. (2015). A cross-level study on the influence of team psychological security on Members' innovative behavior: the mediating role of knowledge sharing. *Science* 4, 966–972.

King, W. R. (2008). Motivating knowledge sharing through a knowledge management system. *Omega* 36, 131–146. doi: 10.1016/j.omega.2005.10.006

Larson and Luthans (2008). Potential added value of psychological capital in predicting work attitudes. *J. Leadersh. Organ. Stud.* 13, 75–92.

Larson,et al. (2008). Easy and efficient parallel processing of massive data sets. *Proc. VLDB Endow.* 1, 1265–1276.

Lee, J. N. (2001). The impact of knowledge sharing, organizational capability and partnership quality on is outsourcing success. *Inf. Manage.* 38, 323–335. doi: 10.1016/S0378-7206(00)00074-4

Letcher, L. (2003). *Psychological Capital and: A Behavioral Economic Approach*. United States: Kansas State University.

Liebowitz, J. (2002). Facilitating innovation through knowledge sharing: a look at the us naval center-carderoek division. *Data Processor Better Bus. Educ.* 42, 1–6.

Ling, A., and Vanno, V. (2012). Relationships between academic performance, perceived group psychological capital, and positive psychological capital of Thai undergraduate students. *Proceeds Soc. Behav. Sci.* 116, 3226–3230.

Linton, J. D. (2009). De-babelizing the language of innovation. *Technovation* 29, 729–737.

Linying, (2017). An examination of perceived organizational support as a multidimensional construct in the context of an expatriateassignment. *J. Manage.* 30, 209–237.

Luthans, (2005). The Linkage between psychological capital and commitment to organizational mission: a study of nurses. *J. Nurs. Adm.* 35, 304–310.

Luthans, F., Luthans, K. W., and Luthans, B. C. (2004). Positive psychological capital: beyond human and capital's. *Bus. Horiz.* 47, 45–50. doi: 10.1016/j.bushor.2003.11.007

Luthans, F., Norman, S. M., Avolio, B. J., and Avey, J. B. (2008). The mediating role of psychological capital in the supportive organizational climate-employee performance relationship. *Organizational Behav.* 29, 219–238. doi: 10.1002/job.507

McDermott, C. M., and O'Connor, G. C. (2002). Managing radical innovation: an overview of emergent strategy issues. *J. Prod. Innov. Manag.* 19, 424–438. doi: 10.1111/1540-5885.1960424

Mooradian, T., Reuzl, B., and Matzler, K. (2006). Who trusts? Personality, trust and knowledge sharing. *Manag. Learn.* 37, 523–540. doi: 10.1177/1350507606073424

Pee, L. G., Kankanhalli, A., and Kim, H. W. (2010). Knowledge sharing in information systems development: a social interdependence perspective. *J. Assoc. Inf. Syst.* 11, 550–575. doi: 10.17705/1jais.00238

Qian, T., and Minggui, G. (2014). An empirical study on the relationship among college Students' knowledge sharing positive psychological capital and learning involvement. *Library Sci. Res.* 6, 97–100.

Qianjun, Z. (2013). Liu Yi.Research on the promoting effect of knowledge sharing on innovation performance in KPO context-moderating effect of task characteristics and knowledge management capability. *Sci. Technol. Progress Policy* 30, 121–125.

Qing, S., Yingying, G., and Hui, W. (2022). Research on the new generation Employees' deviant innovation behavior path from the perspective of differential order pattern. *Modernization Manage.* 1, 94–102.

Qingsong, W., and Daming, Y. (2010). Cross-level analysis on Employees' psychological Capital, Organizational innovation atmosphere and technological innovation performance. *Syst. Eng.* 1, 69–77.

Qingsong, W., Shaorong, C., and Yanping, Q. (2018). Knowledge transfer and technological innovation performance of enterprises: mediating role of psychological capital. *J. Bus. Econ.* 4, 39–48.

Seligman (Ed.) (2002). "Positive psychology; positive prevention, and positive therapy," in *Handbook of Positive Psychology*. 3–9.

Syed-Ikhsan, R. F. (2004). Bench marling knowledge management in a public organization in Malaysia. *Bench Marking Int. J.* 11, 238–266. doi: 10.1108/14635770410538745

Taishan, G., and Yulin, L. (2016). Does enterprise international R&D alliance help breakthrough innovation? *Manage. Sci. Res.* 37, 48–57.

Vanguard, et al. (2010). Perceived organizational support, satisfaction with rewards, and employee job involvement and organizational commitment. *Applied Psychology* 48, 197–209.

Wansong, Z., Xiaolin, S., and Kanliang, W. (2014). Research on influencing factors of knowledge sharing based on social capital and planned behavior theory. *J. Xi 'an Jiaotong Univ. (Social Sci. Ed.)* 34, 43–48.

Weggeman, (2004). Performance management and assessment:methods for improved rater accuracy and employee goal setting. *Hum. Resour. Manag.* 43, 319–336.

Wei, (2015). A multilevel investigation of factors influencing employee service performance and customer outcomes. *Acad. Manage. J.* 41–58.

Xiaofen, Z., and Qiang, L. (2017). The impact of external knowledge sourcing strategy and absorptive capacity on breakthrough innovation performance. *J. Capital Univ. Econ. Bus.* 19, 63–69.

Xiaoxia, Z., and Rui, L. (2012). Research on Eysenck's personality trait theory and individual innovation performance of Enterprise employees. *Sci. Technol. Manage. Res.* 32, 138–141.

Xudong, (2017). Assessing group efficacy: Comparing three methods of measurement. *Small Group Research* 35, 158–173.

Yang, K. P., Chow, C., and Chiu, Y. J. (2014). How unlearning affects radical innovation: the dynamics of social capital and slack resources. *Technol. Forecast. Soc. Chang.* 87, 152–163. doi: 10.1016/j.techfore.2013.12.014

Yim, C., and Tse, D. (2005). The effects of strategic orientations on technology and market-based breakthrough innovations. *J. Mark.* 69, 42–60.

Yuan, D., and Jun, G. (2016). The influence of psychological capital on employees' innovation initiative. *Acad. Exch.* 11, 122–125.

Zarraga, C., and Bonache, J. (2003). Assessing the team environment for knowledge: an empirical analysis. *Int. J. Hum. Resour. Manag.* 14, 1227–1245. doi: 10.1080/0958519032000114282

Zhengde, (2018). Perceived organizational support: a review of the literature. *J. Appl. Psychol.* 87:698.

Zhiming, C. (2016). Research on the effect of Enterprise Knowledge Base on breakthrough innovation performance: a moderating mediating effect model. *South China J. Econ.* 7, 112–132.

Zhui and Qian (2016). Job satisfaction and organizational commitment as predictors of organizational citizenship and in-role behaviors. *J. Manage.* 17, 601–617.

Zifen, L., and Yue, S. (2013). Research on the impact of internal social capital on Employees' innovative behavior--based on the analysis of the mediating role of knowledge sharing. *East China Econ. Manage.* 12, 55–58.

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 15 February 2023
DOI 10.3389/fpsyg.2023.1133324

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University,
China

REVIEWED BY
Yuxiao Wang,
Xi'an Technological University,
China
Ning Wang,
Xi'an Polytechnic University,
China

*CORRESPONDENCE
Jin Han
✉ hj.xjtu.edu.cn@126.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 December 2022
ACCEPTED 24 January 2023
PUBLISHED 15 February 2023

CITATION
Han J, Chen M, Chen Y, Jing Q and Wang S (2023) The study on the relationship between venture capital, tolerance to failure, and enterprise innovation performance. *Front. Psychol.* 14:1133324. doi: 10.3389/fpsyg.2023.1133324

The study on the relationship between venture capital, tolerance to failure, and enterprise innovation performance

Jin Han[1]*, Minling Chen[2], YanXin Chen[3], Qinling Jing[4] and ShuangYan Wang[1]

[1]School of Business, Xi'an University of Finance and Economics, Xi'an, China, [2]School of Economics and Management, Xi'an ShiYou University, Xi'an, China, [3]Foreign Languages School, Kunming University, Kunming, China, [4]School of Economils and Management, Kunming University, Kunming, China

Venture capital not only affects enterprise innovation decisions by providing funds, value-added services and allocating control rights, but also the psychological capital of venture capital can enhance its tolerance for failure in innovation activities of enterprises, and thus have a positive impact on innovation performance of enterprises. This paper uses multivariate and negative binomial regression models, propensity score matching method and Heckman treatment effect model to study the impact mechanism of venture capital on enterprise innovation performance, and the mediation role of venture capital's tolerance for innovation failure in the relationship between the above two; this paper studies the moderating effect of the characteristics of heterogeneous venture capital institutions, such as joint investment strategies and geographical proximity, on the relationship between venture capital failure tolerance and enterprise innovation performance. The results show that venture capital can significantly improve its tolerance for enterprise innovation failure by holding shares and occupying seats on the board of directors of enterprises, thereby bring the increase of the innovation performance of enterprises; if joint investment strategy and close investment are selected, the tolerance of venture capital to innovation failure will have a more obvious effect on the promotion of enterprise innovation performance.

KEYWORDS

venture capital, tolerance to failure, innovation performance, joint investment, geographical proximity

1. Introduction

At present, China's economy is developing in the direction of high quality, and innovation is an important basis for promoting high-quality economic development. The report of the 20th CPC National Congress states that the implementation of the innovation-driven development strategy should be accelerated, the main role of enterprises in scientific and technological innovation should be strengthened, and the level of transformation and industrialization of scientific and technological achievements should be improved. In this context, innovative enterprises are important carriers of technological innovation, and the effectiveness of the implementation of the national innovation-driven development strategy depends on the continuous improvement of the technological innovation capacity of these enterprises.

In the 2022 government work report, it is proposed that in the further implementation of the innovation-driven development strategy, it is required to promote the development of venture capital

and improve the level of financial products and services in the field of innovative science and technology. Domestic and international empirical studies also suggest that venture capital, as an innovative way of financing, is well integrated with technology. In addition to providing companies with the capital necessary, venture capital institutions can also provide value-added services such as management supervision, which play an extremely important role in technological innovation and the transformation of technological achievements. As evidenced by the Venture Capital Development Report, at the end of 2018, the number and amount of venture capital invested in high-tech enterprises reached 9,279 and 175.72 billion RMB, respectively.

Enterprises need to invest a lot of capital in the process of innovation, which is characterized by a relatively long R&D cycle and high risks. The entry of venture capital can help companies to innovate, not only by addressing the lack of capital for research and development but also by providing value-added services in the areas of consulting and management supervision with its own advantages in industries functions and resources endowment, which can contribute to the improvement of enterprises' innovation performance. However, due to the constraints of investment objectives and investment cycles, there is a risk of conflict between the short-term objectives of venture capital and time consuming in innovation activities of firms, which may probably lead to a suppression of corporate technological innovation brought by venture capital. Then will venture capital promote or inhibit business innovation?

As innovative and entrepreneurial enterprises are newly established and their assets can be highly earmarked, there is an information asymmetry between the investing parties, which can lead to mutual hedging. As a result, the configuration of corporate control becomes a common concern for entrepreneurs and venture capitalists to protect their respective interests. And organizational control theory, based on the economics of innovation, states that corporate control rights affects critical decisions regarding corporate innovation so that it further has a significant impact on corporate technological innovation (Xu and Xu, 2012). In the context of venture capital participation, further insight into the mechanisms by which venture capital affects the innovation performance of firms can be found in the control of the firm owned by the venture capitalist (ownership of equity and the right to sit on the board of directors of firms).

Corporate technological innovation is a long and risky process with a long R&D cycle, and the process of innovation requires risk-taking and tolerance from key players (He and Tian, 2020). Besides, the failure tolerance from venture capital institutions reflects their ability to accommodate corporate innovation failures and take risks, and attitudes towards technological innovation failure of a firm can influence corporate culture in terms of tolerance of innovation failures, as well as the attitude of entrepreneurs towards technological innovation failure, which can, in turn, have a significant impact on the development of technological innovation activities and the output of innovation outcomes (Tian and Wang, 2014). The question is therefore posed whether the tolerance of venture capitalists to innovation failure has an impact on their relationship between venture capital and enterprise innovation performance. This subject is important to corporate technological innovation--which is at the core of this paper's research.

Research by domestic and international scholars on the impact of venture capital on corporate innovation performance has been conducted in two major areas:(1) Investigate the impact of venture capital participation on the technological innovation performance of enterprises. (2) The impact of the characteristics of venture capital institutions on technological innovation performance. However, existing research has neglected to examine in depth the mechanisms by which venture capital affects firms' innovation performance. Moreover, considering that the tolerance of venture capital to technological innovation failure of a firm may affect the formation of a fault-tolerant culture and the willingness of entrepreneurs to innovate, it is necessary to investigate the impact of venture capital tolerance to innovation failure concerning the innovation performance of firms. In addition, there is a certain heterogeneity between different types of venture capital institutions, with significant differences in their joint investment strategies and geographical proximity. The relationship between venture capital firms' tolerance for innovation failure and firm innovation performance is further affected by the differences in their joint investment strategies and geographical proximity.

Based on this, firstly, this paper studies the impact of venture capital participation on corporate innovation performance, and the mechanisms by which venture capital affects corporate innovation performance in terms of corporate control rights (ownership of corporate equity, ownership of corporate board seats). Secondly, the mediating effect of a venture capital's tolerance for innovation failure between its shareholding, sending directors to occupy board seats, and the firm's innovation performance is examined. Finally, the moderating effect of these characteristics of heterogeneous venture capital institutions on the relationship between their failure tolerance and firm innovation performance is investigated from two perspectives: joint investment strategy and geographical proximity. Our research provides a theoretical basis for an in-depth study of the relationship among venture capital participation, venture capital tolerance for innovation failure, and corporate innovation performance, as well as an empirical reference for building a fault-tolerant corporate culture and promoting corporate technological innovation.

2. Literature review

2.1. Research on the impact of venture capital participation on corporate innovation

In the research on the impact of venture capital participation on corporate innovation, domestic and foreign scholars have not yet reached a consistent conclusion.

On the one hand, some scholars have found that venture capital participation can reduce information asymmetry and moral hazard problems by providing value-added and supervision services, which can reduce the cost of external financing of enterprises, ultimately promote enterprise innovation. For example, Gu and Qian (2019) used data from Chinese listed companies and found that venture capital promotes enterprise innovation. Li and Yan (2020) found that venture capital can help enterprises make full use of resources spilled over from other firms, thus so as to have a positive impact on the innovation performance of enterprises. In addition, scholars have also found that by improving the internal and external governance mechanisms of firms and reducing uncertainty in the firm's external environment, venture capital can increase the firm's innovation output. For example, Feng et al. (2020) found that venture capital used their extensive management experience and resources to help improve the internal governance structure of firms, ultimately enhancing innovation performance. Zhang et al.

(2021) found that venture capital can effectively improve firms' innovation performance by reducing the uncertainty they face in the R&D process and increasing their risk tolerance. Dong et al. (2021)combined found that VC support not only improves firms' success rate of patent application but also increases the innovation "value" represented by increased citation. Leogrande et al. (2021) found that the level of Venture Capitalist Expenditure is positively associated to Innovation Index.

On the other hand, due to the high risks faced by firms in the process of innovation, the long cycle of innovation returns, and limited by the objective of stage investment, venture capital eagered to recover their capital quickly, thus led to its potential adverse impact on firms' technological innovation. For example, Arvanitis and Stucki (2014) found that firms supported by venture capital did not achieve the objective of improving innovation performance. Cheng and Zou (2020) found that after entering firms, venture capital did not promote higher levels of R&D investment or increased the number of patent applications. Xia and Le (2021) found that venture capital holding equity in firms harmed the level of innovation inputs and output results of firms. Leogrande et al. (2021)found that the level of Venture Capitalist Expenditure is negatively related to government procurement of advanced technology products, medium and hightech products exports.

2.2. Research on the impact of shareholding and dispatching directors of venture capital institutions on corporate innovation performance

Some academics have found that venture capital with shares and board seats can contribute to the innovation performance of companies by increasing their investment in innovation. For example, Gou and Dong (2014) found that the higher the percentage of corporate higher shareholding, the more the venture capital will induce the firm to invest more in innovation by taking control of enterprises. Celikyurt et al. (2014) found that after venture capital owned corporate board seats, firms' R&D efforts, innovation output, and other transactional activities would be increased. However, some scholars have come to the opposite conclusion, for example, Wang and Zhou (2017) found that the shareholding ratio of the parent company of corporate venture capital can both promote and inhibit the R&D investment level, invention patents, and the total number of patent applications.

2.3. A study of the impact of venture capital characteristics on corporate innovation performance

Regarding the study of the attitudes of venture capital towards innovation failures affecting firm innovation, some scholars have found that different venture capital institutions will differ in their attitudes towards innovation failures in firms, which in turn will have different impacts on firm innovation. For example, Chemmanur et al. (2014) compare corporate venture capital with independent venture capital and find that corporate venture capital has a longer investment horizon, is more inclusive of failure, and is better at improving the innovation performance of firms. Tian and Wang (2014) found that the degree of tolerance of venture capital for innovation failure a firm can incentivize better innovation. Wang and Zhou (2017) found that firms that received corporate venture capital funding had significantly higher R&D investment than other firms, while for firms that received funding from independent venture capital, their patent applications were higher than those of other companies.

In terms of investment strategy, some scholars believe that joint investment provides help for enterprises' technological innovation by providing complementary resources. For example, Chen et al. (2017) found that the association of multiple venture capital brings a stronger role in promoting enterprise innovation. Zhang (2020) found that under the joint investment strategy, the total number of enterprise patent applications and invention patent applications will be more. However, academics have also found that conflicts may arise between different investment institutions due to differences in strategies, objectives, and cultural differences, resulting in their inability to promote technological innovation in their firms. For example, Dong et al. (2019) found that the number of indirect linkages of competitors formed between venture capital institutions due to co-investment volume can hurt the innovation output of firms.

A review of the above-mentioned scholars' research findings reveals that, firstly, although some scholars have focused on the impact of venture capital participation on firms' innovation capabilities and performance, they have not conducted further in-depth studies on the mechanisms by which venture capital affects firms' innovation performance. Secondly, although some scholars have paid attention to the fact that the attitude of venture capital to innovation failures in the early stage of enterprises may affect the risk appetite of entrepreneurs, they have not further studied the influence of venture capital institutions' tolerance for innovation failures of enterprises on the relationship between venture capital and enterprise innovation performance. Finally, some studies have paid attention to the impact of the type, investment strategy of venture capital institutions on the innovation performance of enterprises, but due to the different characteristics of joint investment strategy and geographical proximity, some studies have ignored that different types of venture capital have different characteristics due to their own characteristics, and it will have a differential moderating effect on the relationship between the tolerance of innovation failure of enterprises and the innovation performance of enterprises.

By contrast, this paper contributes in several ways. Firstly, based on innovation economics and organizational control theory, the impact of venture capital participation on enterprise innovation performance is studied, and the mechanism of venture capital on enterprise innovation performance is studied from two aspects: shareholding ratio and sending directors to occupy seats on the corporate board of directors, it is of great significance to improve the internal governance mechanism and improve the innovation performance of enterprises. Secondly, based on the perspective of enterprise innovation culture, the mediating effects of the tolerance of venture capital to innovation failure between its shareholding ratio, the number of dispatched directors occupying the board seats and the innovation performance of enterprises are further investigated. Thirdly, the moderating effect of characteristics such as joint investment strategies and geographical proximity of investment institutions on the relationship between failure tolerance of venture capital and firm innovation performance is investigated from the perspective of the existence of heterogeneity of different types of investment institutions, it provides experience for improving the failure tolerance of venture capital and improving the innovation

performance of enterprises. Fourthly, to better identify the "selection effect" and "value-added effect" of venture capital, this paper also adopts the PSM method and Heckman treatment effect model to further test the robustness of the shareholding ratio of venture capital, the impact of dispatched directors on the innovation performance of enterprises, and the mediating effect of failure tolerance of venture capital.

3. Theoretical analysis and research hypotheses

3.1. Effect of venture capital participation on the innovation performance of enterprises

Due to the relatively long cycle of various technological innovation activities carried out by enterprises, the risk of innovation failure is also very high, which makes enterprises often have problems of insufficient investment in R&D funds, etc., and venture capital can solve the problems faced by enterprises such as insufficient R&D investment funds by providing the funds needed by enterprises (Hsu et al., 2014).

If venture capital institutions are willing to invest in enterprises, the positive signals on enterprise operation and innovation will be transmitted to the capital market to certify the quality of enterprises, so that investors are willing to increase the funds invested in enterprises, and then enterprises will use the funds obtained from external investors for technology research and development, accelerating the process of enterprise innovation.

Since there will be a lot of uncertainty in the process of research and development, venture capital can rely on its own professional investment experience, technology and resources to provide enterprises with the professional knowledge and technical resources needed to carry out technological innovation, give strategic guidance to enterprises, and help enterprises innovate research and development models (Dong et al., 2017), reduce the cost of enterprise technological innovation (Lin and Zhang, 2019), thus increasing the efficiency of their technological innovation.

The spillover effect of R&D activities of enterprises often exists, and the resources and information of technological R&D spillover from the industry can realize the flow and dissemination of knowledge among enterprises, and enterprises can grasp the latest technology in the industry, which can avoid repetitive technological innovation and encourage enterprises to engage in innovation with higher technological content through the "demonstration effect" among enterprises. There is a general exchange of innovation resources between firms receiving funding from the same venture capital institutions (González-Uribe, 2020). Venture capital can not only provide funds for these enterprises with complementary innovation resources, but also provide them with useful decision-making support and technical guidance with their industry expertise, resource endowments, and social network in the process of carrying out innovation activities, and through the sharing of innovation resources, it is conducive to the overflow of innovation resources and core technologies obtained by enterprises in the same industry for their technological innovation. Therefore, the hypothesis is formulated:

> *H1*: Venture capital participation can have a catalytic effect on the innovation performance of enterprises.

3.2. The mechanism of venture capital affecting the innovation performance of enterprises

Whereas organizational control theory based on the economics of innovation states that by influencing important decisions regarding firm innovation, the allocation of control over a firm ultimately affects its technological innovation performance (Xu and Xu, 2012). The control rights of an enterprise is mainly reflected in the voting rights (shareholding ratio) and the right to seat on the board of directors. The shareholding ratio of venture capital reflects the level of enterprise control rights and capital investment they have, and the board of directors is the most important decision-making and supervisory body in the corporate governance structure. After investing capital into enterprises, venture capital often try to occupy the seats of the board of directors of enterprises and grasp the decision-making power of important matters of enterprises, strengthen its position and role in the board of directors, improve its monitoring level of enterprises and the corporate governance structure. Therefore, this paper mainly uses the two variables of venture capital shareholding ratio and sending directors to occupy board seats of enterprises to measure the degree of control rights over enterprises, and on this basis, the influence mechanism of venture capital on the innovation performance of enterprises is studied from these two aspects.

3.2.1. The impact of venture capital shareholding on the innovation performance of enterprises

The innovation activities of enterprises are often characterized by high risks, long R&D cycles, and information asymmetry, so when signing investment contracts with enterprises, to obtain more investment returns, venture capital institutions will implement supervision and control of enterprises by allocating control rights to them (Dong et al., 2017), improve the governance level of the enterprise (Xiong and Gui, 2018), influence important decisions in terms of corporate innovation, which in turn will have an impact on the activities carried out by the enterprise in terms of technological research and development and product development. The influence of venture capital shareholding on the innovation performance of companies is mainly reflected in the following aspects.

First of all, the shareholding ratio of venture capital reflects the level of capital invested and the control rights of the enterprise, the higher the shareholding ratio, the more capital and value-added services that venture capital can provide to enterprises, and can help enterprises with their own experience in project management and strategic guidance. In addition, it can reduce the R&D costs and expenses in the process of technological innovation of enterprises, and improve the innovation efficiency of enterprises by providing technical guidance and decision-making support to enterprises in technological innovation and product development.

Secondly, the shareholding ratio of venture capital institutions can send signals to the external capital market about the company's operating conditions and innovation capabilities. The higher the shareholding ratio of investment institutions, the stronger the innovation ability and higher performance of enterprises, and the easier it is to attract funds from external investors, which can improve the willingness of entrepreneurs to innovate, which will increase the investment of enterprise R&D funds, avoid the failure of enterprises' innovation projects due to financial constraints, and ultimately help realize the value-added of enterprise innovation value.

Finally, by their equity holdings in the enterprise, venture capitalists can strengthen their supervision and control over the management of the enterprise and create effective incentive constraints on the entrepreneur. This supervisory control by venture capital on the management of the company services can urge them to actively pursue technological innovation and increase the amount of capital invested in the firm for R&D, which ultimately help to improve the innovation performance of the company. Therefore, hypotheses are made:

> *H2a*: The shareholding of venture capital institutions will have a catalytic effect on the innovation performance of enterprises.

3.2.2. The impact of venture capital's dispatching directors and occupying corporate board seats on the innovation performance of enterprises

Firstly, the board of directors is the most important decision-making and supervisory body in the corporate governance structure. Venture capitalists will often try to occupy seats on the board of directors of the company, hold decision-making power on important corporate matters, strengthen their status and role on the board of directors, improve their level of monitoring of the company, and improve the corporate governance structure. Venture capital give technical advice and guidance in the process of corporate innovation, etc. (Proksch et al., 2016), enhancing the positive effect of venture capital to the innovation efficiency of enterprises (Duan and Chen, 2020).

Secondly, by sending directors to the board of directors of enterprises, venture capital can help the board of directors better evaluate innovation-related policies by their high reputation, management experience, and network of relationships, and can also optimize R&D and innovation activities, guide enterprises hire more external independent directors with professional skills, enhance the professionalism and independence of the board of directors (Xiong and Gui, 2018), improve the decision-making level of important matters of the board of directors, and improve the strength of the board of directors to support enterprise innovation, help enhance the ability of enterprises in innovation and better realize the value-added of enterprise innovation.

Reasonable psychological expectations are key to the success of venture capital. Due to psychological bias, when investors make investment expectations based on inadequate and inaccurate information, they cannot effectively analyze the information, so their expectations about the future are difficult to completely conform to the actual situation, which directly leads to behavioral bias in venture capital. Faced with this problem, venture capital have tightened their grip on the dynamic economic information of start-up companies by sending directors and gaining seats on corporate boards to strengthen their oversight and control over corporate boards. Participation of venture capital in corporate governance can enhance their willingness to provide value-added services to companies, reduce the irrational part of investor expectations, and thus help companies make better entrepreneurial decisions, improve corporate governance, and enhance innovation efficiency. Therefore, hypotheses are made:

> *H2b*: Venture capital institutions that sending directors and occupying seats on corporate boards will promote the innovation performance of enterprises.

3.3. Venture capital shareholding, dispatching directors, venture capital's tolerance for innovation failure, innovation performance of enterprises

Failure tolerance refers to the ability of venture capital to tolerate corporate innovation failures and take risks. Equity financing will affect the technological innovation of enterprises because they can tolerate the failure risk caused by enterprise technological innovation. As a way of equity financing, venture capital by holding corporate shares and dispatching directors, not only invests in enterprises, and provides value-added services such as management supervision, but also effectively reduces the technical and management risks existing in the research and development process by bearing the possible failures of enterprises in the innovation process, and ultimately can bring positive impact on the innovation performance of enterprises.

(1) Due to the short establishment time of innovative and entrepreneurial enterprises and the relatively high degree of asset specialization, to form effective incentives and constraints for entrepreneurs, alleviate the risk of entrapping venture capital caused by entrepreneurs intervening in enterprises when they disagree with venture capital, venture capital avoid investment risks while reducing investment uncertainty by holding enterprise shares and sending directors to occupy board seats of enterprises.

By holding the equity of the enterprise and sending directors to occupy the seats on the board of directors of the enterprise, venture capital institutions determine to a certain extent their tolerance for technological innovation failures of the enterprise and the support for the company's R&D investment. If the venture capital has a high shareholding ratio and sends directors to the board of directors of the enterprise, it can enhance its control over the enterprise, choose to actively participate in corporate governance, and will actively participate in the formulation of major business decisions, strategic guidelines and innovation decisions of the enterprise, realize the convergence of its interests with entrepreneurs, have longer-term support and tolerance for enterprises, have a stronger tolerance for the failure of enterprise R&D and innovation, and have a higher tolerance for the failure of enterprise technological innovation. It will choose to support enterprises to carry out technological innovation activities for a long time.

(2) On the one hand, firms are more likely to establish a culture of fault tolerance as an important part of the firm's innovation culture if venture capitalists are tolerant of possible technological innovation failures of the firm. This will influence entrepreneurs' attitudes towards innovation failures (Tian and Wang, 2014), raise the level of the risk appetite of entrepreneurs, make them willing to tolerate the high risks associated with technological innovation and invest more in R&D, support technical staff in their efforts to conduct technological trial and error (Zhang et al. 2021), which can reduce the cost of technological trial and error and the risks involved in the commercialization of innovative products, which will ultimately improve the innovation efficiency of enterprises. On the other hand, tolerance of innovation failure will strengthen venture capital's belief in investment of in enterprises, and help them get more funds from the outside, reducing the possibility of innovation failure caused by financing constraints in the process of carrying out innovation activities.

On the one hand, venture capital send a positive signal to the External capital market by holding the equity of enterprises, the quality of the enterprise is certified, so that more external investors can be attracted to enter. This measure can reduce the possibility of

technological innovation failure due to capital constraints, improve the entrepreneur's appetite for risk, as well as the willingness to innovate, and realize the convergence of interests between it and venture capital, which can promote venture capital to support and tolerate enterprise technological innovation for a longer time, and the tolerance for enterprise innovation failure will be higher. It will strengthen supervision and control, and urge enterprises to accelerate innovation output and increase the value added of enterprise innovation. On the other hand, venture capital send directors to the board of directors of enterprises, implement supervision over the board of directors of enterprises, enhance the professionalism and independence of corporate boards, reduce the uncertainty they face when investing, improve their tolerance for technological innovation failures of enterprises, and improve their ability to bear various risks of enterprises. This can urge enterprises to carry out long-term and continuous technology research and development, improve their support for enterprise innovation, optimize the relevant processes in the project innovation process, and ultimately improve the innovation efficiency of enterprises.

The psychological capital of venture capital can increase their failure tolerance for the innovation activities of enterprises, which can then have a positive impact on the innovation performance of enterprises. The prospect, perception, concern and incentive degree of venture capital towards enterprises affect and influence entrepreneurs to varying degrees, transform their innovation awareness, and promote the consistency of enterprise values with venture capital' risk preference and innovation willingness, thus increasing the value added of enterprises' innovation. Luthans and Avey et al. (2009) found that it is necessary to improve the psychological capital of entrepreneurial institutional investors. The four dimensions of psychological capital, namely, confidence, hope, optimism, and perseverance, are all positive psychological states, which can improve the cognitive level of venture capital on the expectation of enterprise development prospects, enhance the tolerance of venture capital to the failure of innovation of enterprises, and enhance their willingness to provide value-added services for enterprises. This will not only help the company to build a fault-tolerant culture, but also help the company to obtain additional funding from outside sources and reduce innovation failures caused by financing constraints in innovation activities. Therefore, hypotheses are formulated.

> *H3*: The tolerance of venture capital to innovation failure plays an mediating role between its shareholding ratio, dispatched directors and enterprise innovation performance.

3.4. The moderating effect of joint investment on the relationship between venture capital failure tolerance and the innovation performance of enterprises

Joint investment is often used as an investment strategy by venture capitalists because of the amount of capital required for corporate R&D and the high risk of innovation failure in the early stages of a business. Joint investment among venture capital institutions can provide enterprises with multiple financing channels, which can guarantee enterprises in the process of R&D and can also prevent the cash flow of the company from being affected so that the company has more capital This allows the company to invest in technological innovation. At the same time, the strategy of joint investment is conducive to diversifying the risks of the portfolio and balancing the risks between the various portfolios through phased investment; Venture capital institutions can also share resources and complementary professional skills among themselves by attracting other investment institutions to jointly invest, and share risks. Therefore, if they choose to make a joint investment, it will reduce the investment risks faced by venture capital, and venture capital can also obtain more assets with complementary nature (Wang and Zhou, 2017). Then, the tolerance of venture capital institutions for the failure of enterprises' R&D activities will also be enhanced, and their tolerance for innovation risks will also increase, and they will provide long-term stable and sufficient funds for innovation investment, encourage enterprises to carry out riskier innovation projects, support enterprises to increase their R&D funds, and bring greater incentives for enterprises to innovate (Tian and Wang, 2014), which will ultimately help enterprises to be able to achieve more breakthroughs in science and technology innovation (Lu et al., 2017) and improve their innovation performance. Therefore, hypotheses are made.

> *H4*: The joint investment strategy has a positive moderating effect on the relationship between the failure tolerance of venture capital institutions and the innovation performance of enterprises, and the more joint investment is chosen, the stronger the tolerance of venture capital to innovation failure will promote the innovation performance of enterprises.

3.5. The moderating effect of geographical proximity on the relationship between venture capital failure tolerance and the innovation performance of enterprises

Geographical proximity is important in venture capital investment decisions, with a preference for proximity to mitigate the uncertainty of the investment environment. If you choose local companies to invest nearby, more frequent face-to-face communication can take place between venture capital and companies, and both parties can be able to reduce transportation costs and time costs (Dong et al., 2019) and improve the efficiency, quality of mutual information exchange. At the same time, choose to invest closely, venture capital will face fierce competition, to obtain high-quality innovation projects, their attitude towards the innovation failure of enterprises will be more tolerant, tolerance for innovation failure will be higher, it will rely on its own professional investment experience, technology, network resources, for enterprises to carry out technological innovation to provide professional knowledge, strategic consulting, help enterprises formulate technology research and development, product development policies and strategies. In summary, with the enhancement of the ability of venture capital to take risks of enterprises, the tolerance of enterprises' innovation failures has increased, in this case, frequent and positive contact and communication with entrepreneurs, improve the degree of the risk appetite of entrepreneurs, to promote its initiative in enterprise innovation, and ultimately improve the innovation performance of enterprises. Therefore, hypotheses are made:

> *H5*: Geographical proximity has a positive moderating effect on the relationship between the failure tolerance of venture capital institutions and the innovation performance of enterprises, and if

> the close investment is chosen, the more tolerance of venture capital to innovation failure will promote the innovation performance of enterprises.

4. Study design

4.1. Data sources and sample selection

This paper selects all financing events and listed companies from the CVSource database from January 1, 2000, to December 31, 2019. Depending on the needs of the study, the sample was screened using the following criteria: (1) the CVSource database was used to find the financing data of listed companies from 2000 to 2019,define whether the company accepts the investment of venture capital according to the type of investment institutions; obtain data on VC shareholding ratio and joint investment scale; obtain data on enterprise characteristics; (2) Obtain data on various patent applications of the company from the State Intellectual Property Office and Baiteng.com through the manual collection; (3) Determine whether the board members are dispatched by venture capital and the investment institution to which they belong based on the personal characteristics and resumes of the company's board members disclosed in the Guotai An database (CSMAR); (4) Find the deregistered company from the list of financing events in the CVSource database; on this basis, the data of VC failure tolerance is calculated; (5) Combine relevant data containing the same venture capital institution in the same investment round; (6) Delete samples with missing or missing data. According to the above standard processing, the final 5,119 company-year observations of VC investment were obtained.

4.2. Variable description and definition

4.2.1. Explained variables

Corporate innovation performance. At this point, there is no unified standard for measuring the innovation performance of enterprises in academia, since the current level of information disclosure on innovation input by listed companies in China is not high, and, the number of patent applications selected can measure the effect of corporate innovation activities, which takes into account the corporate innovation input and reflects the efficiency (Chen et al., 2017). The granting of a company's patent is, moreover, affected by the timing of granting as well as external uncertainties, among other factors. Therefore, drawing on studies by other scholars (Chemmanur et al., 2014), this paper uses the total number of patent applications (Patent) (including the number of inventions, utility model, and design patent applications) with a lag of 1 year to measure the performance of corporate innovation. Among the three types of patents mentioned above, invention patents contain more technological elements and are more innovative than the other two types of patents. Therefore, this paper also uses the number of invention patents filed with a one-year lag (Innovation) to measure the technological innovation performance of firms.

4.2.2. Explanatory variables

(1) *VC Involvement*. To study the impact of whether venture capital enters the enterprise and its participation on the innovation performance of the enterprise, this paper sets a dummy variable for venture capital participation, which has a value of "1" if the enterprise receives funds from venture capital institutions in the year of the transaction, and "0" otherwise.

To study the mechanism of VC influencing the innovation performance of enterprises, this paper further uses the two variables of VC shareholding ratio and VC sending directors to the board of directors to measure the impact of VC on the innovation performance of enterprises by mastering control rights of the enterprise.

(2) *VC Share*: According to the data of financing events disclosed by CVSource database, measure the equity ratio of VC in financing events.

(3) *VC Accredited Directors*: After VC invests in the enterprise, before exiting the enterprise, if the venture capital sends directors to the board of directors of the enterprise in that year and has the decision-making power on important matters, the value of this variable is "1"; otherwise, the value of the variable is "0."

4.2.3. Mediation variables

Tolerance: Refers to the extent to which VCs tolerate the failure of technological innovation of a company. This paper uses the investment horizon of a VC between its initial investment and its decision to terminate its investment in an ultimately failed project to measure its failure tolerance (Tian and Wang, 2014). The duration of the VC in the firm that eventually fails is a weighted average, with the weight being the amount of their investment in that firm as a proportion of their total investment in that year.

4.2.4. Moderating variables

(1) *Syndication*. This is measured by the number of VCs investing in a particular venture.

(2) *Distance*. The natural logarithm of the number of train miles between the VC and the enterprise is used to measure.

4.2.5. Control variables

(1) *Stage*: set the dummy variable, that is, if the enterprise is in the early development stage (including the seed stage, and development stage) when receiving investment, the variable takes the value of "1," otherwise, the variable takes the value of "0."(2) *Industry*. According to the industry-level classification in the Qingke database, the industries to which enterprises belong are divided into five categories: broad IT, biotechnology/health, clean technology, services, and tradition. Since the broad IT industry has higher requirements for enterprise innovation than other industries, the technical content is higher, and the difficulty of enterprise innovation will be greater, to better study the impact of venture capital on enterprise innovation performance, this paper focuses on whether the broad IT industry will have an impact on enterprise innovation performance. Consequently, a dummy variable is set to "1" if the VC invests in a company in the broad IT industry, and "0" otherwise. (3) *GDP Growth Rate*. This paper also introduces the variable representing the year of investment into the regression to control for the fixed effects of the year of investment.

4.3. Model building

(1) To test hypotheses H1 and H2a-b, the total number of Patent applications (Patent) and the number of invention patent applications (Innovation) are taken as explained variables to study the influence of venture capital participation, shareholding ratio, dispatched directors on its innovation performance. The following model was set up for testing.

$$\text{Patent / Innovation}_{it+1} = \alpha_0 + \alpha_1 \text{VCInvolvement}_{it} + \alpha_2 \text{Stage}_{it} + \alpha_3 \text{GDPGrowthRate}_{it} + \alpha_4 \text{IT}_{it} + + \gamma_t + \varepsilon_{it} \quad (1)$$

$$\text{Patent / Innovation}_{it+1} = \beta_0 + \beta_1 \text{VCShare / Accredited Directors}_{it} + \beta_2 \text{Stage}_{it} + \beta_3 \text{GDPGrowthRate}_{it} + \beta_4 \text{IT}_{it} + + \gamma_t + \varepsilon_{it} \quad (2)$$

(2) Firstly, to test H3, the Tolerance of venture capital to innovation failure is taken as the explained variable to study the impact of venture capital shareholding ratio and dispatched directors on the tolerance of venture capital failure, and the following model is set for testing.

$$\text{VC Tolerance}_{it} = \gamma_0 + \gamma_1 \text{VCShare / Accredited Directors}_{it} + \gamma_2 \text{Stage}_{it} + \gamma_3 \text{GDPGrowthRate}_{it} + \gamma_4 \text{IT}_{it} + + \gamma_t + \varepsilon_{it} \quad (3)$$

Secondly, the total number of Patent applications (Patent) and the number of invention patent applications (Innovation) are taken as explained variables to study the impact of venture capital shareholding ratio, dispatched directors, and failure tolerance of venture capital on enterprise innovation performance. The following model is set for the test.

$$\text{Patent / Innovation}_{it+1} = \phi_0 + \phi_1 \text{VC Tolerance}_{it} + \phi_2 \text{Stage}_{it} + \phi_3 \text{GDPGrowthRate}_{it} + \phi_4 \text{IT}_{it} + + \gamma_t + \varepsilon_{it} \quad (4)$$

$$\text{Patent / Innovation}_{it+1} = \mu_0 + \mu_1 \text{VCShare / Accredited Directors}_{it} + \mu_2 \text{VC Tolerance}_{it} + \mu_3 \text{Stage}_{it} + \mu_4 \text{GDPGrowthRate}_{it} + \mu_5 \text{IT}_{it} + + \gamma_t + \varepsilon_{it} \quad (5)$$

In the above regression model, The patent represents the total number of patent applications of the enterprise. Considering that the enterprise has not applied for patents in some years, the logarithm of the number of patent applications will be missing. In this paper, the total number of patent applications is added by 1, and then the logarithm is taken. Innovation represents the number of invention applications. In the model, add 1 to the number of invention patent applications to take the logarithm. Since the number of patent applications is a non-negative integer with a discrete distribution, this paper also uses the negative binomial regression model (NBR) for empirical test. γ_t in Equations (1)–(5) represents the fixed effect existing in the investment year, while ε_{it} represents the random disturbance term.

5. Empirical results and analysis

5.1. Descriptive statistics and correlation analysis

Table 1 lists the results of a simple descriptive statistical analysis of each of the main variables. The average number of patent and invention patent applications is 20.289 and 7.052 respectively, indicating that after receiving VC funds, enterprises actively carry out technological innovation activities; the average values of the proportion of equity held by VC and the proportion of directors sent to the board of directors are 3.87% and 0.169% respectively, indicating that the proportion of equity held by VC and the proportion of directors sent to the board of directors are relatively small. Different types of VC have great differences in terms of joint investment scale and geographical proximity. To avoid the influence brought by extreme values, this paper winsorizes all variables at 5% quantile before starting the empirical study, to avoid the problem of multicollinearity caused by the introduction of explanatory variables, mediating variables, and moderating variables.

To compare whether enterprises with or without VC participation have significant differences in patent and other aspects, this paper adopts the mean value test (see Table 2 for the results). The results show that VC participation can not only provide enterprises with the funds needed for innovation, but also provide enterprises with professional knowledge and strategic consultation in technological innovation, and help enterprises improve their innovation ability and performance.

Table 1 shows the correlation coefficients between the VC shareholding ratio, dispatched directors, VC failure tolerance, and enterprise patents. The results show that the VC shareholding ratio and dispatched directors have a significant positive impact on the total number of patent applications and the number of invention patent applications of enterprises, that is, the higher the shareholding ratio, the dispatched directors to the board of directors of enterprises, VC will send a positive signal about the enterprise's innovation ability to the external capital market, at this time, external investors will choose to invest more capital in the enterprise. It is helpful for enterprises to spend more funds on technology research and development, to improve their innovation performance. In addition, both VC shareholding ratio and dispatched directors have a significant positive impact on their tolerance for innovation failure, that is, the higher VC shareholding ratio and dispatched directors to the board of directors of enterprises can enhance their control over enterprises, and have a higher tolerance for technological innovation failure.

5.2. Impact of venture capital participation on enterprise innovation performance

In this part, multivariate regression and negative binomial regression models are used, respectively. After controlling variables such as enterprise development stage, IT industry, and GDP growth rate, as well as the fixed effect existing in the investment year, the influence of VC participation on the total amount of patent applications and invention patent applications of enterprises is studied, respectively. The results are shown in Table 3.

Models 1–2 and 3–4, respectively, show the impact of VC participation on the total amount of patent applications and the number of invention patent applications. At the significance level of 1%, VC participation will have a positive impact on the total number of patent applications and invention patent applications of enterprises. The results show that, VC can solve the problems of insufficient R&D funds by providing the required funds to enterprises engaged in R&D activities; VC provides professional knowledge and technical guidance for enterprises to carry out technological innovation, helps enterprises to innovate by obtaining valuable technologies and resources from enterprises in the same industry. Finally, improve the performance of enterprise innovation. This also proves Hypothesis H1.

10.3389/fpsyg.2023.1133324

TABLE 1 Descriptive statistics of main variables and Pearson correlation analysis of the main variables.

	Observations	Mean value	Standard Deviation	VC Share	Accredited Directors	Patent	Innovation	VC Tolerance	Stage	IT	GDP
VC Share	4,520	3.870	4.253	1	0.356**	0.469**	0.575**	0.268**	0.057**	0.039*	−0.028
Accredited Directors	5,119	0.169	0.375	0.356**	1	0.136**	0.180**	0.104**	0.015	0.006	−0.031
Patent	5,119	20.289	27.187	0.469**	0.136**	1	0.867**	0.217**	−0.061**	−0.076**	−0.033*
Innovation	5,119	7.052	10.061	0.575**	0.180**	0.867**	1	0.197**	−0.066**	0.017	−0.027
VC Tolerance	2,848	6.503	3.042	0.268**	0.104**	0.217**	0.197**	1	0.192**	0.044*	0.033
Stage	5,119	0.4500	0.5	0.057**	0.015	−0.061**	−0.066**	0.192**	1	0.063**	−0.002
IT	5,119	0.388	0.487	0.039*	0.006	−0.076**	0.017	0.044*	0.063**	1	−0.049**
GDP	5,119	1.663	2.096	−0.028	−0.031	−0.033*	−0.027	0.033	−0.002	−0.049**	1

**, * They are significant at the level of 0.01 and 0.05, respectively.

TABLE 2 Mean test.

Variable	VC involvement (*N*=3,646)	NO VC involvement (*N*=1,473)	T-test of sample difference
Patent	21.891	19.798	2.092**
Innovation	9.058	5.560	3.498***
Stage	0.529	0.427	0.102***
IT	0.392	0.377	0.015
GDP	1.668	1.652	0.015

***,**,*They are significant at the level of 0.01 and 0.05, respectively.

TABLE 3 The impact of venture capital involvement on enterprise innovation performance.

Variable	Patent		Innovation	
	OLS	NBR	OLS	NBR
	Model 1	Model 2	Model 3	Model 4
VC involvement	0.200*** (0.035)	0.126*** (0.041)	0.503*** (0.036)	0.511*** (0.040)
Stage	−0.131*** (0.031)	−0.078** (0.036)	−0.226*** (0.033)	−0.177** (0.035)
IT	−0.212*** (0.032)	−0.210*** (0.038)	−0.007 (0.034)	−0.009 (0.036)
GDP	−0.024*** (0.007)	−0.031*** (0.008)	−0.012 (0.008)	−0.012*** (0.008)
Constant	2.437*** (0.036)	3.132*** (0.042)	1.158*** (0.038)	1.807*** (0.042)
Year dummy	Control	Control	Control	Control
Observations	5,115	5,116	5,115	5,116
Adj *R*-squared	0.018		0.041	
F	25.007		55.934	
Log pseudolikelihood		−20,825.66		−15,967.834

The brackets are standard errors, and ***, ** and * are significant at the level of 0.01, 0.05 and 0.1, respectively.

Among the control variables, enterprise development stage, IT industry, and GDP growth rate have a significant negative impact on enterprise innovation performance.

5.3. Impact of venture capital shareholding ratio and directors dispatched on enterprise innovation performance

This part uses multivariate regression and negative binomial regression model respectively, to study the impact of the proportion of equity held by VC and the dispatch of directors on the total number of patent applications and the number of invention patent applications of enterprises. The results are presented in Table 4.

Models 5–6 and 9–10, respectively, show the influence of the VC shareholding ratio on the total amount of patent applications and invention patent applications. At the significance level of 1%, the proportion of equity held by VC has a positive impact on the total

TABLE 4 Impact of VC shareholding and dispatched directors on enterprise innovation performance.

Variable	Patent				Innovation			
	OLS	NBR	OLS	NBR	OLS	NBR	OLS	NBR
	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
VC share	0.028*** (0.004)	0.017*** (0.028)			0.121*** (0.003)	0.104*** (0.002)		
Accredited Directors			0.385*** (0.046)	0.319*** (0.048)			0.623*** (0.056)	0.500*** (0.054)
Stage	−0.128*** (0.039)	−0.189** (0.087)	−0.131*** (0.037)	−0.049 (0.041)	−0.196*** (0.040)	−0.048 (0.049)	−0.192*** (0.044)	−0.049 (0.050)
IT	−0.199*** (0.040)	−0.323*** (0.080)	−0.171*** (0.037)	−0.153*** (0.043)	0.013 (0.041)	0.064 (0.051)	0.055 (0.045)	0.090* (0.052)
GDP	−0.025*** (0.009)	−0.030*** (0.011)	−0.017** (0.009)	−0.022** (0.010)	−0.009 (0.009)	−0.004 (0.012)	−0.013 (0.011)	−0.018 (0.012)
Constant	2.529*** (0.039)	3.524*** (0.100)	2.536*** (0.035)	2.536*** (0.035)	1.002*** (0.040)	1.652*** (0.047)	1.527*** (0.042)	2.376*** (0.047)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control
Observations	3,201	3,202	3,643	3,644	3,157	3,158	3,643	3,644
Adj *R*-squared	0.023		0.028		0.336		0.037	
F	19.719		27.089		399.764		36.073	
Log pseudolikelihood		−13,791.45		−14,926.055		−10,414.851		−12,583.93

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

number of patent applications and the number of invention patent applications. The results show that the higher the shareholding ratio, the more capital, and value-added services it can provide to enterprises. It can provide enterprises with more technical support and guidance for technology research and development and new product development, and the entrepreneurs will also be more willing to innovate, and finally promote the improvement of enterprise innovation performance. This also proves that hypothesis H2a.

Models 7–8 and 11–12 show the impact of VC sending directors to the board of directors on the total number of patent applications and invention patent applications, respectively. At the significance level of 1%, VC sending directors to the board of directors has a positive impact on the total number of patent applications and invention patent applications. The results show that, after dispatching directors to enterprises, VC will strengthen its position and role in the board of directors through hold seats on the board of directors, and give technical advice and guidance in the process of enterprise innovation, rationally allocating various resources used in the process of enterprise innovation, and finally improving the performance of enterprise innovation. This also proves Hypothesis H2b.The influence of each control variable on enterprise innovation performance is the same as that of the full sample.

5.4. Mediating effect of venture capital's tolerance for innovation failure on the relationship between its shareholding, directors dispatch and enterprise innovation performance

To test the mediating effect of the tolerance of venture capital on the relationship among their shareholding ratio, dispatched directors, and enterprise innovation performance, this part test whether the coefficient of variables in the regression model is significant, that is, if β_1 in Equation 2 is significant, γ_1 in Eqaution 3 is significant, and μ_2,$\mu_1$in Equation 5 is significant; also μ_1 less than β_1, if the coefficient is reduced, VC's tolerance for innovation failure will play a part of mediation role; If μ_1 not significant, μ_2 significant, VC plays a complete mediation role in the tolerance of innovation failure.

Firstly, Models 13 and 16 in Table 5 and Models 23 and 26 in Table 6 verify that VC's shareholding ratio and sending directors to the board of directors have an impact on their tolerance for innovation failure. At the significance level of 1%, the proportion of equity held by the VC and the dispatched directors, respectively, have a significantly positive impact on its failure tolerance. The results show that: If the shareholding ratio is high and the directors are sent to the board of directors of enterprises, VC will realize the convergence of its interests with entrepreneurs. They have a higher tolerance for technological innovation failure.

Secondly, through models 14–15 and 17–18 in Table 5 and 24–25 and 27–28 in Table 6, the influence of VC's tolerance for innovation failure on enterprise innovation performance is studied. At the significance level of 1%, VC's tolerance for innovation failure has a significant positive impact on the total number of patent applications and the number of invention patent applications. The results show that: Enterprises supported by VC who can tolerate technological innovation failure are more likely to establish a culture of tolerance for failure, which will affect entrepreneurs' attitude towards innovation failure, improve their risk preference, make them willing to bear higher technological innovation risks, increase R&D investment, achieve the purpose of improving enterprise innovation efficiency.

Finally, Model 19–22 in Table 5 and Model 29–32 in Table 6 are used to study the mediating effect of VC's tolerance for innovation failure on its shareholding ratio, dispatched directors, and enterprise innovation performance. The research results show that after the variable of VC failure tolerance is added when the total

number of patent applications is taken as the explained variable, the coefficient of VC's shareholding ratio decreases from 0.028 to 0.011, and the coefficient of VC's dispatched directors decreases from 0.385 to 0.309. When the number of invention patent applications was taken as the explained variable, the coefficient of VC's shareholding ratio and the coefficient of dispatched directors also decreased. The coefficient of VC's shareholding ratio decreased from 0.121 to 0.114, and the coefficient of VC's dispatched directors decreased from 0.623 to 0.582, and the regression coefficient was still significant. In the negative binomial regression model, VC's shareholding ratio and the coefficient of sending directors also decreased. The results show that VC's tolerance for innovation failure plays a partial mediating effect between its shareholding ratio, dispatched directors, and enterprise innovation performance and hypothesis H3 is verified.

To test the value of the mediating effect produced by VC's innovation failure tolerance, this paper adopts the Process program. The direct effect, indirect effect, and total effect values between VC's shareholding ratio dispatched directors (explanatory variable), VC's tolerance for innovation failure Mediation variables, total patent applications and invention patent applications (explained variable) are estimated, and the results are shown in Table 7. The results show that when the total number of patent applications (number of invention patent applications) is taken as the explained variable, in the first stage, the influence coefficients of VC shareholding ratio and dispatched directors on VC failure tolerance are 0.105 and 0.432 (0.114 and 0.826), respectively, which have a significant impact on the results. In the second stage, in the case of VC shareholding and dispatching directors. The coefficients of the effects of VC failure tolerance on the total number of corporate patent applications (number of invention patent applications) were 0.069 and 0.051 (0.044 and 0.086), respectively, with significant results. That is, the direct effect coefficients of the VC shareholding ratio and dispatched directors on the total amount of patent applications (invention patent applications) are 0.012 and 0.309 (0.114 and 0.582) respectively. The indirect effects of the VC shareholding ratio and dispatched directors on the total amount of enterprise patent applications (invention patent applications) are 0.007 and 0.002 (0.005 and 0.071), respectively, and the results are significant. Therefore, the total effect coefficients of VC's shareholding ratio and dispatched directors on the total amount of patent applications (invention patent applications) are 0.019 and 0.331 (0.119 and 0.653). The partial mediating effect of VC failure tolerance was verified, assuming that H3 passed the test.

5.5. Moderating effect of characteristics of heterogeneous venture capital institutions

There is heterogeneity among different types of venture capital institutions, which are significantly different in joint investment strategy and geographical proximity, and these differences will affect the relationship between venture capital institutions' tolerance of early innovation failure and enterprise innovation performance.

TABLE 5 Impact of venture capital shareholding and failure tolerance on enterprise innovation performance.

Variable	VC Tolerance	Patent		VC Tolerance	Innovation		Patent		Innovation	
	OLS	OLS	NBR	OLS	OLS	NBR	OLS	NBR	OLS	NBR
	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21	Model 22
VC share	0.105*** (0.014)			0.114*** (0.010)			0.011*** (0.006)	0.016*** (0.004)	0.114*** (0.004)	0.093*** (0.003)
VC Tolerance		0.054*** (0.009)	0.092*** (0.011)		0.094*** (0.009)	0.112*** (0.009)	0.069*** (0.009)	0.106*** (0.012)	0.044*** (0.009)	0.082*** (0.009)
Stage	1.264*** (0.126)	−0.068 (0.049)	−0.225** (0.098)	0.956*** (0.132)	−0.227*** (0.058)	−0.181*** (0.060)	−0.092* (0.052)	−0.258** (0.108)	−0.193*** (0.052)	−0.109** (0.055)
IT	0.057 (0.129)	−0.117** (0.049)	−0.232*** (0.090)	0.060 (0.136)	0.139** (0.058)	0.178*** (0.058)	−0.141*** (0.052)	−0.225** (0.099)	0.099* (0.053)	0.170*** (0.056)
GDP	0.033 (0.029)	−0.007 (0.011)	−0.019 (0.015)	0.029 (0.031)	0.002 (0.013)	−0.013 (0.013)	−0.010 (0.012)	−0.031** (0.014)	0.006 (0.012)	−0.001 (0.012)
Constant	5.807*** (0.119)	2.364*** (0.065)	3.071*** (0.107)	5.506*** (0.128)	1.187*** (0.072)	1.887*** (0.073)	2.237*** (0.072)	2.924*** (0.118)	0.845*** (0.069)	1.251*** (0.067)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Observations	1,883	2,179	2,180	1,937	2,297	2,298	1,883	1,884	1,937	1,938
Adj *R*-squared	0.089	0.018		0.095	0.046		0.035		0.348	
F	46.929	11.255		52.069	28.403		14.531		207.781	
Log pseudolikelihood			−9,735.939			−8,251.332		−8,428.775		−6,682.154

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

TABLE 6 Impact of dispatched directors and failure tolerance of venture capital on enterprise innovation performance.

Variable	VC Tolerance	Patent		VC Tolerance	Innovation		Patent		Innovation	
	OLS	OLS	NBR	OLS	OLS	NBR	OLS	NBR	OLS	NBR
	Model 23	Model 24	Model 25	Model 26	Model 27	Model 28	Model 29	Model 30	Model 31	Model 32
Accredited Directors	0.432*** (0.149)			0.826*** (0.163)			0.309*** (0.059)	0.266*** (0.058)	0.582*** (0.072)	0.451*** (0.065)
VC Tolerance		0.054*** (0.009)	0.092*** (0.011)		0.094*** (0.009)	0.112*** (0.009)	0.051*** (0.008)	0.073*** (0.007)	0.086*** (0.009)	0.108*** (0.009)
Stage	1.526*** (0.119)	−0.068 (0.049)	−0.225** (0.098)	1.182*** (0.128)	−0.227*** (0.058)	−0.181*** (0.060)	−0.068 (0.049)	−0.025 (0.050)	−0.220*** (0.057)	−0.164*** (0.061)
IT	0.113 (0.122)	−0.117** (0.049)	−0.232*** (0.090)	0.206 (0.131)	0.139** (0.058)	0.178*** (0.058)	−0.114** (0.048)	−0.076 (0.050)	0.144** (0.057)	0.193*** (0.058)
GDP	0.050* (0.028)	−0.007 (0.011)	−0.019 (0.015)	0.050* (0.030)	0.002 (0.013)	−0.013 (0.013)	−0.007 (0.011)	−0.017 (0.011)	0.003 (0.013)	−0.010 (0.013)
Constant	5.866*** (0.107)	2.364*** (0.065)	3.071*** (0.107)	5.586*** (0.115)	1.187*** (0.072)	1.887*** (0.073)	2.320*** (0.066)	2.266*** (0.058)	1.121*** (0.072)	1.794*** (0.072)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Observations	2,179	2,179	2,180	2,297	2,297	2,298	2,179	2,180	2,297	2,298
Adj *R*-squared	0.075	0.018		0.048	0.046		0.030		0.072	
F	44.935	11.255		29.891	28.403		14.545		36.504	
Log pseudolikelihood			−9,735.939			−8,251.332		−9,232.265		−8,223.702

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

TABLE 7 Direct, indirect, and total effects of VC shareholding and dispatched directors on enterprise innovation performance through their failure tolerance.

Variable	Stage		Effect		
	Phase I	Phase II	Direct effect	Indirect effect	Total effect
VC Share	0.105*** (0.114***)	0.069*** (0.044***)	0.012** (0.114***)	0.007*** (0.005***)	0.019*** (0.119***)
VC Accredited Directors	0.432** (0.826***)	0.051*** (0.086***)	0.309*** (0.582***)	0.002*** (0.071***)	0.331*** (0.653***)

In parentheses are the effect values corresponding to the invention patent as the explained variable，***, **, and *are significant at the level of 0.01, 0.05, and 0.1, respectively.

5.5.1. Moderating effect of joint investment on the relationship between VC failure tolerance and enterprise innovation performance

To study the moderating effect of joint investment strategy on the relationship between VC's failure tolerance and enterprise innovation performance, this paper divides the samples into groups and divides the samples into individual investment and joint investment samples according to the number of joint investment institutions. On this basis, regression analysis is carried out for VC in different samples. The relationship between innovation failure tolerance and innovation performance in the early stage is studied. The results are shown in Table 8.

Table 8 shows the moderating effect of joint investment strategy on the relationship between VC failure tolerance, total patent applications, and the number of invention patent applications. Models 33, 35 and 37, 39 show the regression coefficient between the tolerance of VC who choose joint investment and independent investment for innovation failure and the total number of enterprise patent applications (number of invention patent applications) are 0.063 and 0.018 (0.1 and 0.074), respectively, except that when the total amount of patent applications is taken as the explained variable, the coefficient of investment alone is not significant. In other cases, the regression coefficients were significant at the 1% level. The research results show that joint investment will reduce the investment risks faced by VC, VC's tolerance of innovation failure will also increase, it will support enterprises to carry out high-risk R&D innovation, and bring more incentive effect to enterprise innovation. The above results show that the joint investment strategy has a positive moderating effect on the relationship between the VC's tolerance of innovation failure in the early stage and the firm's innovation performance This result confirms hypothesis H4.

5.5.2. The moderating effect of geographical proximity on the relationship between VC failure tolerance and enterprise innovation performance

To study the moderating effect of geographical proximity on the relationship between VC's failure tolerance and an enterprise's innovation performance, this paper grouped the samples and divided them into remote and near-distance investment samples according to the mean value of geographical distance. On this basis, regression analysis was conducted on VC in different samples. The relationship

10.3389/fpsyg.2023.1133324

between innovation failure tolerance and innovation performance is studied. The results are shown in Table 9.

Table 9 shows the moderating effect of geographical proximity on the relationship between VC failure tolerance, the total amount of patent applications, and the number of invention patent applications. Models 41, 43, 45 and 47 show that the regression coefficients of VC's tolerance of innovation failure for short distance investment and long distance investment to the total number of enterprise patent applications (number of invention applications) are 0.062 and 0.046 (0.12 and 0.072), respectively, which are significant at the 1% level. The research results

TABLE 8 Regression results of the moderating effect of joint investment on the relationship between VC failure tolerance and enterprise innovation performance.

Variable	Patent				Innovation			
	Joint investment		Independent investment		Joint investment		Independent investment	
	OLS	NBR	OLS	NBR	OLS	NBR	OLS	NBR
	Model 33	Model 34	Model 35	Model 36	Model 37	Model 38	Model 39	Model 40
VC Tolerance	0.063*** (0.009)	0.085*** (0.008)	0.018 (0.020)	0.039** (0.017)	0.100*** (0.010)	0.126*** (0.010)	0.074*** (0.023)	0.073*** (0.019)
Stage	−0.101* (0.053)	−0.061 (0.055)	0.148 (0.131)	0.116 (0.125)	−0.230*** (0.062)	−0.192*** (0.067)	−0.152 (0.154)	−0.100 (0.147)
IT	−0.191*** (0.053)	−0.132** (0.055)	0.314** (0.130)	0.196 (0.120)	0.057 (0.063)	0.118* (0.064)	0.674*** (0.161)	0.466*** (0.141)
GDP	−0.001 (0.012)	−0.017 (0.013)	−0.061** (0.026)	−0.049** (0.024)	0.013 (0.015)	−0.008 (0.016)	−0.072** (0.033)	−0.056** (0.025)
Constant	2.338*** (0.071)	2.756*** (0.069)	2.451*** (0.162)	2.902*** (0.141)	1.143*** (0.079)	1.800*** (0.082)	1.320*** (0.188)	2.218*** (0.169)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control
Observations	1,833	1,834	345	346	1,934	1,935	362	363
Adj *R*-squared	0.028		0.024		0.050		0.064	
F	14.180		3.097		26.314		7.184	
Log pseudolikelihood		−7,778.644		−1,460.631		−6,905.569		−1,354.134

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05 and 0.1, respectively.

TABLE 9 Regression results of the moderating effect of geographical proximity on the relationship between VC failure tolerance and enterprise innovation performance.

Variable	Patent				Innovation			
	Proximity investment		Long distance investment		Proximity investment		Long distance investment	
	OLS	NBR	OLS	NBR	OLS	NBR	OLS	NBR
	Model 41	Model 42	Model 43	Model 44	Model 45	Model 46	Model 47	Model 48
VC Tolerance	0.062*** (0.015)	0.055*** (0.012)	0.046*** (0.011)	0.038*** (0.009)	0.120*** (0.016)	0.082*** (0.012)	0.072*** (0.012)	0.051*** (0.008)
Stage	−0.121 (0.087)	−0.074 (0.058)	−0.023 (0.064)	−0.015 (0.040)	−0.203* (0.104)	−0.086 (0.061)	−0.090 (0.069)	−0.035 (0.040)
IT	−0.139 (0.089)	−0.099 (0.060)	−0.098 (0.062)	−0.067* (0.039)	0.141 (0.107)	0.060 (0.064)	0.006 (0.068)	−0.005 (0.040)
GDP	−0.002 (0.021)	0.002 (0.018)	−0.001 (0.014)	−0.002 (0.009)	−0.001 (0.025)	0.003 (0.021)	0.014 (0.015)	0.007 (0.009)
Constant	2.413*** (0.119)	2.967*** (0.096)	2.363*** (0.083)	3.034*** (0.060)	1.046*** (0.135)	2.127*** (0.101)	1.916*** (0.089)	2.797*** (0.062)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control
Observations	631	632	1,393	1,394	672	673	1,414	1,415
Adj *R*-squared	0.026		0.011		0.074		0.024	
F	5.141		4.980		14.369		9.682	
Log pseudolikelihood		−2,710.857		−5,953.438		−2,453.025		−5,850.723

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05 and 0.1, respectively.

show that, in the case of close-range investment, VC will face fierce competition. To obtain high-quality innovation projects, VC will be more tolerant of possible technological innovation risks. VC will provide help for enterprise technology research and development and value creation. Finally, it helps enterprises achieve the purpose of improving innovation performance.

The above results show that geographical proximity has a positive moderating effect between VC's tolerance for innovation failure of an enterprise and its innovation performance. This result confirms hypothesis H5.

6. Robustness analysis

6.1. Propensity score matching analysis

The above research shows that enterprises with venture capital participation, higher shareholding ratio, and sending directors to the board of directors have higher innovation performance. Considering that such results may be caused by strong innovation ability and high innovation performance of enterprises, The above influence of venture capital participation, shareholding and dispatched directors on enterprise innovation performance may come from the "selection effect" in advance, rather than the value-added effect brought by holding enterprise equity and sending directors afterwards. In order to better identify the "selection effect" and "value-added effect" of VC, the propensity score matching method (PSM) is used for analysis, and the nearest neighbor matching method is combined with the self-sampling method.

First of all, this paper studies the effects of VC's shareholding ratio and the dispatch of directors on their tolerance for innovation failure and corporate innovation performance. The enterprises with higher than average VC holding ratio and sending directors were taken as the treatment group, and the enterprises with lower than average VC holding ratio and not sending directors were taken as the control group, and the control variables were taken as matching variables for propensity score matching analysis. The average processing effect results of VC's shareholding ratio, dispatched directors on failure tolerance and enterprise innovation performance before and after matching are shown in Table 10. After matching, at the significant level of 1%, the total number of patent applications and invention patent applications of enterprises are different from 0.After matching, the mean value of total patent applications (number of invention patent applications) of the group with higher shareholding ratio and dispatched directors were 2.478 and 2.726 (2.574 and 2.042), respectively, and the average ATT treatment effect was 0.179 and 0.385 (1.479 and 0.601), respectively. In addition, both before and after matching, VC's tolerance for innovation failure is different from 0. After matching, VC's mean tolerance for innovation failure is 7.464 and 7.149, respectively, and ATT's average treatment effect is 0.758 and 0.472, respectively. Compared with other VCS, those who hold a higher proportion of corporate equity and send directors to occupy the seats of the board of directors will have a higher tolerance for innovation failure, and the innovation performance of the enterprises they invest in will also be higher.

Secondly, this paper uses PSM to match each VC that holds corporate equity and dispatches directors with a VC that is similar in other aspects but does not hold corporate equity and dispatches directors. On this basis, regression analysis is carried out. First, the enterprise development stage and industry attributes, as well as the year variables as matching variables; Secondly, the Logit model is used to estimate the probability of VC holding corporate equity and dispatching directors. Thirdly, for each VC holding corporate equity and dispatching directors, a VC with similar propensity score, without holding corporate equity and dispatching directors is matched; Finally, regression analysis was conducted again on the obtained paired samples, and the results were shown in Tables 11–13.

(1) Models 49–50 and 53–54 in Table 11 and 51–52 and 55–56 in Table 11 show that, at the significance level of 1%, the proportion of equity held by VC and the number of directors dispatched by VC have a positive impact on the total number of patent applications and the number of invention patent applications of enterprises. The higher the proportion of VC shares, the more directors are dispatched to the board of directors of enterprises, ultimately help enterprises to achieve the purpose of improving innovation performance.

(2) Models 57 and 60 in Tables 12 and 67 and 70 in Table 13 show that, at the significance level of 1%, the proportion of equity held by VC and the dispatch of directors have a positive impact on its tolerance of innovation failure. If VC has a high proportion of shareholding and sends directors to the board of directors of enterprises, there will also be a higher tolerance for failure in technological innovation.

(3) Models 58–59 and 61–62 in Table 12 and 68–69 and 71–72 in Table 13 show that VC's tolerance for innovation failure has a positive impact on the total number of patent applications and the number of invention patent applications under the significance level of 1%. If VC has a high tolerance for innovation failure, entrepreneurs' risk preference will also increase, so as to achieve the purpose of improving enterprise innovation performance.

(4) Models 63–66 in Table 12 and 73–76 in Table 13 show that after adding VC's innovation failure tolerance, the coefficient of VC's shareholding ratio and dispatched directors decrease significantly. VC's tolerance for innovation failure plays a partial mediating effect among its shareholding ratio, dispatched directors, and enterprise innovation performance. After controlling the sample selection effect, VC that holds corporate equity and sends directors still has a promoting effect on corporate innovation performance, which indicates that VC improves its tolerance for corporate technological innovation failure by holding corporate equity and sending directors to the board of directors after the event, and on this basis also improves corporate innovation performance.

6.2. Heckman two-step regression analysis

Since PSM can only control the effects of matched variables, there is no way to control other unobserved variables. Therefore, next, the Heckman two-step regression model will be used to control the influence of other unobserved variables. According to the studies of Xiong and Gui (2018), Guo and Jiang (2013), and other scholars, whether the enterprise is located in the Pearl River Delta, Yangtze River Delta and Beijing-Tianjin Region (Region) is used as the instrumental variable of VC participating enterprises in this paper.VC located in these regions developed relatively fast, and enterprises located in these areas are more likely to obtain VC funds. Therefore, in the first stage of the Heckman model, this variable are used as the instrumental variable for VC participation; Then, the unobtainable variable (Mills) that affects whether VC

TABLE 10 Average treatment effect (ATT) of VC shareholding ratio, dispatched directors' tolerance to failure, and enterprise innovation performance.

Variable	Sample	Average treatment effect of VC shareholding ratio on its failure tolerance and enterprise innovation performance					Average treatment effect of VC dispatched directors on their failure tolerance and enterprise innovation performance				
		Processing group	Control group	ATT	Standard error	*T* value	Processing group	Control group	ATT	Standard error	*T* value
Innovation	Before matching	2.574	1.128	1.447	0.062	23.32***	2.042	1.410	0.632	0.072	8.79***
	After matching	2.574	1.095	1.479	0.067	21.92***	2.042	1.442	0.601	0.075	8.03***
Patent	Before matching	2.478	2.399	0.078	0.053	1.48	2.726	2.325	0.400	0.058	6.89***
	After matching	2.478	2.297	0.179	0.058	3.08***	2.726	2.340	0.385	0.060	6.46***
VC Tolerance	Before matching	7.464	6.275	1.189	0.178	6.69***	7.149	6.695	0.454	0.202	2.24**
	After matching	7.464	6.706	0.758	0.198	3.82***	7.149	6.677	0.472	0.218	2.16**

TABLE 11 Impact of VC shareholding and dispatched directors on enterprise innovation performance.

Variable	Patent				Innovation			
	OLS	NBR	OLS	NBR	OLS	NBR	OLS	NBR
	Model 49	Model 50	Model 51	Model 52	Model 53	Model 54	Model 55	Model 56
VC Share	0.030*** (0.004)	0.020*** (0.003)			0.121*** (0.003)	0.086*** (0.002)		
Accredited Directors			0.480*** (0.058)	0.292*** (0.036)			0.620*** (0.074)	0.323*** (0.040)
Stage	−0.117*** (0.042)	−0.064** (0.026)	−0.222*** (0.059)	−0.128*** (0.037)	−0.202*** (0.043)	−0.145*** (0.028)	−0.277*** (0.075)	−0.130*** (0.041)
IT	−0.219*** (0.043)	−0.128*** (0.026)	−0.056 (0.060)	−0.037 (0.037)	0.010 (0.044)	−0.002 (0.029)	0.111 (0.076)	0.060 (0.042)
GDP	−0.026** (0.010)	−0.016** (0.007)	−0.022 (0.013)	−0.012 (0.009)	−0.004 (0.011)	−0.007 (0.007)	−0.022 (0.017)	−0.010 (0.010)
Constant	2.517*** (0.043)	3.120*** (0.034)	2.451*** (0.061)	3.081*** (0.046)	0.986*** (0.043)	1.891*** (0.037)	1.568*** (0.078)	2.541*** (0.052)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control
Observations	2,772	2,773	1,407	1,408	2,799	2,800	1,407	1,408
Adj *R*-squared	0.027		0.054		0.342		0.055	
F	20.040		21.095		364.224		21.466	
Log pseudolikelihood		−11,398.963		−5,828.795		−9,218.066		−5,107.579

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

participates in the enterprise is obtained. Finally, in the second phase of the Heckman model, Mills is introduced as a control variable. The results are shown in Tables 14, 15.

In the first-stage model, the coefficient of Region is significantly positive at the level of 1%, indicating that if an enterprise is located in the Pearl River Delta, Yangtze River Delta, and Beijing and Tianjin, it is easier to obtain VC funds. In the second-stage regression model (for simplicity, only the results of the NBR regression model are listed, and the results of the multivariate regression model are similar to those of the NBR model), the results show that: (1) At the significance level of 1%, VC's shareholding ratio and sending directors to the board of directors have a significant positive impact on the total number of patent applications and invention patent applications; (2) After VC's tolerance for innovation failure is added, when the number of patent applications and the number of invention patent applications are taken as the explained variables, the coefficient of the VC's shareholding ratio and dispatched directors both decrease (when the total number of patent applications is taken as the explained variable, the coefficient of shareholding ratio of VC is not significant). VC's tolerance for innovation failure plays a mediating role in the relationship between its shareholding ratio, dispatched directors, and enterprise innovation performance.

TABLE 12 Impact of venture capital shareholding and failure tolerance on enterprise innovation performance.

Variable	VC Tolerance	Patent		VC Tolerance	Innovation		Patent		Innovation	
	OLS	OLS	NBR	OLS	OLS	NBR	OLS	NBR	OLS	NBR
	Model 57	Model 58	Model 59	Model 60	Model 61	Model 62	Model 63	Model 64	Model 65	Model 66
VC Share	0.108*** (0.015)			0.109*** (0.010)			0.016*** (0.006)	0.007* (0.004)	0.116*** (0.004)	0.081*** (0.003)
VC Tolerance		0.072*** (0.010)	0.061*** (0.008)		0.111*** (0.011)	0.078*** (0.008)	0.067*** (0.010)	0.057*** (0.008)	0.044*** (0.009)	0.032*** (0.007)
Stage	1.288*** (0.138)	−0.068 (0.056)	−0.039 (0.037)	0.843*** (0.142)	−0.181*** (0.067)	−0.074* (0.038)	−0.069 (0.056)	−0.037 (0.036)	−0.172*** (0.055)	−0.111** (0.036)
IT	0.023 (0.142)	−0.133** (0.056)	−0.097*** (0.037)	0.074 (0.148)	0.164** (0.069)	0.080** (0.040)	−0.140** (0.056)	−0.099*** (0.037)	0.097* (0.057)	0.019 (0.039)
GDP	0.041 (0.034)	−0.010 (0.013)	−0.007 (0.010)	0.043 (0.035)	0.011 (0.016)	0.010 (0.010)	−0.010 (0.013)	−0.007 (0.010)	0.005 (0.013)	−0.007 (0.010)
Constant	5.816*** (0.136)	2.253*** (0.078)	2.902*** (0.059)	5.558*** (0.139)	1.051*** (0.090)	2.157*** (0.067)	2.220*** (0.079)	2.895*** (0.058)	0.800*** (0.075)	1.824*** (0.055)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Observations	1,610	1,611	1,612	1,710	1,706	1,711	1,610	1,611	1,710	1,711
Adj *R*-squared	0.084	0.033		0.083	0.059		0.037		0.362	
F	37.735	14.841		39.530	27.676		13.405		194.865	
Log pseudolikelihood			−6,887.462			−6,290.641		−6,882.090		−5,939.336

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

TABLE 13 Impact of dispatched directors and failure tolerance of venture capital on enterprise innovation performance.

Variable	VC Tolerance	Patent		VC Tolerance	Innovation		Patent		Innovation	
	OLS	OLS	NBR	OLS	OLS	NBR	OLS	NBR	OLS	NBR
	Model 67	Model 68	Model 69	Model 70	Model 71	Model 72	Model 73	Model 74	Model 75	Model 76
Accredited Directors	0.618*** (0.198)			1.536*** (0.211)			0.318*** (0.076)	0.205*** (0.048)	0.541*** (0.094)	0.282*** (0.052)
VC Tolerance		0.033** (0.013)	0.029*** (0.010)		0.107*** (0.014)	0.065*** (0.009)	0.027** (0.013)	0.028*** (0.010)	0.088*** (0.014)	0.056*** (0.009)
Stage	1.969*** (0.200)	−0.071 (0.081)	−0.052 (0.052)	1.362*** (0.212)	−0.336*** (0.095)	−0.143*** (0.052)	−0.078 (0.080)	−0.060 (0.053)	−0.317*** (0.094)	−0.132** (0.052)
IT	0.027 (0.205)	0.005 (0.079)	0.004 (0.050)	0.242 (0.218)	0.224** (0.096)	0.118** (0.054)	0.018 (0.078)	0.009 (0.050)	0.237** (0.094)	0.124** (0.053)
GDP	0.106** (0.044)	−0.026 (0.017)	−0.018 (0.011)	0.099** (0.047)	−0.030 (0.021)	−0.017 (0.012)	−0.028 (0.017)	−0.019 (0.011)	−0.032 (0.020)	−0.019 (0.012)
Constant	5.409*** (0.197)	2.588*** (0.100)	3.272*** (0.051)	4.698*** (0.208)	1.352*** (0.111)	2.432*** (0.073)	2.470*** (0.103)	3.072*** (0.077)	1.211*** (0.112)	2.344*** (0.075)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Observations	855	855	856	930	930	931	855	856	930	931
Adj *R*-squared	0.115	0.005		0.095	0.066		0.024		0.097	
F	28.860	2.023		25.395	17.337		5.160		21.017	
Log pseudolikelihood			−3,708.425			−3,515.168		−3,701.349		−3,503.909

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

10.3389/fpsyg.2023.1133324

TABLE 14 Heckman treatment effect of VC's shareholding and dispatched directors on enterprise innovation performance.

Variable	Phase I	Phase II			
	VC Involvement	Patent		Innovation	
	Model 77	Model 78	Model 79	Model 80	Model 81
Region	0.159*** (0.038)				
VC Share		0.018*** (0.003)		0.085*** (0.002)	
Accredited Directors			0.239*** (0.030)		0.350*** (0.034)
Mills		0.323 (0.317)	0.209 (0.300)	0.128 (0.343)	−0.247 (0.318)
Stage		−0.074*** (0.024)	−0.076*** (0.023)	−0.140*** (0.027)	−0.095*** (0.024)
IT		−0.116*** (0.024)	−0.101*** (0.023)	−0.001 (0.027)	0.034 (0.025)
GDP Growth Rate		−0.015** (0.006)	−0.010* (0.006)	−0.013** (0.007)	−0.007 (0.006)
Constant	0.459*** (0.031)	2.971*** (0.152)	3.030*** (0.145)	1.862*** (0.165)	2.326*** (0.155)
Year dummy	Control	Control	Control	Control	Control
Observations	5,119	3,202	3,644	3,158	3,644
Log likelihood	−3,063.5				
Log pseudolikelihood		−13,159.395	−14,930.628	−10,435.372	−12,592.09

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

TABLE 15 Heckman treatment effect of VC's shareholding, dispatching directors and tolerance of failure on enterprise innovation performance (Phase II).

Variable	VC Tolerance	Patent		VC Tolerance		Innovation	Patent		Innovation	
	Model 82	Model 83	Model 84	Model 85	Model 86	Model 87	Model 88	Model 89	Model 90	Model 91
VC Share	0.105*** (0.014)			0.114*** (0.010)			0.004 (0.004)		0.080*** (0.003)	
Accredited Directors		0.432*** (0.149)			0.827*** (0.163)			0.197*** (0.040)		0.327*** (0.045)
VC Tolerance			0.046*** (0.007)			0.064*** (0.007)	0.059*** (0.008)	0.045*** (0.007)	0.035*** (0.007)	0.060*** (0.007)
Mills	−1.714 (1.654)	−1.997 (1.578)	0.849** (0.411)	−0.312 (1.755)	−1.086 (1.696)	1.097** (0.432)	1.115** (0.443)	0.879** (0.410)	1.013** (0.455)	1.125*** (0.432)
Stage	1.264*** (0.126)	1.524*** (0.119)	−0.043 (0.032)	0.956*** (0.132)	1.181*** (0.128)	−0.096*** (0.032)	−0.056 (0.034)	−0.045 (0.032)	−0.126*** (0.034)	−0.094*** (0.032)
IT	0.049 (0.129)	0.103 (0.123)	−0.076** (0.031)	0.058 (0.137)	0.200 (0.131)	0.071** (0.034)	−0.092*** (0.034)	−0.073** (0.031)	0.028 (0.036)	0.077** (0.034)
GDP Growth Rate	0.032 (0.029)	0.05* (0.028)	−0.005 (0.008)	0.029 (0.031)	0.050* (0.030)	0.002 (0.008)	−0.006 (0.009)	−0.005 (0.008)	−0.008 (0.009)	−0.001 (0.008)
Constant	6.627*** (0.801)	6.823*** (0.764)	2.578*** (0.206)	5.655*** (0.849)	6.106*** (0.820)	1.709*** (0.216)	2.358*** (0.22)	2.532*** (0.205)	1.357*** (0.224)	1.652*** (0.215)
Year dummy	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Observations	1,884	2,180	2,180	1,938	2,298	2,298	1,884	2,180	1,938	2,298
Adj *R*-squared	0.089	0.075		0.095	0.048					
F	37.76	36.28		41.64	23.99					
Log pseudolikelihood			−9,284.05			−8,321.048	−8,026.31	−9,273.553	−6,738.124	−8,297.463

The brackets are standard errors, and ***, **, and * are significant at the level of 0.01, 0.05, and 0.1, respectively.

Mills in model 78–81 are not significant, while Mills in model 88–91 are significant, indicating that there is a certain degree of self-selection problem, after controlling the self-selection bias, VC's shareholding ratio and dispatched directors have significantly promoted enterprise innovation performance by tolerating enterprise innovation failure. Hypotheses H2-H3 still hold.

7. Conclusions and discussion

7.1. Research conclusion

Firstly, this paper study the influence of venture capital participation on enterprise innovation performance and the mechanism of venture capital impact on enterprise innovation performance from two aspects: shareholding ratio and dispatched directors to occupy the seats of enterprise board of directors. Secondly, we further study the mediating effect of venture capital institutions' tolerance for innovation failure on the relationship between their shareholding, dispatched directors, and enterprise innovation performance. The main findings are as follows: (1) The participation of venture capital will have a significantly positive impact on the innovation performance of enterprises. It promotes the innovation performance of enterprises by holding corporate equity and sending directors to the board of directors. The higher the shareholding ratio of venture capital is, the directors dispatched to the board of directors will effectively supervise and control the enterprise, give technical guidance in the process of enterprise innovation, rationally allocate various resources used in the process of enterprise innovation, and ultimately improve the performance of enterprise innovation. (2) Venture capital's tolerance for innovation failure plays a partial mediating role in the relationship between its shareholding ratio, dispatched directors, and enterprise innovation performance. By holding shares of enterprises and sending directors to occupy seats on the board of directors, venture capital improves their tolerance for the failure of technological innovation of enterprises, urges enterprises to optimize various processes of project innovation, finally, it helps enterprises achieve the purpose of improving innovation performance. (3) As joint investment can reduce the investment risks faced by venture capital, their tolerance for innovation failure will also increase, and the funds they provide to enterprises will also increase. Accordingly, enterprises will also carry out more R&D on high-risk technologies and products, which is ultimately conducive to improving the innovation performance of enterprises. (4) In the case of close-range investment, with the increase of the tolerance of venture capital to enterprise innovation failure, entrepreneurs' preference for risk will also increase, which will help them better support enterprise innovation.

7.2. Countermeasures and suggestions

This paper also puts forward some suggestions from the perspective of practice: (1) By holding shares of enterprises and sending directors to occupy board seats, venture capital institutions improve their tolerance for the failure of early technological innovation, and ultimately promote enterprise innovation. Therefore, venture capital should be encouraged to actively participate in corporate governance. By increasing the proportion of shareholding and dispatching directors, venture capital should improve its tolerance of innovation failure, which can ultimately improve the efficiency of enterprise innovation. (2) Venture capital institutions with different knowledge, experience, and relationship networks, as well as with different geographical preferences, can be encouraged to join together to invest in companies. Strengthening the communication among investment institutions, so that they can provide complementary value-added services to enterprises to improve the innovation ability and performance of enterprises. (3) The government should improve the laws and regulations on intellectual property protection and other related aspects, create a good legal environment, help innovative enterprises to innovate more actively.

7.3. Limitations and future research direction

This paper also has certain shortcomings: due to the problem of data availability, this paper mainly adopts the data of patent applications when measuring the innovation performance of enterprises, which will have a certain influence on the research conclusion. In view of this deficiency, follow-up research can expand the scope of data collection, further obtain data on enterprise innovation investment, patent authorization and other aspects, and comprehensively measure the performance of enterprise innovation, which can better improve the reliability of research conclusions.

7.4. Theoretical contributions

Firstly, although some scholars have focused on the impact of venture capital participation on firms' innovation, they have not conducted further in-depth studies on the mechanisms by which venture capital affects firms' innovation performance. This paper is based on innovation economics and organizational control theory, the impact of venture capital participation on enterprise innovation performance is studied, and the mechanism of venture capital on enterprise innovation performance is studied from two aspects: shareholding ratio and sending directors to occupy seats on the corporate board of directors. Secondly, although some scholars have paid attention to the fact that the attitude of venture capital to innovation failures of enterprises may affect the risk appetite of entrepreneurs, they have not further studied the influence of venture capital' tolerance for innovation failures of enterprises on the relationship between venture capital and enterprise innovation performance. This article is based on the perspective of enterprise innovation culture, the mediating effects between venture capital firms' tolerance of innovation failure in terms of shareholding, the appointment of directors to occupy board seats, and firms' innovation performance are further investigated. Thirdly, some studies have paid attention to the impact of the type, investment strategy of venture capital institutions on the innovation performance of enterprises, some studies have ignored that different types of venture capital have different characteristics due to their own characteristics, and their tolerance for innovation failure of enterprises and the innovation performance of enterprises will have differentiated moderating effects, from the perspective of heterogeneity of different types of investment institutions, the moderating effect of characteristics such as joint investment strategies and geographical proximity of investment institutions on the relationship between failure tolerance of venture capital and firm innovation performance is investigated. Fourthly, to better identify the "selection effect" and "value-added effect" of venture capital particiption, this paper also adopts the PSM method and Heckman treatment effect model to further test the robustness of the impact of the VC's shareholding ratio, dispatched directors on the innovation performance of enterprises, and the mediating effect of failure tolerance of venture capital institutions. Finally, Based on relevant psychological theories, this paper studies the impact of venture capital' psychological capital on innovation performance by influencing their tolerance for innovation failure. It provides a theoretical basis for in-depth study of the relationship between the participation of venture capital, the tolerance of venture capital for the innovation failure of enterprises and the innovation performance of enterprises, and also provides experience reference for the

establishment of enterprise culture in fault tolerance and the promotion of enterprise scientific and technological innovation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

JH was responsible for writing—original draft, formal analysis, methodology, and conceptualization of this study. MC contributed to paper writing and hypothesis model design. YC Participated in the paper translating. QJ participated in the paper writing and analyzed data. SW collected and screened literature. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the following fund projects, namely Humanities and Social Sciences Research Youth Foundation of Ministry of Education of China (18YJC630046), Shaanxi Soft Science Research Program (2020KRM132).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1133324/full#supplementary-material

References

Arvanitis, S., and Stucki, T. (2014). The impact of venture capital on the persistence of innovation activities of start-ups. *Small Bus. Econ.* 42, 849–870. doi: 10.1007/s11187-013-9499-3

Avey, J. B., Luthans, F., and Jensen, S. M. (2009). Psychological capital: a positive resource for combating employee stress and turnover. *Hum. Resour. Manag.* 48, 677–693. doi: 10.1002/hrm.20294

Celikyurt, U., Sevilir, M., and Shivdasani, A. (2014). Venture capitalists on boards of mature public firms. *Rev. Financ. Stud.* 27, 56–101. doi: 10.1093/rfs/hhs096

Chemmanur, T. J., Loutskina, E., and Tian, X. (2014). Corporate venture capital, value creation, and innovation. *Rev. Financ. Stud.* 27, 2434–2473. doi: 10.1093/rfs/hhu033

Chen, S., He, W. L., and Zhang, R. (2017). Venture capital and Enterprise innovation: influence and potential mechanism. *Manage. World* 1, 158–169. doi: 10.19744/j.cnki.11-1235/f.2017.01.014

Cheng, L. W., and Zou, S. (2020). Research on the impact of venture capital's later entry on enterprise innovation performance——choice effect or value added effect? *Manag. Rev.* 32, 80–90. doi: 10.14120/j.cnki.cn11-5057/f.2020.01.011

Dong, W., Li, Y., Lv, X., and Yu, C. (2021). How does venture capital spur the innovation of environmentally friendly firms? Evidence from China. *Energy Econ.* 103:105582. doi: 10.1016/j.eneco.2021.105582

Dong, J., Shi, G. P., and Guo, L. (2019). Joint venture capital, indirect connection of competitors and Enterprise innovation. *R & D Manag.* 31, 91–101. doi: 10.13581/j.cnki.rdm.2019.02.009

Dong, J., Wang, J. P., Zhai, H. Y., and Li, W. (2017). Service or monitoring: venture capital Institutions' Management of start-ups—from the perspective of industry expertise and uncertainty. *Manage. World* 6, 82–103. doi: 10.19744/j.cnki.11-1235/f.2017.06.008

Duan, Y. Q., and Chen, J. (2020). How venture capital affects Enterprise innovation -- research review and Prospect. *Foreign Econ. Manag.* 43, 136–152. doi: 10.16538/j.cnki.fem.20200714.401

Feng, X., Chan, K. C., and Lo, Y. L. (2020). Are venture capitalist-backed IPOs more innovative? Evidence from an emerging market. *N. Am. J. Econ. Financ.* 51:100839. doi: 10.1016/j.najef.2018.08.022

González-Uribe, J. (2020). Exchanges of innovation resources inside venture capital portfolios. *J. Financ. Econ.* 135, 144–168. doi: 10.1016/j.jfineco.2019.05.017

Gou, Y., and Dong, J. (2014). Research on the influence of venture capital background on Enterprise technology innovation. *Sci. Res. Manag.* 35, 35–42. doi: 10.19571/j.cnki.1000-2995.2014.02.005

Gu, W., and Qian, X. (2019). Does venture capital Foster entrepreneurship in an emerging market. *J. Bus. Res.* 101, 803–810. doi: 10.1016/j.jbusres.2018.12.011

Guo, D., and Jiang, K. (2013). Venture capital investment and the performance of entrepreneurial firms: evidence from China. *J. Corp. Finan.* 22, 375–395. doi: 10.1016/j.jcorpfin.2013.07.001

He, J., and Tian, X. (2020). Institutions and innovation: a review of recent literature. *Annu. Rev. Financ. Econ.* 2020:35. doi: 10.2139/ssrn.3530214

Hsu, P. H., Tian, X., and Yan, X. (2014). Financial development and innovation: cross-country evidence. *J. Financ. Econ.* 112, 116–135. doi: 10.1016/j.jfineco.2013.12.002

Leogrande, Angelo, Costantiello, Alberto, and Laureti, Lucio. (2021). The Impact of Venture Capital Expenditures on Innovation in Europe. *MPRA Paper*. doi: 10.21203/RS.3.RS-936328/V1

Li, M. Y., and Yan, T. H. (2020). Venture capital, technological innovation and Enterprise performance: influence mechanism and empirical test. *Sci. Res. Manag.* 41, 70–78. doi: 10.19571/j.cnki.1000-2995.2020.07.008

Lin, M. X., and Zhang, Z. W. (2019). Venture capital shareholding: "pursuing love" or "pursuing profits"—— adjustment test based on the perspective of entrepreneurship. *Shang Hai J. Econ.* 2, 99–109. doi: 10.19626/j.cnki.cn31-1163/f.2019.02.011

Lu, Y., Zhang, Y. Q., Jia, R., and Li, J. H. (2017). "Syndicate"venture capital and Enterprise innovation. *J. Financ. Res.* 6, 159–175. doi: 10.19626/j.cnki.cn31-1163/f.2019.02.011

Proksch, D., Stranz, W., Röhr, N., Ernst, C., Pinkwar, A., and Schefczyk, M. (2016). Value-adding activities of venture capital companies: a content analysis of Investor's original documents in Germany. *Ventur. Cap.* 19, 129–146. doi: 10.1080/13691066.2016.1242573

Tian, X., and Wang, T. Y. (2014). Tolerance for failure and corporate innovation. *Rev. Financ. Stud.* 27, 211–255. doi: 10.1093/rfs/hhr130

Wang, L., and Zhou, F. Z. (2017). Can corporate venture capital promote innovation more than independent venture capital—— empirical research based on listed companies. *Sci. Sci. Manag. S. & T.* 38, 120–134.

Xia, Q. H., and Le, Y. (2021). Does venture capital promote technological innovation of Chinese enterprises? *Sci. Res. Manag.* 42, 189–199. doi: 10.19571/j.cnki.1000-2995.2021.07.021

Xiong, J. C., and Gui, H. F. (2018). Venture capital, resident directors and Enterprise innovation: influence and mechanism. *J. Contemp. Financ. Econ.* 4, 123–132. doi: 10.13676/j.cnki.cn36-1030/f.2018.04.012

Xu, N., and Xu, X. Y. (2012). The duality of control right incentive and the dynamic ability of technological innovation—— an empirical analysis based on panel data of high tech listed companies. *China Ind. Econ.* 10, 109–121. doi: 10.19581/j.cnki.ciejournal.2012.10.010

Zhang, W. K. (2020). Venture capital intervention and Enterprise innovation: empirical evidence based on PSM model. *Sci. Technol. Prog. Policy.* 37, 10–18. doi: 10.6049/kjjbydc.Q201908773

Zhang, L., Zhang, T. L., and Zhang, S. (2021). Research on the impact of venture capital on technological innovation performance——based on the regulatory effect of government intervention. *Sci. Technol. Manag. Res.* 3, 100–108. doi: 10.3969/j.issn.1000-7695.2021.03.015

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 17 February 2023
DOI 10.3389/fpsyg.2023.1097936

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University,
China

REVIEWED BY
Sulphey M. M,
Prince Sattam Bin Abdulaziz University,
Saudi Arabia
Lixia Yao,
Zhejiang Gongshang University,
China
Fan Chao,
Renmin University of China, China

*CORRESPONDENCE
Ying Zhang
✉ angie17@qq.com
Rong Jiang
✉ jiang_rong@aliyun.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 14 November 2022
ACCEPTED 25 January 2023
PUBLISHED 17 February 2023

CITATION
Hu R, Li Y, Huang J, Zhang Y, Jiang R and Dunlop E (2023) Psychological capital and breakthrough innovation: The role of tacit knowledge sharing and task interdependence. *Front. Psychol.* 14:1097936. doi: 10.3389/fpsyg.2023.1097936

Psychological capital and breakthrough innovation: The role of tacit knowledge sharing and task interdependence

Rui Hu[1], Yingchao Li[2], Jiayu Huang[3], Ying Zhang[3,4]*, Rong Jiang[5]* and Elizabeth Dunlop[4]

[1]School of International Languages and Cultures, Yunnan University of Finance and Economics, Kunming, Yunnan, China, [2]School of Logistics and Management Engineering, Yunnan University of Finance and Economics, Kunming, Yunnan, China, [3]International Business School, Yunnan University of Finance and Economics, Kunming, Yunnan, China, [4]School of Business, Charles Sturt University, Wagga Wagga, NSW, Australia, [5]Institute of Intelligence Applications, Yunnan University of Finance and Economics, Kunming, Yunnan, China

Compared with incremental innovation, breakthrough innovation is essential to sustaining competitive advantage, but breakthrough innovation has the characteristics of high standards and strict requirements. As the main body and foundation of enterprises, the attitude and behavior of employees play a vital role in enterprise innovation. Based on the positive organizational behavior theory and knowledge management theory, the purpose of this paper is to investigate the relationship between psychological capital and breakthrough innovation, and we also integrate tacit knowledge sharing and task interdependence into the research framework, so as to further explore the influence mechanism of employees' psychological capital on breakthrough innovation. Utilizing a quantitative method, this study takes employees of Yunnan coffee enterprises as investigation objects, the data was analyzed using regression analysis through SPSS 24.0, and the existence of mediation was further verified by Bootstrap test. The results showed that the psychological capital of employees have a positive impact on breakthrough innovation; tacit knowledge sharing partially mediates the relationship between psychological capital and breakthrough innovation; and task interdependence plays a moderating role, that is, the stronger the task interdependence, the stronger the influence of employee psychological capital on breakthrough innovation. This study enriches the research on the influencing factors of breakthrough innovation of Yunnan coffee industry, expands the application scenarios of the related theory, emphasizes that the importance of psychological capital and the breakthrough innovation is the result of the interaction and value-added linkage of various internal and external resources.

KEYWORDS

psychology capital, tacit knowledge sharing, task interdependence, breakthrough innovation, positive organizational behavior

1. Introduction

In May 2020, the Chinese Government formulated and released "*Several Key Measures for Strengthening Basic Research under the New Situation*," which was specifically proposed to establish an exemption mechanism for free exploration and disruptive innovation activities and put forward to give tolerance and encouragement to the failure of innovation activities. On August 15, 2022, "*the Action Plan for Improving Enterprise Technological Innovation Capacity (2022–2023)*," jointly

formulated by the Ministry of Science and Technology and the Ministry of Finance of China, was released. The plan clearly puts forward a series of supportive policies and measures, such as preferential tax policies, talent introduction plan, and financial support, to guide various enterprises to increase independent innovation, reduce research and development costs, and improve the internationalization level of enterprise innovation. Based on the guiding ideology of the general direction proposed by the state, the local governments are also constantly implementing a number of favorable innovation policies for enterprises, accelerating the accumulation of innovation elements to enterprises, ensuring that all kinds of enterprises achieve positive results in leading high-quality development through scientific and technological innovation, and helping backbone enterprises to become national strategic scientific and technological forces. Thus, with the increasingly fierce international competition and the turbulence of the market environment, continuous innovation is the only way to maintain effective survival. The prosperity of the country depends on the efforts of all people in society, as every layer of society is interlinked.

Compared with incremental innovation, breakthrough innovation is the key for enterprises to obtain competitive advantages and ensure long-term development (Jansen et al., 2006). Breakthrough innovation is a challenge, which involves the reconstruction and subversion of the existing knowledge, technology and products (Therrien et al., 2011; Wang et al., 2017), and its success will achieve fundamental change. But generally speaking, breakthrough innovation has two characteristics: high yield and high risk. First of all, breakthrough innovation is a subversion of previous mature technologies and markets, so its activities are faced with huge risks and uncertainties (Gilson and Madjar, 2011; Jia, 2018). Secondly, enterprises will get more development opportunities and huge benefits, if the breakthrough innovation can be successful (O'Reilly III and Tushman, 2013). Despite the importance of breakthrough innovation, both theory and practice show that not all companies can profit from innovation, and the failure rate of innovation attempts is still at a high level.

As the main body and foundation of enterprises, the working attitude and ability of the employees determine the work quality of the team, which then affect the achievement of organisational objective degree and the overall performance level of the enterprise. Therefore, most enterprises currently have a relatively reasonable mechanism for employee recruitment, training, incentive and promotion process, so as to train high-quality enterprise successors as far as possible. With the gradual rise of psychology in research fields, the role of psychological capital is also becoming prominent. It refers to an internal positive mental state of an individual (Luthans and Youssef, 2004), usually including four dimensions: self-efficacy, optimism, hope, and resilience. Recent research perspectives on employees' psychological capital tend to be diversified, covering themes such as personal job satisfaction, job performance, innovative behavior and ability, and so on (Alessandri et al., 2018; Kumar et al., 2022; Okros and Vîrgă, 2022). In general, psychological state will affect the output of individual behavior. As one of the important resources of enterprises, the positive role of psychological capital is far more than we think (Larson and Luthans, 2006).

As the saying goes, "knowledge is power." In the current society, the knowledge reserve represents the basic abilities of an individual. For both individuals and enterprises, knowledge is the cornerstone of success, the source of wealth growth, and one of the most important factors for gaining a competitive advantage (Du Plessis, 2007). Compared with the easy acquisition, preservation and dissemination of explicit knowledge, tacit knowledge is a kind of more private knowledge that is hidden in the individual's mind and cannot be compiled with logical thinking. This type of knowledge is difficult to acquire, spread, and preserve directly, and will play a vital role in the development of enterprises (Nonaka and Takeuchi, 1995). Therefore, the identification and acquisition of tacit knowledge is an important way for enterprises to obtain effective information, but the transformation, sharing and application of tacit knowledge is the key for enterprises to achieve breakthrough innovation. Generally speaking, the sharing of tacit knowledge depends on the individual's subjective willingness, and they will measure the possible pros and cons before deciding whether to share them (Ryan and O'Connor, 2013; Duan et al., 2018). However, we believe that individuals with different levels of psychological capital have different criteria in the measurement of risk and return, which will also affect their willingness to share tacit knowledge. On the other hand, task interdependence can reflect the frequency of communication among team members to some extent (Campion et al., 1996). The stronger the task interdependence, the more necessary communication between members, and the greater the possibility of information or knowledge sharing, which will have a direct or indirect impact on performance.

Yunnan coffee industry has a history of more than 100 years. Although it has unique regional advantages and policy support, the development of Yunnan coffee industry has faced many challenges in the context of the rapid growth of China's coffee consumption market in recent years. At present, there are more than 420 coffee enterprises in Yunnan Province, but the overall brand effect is small, the deep processing technology is insufficient, the industrial chain is immature, and the innovation ability of some enterprises has been improved slowly. Therefore, Yunnan coffee industry is in urgent need of transformation and upgrading to improve its competitiveness.

Accordingly, this paper aims to explore the relationship and influence mechanism between employee psychological capital, tacit knowledge sharing and enterprise breakthrough innovation by studying the state of Yunnan coffee enterprises. Combined with the role of task interdependence, the purpose is to provide a new perspective for enterprise breakthrough innovation research, and improve the awareness of the importance of employees' psychological capital. Meanwhile, this research also provides a useful reference for the improvement of team cooperation efficiency and enterprise innovation performance.

2. Literature review and hypotheses development

2.1. Psychological capital and breakthrough innovation

Psychological capital refers to a positive mental state including self-efficacy, hope, optimism and resilience presented by individuals during their growth and development. All of the four dimensions are the mentality that we need and are necessary to maintain in study and work.

First, self-efficacy is people's belief in completing a task or work behavior (Bandura, 1977), which can directly affect the individual's thoughts, motivation, attitudes, and behavior. In another word, it represents a degree of confidence. Confident individuals are often able to master learning methods and essentials quickly, believing that they can use their own professional knowledge and ability to solve different

problems and get better outcomes (Abbas and Raja, 2015). It has been shown that employees with high self-efficacy are often more confident in handling complex interpersonal relationships, will actively express and share their views in the team, and build good relationships with their colleagues, thus showing a high level of active socialization (Parker, 1998). Usually, individuals with high self-efficacy are more motivated to choose more difficult tasks (Luthans et al., 2010). Further, self-efficacy can provide psychological support for employees' creative activities (Malik et al., 2015), and they prefer to choose positive coping strategies against stress to stick to goals (Bandura, 2001; Tang, 2020). As the driving force of individual creativity, self-efficacy has a positive impact on their creative activities, innovative attitudes and behaviors (Gong et al., 2009; Ahlin et al., 2014; Chen et al., 2016; Klaeijsen et al., 2018), including corporate employees and entrepreneurs in different industries.

As the saying goes, no matter how long the night is, the day will come. Hope is an important positive psychological resource, and also a future-oriented emotional variable, that will affect the individual's ideological attitude and behavior mode of future development (Scioli et al., 2011). When individual development encounters barriers and faces great stress, hope as a positive cognitive model can help them to actively meet difficulties and challenges (Snyder and Lopez, 2002; Valle et al., 2006). Employees with high levels of hope are better at setting challenging goals and seeking all available resources to accomplish them. Even when they encounter difficulties, they can always keep a positive attitude and constantly break through themself to produce more innovative behaviors (Luthans et al., 2008). Most studies agree with the positive role of hope, including in physical and mental health, job satisfaction, job motivation, and job performance (Peterson and Luthans, 2003; Lee and Na, 2013; Fourati and Attitalah, 2018).

In addition, optimism, as a typical cognitive feature, was studied by most early scholars in combination with physical and mental health. Over time, some hidden characteristics have also been gradually introduced into social science research. Optimism is generally defined as the expectation of positive future outcomes, and there is no doubt that optimism has a positive impact on human health (Scheier and Carver, 1985; Friedman et al., 1992). Optimism encourages individuals to remain enthusiastic about their life and work (Hmieleski and Baron, 2009), thus becoming more likely to set challenging goals, and pursue innovative activities to seize market opportunities for higher performance (Fang et al., 2012). What is important is that they can withstand failures and setbacks, not fall into depression and anxiety, and get out of trouble quickly (Gibbons et al., 2000). Shepperd et al. (2017) believe that optimism plays a role in improving interpersonal relationships, and some scholars also believe that optimistic managers will have an impact on their strategic choices and the development and performance of enterprises (Dushnitsky, 2010; Papenhausen, 2010; Paolillo et al., 2015), but they should not be blindly optimistic.

What's more, resilience is one of the most important factors affecting individual development and represents an adaptive behavior ability (Luthans et al., 2008; Näswall et al., 2019). That is, individuals can recover in the face of difficulties in life, work failure and other problems quickly, and have the courage to start all over again (Bardoel et al., 2014; Britt et al., 2016; Linnenluecke, 2017), so as to achieve better growth and development. Studies have shown that resilience can improve employee job satisfaction and happiness (Luthans et al., 2007; Kuntz et al., 2017), develop good social skills, maintain a good organizational atmosphere (Cooke et al., 2019), and thus improve performance.

Although the success of the enterprise breakthrough innovation can generate huge benefits, before the success the breakthrough innovation activities will face huge risks, because it is the subversion of the previous mature technologies and markets. Therefore, as the main body of the enterprise, in this case, in addition to excellent skills, the positive psychological state of employees is a stabilizer for the enterprise. As mentioned above, positive psychological capital enables employees and teams in a better working condition, realize positive organizational behavior, remain optimistic about innovation activities, recover quickly from setbacks and failures, and then have the confidence and courage to try again to achieve final success. Fang et al. (2019) mentioned in his research that psychological capital, as a positive mental state, can enhance employees' motivation to innovate. Gao et al. (2020) takes entrepreneurs as research objects and concludes that entrepreneurs with a higher level of psychological capital have stronger innovation initiative and are more likely to generate creative innovation behaviors. Kumar et al., (2022), based on the study of Indian hotel industry employees, believes that psychological capital has a positive correlation with its innovative work behavior. Some scholars also believe that entrepreneurs who are usually full of optimism and hope are more capable of helping enterprises to innovate their business models (Fourati and Attitalah, 2018; Zhou et al., 2022). Dórdio et al. (2022) studied the relationship between team psychological capital and innovation by taking team learning as the mediating variable, and the results showed that the higher the level of the team psychological capital, the more the innovation output. Yuan and Chai (2020) investigated high-tech enterprises and concluded that employees with higher innovation ability generally showed a higher level of psychological capital. Le (2020) suggested that enriching employees' psychological capital may be a favorable choice and an important method to improve enterprises' innovation ability. Alshebami (2021) focused on small and medium-sized enterprises in Saudi Arabia, arguing that psychological capital can improve employee job satisfaction and motivate them to try innovation. Previous studies have confirmed that psychological capital is closely related to innovation performance (Judge and Bono, 2001; Tang, 2020; Brunetto et al., 2022). Thus, it is hypothesized that:

> *Hypothesis 1*: Psychology capital is positively related to Breakthrough Innovation.

2.2. The mediating role of tacit knowledge sharing

2.2.1. Psychology capital and tacit knowledge sharing

Knowledge-sharing behavior is a communication process between knowledge providers and knowledge seekers, and the purpose of communication is to obtain the required information and internalize the knowledge (Wang and Noe, 2010; Vuori and Okkonen, 2012). As most scholars agree, knowledge is usually divided into explicit knowledge and tacit knowledge (Nonaka and Takeuchi, 1995), and the economic value of the two is different; with tacit knowledge being more valuable (Reychav and Weisberg, 2010). Holste and Fields (2010) have proposed that tacit knowledge is the most core strategic resource of an enterprise in the era of knowledge economy. Therefore, it can be seen that promoting the sharing of tacit knowledge and playing the role of tacit knowledge will help the organization to break through new

technologies, gain continuous competitive advantages, and achieve sustainable development.

Tacit knowledge is a kind of knowledge hidden in the individual's mind and unique to the individual, including their own learning methods, working skills, inspiration, etc. Therefore, the sharing of tacit knowledge is not an obligation of an individual, they have the right to choose whether to share it or not (Jones and Jordan, 1998). On the other hand, as employees are often faced with fierce competition, they are wary of sharing their hidden knowledge, because they worry about losing their unique value and competitive advantage (George, 1995; Taegoo and Gyehee, 2013). Therefore, how to enhance employees' willingness to share tacit knowledge has become an important topic (Terhorst et al., 2018). Wang and Noe (2010) have suggested that there is a range of factors affecting knowledge sharing, including the organizational level, team level, and individual level. Employees' willingness to communicate, cooperate and share knowledge is highly related to their level of psychological capital (Ghazinour et al., 2014).

Previous studies have explored the relationship with knowledge sharing through the dimension of psychological capital, and most of them recognize the positive role of psychological capital (Kollock, 1999; Quigley et al., 2007; Shin et al., 2007; Hau and Kim, 2011; Panahi et al., 2016). Thus, it is hypothesized that:

> *Hypothesis 2*: Psychological capital is positively related to tacit knowledge sharing.

2.2.2. Tacit knowledge sharing and breakthrough innovation

Enterprises usually treat breakthrough innovation with high standards and strict requirements. So almost every major accomplishment in enterprises with the numerous exploration and attempts. We believe that the positive mental state of employees can promote the sharing of tacit knowledge, and the tacit knowledge sharing with high economic value can help to maintain a good communication relationship among team members to better cooperate and achieve breakthroughs.

Although there is little direct research on tacit knowledge sharing and breakthrough innovation, we can interpret the relationship between them from different perspectives. As the basis of individual innovation behavior, the generation of innovative thinking is the result of knowledge exchange, accumulation and application (Oliveira et al., 2015). Studies have shown that knowledge sharing is part of learning within an organization, the information and knowledge sharing among members will contribute greatly to the team and the organization (Wang and Wang, 2012; Kim and Lee, 2013), which can help the employees develop creative thinking and innovation behavior (Baradarani and Kilic, 2018; Gao et al., 2020; Kumar et al., 2022), improve market acuity and conduct innovative activities in a timely and effective manner (Lin C. P., 2007; Lin H. F., 2007). García-Álvarez (2015) concluded that tacit knowledge can positively promote innovation in products and processes. Jiang and Chen (2018) have confirmed that team members actively share their knowledge and skills, which will help promote the team's knowledge integration ability, improve the internal knowledge integration mechanisms and thus ensure the smooth progress of innovation activities. Tacit knowledge can break through, enrich and expand the existing internal knowledge structure and database, which is more conducive to the implementation of breakthrough innovation (Mascitelli, 2000; Prabhu et al., 2005; Laursen and Salter, 2006). In general, both tacit knowledge and knowledge sharing will have a significant impact on enterprise innovation. Thus, it is hypothesized that:

> *Hypothesis 3*: Tacit knowledge sharing is positively related to breakthrough innovation.

2.2.3. Psychology capital, tacit knowledge sharing and breakthrough innovation

Based on the above analysis, we can see that there is a certain correlation between employee psychological capital, tacit knowledge sharing and breakthrough innovation. First of all, we know that employees with high psychological capital have rich knowledge reserve, believe in their own abilities, tend to choose challenging and innovative tasks, and achieve innovative performance by constantly breaking through themselves (Zhou et al., 2022). Compared with employees with lower levels of psychological capital, they are more able to accumulate experience, gain experience from failure, and learn new knowledge. On the other hand, since tacit knowledge sharing is not an employee's job duty and obligation, whether employees are willing to share their unique knowledge and skills depends on their personal thoughts and psychological factors to some extent (Ghazinour et al., 2014). If an employee has a high level of psychological capital, it means that he often keeps himself in a positive mood and working state, which will strengthen his collectivism concept and thus produce the willingness to share tacit knowledge (Chiu et al., 2017). However, employees with low level of psychological capital usually have strong exclusivity and tend to be individualistic, mainly due to lack of trust in colleagues, so that they are less willing to share knowledge (Mura et al., 2021), especially tacit knowledge. Alves and Pinheiro (2022) also proved that individual psychological factors will affect the sharing of tacit knowledge within a team. Secondly, with the gradual transformation of economy, knowledge is increasingly recognized as an intangible and valuable resource (Thomas and Gupta, 2022). Explicit knowledge that is readily available to the general public lacks competitiveness in its exploitable value, but the sharing of tacit knowledge is an effective and important way to obtain unique information (Noori Sepehr and Keikavoosi-Arani, 2019). For enterprises, although it is difficult to acquire tacit knowledge, it has high economic value and can help enterprises make breakthrough progress.

In general, because tacit knowledge is private, its sharing almost depends on the will of the individual. Therefore, psychological capital will affect individuals' sharing of tacit knowledge, and employees with different levels of psychological capital will have different willingness to share tacit knowledge. The sharing of tacit knowledge can transform individual knowledge into organizational knowledge, improve work efficiency and develop innovative behaviors (Gao et al., 2020), thus affecting organizational innovation efficiency and the possibility of radical innovation (Mascitelli, 2000). Therefore, according to the principle of mediating variable selection, tacit knowledge sharing has a strong correlation with psychological capital and breakthrough innovation, and this study believes that tacit knowledge sharing will play a mediating role. Thus, it is hypothesized that:

> *Hypothesis 4*: Tacit knowledge sharing mediates the relationship between psychological capital and breakthrough innovation.

2.3. The moderating role of task interdependence

Generally speaking, task interdependence reflects the extent of how interdependent team members depend on each other while completing their work, including the required knowledge, information, materials, and a series of behaviors (Wageman, 1995; Wageman and Gordon, 2005; Yang, 2020). The degree of task interdependence determines the frequency of communication between team members and the efficiency of teamwork. Highly interdependent work requires members to strengthen communication and coordination, allocate tasks reasonably, and make full use of their knowledge and skills to achieve their work goals together (Wageman and Gordon, 2005; Han and Bai, 2014; Fong et al., 2018). On the other hand, when the members realize that they need the help of other members to complete their work, they will automatically manage their emotions, reduce the generation of speculation, take the initiative to exchange and share information with the members, and improve their knowledge reserve (Van Der Vegt et al., 2000; Vidyarthi et al., 2014). The interdependence of tasks facilitates employees to produce positive organizational civic behavior (Bachrach et al., 2006), enhance members' sense of collective responsibility and honor, weaken knowledge hiding (Černe et al., 2014), improve internal creativity (Gilson and Shalley, 2004), and promote the achievement of common goals. In contrast, with low task interdependence, members can perform their work independently, without relying on the help of other members, and in turn have less willingness to share their own knowledge and information.

Employees with a high level of psychological capital can just meet the requirements of task interdependence, that is, active communication and cooperation. They are good at communication, can maintain a good communication relationship, and are willing to share their knowledge and information, so as to help improve the teamwork ability and work efficiency. Although there are few direct studies on task interdependence, psychological capital and breakthrough innovation performance, task interdependence as a moderator variable has been relatively mature. Some scholars have demonstrated the moderating role of task interdependence between knowledge management and creativity (Staples and Webster, 2008; Hon and Chan, 2013). Fong et al. (2018) have proposed that the stronger the task interdependence, the weaker the negative relationship between knowledge hiding and team creativity. Through previous studies, it can be found that task interdependence can moderate the individual's behavior, psychology, and team performance. Thus, it is hypothesized that:

> *Hypothesis 5*: Task interdependence moderates the relationship between psychological capital and breakthrough innovation.

Figure 1 presents our research framework.

3. Methodology

3.1. Data collection

First, as a pilot study, 20 academics from universities in China were invited to evaluate the validity and reliability of the proposed questionnaire. Secondly, with the assistance of the Chinese Chamber of Commerce List, we randomly selected 15 key enterprises in the coffee industry in Yunnan Province, covering Kunming, Baoshan and Pu'er cities. We distributed the questionnaires to the employees of these enterprises. Due to the spread of the COVID-19 pandemic, the data was gathered *via* the standardized online platform. The survey period was 6 weeks. Finally, a total of 500 responses were collected, with 24 cases contained over 25% missing value and 56 cases failed to satisfy the criteria for the research, resulting in a final data set of 420 usable questionnaires, and the effective response rate of the questionnaire was 84%.

Our questionnaire includes five parts: basic information of individuals and enterprises, psychological capital of employees, tacit knowledge sharing, task interdependence and breakthrough innovation. The questionnaire of each variable adopts the mature scale at home and abroad, and has been revised under the guidance of experts. The questionnaire was mainly filled out by employees of coffee enterprises in Yunnan province, who answered relevant questions according to their own actual conditions to assist us in collecting their psychological capital information. Among the respondents, 56.4% are male and 43.6% female; 56.9% are employees under 40, 20.7% are 41–50, 22.3% are over 50; 52.6% had college degree or below, 36.4% had bachelor's degree, 11% had master's degree or above; In terms of working years, 30.5% for 2–5 years, 28.8% for 6–10 years, and 28.6% are over 10 years. Specific information can be given in Table 1.

3.2. Measurements of variables

3.2.1. Psychological capital

Psychological capital was measured with the scale which was designed by Luthans et al. (2007). The scale contains four dimensions: self-efficacy, hope, resilience, and optimism, each with 6 items and a total of 24 items. All items were scored on a five-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). Some sample items are: "I can think of many ways to reach my current goals"; "I am confident that I could deal efficiently with unexpected events." The Cronbach's alpha coefficient of the overall scale was 0.972, and the KMO value of the scale was 0.970 with significant Bartlett test results, and the cumulative variance contribution rate was 65.136%. Factor loading coefficient is between 0.715 and 0.803.

3.2.2. Breakthrough innovation

For the measurement of breakthrough innovation, we mainly draw on the scales developed by Zhou and Li (2012) and Alexander and Van Knippenberg (2014). The scale includes four items, and some sample items are: "The company has introduced brand-new technologies and ideas for innovation"; "The company has developed brand-new products." These items are rated on a five-point Likert scale from 1 for "Strongly Disagree" to 5 for"Strongly Agree." The Cronbach's alpha coefficient of the overall scale was 0.888, and the KMO value of the scale was 0.826 with significant Bartlett test results, and the cumulative variance contribution rate was 75.018%. Factor loading coefficient is between 0.711 and 0.742.

3.2.3. Tacit knowledge sharing

Tacit knowledge sharing was measured by 6 items scale developed by Scott and Bruce (1994). Examples of items in this section are: "I would like to share my work experience with my colleagues"; "I am willing to share my unique expertise if my colleagues need and request"; "I will share my ideas and inspiration with my colleagues." The Cronbach's alpha coefficient of the overall scale was 0.924, and the KMO

10.3389/fpsyg.2023.1097936

TABLE 1 Sample characteristics.

Variables	Classification	*N*	Percent
Gender	Male	237	56.4
	Female	183	43.6
Age	18–25	32	7.6
	26–30	79	18.8
	31–40	128	30.5
	41–50	87	20.7
	51–60	72	17.1
	>60	22	5.2
Educational background	Technical secondary school and below	107	25.5
	Junior college	114	27.1
	Bachelor's degree	153	36.4
	Master's degree	41	9.8
	PhD degree and above	5	1.2
Working life	<1 year	51	12.1
	2-5 years	128	30.5
	6-10 years	121	28.8
	10 years and above	120	28.6
Type of job	General staff	290	69.0
	Low-level managers	75	17.9
	Middle managers	45	10.7
	Senior managers	10	2.4
Enterprise size	1–99 people	116	27.6
	100–499 people	108	25.7
	500–1,999 people	114	27.1
	2,000–4,999 people	60	14.3
	>5,000 people	22	5.2
Team size	<5 people	31	7.38
	6–10 people	72	17.14
	11–15 people	152	36.2
	15–20 people	85	20.24
	>20 people	80	19.05
Type of enterprise	State-owned enterprise	82	19.52
	Private enterprise	176	41.91
	Foreign-owned enterprise	91	21.67
	Public institution	55	13.10
	Other types	16	3.81
Team life	<1 month	36	8.571
	1–6 months	82	19.524
	6–12 months	88	20.952
	1–2 years	90	21.429
	>2 years	124	29.524

value of the scale was 0.911 with significant Bartlett test results, and the cumulative variance contribution rate was 72.483%. Factor loading coefficient is between 0.7 and 0.826.

3.2.4. Task interdependence

For the measurement of breakthrough innovation, we utilized the scale developed by Van Der Vegt (2000). This scale has five items, including "I need information and opinions from my colleagues to do my job well"; "Team members need to cooperate to do the job well"; "Team members need to communicate regularly on work-related issues." The Cronbach's alpha coefficient of the overall scale was 0.884, and the KMO value of the scale was 0.871 with significant Bartlett test results, and the cumulative variance contribution rate was 68.85%. Factor loading coefficient is between 0.651 and 0.867.

The KMO value of the overall questionnaire was 0.968 if the Bartlett-test result was significant, which was suitable for the next analysis.

4. Results

4.1. Descriptive statistics and correlation analysis

Table 2 shows each variable's mean and standard deviation as well as the correlation of the variables. From the results shown in the table, we can find that all the variables are significantly positively correlated. This means there is a significant positive correlation between psychological capital, tacit knowledge sharing and breakthrough innovation.

4.2. Assessment of reliability and validity

The reliability and validity of the measurement model were examined using Cronbach's alpha and Confirmatory Factor Analysis (CFA). First, the Cronbach's alpha coefficient of each scale ranged from 0.884 to 0.972, while construct reliability (CR) values were greater than 0.7 and ranged from 0.889 to 0.972, it exhibited internal consistency and the scale had good reliability for analysis. The Average Variance Extracted (AVE) values in this study ranged between 0.621 and 0.67. This is greater than the prescribed value of 0.50, which is indicated the convergent validity. The specific results are shown in Table 3. In addition, if the square root of the AVE of a construct is greater than the value of its inter-correlations with other constructs, then it has an excellent discriminative validity. The results are shown in Table 4, and the values on the slash are greater than the others. The results of Harman's single factor test showed that the variation indicated by the single factor solution remained below the required level of 40%.

We also evaluate the fit of the model by some goodness of fit indices, such as root mean square error of approximation (RMSEA), comparative fit index (CFI), root mean square residual (RMR), and nonnormed fit index (NNFI). The indices of the final model fit reported that overall fit was within range of acceptance with $\chi^2/df = 2.902 < 3$, RMSEA = 0.067, RMR = 0.048, CFI = 0.915, NNFI = 0.909. Table 5 shows the specific indicators and judgment criteria. Since the result of the model fitting will be affected by many factors not all of the indicators will achieve very good evaluation results. Usually, we only consider whether most of the indicators meet the evaluation criteria.

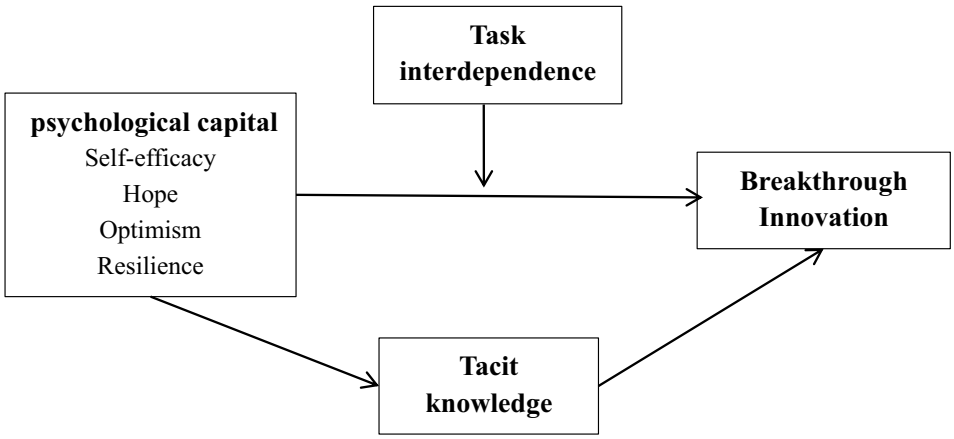


FIGURE 1
Research framework.

TABLE 2 Descriptive statistics and correlation analysis.

Variables	Mean	SD	Psychology capital	Tacit knowledge sharing	Breakthrough innovation	Task interdependence
Psychology capital	3.0586	0.91654	1			
Tacit knowledge sharing	3.0397	0.91493	0.606**	1		
Breakthrough innovation	3.1074	0.85145	0.515**	0.463**	1	
Task interdependence	3.2907	0.95642	0.329**	0.308**	0.578**	1

**Correlation is significant at the 0.01 level (two-tailed).

4.3. Hypotheses testing

4.3.1. Tests of the relationship between psychological capital and breakthrough innovation

Most of the regression analysis in this article was performed using SPSS 24.0 software. Hierarchical regression was used to examine the relationship between psychological capital and breakthrough innovation. We constructed regression Model 1 and Model 2 with breakthrough innovation as the dependent variable, as shown in Table 6. In Model 1, some control variables were introduced: gender, age, educational background, working life, enterprise size, type of job and enterprise and so on. Model 2 added independent variable psychological capital on the basis of Model 1. We measure the multicollinearity of the independent variables by testing the variance inflation factor (VIF), and it was found that the maximum VIF was less than 5, and the Durbin-Watson value were also within reasonable limits, indicating that there was no serious multicollinearity problem in this study. After the addition of psychological capital, the F value of Model 2 increased to 14.864 and was significant, R^2 also increased to 0.286 and the coefficient of PC is 0.485, indicating that psychological capital has a significant positive impact on breakthrough innovation ($t = 11.918$, $p < 0.001$), and Hypotheses 1 was verified.

4.3.2. Tests of the mediating effect of tacit knowledge sharing

According to the mediation effect testing step proposed by Baron and Kenny (1986), we first used stepwise regression to test the mediating effect of tacit knowledge sharing in the relationship between psychological capital and breakthrough innovation. First, Model 3 in Table 7 has shown that the coefficient of PC is 0.586 and the effect was significant ($p < 0.001$), which is indicated that psychological capital was positively related to tacit knowledge sharing, Hypotheses 2 was verified. Second, from Model 4 we can see that the regression coefficient of TKS was 0.428 and the effect was significant ($p < 0.001$), this regression result has proved that tacit knowledge sharing can have a positive impact on breakthrough innovation, Hypotheses 3 was verified. Third, Model 5 added the independent variable psychological capital and mediator variable tacit knowledge sharing. The results showed that both coefficients remained significant, they were 0.353 ($p < 0.001$) and 0.225 ($p < 0.001$), proving that tacit knowledge sharing plays a mediating role in the relationship between psychological capital and breakthrough innovation. The above model tests are all based on the results validated by Model 2, that is, the positive impact of psychological capital on breakthrough innovation. Table 7 shows the more details.

In addition, to further verify the mediating effect of tacit knowledge sharing, we used the Bootstrap sampling test. The results are also shown in Table 7. The confidence level was set to be 95% and the number of random sampling was set to be 1,000. It is generally believed that if the 95% confidence interval of the distribution does not contain 0, the mediating effect is significant. It can be seen that the lower limit is 0.068 and the upper limit is 0.216, excluding 0, indicating that the tacit knowledge sharing plays a partial mediating role. Thus, Hypotheses 4 was verified.

4.3.3. Tests of the moderating effect of task interdependence

To verify the moderating effect of task interdependence, we standardized the variables to generate interactive item about

10.3389/fpsyg.2023.1097936

TABLE 3 Validity test results.

Variable	Item	Factor loading	Cronbach's alpha	AVE	CR
Psychology capital	PC1	0.744	0.972	0.635	0.972
	PC2	0.735			
	PC3	0.769			
	PC4	0.741			
	PC5	0.74			
	PC6	0.777			
	PC7	0.765			
	PC8	0.737			
	PC9	0.761			
	PC10	0.762			
	PC11	0.715			
	PC12	0.758			
	PC13	0.756			
	PC14	0.751			
	PC15	0.803			
	PC16	0.748			
	PC17	0.774			
	PC18	0.759			
	PC19	0.77			
	PC20	0.786			
	PC21	0.794			
	PC22	0.8			
	PC23	0.77			
	PC24	0.752			
Breakthrough innovation	BI1	0.712	0.888	0.67	0.89
	BI2	0.711			
	BI3	0.742			
	BI4	0.713			
Tacit knowledge sharing	KS1	0.753	0.924	0.669	0.924
	KS2	0.786			
	KS3	0.826			
	KS4	0.817			
	KS5	0.783			
	KS6	0.700			
Task interdependence	TI1	0.776	0.884	0.621	0.889
	TI2	0.651			
	TI3	0.867			
	TI4	0.865			
	TI5	0.766			

AVE > 0.5 or CR > 0.7, indicating a high polymerization validity.

psychology capital and task interdependence. We found that in Table 8, the coefficient of "PC*TI" which is an interaction term, is 0.163 and significant ($p < 0.001$). This suggests that task interdependence can effectively adjust the relationship between psychological capital and breakthrough innovation. Thus, Hypotheses 5 were supported. Meanwhile, Figure 2 is designed to more intuitively show the moderating effect of task interdependence. As shown in the figure, the stronger the task interdependence, the more likely employees are to improve their psychological capital level and then play a positive role in breakthrough innovation.

5. Conclusion and discussion

5.1. Conclusion

With the development of the society, the current scholars pay more attention to the psychological capital of employees. This study selected the Yunnan coffee industry as the research object to explore whether the psychological capital of employees will have an impact on enterprise breakthrough innovation, and consider the role of tacit knowledge sharing and task interdependence, to further explore the influence mechanism. Based on the analysis results, we have the following conclusions:

First, psychological capital has a significant and positive impact on enterprise breakthrough innovation. Psychological capital represents a positive attitude; the higher the psychological capital level of employees, the more inclined to choose challenging and innovative tasks, use perseverance to accomplish goals, not afraid of difficulties and setbacks, with resilience, can quickly recover from failure and sum up experience, provide a stable foundation and good resources for enterprises to achieve breakthrough innovation.

Second, tacit knowledge acquisition plays a partially mediating role in the relationship between psychological capital and breakthrough innovation performance. For an enterprise, knowledge is the foundation of achievement. If the employees lack the rich knowledge reserve, then the enterprise lacks the core and cannot make any innovation attempt, especially the tacit knowledge. Our study concluded that employees with a higher level of psychological capital have a stronger willingness to share tacit knowledge. Sharing tacit knowledge among team members is conducive to brainstorming activities, generating more innovative ideas and behaviors, and thus improving innovation performance. The tacit knowledge has high economic value and can help enterprises to gain more competitive advantages.

Third, task interdependence plays a moderating role in the relationship between psychological capital and breakthrough innovation performance. Task interdependence can influence the frequency and quality of communication among members, reduce knowledge hiding, promote knowledge sharing, and thus improve team creativity and innovation performance. In a word, with the enhancement of task interdependence, the role of psychological capital in promoting breakthrough innovation of the enterprise will increase.

5.2. Theoretical contribution and practical implications

5.2.1. Theoretical contribution

The study makes a variety of theoretical contributions to the literature. First of all, in the past, many scholars have studied the impact of employees' psychological factors on their own behavior or performance, but this study is the first to combine psychological capital, tacit knowledge sharing and enterprise breakthrough innovation. No studies have attempted to link the current model to the development of

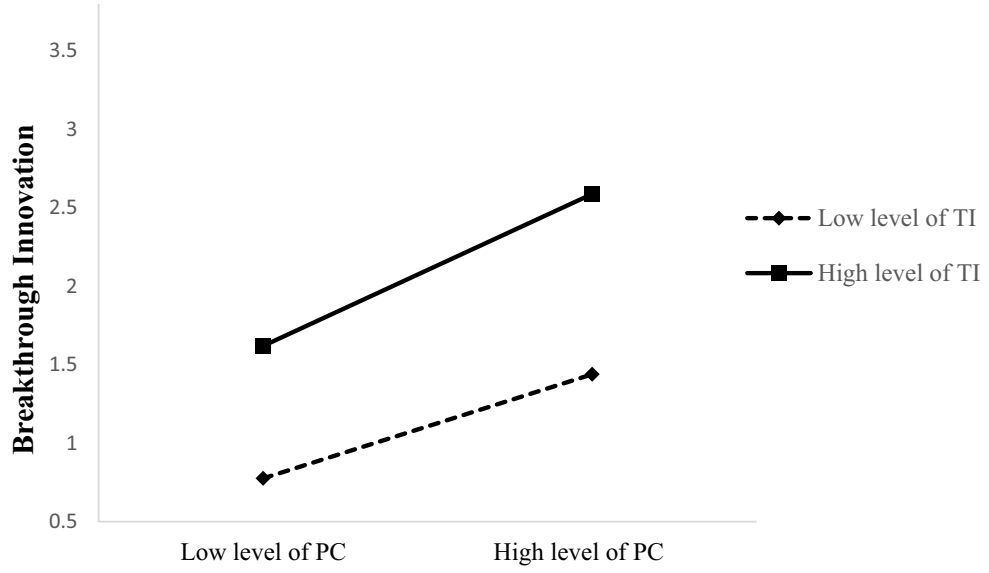


FIGURE 2
The moderating effect of task interdependence. PC, psychological capital; TKS, Tacit knowledge sharing; TI, Task interdependence.

TABLE 4 Results of Pearson correlation analysis between factors and AVE square root values.

	Psychology capital	Breakthrough innovation	Tacit knowledge sharing	Task interdependence
Psychology capital	0.797			
Breakthrough innovation	0.516	0.819		
Tacit knowledge sharing	0.603	0.463	0.818	
Task interdependence	0.329	0.578	0.308	0.788

The number on the diagonal is the root value of the AVE for this factor.

TABLE 5 Fit indices.

Indicators	Judgment	Score
X^2/df	<3	2.902
RMSEA	<0.10	0.067
RMR	<0.05	0.048
CFI	>0.9	0.915
NNFI	>0.9	0.909

df, Degree of freedom; X^2, Chi-Square; RMSEA, Root mean square error of approximation; CFI, Comparative fit index; RMR, Root mean square residual; NNFI, Nonnormed fit index.

the coffee industry in Yunnan Province. This research has enriched the research content and expanded the research scope by analyzing it across different levels.

Secondly, many existing literatures focus on the impact of employees' psychological capital on their own ability and work performance, and there are insufficient studies on how psychological capital promotes performance at the enterprise level. The empirical results of this study show that the high level of psychological capital of employees will improve the possibility of enterprises to achieve breakthrough innovation. The cross-level analysis complements the relevant research in this field.

Finally, based on positive organizational behavior theory, social exchange theory, job demand-resource model and knowledge management theory, this paper discusses the impact of employee psychological capital and tacit knowledge sharing on enterprise breakthrough innovation. At the same time, we also consider the moderating effect of task interdependence. This study extends the application range of these theories and enriches the research achievements in related fields.

5.2.2. Practical implications

Our results have practical implications for coffee enterprises in Yunnan Province. First of all, employees' psychological capital is conducive to enterprises' breakthrough innovation. Therefore, it is beneficial for enterprises to pay attention to the psychological capital of candidates in the recruitment process. As a kind of positive psychological resources, psychological capital can be developed through training and other ways. Enterprises should pay attention to the positive role of employees' psychological capital, provide strong organizational support and complete working conditions, enhance employees' sense of organizational integration and master awareness, improve the level of employees' psychological capital through effective ways, and then make beneficial contributions to the organization.

Secondly, our research also shows that psychological capital can play a role in breakthrough innovation through tacit knowledge sharing. Therefore, it is very important for enterprises to pay attention to tacit knowledge sharing. The coffee industry in Yunnan province is faced with the problems of not getting the industry trends in time and not being well-informed, so it needs to expand the source channels constantly. Within the enterprise, knowledge sharing among employees

TABLE 6 Hierarchical regression analysis of Psychological Capital and Breakthrough Innovation.

Model 1				Model 2			
Variable	Regression coefficient	*t*	*p*		Regression coefficient	*t*	*p*
Const	3.816***	7.963	0.000	Const	2.072***	4.728	0.000
PC				PC	0.485***	11.918	0.000
Gender	−0.324**	−2.206	0.028	Gender	−0.13	−1.016	0.310
Age	−0.041	−0.586	0.558	Age	0.001	0.008	0.993
Educational background	0.017	0.373	0.709	Educational background	0.001	0.035	0.972
Working life	−0.058	−0.601	0.548	Working life	−0.056	−0.67	0.503
Enterprise size	−0.046	−1.192	0.234	Enterprise size	−0.076**	−2.285	0.023
Type of job	0.054*	1.657	0.098	Type of job	0.004	0.068	0.946
Team size	−0.018	−0.469	0.639	Team size	−0.054*	−1.657	0.098
Type of enterprise	0.048	1.131	0.259	Type of enterprise	0.066*	1.788	0.075
Team life	0.061**	2.122	0.034	Team life	0.031	0.848	0.397
R^2	0.038			R^2	0.286		
Adjusted R^2	0.014			AdjustedR^2	0.267		
ΔR^2	0.038			ΔR^2	0.249		
F	$F = 1.595$, $p = 0.105$			*F*	$F = 14.864$, $p = 0.000$***		

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$; PC, psychological capital. Model 1 is the model of control variables.

TABLE 7 Regression analysis of the mediating effect of Tacit knowledge sharing.

	Model 3			Model 4			Model 5		
Variables	Regression coefficient	*t*	*p*	Regression coefficient	*t*	*p*	Regression coefficient	*t*	*p*
Const	1.893***	4.321	0.000	2.102***	4.579	0.000	1.646***	3.764	0.000
PC	0.586***	14.403	0.000				0.353***	7.24	0.000
TKS				0.428***	10.264	0.000	0.225***	4.664	0.000
Gender	0.193**	−2.183	0.030	−0.006	−0.066	0.948	0.017	0.199	0.843
Age	0.009	−0.145	0.885	−0.016	−0.252	0.801	0.002	0.042	0.967
Educational background	0.03	−0.74	0.460	0.022	0.525	0.600	0.008	0.206	0.837
Working life	0.078	−0.932	0.352	−0.024	−0.274	0.784	−0.038	0.471	0.638
Enterprise size	0.019	0.573	0.567	−0.07**	−2.023	0.044	−0.081**	2.474	0.014
Type of job	0.034	−0.601	0.548	0.041	0.714	0.475	0.011	0.208	0.835
Team size	0.01	0.278	0.781	0.053	1.39	0.165	0.063*	1.768	0.078
Type of enterprise	0.027	−0.835	0.404	−0.025	−0.738	0.461	−0.048	1.505	0.133
Team life	0.052	1.396	0.164	0.019	0.498	0.619	0.02	0.546	0.585
R^2	0.382			0.235			0.322		
Adjusted R^2	0.364			0.214			0.301		
F	$F = 22.926$, $p = 0.000$***			$F = 11.397$, $p = 0.000$***			$F = 16.132$, $p = 0.000$***		
Bootstrap test				Mediating effect	SE		95% Boot CI	Result	
Psychological capital Tacit knowledge sharing breakthrough innovation				0.132	0.036		[0.068–0.216]	Partial mediation	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. PC, psychological capital; TKS, Tacit knowledge sharing; BI, Breakthrough Innovation; TI, Task interdependence.

is an effective way to obtain resource information. Tacit knowledge sharing among members will not only get the knowledge needed within the organization, but can also be a way to obtain potential external information and resources. Enterprises should give incentives to encourage and recognize the knowledge-sharing behavior of employees, and try to develop an effective management system for tacit knowledge acquisition, sharing, and application, so as to improve the knowledge reserve ability of enterprises.

Further, in the case of strong task interdependence, the positive relationship between employees' psychological capital and breakthrough

TABLE 8 Regression analysis of the moderating effect of task interdependence.

Model 6				
Variables	Regression coefficient	SE	*t*	*p*
Const	2.701***	0.505	5.345	0.000
PC	0.198	0.123	1.607	0.109
TI	0.066	0.107	0.611	0.541
PC*TI	0.163***	0.035	4.631	0.000
Gender	0.026	0.075	0.343	0.732
Age	0.005	0.051	0.096	0.924
Educational background	0.012	0.034	0.356	0.722
Working life	0.049	0.07	0.695	0.487
Enterprise size	0.059**	0.028	2.082	0.038
Type of job	0.006	0.047	0.136	0.892
Team size	0.048*	0.028	1.751	0.081
Type of enterprise	0.062**	0.031	2.011	0.045
Team life	0.003	0.031	0.081	0.935
R^2	0.496			
Adjusted R^2	0.479			
ΔR^2	0.496			
F	$F(13, 406) = 30.679$, $p = 0.000$***			

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. PC, psychological capital; TKS, Tacit knowledge sharing; BI, Breakthrough Innovation; TI, Task interdependence.

innovation is more obvious. Our study found that when employees need information from others to complete their own work, their teams will communicate frequently, and they are more willing to share tacit knowledge. Because a success cannot rely on the efforts of one person, the good communication and cooperation of the team can effectively solve the difficulties encountered in the process of trying, especially when they cannot move forward. Therefore, knowledge hiding should be reduced and knowledge sharing should be increased by strengthening the task interdependence of the team.

6. Limitations and future research

Our study has several limitations that should be noted. First, the data collection of this study focused only on the Yunnan coffee industry, and whether the conclusion is generalizable remains to be verified. Future research can be explored from different industries, provinces or countries to expand the research scope. Second, in the selection of mediator variables, in addition to tacit knowledge sharing, the aspects of the acquisition, transfer, and the externalization of tacit knowledge can also be considered for future research. Moreover, future research may also select different moderator variables from different levels to further explore the influence mechanism between psychology capital and enterprise innovation. Finally, the dimensional division of the variables and the design of the questionnaire items will change according to the different scholars, and then produce different analysis results. Future research could select different scales to redesign the questionnaire and choose different samples to collect the data for analysis.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

RH contributed to the conception and design of the current study. JH performed the data collection. YL was responsible for drafting the manuscript, as well as the analysis and interpretation of data. YZ collected, analyzed the data, as well as helped to perform the analysis with constructive discussions. ED helped to revise and refine the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the National Natural Science Foundation of China (Award Nos.: 72271214 and 71762033) and the Yunnan Philosophy Social Science Foundation (YNPOPSS Award No.: ZD202213).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abbas, M., and Raja, U. (2015). Impact of psychological capital on innovative performance and job stress. *Can. J. Adm. Sci.* 32, 128–138. doi: 10.1002/cjas.1314

Ahlin, B., Drnovšek, M., and Hisrich, R. D. (2014). Entrepreneurs' creativity and firm innovation: the moderating role of entrepreneurial self-efficacy. *Small Bus. Econ.* 43, 101–117. doi: 10.1007/s11187-013-9531-7

Alessandri, G., Consiglio, C., Luthans, F., and Borgogni, L. (2018). Testing a dynamic model of the impact of psychological capital on work engagement and job performance. *Career Dev. Int.* 23, 33–47. doi: 10.1108/CDI-11-2016-0210

Alexander, L., and Van Knippenberg, D. (2014). Teams in pursuit of radical innovation: a goal orientation perspective. *Acad. Manag. Rev.* 39, 423–438. doi: 10.5465/amr.2012.0044

Alshebami, A. S. (2021). The influence of psychological capital on employees' innovative behavior: mediating role of employees' innovative intention and employees' job satisfaction. *SAGE Open* 11. doi: 10.1177/21582440211040809

Alves, R. B. C., and Pinheiro, P. (2022). Factors influencing tacit knowledge sharing in research groups in higher education institutions. *Admin. Sci.* 12:89. doi: 10.3390/admsci12030089

Bachrach, D. G., Powell, B. C., Bendoly, E., and Richey, R. G. (2006). Organizational citizenship behavior and performance evaluations: exploring the impact of task interdependence. *J. Appl. Psychol.* 91, 193–201. doi: 10.1037/0021-9010.91.1.193

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84, 191–215. doi: 10.1037/0033-295X.84.2.191

Bandura, A. (2001). Social cognitive theory: an agentic perspective. *Annu. Rev. Psychol.* 52, 1–26. doi: 10.1146/annurev.psych.52.1.1

Baron, R. M., and Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology,* 51, 1173–82

Baradarani, S., and Kilic, H. (2018). Service innovation in the hotel industry: culture, behavior, performance. *Serv. Ind. J.* 38, 897–924. doi: 10.1080/02642069.2017.1420172

Bardoel, E. A., Pettit, T. M., De Cieri, H., and McMillan, L. (2014). Employee resilience: an emerging challenge for HRM. *Asia Pac. J. Hum. Resour.* 52, 279–297. doi: 10.1111/1744-7941.12033

Britt, T. W., Shen, W., Sinclair, R. R., Grossman, M. R., and Klieger, D. M. (2016). How much do we really know about employee resilience? *Ind. Organ. Psychol.* 9, 378–404. doi: 10.1017/iop.2015.107

Brunetto, Y., Saheli, N., Dick, T., and Nelson, S. (2022). Psychosocial safety climate, psychological capital, healthcare SLBs' wellbeing and innovative behaviour during the COVID-19 pandemic. *Public Perform. Manag. Rev.* 45, 751–772. doi: 10.1080/15309576.2021.1918189

Campion, M. A., Papper, E. M., and Medsker, G. J. (1996). Relations between work team characteristics and effectiveness: a replication and extension. *Pers. Psychol.* 49, 429–452. doi: 10.1111/j.1744-6570.1996.tb01806.x

Černe, M., Nerstad, C. G., Dysvik, A., and Škerlavaj, M. (2014). What goes around comes around: knowledge hiding, perceived motivational climate, and creativity. *Acad. Manag. J.* 57, 172–192. doi: 10.5465/amj.2012.0122

Chen, T., Li, F., and Leung, K. (2016). When does supervisor support encourage innovative behavior? Opposite moderating effects of general self-efficacy and internal locus of control. *Pers. Psychol.* 69, 123–158. doi: 10.1111/peps.12104

Chiu, C. K., Lin, C. P., Tsai, Y. H., and Teh, S. F. (2017). Enhancing knowledge sharing in high-tech firms the moderating role of collectivism and power distance. *Cross Cult. Strat. Manag.* 25, 468–491. doi: 10.1108/CCSM-03-2017-0034

Cooke, F. L., Wang, J., and Bartram, T. (2019). Can a supportive workplace impact employee resilience in a high pressure performance environment? An investigation of the Chinese banking industry. *Appl. Psychol.* 68, 695–718. doi: 10.1111/apps.12184

Dórdio, D. I., Assunção, M., Rebelo, T., Lourenço, P. R., and Alves, M. (2022). Innovation in teams: the role of psychological capital and team learning. *J. Psychol.* 156, 11–14. doi: 10.1080/00223980.2021.20143

Du Plessis, M. (2007). The role of knowledge management in innovation. *J. Knowl. Manag.* 11, 20–29. doi: 10.1108/13673270710762684

Duan, G., Pang, C., and Hui, J. (2018). A multilevel analysis of relationships among mianzi, reward/punishment and knowledge sharing. *Sci. Res. Manag.* 39, 161–168. doi: 10.19571/j.cnki.1000-2995.2018.08.018

Dushnitsky, G. (2010). Entrepreneurial optimism in the market for technological inventions. *Organ. Sci.* 21, 150–167. doi: 10.1287/orsc.1090.0454

Fang, Y.-C., Chen, J.-Y., Wang, M.-J., and Chen, C.-Y. (2019). The impact of inclusive leadership on employees' innovative behaviors: the mediation of psychological capital. *Front. Psychol.* 10:1803. doi: 10.3389/fpsyg.2019.01803

Fang, N., Zhang, Y. L., and Li, T. (2012). The entrepreneurs' confidence, optimism and performance of new ventures——an empirical study on 145 new ventures. *Econ. Manag. J.*. doi: 10.19616/j.cnki.bmj.2012.01.011

Fong, P. S., Men, C., Luo, J., and Jia, R. (2018). Knowledge hiding and team creativity: the contingent role of task interdependence. *Manag. Decis.* 56, 329–343. doi: 10.1108/MD-11-2016-0778

Fourati, H., and Attitalah, R. B. (2018). Entrepreneurial optimism, the nature of entrepreneurial experience and debt decision for business start-up. *International Journal of Innovation Management* 22:1850024.

Friedman, L. C., Nelson, D. V., Baer, P. E., Lane, M., Smith, F. E., and Dworkin, R. J. (1992). The relationship of dispositional optimism, daily life stress, and domestic environment to coping methods used by cancer patients. *J. Behav. Med.* 15, 127–141. doi: 10.1007/BF00848321

Gao, Q., Wu, C., Wang, L., and Zhao, X. (2020). The entrepreneur's psychological capital, creative innovation behavior, and enterprise performance. *Front. Psychol.* 11:1651. doi: 10.3389/fpsyg.2020.01651

García-Álvarez, M. T. (2015). Analysis of the effects of ICTs in knowledge management and innovation: the case of Zara Group. *Comput. Hum. Behav.* 51, 994–1002. doi: 10.1016/j.chb.2014.10.007

George, B. G. (1995). Relationship-based approach to leadership: Development of leader-member exchange (LMX) theory of leadership over 25 years: Applying a multilevel multi-domain perspective.. *The Leadership Quarterly,* 6, 219–247.

Ghazinour, S., Sharafi, A., Mahabadi, M., Forouhar, M., and Riahi, S. (2014). Explain the role of psychological capital in knowledge sharing of an organization. *Int. J. Manag. Acad.* 2, 51–57.

Gibbons, F. X., Blanton, H., Gerrard, M., Buunk, B., and Eggleston, T. (2000). Does social comparison make a difference? Optimism as a moderator of the relation between comparison level and academic performance. *Personal. Soc. Psychol. Bull.* 26, 637–648. doi: 10.1177/0146167200267011

Gilson, L. L., and Madjar, N. (2011). Radical and incremental creativity: antecedents and processes. *Psychol. Aesthet. Creat. Arts* 5, 21–28. doi: 10.1037/a0017863

Gilson, L. L., and Shalley, C. E. (2004). (2004) a little creativity goes a long way: an examination of teams' engagement in creative processes. *J. Manag.* 30, 453–470. doi: 10.1016/j.jm.2003.07.001

Gong, Y., Huang, J. C., and Farh, J. L. (2009). Employee learning orientation, transformational leadership, and employee creativity: the mediating role of employee creative self-efficacy. *Acad. Manag. J.* 52, 765–778. doi: 10.5465/amj.2009.43670890

Han, H. G., and Bai, Y. (2014). In need of each other: the moderator of task interdependence between LMX variability and justice. *J. Nurs. Manag.* 22, 743–750. doi: 10.1111/jonm.12009

Hau, Y. S., and Kim, Y. G. (2011). Why would online gamers share their innovation-conducive knowledge in the online game user community? Integrating individual motivations and social capital perspectives. *Comput. Hum. Behav.* 27, 956–970. doi: 10.1016/j.chb.2010.11.022

Hmieleski, K. M., and Baron, R. A. (2009). Entrepreneurs' optimism and new venture performance: a social cognitive perspective. *Acad. Manag. J.* 52, 473–488. doi: 10.5465/amj.2009.41330755

Holste, J. S., and Fields, D. (2010). Trust and tacit knowledge sharing and use. *J. Knowl. Manag.* 14, 128–140. doi: 10.1108/13673271011015615

Hon, A. H. Y., and Chan, W. W. H. (2013). Team Creative Performance. *Cornell Hospitality Quarterly* 54, 199–210.

Jansen, J. J., Van Den Bosch, F. A., and Volberda, H. W. (2006). Exploratory innovation, exploitative innovation, and performance: effects of organizational antecedents and environmental moderators. *Manag. Sci.* 52, 1661–1674. doi: 10.1287/mnsc.1060.0576

Jia, N. (2018). Corporate innovation strategy and stock price crash risk. *J. Corp. Finan.* 53, 155–173. doi: 10.1016/j.jcorpfin.2018.10.006

Jiang, Y., and Chen, C. C. (2018). Integrating knowledge activities for team innovation: effects of transformational leadership. *J. Manag.* 44, 1819–1847. doi: 10.1177/0149206316628641

Jones, P., and Jordan, J. (1998). Knowledge orientations and team effectiveness. *Int. J. Technol. Manag.* 16, 152–161. doi: 10.1504/IJTM.1998.002651

Judge, T. A., and Bono, J. E. (2001). Relationship of core self-evaluations traits--self-esteem, generalized self-efficacy, locus of control, and emotional stability--with job satisfaction and job performance: a meta-analysis. *J. Appl. Psychol.* 86, 80–92. doi: 10.1037/0021-9010.86.1.80

Kim, T. T., and Lee, G. (2013). Hospitality employee knowledge-sharing behaviors in the relationship between goal orientations and service innovative behavior. *Int. J. Hosp. Manag.* 34, 324–337. doi: 10.1016/j.ijhm.2013.04.009

Klaeijsen, A., Vermeulen, M., and Martens, R. (2018). Teachers' innovative behaviour: the importance of basic psychological need satisfaction, intrinsic motivation, and occupational self-efficacy. *Scand. J. Educ. Res.* 62, 769–782. doi: 10.1080/00313831.2017.1306803

Kollock, P. (1999). The economies of online cooperation: gifts and public goods in cyberspace. *Commun. Cyberspace* 239.

Kumar, D., Upadhyay, Y., Yadav, R., and Goyal, A. K. (2022). Psychological capital and innovative work behaviour: the role of mastery orientation and creative self-efficacy. *Int. J. Hosp. Manag.* 102:103157. doi: 10.1016/j.ijhm.2022.103157

Kuntz, J. R., Malinen, S., and Näswall, K. (2017). Employee resilience: directions for resilience development. *Consult. Psychol. J.* 69, 223–242. doi: 10.1037/cpb0000097

Larson, M., and Luthans, F. (2006). Potential added value of psychological capital in predicting work attitudes. *J. Leadersh. Organ. Stud.* 13, 75–92. doi: 10.1177/10717919070130020601

Laursen, K., and Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strateg. Manag. J.* 27, 131–150. doi: 10.1002/smj.507

Le, P. B. (2020). How transformational leadership facilitates radical and incremental innovation: the mediating role of individual psychological capital. *Asia Pac. J. Bus. Admin.* 12, 205–222. doi: 10.1108/APJBA-04-2020-0129

Lee, J. K., and Na, B. M. (2013). The effects of entrepreneurs' hope on emotional exhaustion and psychological well-being. *Asia Pac. J. Bus. Ventur. Entrep.* 8, 1–8. doi: 10.16972/apjbve.8.4.201312.1

Lin, C. P. (2007). To share or not to share: modeling tacit knowledge sharing, its mediators and antecedents. *J. Bus. Ethics* 70, 411–428. doi: 10.1007/s10551-006-9119-0

Lin, H. F. (2007). Knowledge sharing and firm innovation capability: an empirical study. *Int. J. Manpow.* 28, 315–332. doi: 10.1108/01437720710755272

Linnenluecke, M. K. (2017). Resilience in business and management research: a review of influential publications and a research agenda. *Int. J. Manag. Rev.* 19, 4–30. doi: 10.1111/ijmr.12076

Luthans, F., Avey, J. B., Avolio, B. J., and Peterson, S. J. (2010). The development and resulting performance impact of positive psychological capital. *Hum. Resour. Dev. Q.* 21, 41–67. doi: 10.1002/hrdq.20034

Luthans, F., Avolio, B. J., Avey, J. B., and Norman, S. M. (2007). Positive psychological capital: measurement and relationship with performance and satisfaction. *Pers. Psychol.* 60, 541–572. doi: 10.1111/j.1744-6570.2007.00083.x

Luthans, F., Norman, S. M., Avolio, B. J., and Avey, J. B. (2008). The mediating role of psychological capital in the supportive organizational climate—employee performance relationship. *J. Organ. Behav.* 29, 219–238. doi: 10.1002/job.507

Luthans, F., and Youssef, C. M. (2004). Human, social, and now positive psychological capital management: investing in people for competitive advantage. *Organ. Dyn.* 33, 143–160. doi: 10.1016/j.orgdyn.2004.01.003

Malik, M. A. R., Butt, A. N., and Choi, J. N. (2015). Rewards and employee creative performance: moderating effects of creative self-efficacy, reward importance, and locus of control. *J. Organ. Behav.* 36, 59–74. doi: 10.1002/job.1943

Mascitelli, R. (2000). From experience: harnessing tacit knowledge to achieve breakthrough innovation. *J. Prod. Innov. Manag.* 17, 179–193. doi: 10.1111/1540-5885.1730179

Mura, L., Zsigmond, T., and Machová, R. (2021). The effects of emotional intelligence and ethics of SME employees on knowledge sharing in central-European countries. *Oecon. Copernic.* 12, 907–934. doi: 10.24136/oc.2021.030

Näswall, K., Malinen, S., Kuntz, J., and Hodliffe, M. (2019). Employee resilience: development and validation of a measure. *J. Manag. Psychol.* 34, 353–367. doi: 10.1108/JMP-02-2018-0102

Nonaka, I., and Takeuchi, H. (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York, NY: Oxford University Press.

Noori Sepehr, M., and Keikavoosi-Arani, L. (2019). The relationship between effective factors on knowledge sharing among faculty members of Alborz University of Medical Sciences. *Entomol. Appl. Sci. Lett.* 6, 24–32.

Okros, N., and Vîrgă, D. (2022). How to increase job satisfaction and performance? Start with thriving: the serial mediation effect of psychological capital and burnout. *Int. J. Environ. Res. Public Health* 19:8067. doi: 10.3390/ijerph19138067

Oliveira, M., Curado, C. M., Maçada, A. C., and Nodari, F. (2015). Using alternative scales to measure knowledge sharing behavior: are there any differences? *Comput. Hum. Behav.* 44, 132–140. doi: 10.1016/j.chb.2014.11.042

O'Reilly, C. A. III, and Tushman, M. L. (2013). Organizational ambidexterity: past, present, and future. *Acad. Manag. Perspect.* 27, 324–338. doi: 10.5465/amp.2013.0025

Panahi, S., Watson, J., and Partridge, H. (2016). Information encountering on social media and tacit knowledge sharing. *J. Inf. Sci.* 42, 539–550. doi: 10.1177/0165551515598883

Paolillo, A., Platania, S., Magnano, P., and Ramaci, T. (2015). Organizational justice, optimism and commitment to change. *Procedia Soc. Behav. Sci.* 191, 1697–1701. doi: 10.1016/j.sbspro.2015.04.479

Papenhausen, C. (2010). Managerial optimism and search. *J. Bus. Res.* 63, 716–720. doi: 10.1016/j.jbusres.2009.05.007

Parker, S. K. (1998). Enhancing role breadth self-efficacy: the roles of job enrichment and other organizational interventions. *J. Appl. Psychol.* 83, 835–852. doi: 10.1037/0021-9010.83.6.835

Peterson, S. J., and Luthans, F. (2003). The positive impact and development of hopeful leaders. *Leadersh. Organ. Dev. J.* 24, 26–31. doi: 10.1108/01437730310457302

Prabhu, J. C., Chandy, R. K., and Ellis, M. E. (2005). The impact of acquisitions on innovation: poison pill, placebo, or tonic? *J. Mark.* 69, 114–130. doi: 10.1509/jmkg.69.1.114.55514

Quigley, N. R., Tesluk, P. E., Locke, E. A., and Bartol, K. M. (2007). A multilevel investigation of the motivational mechanisms underlying knowledge sharing and performance. *Organ. Sci.* 18, 71–88. doi: 10.1287/orsc.1060.0223

Reychav, I., and Weisberg, J. (2010). Bridging intention and behavior of knowledge sharing. *J. Knowl. Manag.* 14, 285–300. doi: 10.1108/13673271011032418

Ryan, S., and O'Connor, R. V. (2013). Acquiring and sharing tacit knowledge in software development teams: an empirical study. *Inf. Softw. Technol.* 55, 1614–1624. doi: 10.1016/j.infsof.2013.02.013

Scheier, M. F., and Carver, C. S. (1985). Optimism, coping, and health: assessment and implications of generalized outcome expectancies. *Health Psychol.* 4, 219–247. doi: 10.1037/0278-6133.4.3.219

Scioli, A., Ricci, M., Nyugen, T., and Scioli, E. R. (2011). Hope: its nature and measurement. *Psychol. Relig. Spiritual.* 3, 78–97. doi: 10.1037/a0020903

Scott, S. G., and Bruce, R. A. (1994). Determinants of innovative behaviour: a path model of individual innovation at workplace. *Acad. Manag. J.* 37, 580–607.

Shepperd, J. A., Pogge, G., and Howell, J. L. (2017). Assessing the consequences of unrealistic optimism: challenges and recommendations. *Conscious. Cogn.* 50, 69–78. doi: 10.1016/j.concog.2016.07.004

Shin, S. K., Ishman, M., and Sanders, G. L. (2007). An empirical investigation of socio-cultural factors of information sharing in China. *Inf. Manag.* 44, 165–174. doi: 10.1016/j.im.2006.11.004

Snyder, C. R., and Lopez, S. J. (2002). Handbook of positive psychology. *Oxford University Press.*

Staples, D. S., Webster, J. (2008). Exploring the effects of trust, task interdependence and virtualness on knowledge sharing in teams. *Information Systems Journal,* 18, 617–640.

Taegoo, T. K., and Gyehee, L. (2013). Hospitality employee knowledge-sharing behaviors in the relationship between goal orientations and service innovative behavior. *International Journal of Hospitality Management* 34, 324–337.

Tang, J. J. (2020). Psychological capital of entrepreneur teams and human resource development. *Front. Psychol.* 11:274. doi: 10.3389/fpsyg.2020.00274

Terhorst, A., Lusher, D., Bolton, D., Elsum, I., and Wang, P. (2018). Tacit knowledge sharing in open innovation projects. *Proj. Manag. J.* 49, 5–19. doi: 10.1177/8756972818781628

Therrien, P., Doloreux, D., and Chamberlin, T. (2011). Innovation novelty and (commercial) performance in the service sector: a Canadian firm-level analysis. *Technovation* 31, 655–665. doi: 10.1016/j.technovation.2011.07.007

Thomas, A., and Gupta, V. (2022). Tacit knowledge in organizations: bibliometrics and a framework-based systematic review of antecedents, outcomes, theories, methods and future directions. *J. Knowl. Manag.* 26, 1014–1041. doi: 10.1108/JKM-01-2021-0026

Valle, M. F., Huebner, E. S., and Suldo, S. M. (2006). An analysis of hope as a psychological strength. *J. Sch. Psychol.* 44, 393–406. doi: 10.1016/j.jsp.2006.03.005

Van Der Vegt, G., Emans, B., and Van De Vliert, E. (2000). Team members' affective responses to patterns of intragroup interdependence and job complexity. *J. Manag.* 26, 633–655. doi: 10.1177/014920630002600403

Vidyarthi, P. R., Anand, S., and Liden, R. C. (2014). Do emotionally perceptive leaders motivate higher employee performance? The moderating role of task interdependence and power distance. *Leadersh. Q.* 25, 232–244. doi: 10.1016/j.leaqua.2013.08.003

Vuori, V., and Okkonen, J. (2012). Knowledge sharing motivational factors of using an intra-organizational social media platform. *J. Knowl. Manag.* 16, 592–603. doi: 10.1108/13673271211246167

Wageman, R. (1995). Erratum: interdependence and group effectiveness. *Adm. Sci. Q.* 40:367. doi: 10.2307/2393648

Wageman, R., and Gordon, F. M. (2005). As the twig is bent: how group values shape emergent task interdependence in groups. *Organ. Sci.* 16, 687–700. doi: 10.1287/orsc.1050.0146

Wang, S., and Noe, R. A. (2010). Knowledge sharing: a review and directions for future research. *Hum. Resour. Manag. Rev.* 20, 115–131. doi: 10.1016/j.hrmr.2009.10.001

Wang, P., Van De Vrande, V., and Jansen, J. J. (2017). Balancing exploration and exploitation in inventions: quality of inventions and team composition. *Res. Policy* 46, 1836–1850. doi: 10.1016/j.respol.2017.09.002

Wang, Z., and Wang, N. (2012). Knowledge sharing, innovation and firm performance. *Expert Syst. Appl.* 39, 8899–8908. doi: 10.1016/j.eswa.2012.02.017

Yuan, Y., and Chai, H. (2020). Relationship between psychological capital and innovation behavior of employees in high-tech enterprises. *Rev. Argentina de Clín. Psicol.* 29:860.

Yang, W. C. (2020). The Relationship between Workplace Ostracism, TMX, Task Interdependence, and Task Performance: A Moderated Mediation Model. *International Journal of Environmental Research and Public Health* 17, 4432.

Zhou, K. Z., and Li, C. B. (2012). How knowledge affects radical innovation: knowledge base, market knowledge acquisition, and internal knowledge sharing. *Strateg. Manag. J.* 33, 1090–1102. doi: 10.1002/smj.1959

Zhou, J., Liu, Y., Yang, P., and Cao, Q. (2022). How to realize business model innovation for new ventures? Psychological capital and social capital perspective. *Front. Psychol.* 13:707282. doi: 10.3389/fpsyg.2022.707282

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 27 February 2023
DOI 10.3389/fpsyg.2023.1132550

OPEN ACCESS

EDITED BY
Yunlong Duan,
Yunnan University of Finance and Economics, China

REVIEWED BY
Wang Molin,
East China University of Science and Technology, China
Xinqi Zhang,
Guizhou University of Finance and Economics, China

*CORRESPONDENCE
Jiabin Hu
✉ hujiabin1217@foxmail.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 27 December 2022
ACCEPTED 02 February 2023
PUBLISHED 27 February 2023

CITATION
Yu L and Hu J (2023) Employee equity incentive, executive psychological capital, and enterprise innovation.
Front. Psychol. 14:1132550.
doi: 10.3389/fpsyg.2023.1132550

Employee equity incentive, executive psychological capital, and enterprise innovation

Liping Yu[1,2] and Jiabin Hu[2]*

[1]Business School, Changzhou University, Changzhou, China, [2]School of Statistics and Mathematics, Zhejiang Gongshang University, Hangzhou, China

The input and deployment of human resources, such as senior executives and the core employees involved in different innovation processes, is key to developing enterprise innovation activities. Under the same framework, it is crucial to explore how employee equity incentive and senior executives' psychological capital affect enterprise innovation. This paper's research sample comprises listed companies that implemented equity incentives in the A-share market from 2010 to 2021, examining the relationship between executive psychological capital, and enterprise innovation. This study found that: (1) Employee equity incentive and executives' psychological capital can significantly improve the quality of innovation output while promoting enterprises to increase the quantity of innovation outputs; (2) Executive psychological capital contributes to the intermediary effect between employee equity incentive and enterprise innovation; (3) R&D investment has a positive moderating effect on employee equity incentive, senior executives' psychological capital and enterprise innovation; (4) The innovation incentive effect brought by the implementation of stock options by enterprises is more significant, which also makes the psychological capital of executives maintain a positive role in enterprise innovation; (5) In addition, the positive effects of employee equity incentive and executive psychological capital on enterprise innovation are affected by different property rights. The positive effects of employee equity incentive and executive psychological capital on enterprise innovation in state-owned enterprises are not high.

KEYWORDS

employee equity incentive, senior executives' psychological capital, enterprise innovation output, intermediary effect, regulatory effect

1. Introduction

The world's economic structure will face subversive changes during centennial change. Presently, China's economic form is already undergoing changes. As the micro-foundation of high-quality development, enterprises bear the goal of driving the improvement of national independent innovation capability. How to accelerate the number of innovation achievements and improve the quality of innovation output is the focus of academic circles. Unlike ordinary investment activities, enterprise innovation activities have high risks, large investment and a long cycle, which depend on the input of resources and the improvement of efficiency (Jefferson et al., 2006; Hirshleifer et al., 2012), among which the input and use of human resources are more critical (Cho et al., 2016). In the principal-agent chain of enterprises (shareholders – executives – employees), executives are in front of employees. The existing research mainly discusses how the psychological capital of executives (Gao et al., 2020; Wang

et al., 2021) and the characteristics of senior executives (Chen et al., 2016) affect the innovation of enterprises by influencing the innovative behavior of employees. Employees are also an important part of the chain, and their efforts will directly affect the realization of the innovation goals of senior executives. In view of this, how to stimulate their willingness to innovate has become one of the hot topics. For enterprises, although executives determine the allocation of innovation input, the performance of enterprise innovation output is affected by core employees. The continuous innovation ability comes from the joint role of executives and core employees. It is extremely necessary to put employees and executives in the same framework to explore the relationship between them and their impact on enterprise innovation.

From the perspective of innovation process, senior executives dominate the investment of innovation resources. As a trait of senior executives, psychological capital has been proved to have a greater impact on innovation decision-making than other factors in many studies (Li et al., 2020). In the process of innovation, employees influence the effect of "R&D input into innovation output" transformation, employee equity incentives has the characteristics of long validity, wide range and prominent convexity, which makes it an indispensable compensation tool to motivate employees to innovate (Manso, 2011; Ederer and Manso, 2013). Currently, only a few literatures attempt to explore the internal mechanism of employee equity incentive affecting innovation. From the perspective of principal-agent relationship, some scholars believe that equity incentives can alleviate the senior executive–employee agency problem (Wu and Tu, 2007), improve employees' sense of belonging and willingness to innovate (Mao and Weathers, 2019), and then improve the efficiency of enterprise innovation (Tsang et al., 2021), improve the sense of belonging among employees, thus improving enterprise innovation efficiency (Tsang et al., 2021). A few scholars also believe from the incentive theory that employee equity incentives have a classification effect, retaining talent with higher R&D enthusiasm and wind direction commitment (Hall and Murphy, 2003; Oyer and Schaefer, 2005). However, limited by people's inherent cognition and data availability, the internal mechanism of core employee equity incentives that affect enterprise innovation still lacks empirical evidence, and most of the literature is still discussed and analyzed from the perspective of executives. From the above, it is necessary to answer what effect does employee equity incentives play on enterprise innovation, and how does senior executives' psychological capital affect the relationship between the two?

This paper takes the listed companies with A-share equity incentive from 2010 to 2021 as the research sample. Explore the positive and negative effects of senior executives' psychological capital and employee equity incentives on enterprise innovation, and the role of senior executives' psychological capital in the latter two. Compared with previous studies, the innovative contribution of this research are: First, the existing psychological capital of senior executives is mostly measured by the scale questionnaire, which is difficult to put together with such variables from enterprise samples as employee equity incentives. The indicator system of psychological capital of senior executives developed in this paper can make it applied to more extensive empirical research. Second, the continuous innovation ability of enterprises comes from the joint action of senior executives and core employees. However, the existing literature rarely places the two under the same framework for research. This paper will expand this research in order to provide reference for the theory and practice of enterprise innovation management. Third, since enterprise innovation requires not only "incremental" but also "quality improvement" to understand the mechanism guiding employee equity incentives and senior executives' psychological capital on enterprise innovation more comprehensively, this paper conducts research from the two levels of quantity and quality of enterprise innovation achievements. Considering that enterprise innovation needs not only "increment" but also "quality improvement," in order to understand the mechanism of employee equity incentive and executive psychological capital on enterprise innovation more comprehensively, this paper conducts research from the two levels of quantity and quality of enterprise innovation achievements. Fourth, according to principal-agent theory，equity incentive effectively alleviates the agency problem between senior executives and employees, and promotes the interconnection among employees, senior executives and enterprises. From this perspective, it is worth examining the role played by senior executives' psychological capital in employee equity incentives and enterprise innovation. Fifth, this paper provides empirical evidence of the difference in the effectiveness of executive psychological capital and employee equity incentives under varying property rights and forms of equity incentive.

2. Literature review

2.1. Literature on senior executives as the main body of enterprise innovation research

In the long run, the value advantage of enterprise innovation comes from the input and use of "people" (Baron and Armstrong, 2007). As innovation decision-makers, senior executives are critical for innovation. Limited by the characteristics of innovation, as well as the hedonism (Bernstein, 2015) and myopia (Fang et al., 2014) that executives may have, executives' psychological capital plays an increasingly important role as a special enterprise resource capability in many studies on the effect of senior executives on enterprise innovation (Lafuente et al., 2019; Li et al., 2020). Executive psychological capital can be defined as the stable psychological characteristics and positive psychological state that senior executives possess. It is a "*state-like*" element that integrates personality traits and mental state, as well as a synthesis of, for example, self-efficacy and psychological resilience.

From the perspective of executives' psychological capital, subsequent studies explored its impact on enterprise innovation from the following angles:

1. According to the agency theory, the psychological capital of leaders acts on innovation performance by exerting influence on themselves and employees. On the one hand, Managers with high-level psychological capital have stronger motivation to make plans, find resources to respond to innovation needs, and quickly rebound from innovation failures to conduct more innovative activities (Russo and Stoykova, 2015; Hallak et al., 2018). On the other hand, high psychological resilience will also produce a downward transmission effect, strengthen employees' psychological resilience (Sihvola et al., 2022), improve employees' innovation behavior (Wang et al., 2021).

2. How the heterogeneity of executives' spirit of self-sacrifice, overconfidence, and experience affect enterprise innovation. With the deepening of research, a few scholars pointed out that senior executives' personal characteristics, experiences, and even overconfidence would have a heterogeneous impact on innovation decisions (Mao and Zhang, 2018). Others agree that self-sacrificing leadership can greatly enhance employee cohesion, fulfill the regulatory role of psychological capital, and thus affect the effectiveness of team innovation (Van Knippenberg and Van Knippenberg, 2005).
3. The role of short-sighted constraints and risk-bearing capacity in enterprise innovation. The risk of innovation will aggravate the shortsightedness of senior executives (Fang et al., 2014), reduce their risk-bearing capacity and innovation willingness, which is not conducive to enterprise innovation.

2.2. Literature on the relationship between employees and enterprise innovation

At present, people have cognitive biases about the innovative effects of employees. With reference to the research of Zaltman et al. (1973) and other scholars, the innovation process can be divided into four stages (as shown in Figure 1): the formation of innovation ideas, innovation decisions (making innovation plans and resource allocation), decision implementation and feedback, and innovation output. Intuitively, executives have more influence on the innovation decision-making stage. Although employees have less influence and cannot participate in innovation decision-making, they play an irreplaceable role in the formation of innovation ideas (Bradley et al., 2016 ; Chang et al., 2015) and the implementation and feedback on decisions. The relationship between employee equity incentives and enterprise innovation has gradually aroused academic discussion in recent years. However, the relevant literature is still limited, and a consistent conclusion cannot be drawn.

From the perspective of principal-agent theory, in the principal-agent chain, the performance of employees affects the rights and interests of executives and shareholders, most studies believe that equity incentives can greatly alleviate employee–enterprise information asymmetry, connect employees and enterprises, enhance innovation cooperation and supervision among employees, and then improve innovation efficiency (Brander and Zhang, 2017; Tsang et al., 2021). From the perspective of incentive theory, some scholars pointed out that equity incentives can enhance employees' psychological ownership perception and promote employees' sense of belonging to the organization, while the classification effect can retain talent (Oyer and Schaefer, 2005; Torp and Nielsen, 2018), improve employees' R&D enthusiasm (Mehta et al., 2017), and motivate employees to share technology and knowledge (Mao and Weathers, 2019). In addition, equity incentives enhance employees' willingness to take risks. In addition, equity incentives enhance employees' willingness to take risks.

2.3. Literature on the relationship between executives, employees, and enterprise innovation

Improvements to the innovation level depend not only on the decisions of senior executives but also on implementation by core employees. Therefore, the academic community began conducting enterprise innovation research based on both executives and employees to maximize their role in enterprise innovation. Initially, they applied their research perspective to the executive–employee pay gap and enterprise innovation (Ding et al., 2009). In this regard, there are two opposing views: First, based on championship theory, the widening pay gap can effectively stimulate innovation willingness among lower-level employees, reduce supervision costs, and may help improve innovation performance (Burns et al., 2013). Second, considering the higher risk of improving the quality of innovation and the existence of social comparison theory, the widening of the salary gap is not conducive to team cooperation and reduces employee innovation enthusiasm for high-quality innovation achievements, ultimately damaging the quality of innovation (Siegel and Hambrick, 2005). As equity incentives have become the main incentive mechanism used by enterprises, some studies have begun comparing the effects of such incentives on executives and employees to determine the main group responsible for incentive innovation. Some scholars pointed out that senior executives' equity incentives cannot directly affect innovation efficiency by driving output through innovation input (Edmans et al., 2017), while employee equity incentives can increase innovation output by improving innovation efficiency (Hochberg and Lindsey, 2010). In addition, some scholars discussed the relationship between executives' overseas experience, employees' skills, and enterprise innovation (Hattori and Lapidus, 2004), while others considered building a model of executives, employees' attention, and innovation output (Muller and Whiteman, 2015).

2.4. Review

From the above, it is evident that the areas worthy of further supplementary research include the following:

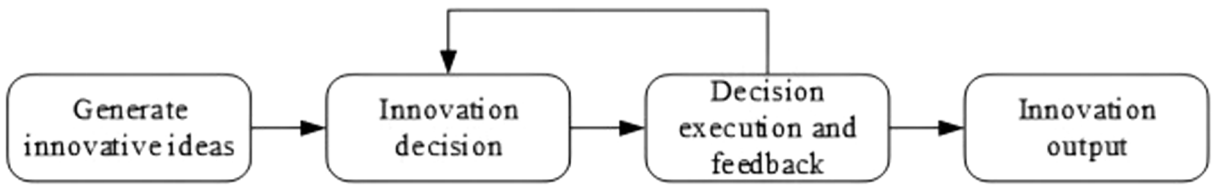


FIGURE 1
Enterprise innovation process.

1. The effectiveness of core employees in enterprise innovation and how employee innovation enthusiasm could be stimulated.
2. The effect of employee equity incentive in the process of enterprise innovation: Limited by data availability, more scholars only discuss the theoretical mechanism that employee equity incentive affects enterprise innovation, but neglect to provide evidence for it.
3. Executive psychological capital may play a mediating role in the impact of employee equity incentives on enterprise innovation: Starting from agency theory, Equity incentive can effectively alleviate the agency problem between executives and employees, promote the connection between them and the enterprise, improve innovation efficiency, and in turn affect executives' decision-making.
4. The impact of R&D investment on senior executives' decision-making and the implementation effect of employees; the effect of employee equity according to the type of equity incentive, and; the impact of varying property rights and institutional background on the effectiveness of executive psychological capital and employee equity incentives: R&D investment is not only a key variable influencing senior executives' decision-making, but also a guarantee in determining the implementation effect of employees, which may play a regulatory role. Furthermore, the effect of employee equity incentives should vary according to the type of equity incentive. In addition, when combined with China's institutional background, the effectiveness of executive psychological capital and employee equity incentives may vary significantly under different property rights. However, existing research seems to afford little consideration to these three points.

3. Theoretical analysis and hypothesis presentation

3.1. Theoretical analysis of the impact of employee equity incentive on enterprise innovation

In the enterprise, senior executives and core employees are at an important link in the principal-agent chain. When combined with the four stages of the innovation process, we can see that innovation activities cannot be carried out without the innovation decisions made by senior executives and the efforts of core employees who implement the decisions. The efforts of key employees directly determine the effect of the transformation of "R&D input into innovation output." In fact, the absence of the role of core employees, that is, the interests of shareholders, executives, and employees, and where employees are inconsistent, may not be conducive to the innovation output of enterprises. Employee equity incentives provide an effective solution to this problem. The research advances three reasons why equity incentives for core employees are conducive to accelerating enterprise innovation.

First, From the perspective of principal-agent theory, on the one hand, employee equity incentives alleviate the shareholder–employee agency problem, connecting their rights and interests, these incentives can effectively stimulate employees' willingness to innovate, improve employees' sense of belonging to the enterprise (Torp and Nielsen, 2018), and reduce the talent turnover rate. On the other hand, the implementation of employee equity incentives can encourages employees to supervise each other, forming a more lasting incentive effect. In addition, they can encourage senior executives to increase investment and improve innovation efficiency (Tsang et al., 2021).

Second, From the perspective of incentive theory, the classified incentive effect generated by equity incentives can facilitate the retention of talent with higher innovation enthusiasm and initiative, effectively guaranteeing the vitality of internal R&D in enterprises.

Third, long term effective equity incentive can avoid the emergence of shortsightedness of core employees, improve their willingness to bear risks, increase their tendency to favor long-term benefits, and induce improvements in innovation efficiency (Chang et al., 2015).

According to the above theoretical analysis, the stronger the equity incentive given to core employees, the better the incentive effect. Under the same innovation conditions, enterprises will get more and higher quality innovation output. Therefore, the following assumption can be made:

> *H1a*: The higher the intensity of equity incentive given to employees, the greater the positive effect on the quantity of innovation output of enterprises.
>
> *H1b*: The higher the intensity of equity incentives given to employees, the more conducive to improving the quality of enterprise innovation output.

3.2. Theoretical analysis of the impact of executives' psychological capital on enterprise innovation

As a special enterprise resource capability, many studies have confirmed that the enhancement effect of senior executives' psychological capital on innovation performance is far greater than that of other resource capabilities (Li et al., 2020). In this paper, senior executives' psychological capital is defined as the stable psychological characteristics and positive psychological state of senior executives, which synthesizes self-efficacy, emotional stability, psychological resilience, and other dimensions. This paper advances the following reasons for the strong effect of senior executives' psychological capital on enterprise innovation:

First, In the principal-agent chain of enterprises, senior executives are in front of employees, and the psychological capital of senior executives has a downward transmission effect, On the one hand, senior executives have a strong sense of self-efficacy, and their confidence can engender an environment conducive to organizational innovation. On the other hand, it can significantly affect employees' innovation behavior (Wang et al., 2021), and enhance their psychological resilience, sense of organizational belonging, and even risk-bearing level, thus affecting innovation efficiency. Second, according to "time-oriented theory," executives' subjective preferences for the future greatly affect the innovation in and development of enterprises. Executives with higher psychological capital are more concerned about the long-term impact of the enterprise. They optimize their professional and strategic visions and tend to be optimistic about the future value of enterprise innovation, driving them to be more decisive regarding existing innovation decisions and effectively improving innovation performance. Third, the experience

of senior executives, their personal characteristics, and other factors affect innovation decision-making (Hambrick and Mason, 1984). Long cycle, high investment and high risk innovation activities make senior executives unable to judge innovation performance, which may lead to short-sighted behavior. At this time, senior executives with high levels of psychological capital show resilience, making them more risk-tolerant (Fatoki, 2018) and more willing to innovate.

Based on the foregoing, corresponding assumptions can be made:

> *H2a*: The psychological capital of executives has a positive impact on the quantity of innovation output of enterprises. The higher the psychological capital, the greater the positive effect.
>
> *H2b*: The psychological capital of executives has a positive impact on the quality of innovation output of enterprises. The higher the psychological capital, the greater the positive effect.

3.3. Theoretical analysis of the relationship between employee equity incentive, executive psychological capital, and enterprise innovation

3.3.1. The intermediary effect of senior executives' psychological capital on employee equity incentive and enterprise innovation

The development of enterprise innovation activities requires movement through many links. The only parts that can be controlled by human resources are R&D resource input and enterprise innovation output. Among them, senior executives play a decisive role in the amount of innovation input. As direct innovators, the efforts of core employees greatly affect the transformation effect of "input into output" and the feedback on innovation decisions. The psychological capital and risk preference of senior executives are key factors in decision-making. In practice, it is found that relying solely on senior executives to discover investment opportunities and determine resource allocation may not improve innovation performance. Moreover, the shortsightedness of senior executives and the principal–agent problem involving employees make senior executives psychologically prefer short-term returns and low-risk innovation activities.

According to agency theory, employees are at an important link in the principal-agent chain, and their efforts directly affect the realization of the innovation goals of senior executives and the rights and interests of senior executives. Employee equity incentives can effectively alleviate the senior executive–employee agency problem, stimulate the innovation ability of employees, and bring better positive market reaction for enterprises (Fang et al., 2015). It makes senior executives pay more attention to realizing the enterprise's long-term value, enhances their willingness to take risks, and gives them a stronger internal motivation to deal with high-risk investments; Starting from the innovation process and combining the incentive theory, equity incentive for core employees can produce innovation incentive effect, increasing their diligence and motivation to innovate, thereby effectively improving the input–output conversion rate and innovation benefits. Also, implementing these incentives plays a positive feedback role in innovation decisions, in turn, strengthening senior executives' psychological capital and urging these executives to gradually increase R&D investment in high-risk, innovative projects.

From this perspective, employee equity incentives can positively impact enterprise innovation by enhancing senior executives' psychological capital and improving their risk preferences. Accordingly, we advance the following assumption:

> *H3a*: The psychological capital of executives plays an intermediary role between employee equity incentives and the quantity of enterprise innovation outputs.
>
> *H3b*: The psychological capital of executives plays an intermediary role between employee equity incentives and the quality of enterprise innovation outputs.

3.3.2. The impact of the forms of employee equity incentive on the effectiveness of employee equity incentives and executive psychological capital

Stock option and restricted stock are two forms of equity incentive for Chinese listed companies. The return and risk of equity option forms are not equal, which will constitute the incentive effect of sharing risks. The value of restricted stock positively correlates with the stock price of the enterprise so that the employees can obtain certain returns, which may produce the risk aversion effect. On the one hand, it may reduce the risk tolerance of core employees, thus leading to the enterprise's lack of overall innovation motivation. On the other hand, because the rights and interests of senior executives are related to enterprise performance (Minnick and Noga, 2010), the risk aversion effect of employee equity incentives makes senior executives more inclined to low-risk, high-return projects, hindering high-quality innovation activities with greater risk.

Based on the foregoing, corresponding assumptions can be made:

> *H4a*: Compared with the implementation of stock options, the implementation of restricted stock will reduce the positive effects of employee equity incentive and executive psychological capital on the quantity of innovation output.
>
> *H4b*: Compared with the implementation of stock options, the implementation of restricted stock will reduce the positive effects of employee equity incentive and executive psychological capital on the quality of innovation output.

3.3.3. The innovation effect of employee equity incentive and executives' psychological capital is affected by the nature of property rights

When combined with China's institutional background, under different property rights, Whether the effectiveness of employee equity incentives and senior executives' psychological capital have a positive effect on enterprise innovation is affected by different property rights. State owned enterprises enjoy more policy support and subsidies than non-state-owned enterprises but also face many government goals, tasks, and policy constraints. As for the "executive executives" of state-owned enterprises, their political promotion motivation urges them to pay more attention to their "achievements" in office, leading to them having low enthusiasm for innovation and a low willingness to take risks. They may attach importance to innovation output in the short term and ignore encouraging enterprises to carry out high-quality innovation activities. For the core employees of state-owned enterprises,

in an environment with many policy restrictions, plans regarding employee equity incentives issued by these state-owned enterprises tend to be welfare-based, limiting the incentive effect of the equity plan and making it difficult to mobilize employees' motivation for innovation.

Based on the foregoing, corresponding assumptions can be made:

> *H5*: The positive effects of employee equity incentive and executive psychological capital on enterprise innovation are affected by different property rights. The positive effects of employee equity incentive and executive psychological capital on the quantity and quality of innovation output of state-owned enterprises are not high.

In summary, this paper's theoretical model can be summarized as follows (Figure 2):

4. Research design

4.1. Sample selection and data source

This paper uses relevant data from the CSMAR database to select companies listed on the A-share market that implemented equity incentives from 2010 to 2021 as its research sample. On this basis, this study screens the data on senior executives' psychological capital, innovation output, R&D input, and other relevant variables. The filter conditions are as follows:

1. It considers the particularity of financial enterprise data and the instability of ST and * ST company data. Both parts of the relevant data are eliminated.
2. Equity incentives for core employees is the key explanatory variable in this paper. The data of companies that do not carry out equity incentives for employees and only carry out equity incentives for senior executives are excluded.
3. Executive psychological capital is also a key explanatory variable applied in this paper, and related data is matched with employee equity incentives data.
4. In this paper, the number of patent and invention patent applications are used to measure the quantity and quality of enterprise innovation. In this regard, companies without patent applications or invention patent application data are excluded.

After manually screening relevant data according to the above conditions, 669 observations are obtained to assess the impact of executive psychological capital and employee equity incentive on the number of examples of enterprise innovation. Furthermore, 567 observations are obtained to study the impact of executive psychological capital and employee equity incentives on the quality of enterprise innovation. The data obtained is unbalanced panel data.

4.2. Variable selection and definition

4.2.1. Explained variable: Innovation output (Innovation)

By referring to the research in relevant fields, these indicators are selected to measure the two levels of enterprise innovation output: quantity and quality. In this study, the innovation output at the enterprise quantity level will be represented by the total number of patent applications (including inventions, utility models, and design patents) (*T_Innovation*). Although the number of patents granted and the number of patent applications can reflect the innovation output of enterprises, compared with patent authorization, patent applications can more accurately depict real-time patent innovation (Griliches, 1990) and better reflect the innovation efficiency of enterprises. In addition, the innovation output of enterprise quality can be represented by the total number of invention patents (*Q_Innovation*). International scholars believe that patents of great importance and high technical levels will be cited more frequently. So, in their research, they often use the number of patent citations by enterprises in that year to measure the quality of innovation output (Bradley et al., 2016). However, patent citations take time, and there is a lack of relevant statistics in China. However, due to their required large investment in R&D, high technology content, and high-value achievements, invention patents can better demonstrate the substantive innovation levels of enterprises, and are an appropriate indicator of the quality of enterprises' innovation output.

4.2.2. Explanatory variable: Employee equity incentive intensity (*Esop*)

The Administrative Measures for Equity Incentives of Listed Companies stipulates that the objects of equity incentives can be senior executives, directors, core technicians, and core business personnel. In this paper, the latter two are defined as "core employees." Regarding research in related fields (Call et al., 2017), the employee equity incentive intensity is represented by the proportion of incentive shares (options and restricted stocks) granted to core employees in equity incentive plans among the total number of shares of the company is selected. It should be noted that although the newly added or accumulated grants can be used for measurement, it is more logical that this paper selects the newly added grants for the core employees' incentive shares, considering that employees may exercise their rights after reaching performance goals and being granted incentives.

4.2.3. Mediating variable: Executive psychological capital (*Pyc*)

The psychological capital of senior executives has the nature of both personal emotions and personality traits, and its connotation is the positive psychological state and psychological characteristics of senior executives (Luthans et al., 2007; Russo and Stoykova, 2015). It includes three sub-dimensions: self-efficacy, emotional stability, and psychological resilience. In this paper, the entropy weight method is used to determine the weight of multi-dimensional indicators. Then, the indicators are synthesized to obtain personal psychological capital, while the psychological capital of the company executives included in the study sample is obtained by averaging the sum of all executives' psychological capital.

4.2.3.1. Self-efficiency

The sense of self-efficacy refers to the confidence of senior executives regarding their future expectations and their own strengths. It is generally believed that the more educated an individual, the higher their cognitive learning ability and knowledge reserve level. Therefore, they should be more willing to bear risks in innovation investment (Huang and Sheng, 2013) and show higher self-confidence. Moreover, the longer the senior executive serves, the stronger their

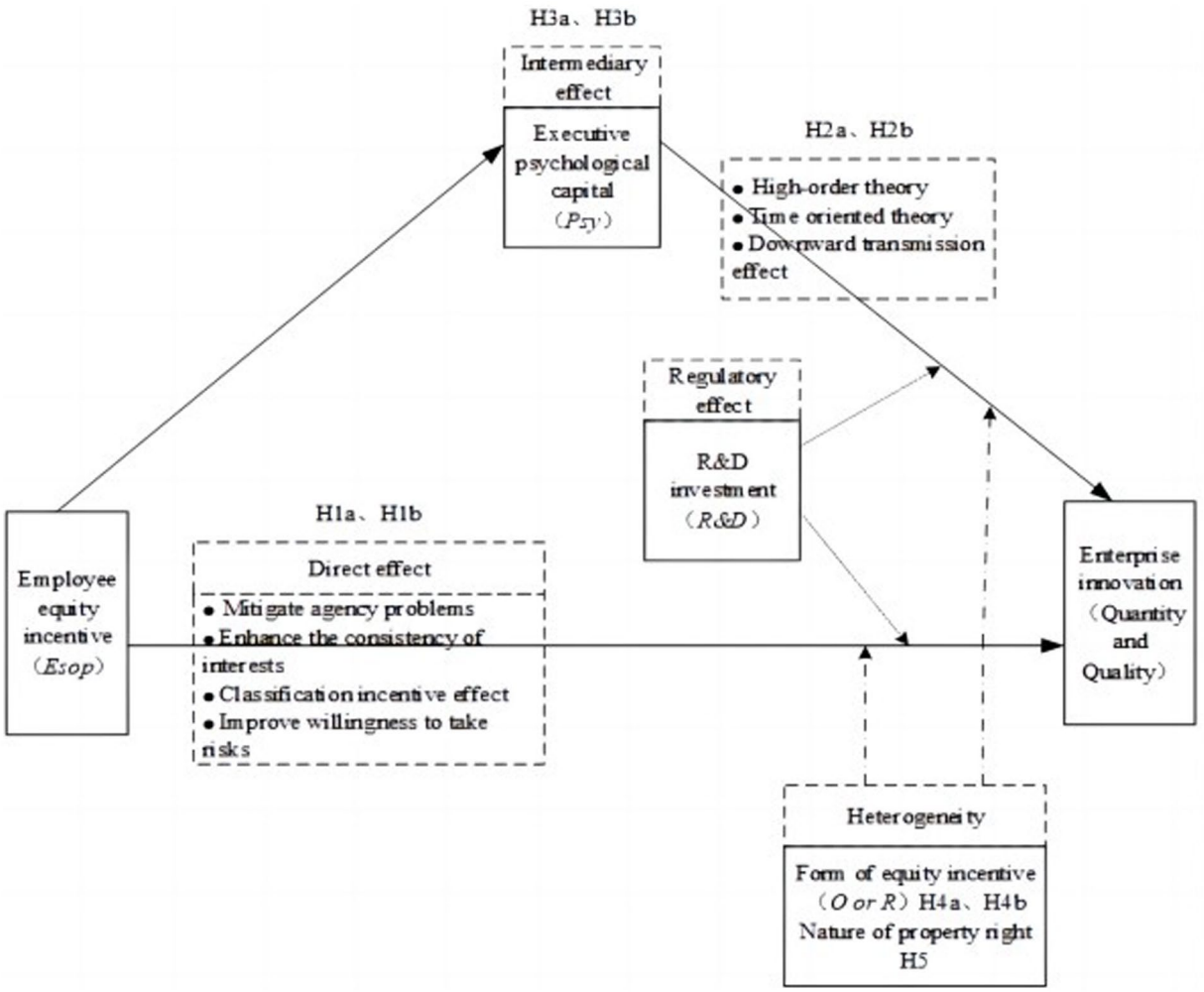


FIGURE 2
Theoretical model.

management experience and professional competence, and the higher their self-efficacy when operating in a complex decision-making environment. Therefore, this paper selects senior executives' educational background and tenure as indicators to measure self-efficacy. The educational background of senior executives is measured by the equivalent weighting method. The educational background of technical secondary school and lower is assigned a value of one, that of junior college is assigned a value of two, an undergraduate education background is assigned a value of three, that of a master's degree is assigned a value of four, and a doctoral educational background doctor is assigned a value of five. The tenure of office is expressed according to the time over which the senior executives included in the sample companies have held their current positions.

4.2.3.2. Emotional stability

Emotional stability reflects executives' control over their emotions. Many scholars believe that as they grow older, the emotional threshold of senior executives will rise due to their rich experience, they will not be easily disturbed by the outside world, and their emotional stability will be high. Some scholars also pointed out that the fairness of salary will significantly affect the psychological balance and behavior choice of executives, and the fairness of relative salaries can effectively adjust the conflict between managers and shareholders. Therefore, this paper selects age and relative salary as indicators to measure emotional stability. Age is expressed by the current age of senior executives from sample companies. Relative compensation is expressed by comparing executive compensation with the average of all executive compensation given by the company in the same year.

4.2.3.3. Psychological resilience

As an integral part of positive psychological capital (Rego et al., 2021), executive psychological capital refers to the ability to effectively cope with stress, adversity, frustration, and other situations, and quickly recover from psychological conditions (Den Hartigh and Hill, 2022). The psychological resilience of senior executives is affected by their personal experiences (Santoro et al., 2020). For example, senior executives with advanced academic backgrounds demonstrate more rigorous thinking, stronger self-discipline, and perseverance in exploration (Francis et al., 2015), and the intellectual capital they have enables them to deal with problems more calmly and rationally. As another example, senior executives with overseas backgrounds, including educational and professional experiences, have incurred more economic and energy

costs, greatly improving their anti-pressure ability. Therefore, this paper selects academic background and overseas background as indicators to measure psychological resilience. Academic and overseas backgrounds are measured by the equal weight assignment method. There is no relevant background in Assignment 1; however, there is relevant background in Assignment 2 (see Table 1).

4.2.4. Adjusting variable: R&D investment intensity (*R&D*)

Review the relevant literature (Aghion et al., 2013; Cornaggia et al., 2015). Existing studies mainly measured the intensity of R&D investment through "R&D investment/(total assets or market value or operating income)." The operating income of the sample of listed companies selected for this study is vulnerable to profit manipulation, operation management, and other factors, and the market value is difficult to estimate. Therefore, this paper measures the intensity of R&D investment by taking the "R&D expenses/total assets" in the annual reports of the sample companies.

4.2.5. Control variables

Combing relevant literature for reference (Chang et al., 2015; Fang et al., 2015; Call et al., 2017). Combined with the actual development of Chinese enterprises, the following variables are selected as this study's control variables: Enterprise scale (*Size*); Capital intensity (*Tangibility*); Enterprise age (*Age*); Enterprise performance (*ROA*); Lever level (*Lev*); Intangible assets (*Inlc*); Enterprise equity concentration (*Vrd*) (see Table 2).

TABLE 1 Index system of senior executives' psychological capital.

Variable	Level I indicators	Weight	Secondary indicators	Weight
Pyc	*Self-efficacy*	0.4034	*Degree*	0.2359
			Duration	0.1675
	Emotional stability	0.2651	*T-age*	0.0593
			Relative	0.2058
	Psychological resilience	0.3315	*Academic*	0.1988
			Overseas	0.1327

4.3. Research model design

4.3.1. Employee equity incentive, senior executives' psychological capital, and enterprise innovation output

This paper mainly examines the direct relationship between employee equity incentive, executive psychological capital and enterprise innovation output, and examines the impact of executive psychological capital and employee equity incentive on enterprise innovation output in terms of quantity and quality by building Models (1) and (2):

$$T\_Innovation_{it} = c + \alpha Esop_{m,it} + \chi Pyc_{it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \quad (1)$$

$$Q\_Innovation_{it} = c + \alpha Esop_{m,it} + \chi Pyc_{it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \quad (2)$$

In Formulae (1) and (2), "*T_Innovationit*" and "*Q_Innovationit*" represent the quantity and quality of enterprise innovation output, respectively; "$Esop_{it}$" refers to employee equity incentives, "α" is the elastic coefficient of these incentives, "*c*" is a constant term, "$control_{it}$" is a series of control variables, and "μ" represents the random disturbance term.

This paper seeks to alleviate the problem of heteroscedasticity and sequence correlation that may occur in the regression of the two models, as well as improve the robustness of the regression results by making a robust adjustment to the standard error of the regression coefficient.

4.3.2. The intermediary effect of senior executives' psychological capital on employee equity incentive and enterprise innovation

This paper tests the intermediary effect executives' psychological capital may play on employee equity incentive and

TABLE 2 Variables definition.

Variable properties	Variable names	Symbol	Variable calculation
Interpreted variables	Quantity of innovation outputs	*T_ Innovation*	Ln(1 + Total number of patent applications)
	Quality of innovation output	*Q_ Innovation*	Ln(1 + Number of invention patent applications)
Explanatory variable	Staff equity incentive intensity	*Esop*	Total number of shares granted to key employees/Total number of company shares
Intermediary variable	Executive psychological capital	*Pyc*	Self-efficacy, Emotional stability, Psychological resilience (Entropy weight method)
Regulating variable	R&D investment intensity	*R&D*	R&D expenses/Total assets
Control variables	Enterprise scale	*Size*	Natural logarithm of total assets
	Capital intensity	*Tangibility*	Net fixed assets/Total assets
	Enterprise age	*Age*	Value year - Establishment year (natural logarithm)
	Enterprise performance	*ROA*	Net profit/Total assets
	Lever level	*Lev*	Total liabilities/Total assets
	Intangible assets	*Inlc*	Natural logarithm of net intangible assets
	Enterprise equity concentration	*Vrd*	Shareholding ratio of the largest shareholder (%)

enterprise innovation (i.e., to test hypothesis H3) by applying Baron and Kenny, 1986 intermediary test method for reference and analyzing it by combining the stepwise regression method with the Sobel test. First, from the level of quantity and quality of innovation output, the study builds the Recursive Models (3) and (4) as follows:

$$\begin{cases} T\_Innovation_{it} = c_1 + \gamma Esop_{m,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \\ Pyc_{it} = c_2 + \alpha ESop_{m,it} + \sum_j \beta_j control_{it} + \lambda_1 + \mu_{it} \\ T\_Innovation_{it} = c_3 + \gamma Esop_{m,it} + \ddot{a} Pyc_{m,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \end{cases} \quad (3)$$

$$\begin{cases} Q\_Innovation_{it} = c_1 + \gamma Esop_{m,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \\ Pyc_{it} = c_2 + \pm ESop_{m,it} + \sum_j \beta_j control_{it} + \lambda_1 + \mu_{it} \\ Q\_Innovation_{it} = c_3 + \gamma' Esop_{m,it} + \delta Pyc_{m,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \end{cases} \quad (4)$$

The specific analytical process for the intermediary effect is as follows:

1. Analyze the regression of employee equity incentives to enterprise innovation, using the regression coefficient γ. If it is not significant, there is no intermediary effect. If γ is significant, proceed to the next step.
2. Test the regression coefficient in turn α、and γ'. If both coefficients are significant, there is a mediating effect. If at least one is not significant, the Sobel test should be conducted, and an assessment should be made according to the significance of the test results.
3. Test the regression coefficient after obtaining the results of the intermediary effect according to the previous step on δ. If it is not significant, then senior executives' psychological capital plays a complete intermediary effect. On the contrary, such an outcome reveals a partial intermediary effect.

4.3.3. The moderating effect of R&D investment on employee equity incentive, senior executives' psychological capital, and enterprise innovation

This paper tests the moderating effect of R&D investment on employee equity incentive, executives' psychological capital, and enterprise innovation (i.e., to test hypotheses H4 and H5), by applying the hierarchical adjustment regression analysis method to assess the moderating effect. The following model can be constructed by taking the moderating effect of R&D investment on employee equity incentives and enterprise innovation as an example:

$$\begin{cases} T\_Innovation_{it} = c_1 + \alpha_1 Esop_{e,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \\ T\_Innovation_{it} = c_2 + \alpha_2 Esop_{e,it} + \chi Esop_{e,it} \times R\&D_{it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \end{cases} \quad (5)$$

$$\begin{cases} Q\_Innovation_{it} = c_1 + \alpha_1 Esop_{e,it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \\ Q\_Innovation_{it} = c_2 + \alpha_2 Esop_{e,it} + \chi Esop_{e,it} \times R\&D_{it} + \sum_j \beta_j control_{it} + \lambda_i + \mu_{it} \end{cases} \quad (6)$$

The model constructed by testing the moderating effect of R&D investment on executives' psychological capital and enterprise innovation is similar to Model (6) above, so it will not be repeated. According to the above Models (5) and (6), the significance of regression coefficient χ after the cross-multiplication of R&D (regulating variable) and *Esop* can be tested and analyzed to determine whether R&D investment has a regulating effect.

4.4. Research model design

Table 3 presents the descriptive statistical results of this paper's main variables from the two levels of the quantity and quality of enterprise innovation output. The innovation output at the quantitative level is measured by the total number of patent applications, while the output at the qualitative level is represented by the number of development patent applications. Table 3 shows that the average value of the number of innovation output is 3.772, the maximum value is 9.373, while the average value of the quality of innovation output is 2.916 and the maximum value is 8.951. These data show that existing enterprises still focus onthe quantity of the achievement output in innovation, whose overall quality level is not high. The average value of employee equity incentive is 0.023 and 0.022, respectively, indicating that the sample companies only have about 2% equity incentive for core employees, and the intensity of equity incentive is low. The standard deviation of senior executives' psychological capital and employee equity incentive is small, indicating that the dispersion of relevant data is stable and less affected by abnormal and extreme values. In addition, the standard deviations of other control variables are within a reasonable range and are appropriately representative.

5. Empirical results

5.1. Multicollinearity diagnosis of variables

The choice of multiple variables makes the regression analysis more comprehensive, but the multicollinearity problem among independent variables may also lead to the reduction of the accuracy

TABLE 3 Descriptive statistics of variables.

Variables	*T_Innovation*				*Q_Innovation*			
	Average value	Min	Standard deviation	Max	Average value	Min	Standard deviation	Max
Innovation	3.775	0.693	1.371	9.373	2.916	0.693	1.337	8.951
Esop	0.023	0.001	0.022	0.155	0.022	0.001	0.021	0.155
Pyc	7.154	5.453	0.508	9.345	7.150	5.984	0.519	9.345
R&D	7.721	0.110	9.724	167.410	7.989	0.020	10.455	167.410
Size	21.986	19.744	1.105	26.237	21.808	19.744	1.028	26.237
Tangibility	0.163	0.003	0.119	0.669	0.161	0.003	0.114	0.611
Age	2.705	0.693	0.382	3.526	2.688	1.386	0.384	3.526
ROA	0.063	−0.439	0.060	0.295	0.062	−0.439	0.056	0.295
Lev	0.355	0.034	0.177	0.891	0.335	0.034	0.170	0.789
Inlc	0.041	0.001	0.046	0.486	0.037	0.001	0.033	0.322
Vrd	32.508	4.080	14.164	81.180	31.381	4.080	13.757	75.170

TABLE 4 Collinearity test result (VIF).

Variables	Model (1)	Model (2)
	T_In	*Q_In*
Esop	1.038	1.028
Pyc	1.111	1.092
R&D	1.297	1.359
Size	1.613	1.621
Tangibility	1.121	1.149
Age	1.137	1.139
ROA	1.356	1.318
Lev	2.290	2.229
Inlc	1.063	1.066
Vrd	1.062	1.047
VIF mean	1.309	1.305
N	669	567

of the parameter estimation during the regression, so that the influence degree of independent variables cannot be accurately judged. Based on this, it is necessary to carry out multicollinearity diagnosis for the selected variables before regression. The common way is to use SPSS software to carry out variance expansion factor test (VIF test). When the VIF is less than 10, it is proved that there is no strict collinearity problem between variables. According to the collinearity diagnosis results (Table 4), the VIF values of all variables in Model 1 and Model 2 are less than 3 and close to 1, which proves that there is no collinearity problem between variables, and the settings of Model 1 and Model 2 are more reasonable.

5.2. Analysis of basic regression results

Table 5 mainly applies the model constructed above to conduct regression analyses on the relationship between senior executives' psychological capital, employee equity incentives, and enterprise innovation. Model (1) reported the regression results of the impact of senior executives' psychological capital and employee equity incentives on the number of enterprise innovation outputs. According to the results, the higher the intensity of employee equity incentives, the greater the positive impact on the number of enterprise innovation outputs. The positive impact coefficient is 0.175, which is significant at the 10% level. Similarly, there is also a significant positive correlation between senior executives' psychological capital and the number of enterprises' innovative outputs. The value of executives' psychological capital influencing innovation is 0.152. Model (2) reported the regression coefficient value of the impact of senior executives' psychological capital and employee equity incentive on the quality of enterprise innovation output. Based on the regression value, the impact coefficient of employee equity incentive was 0.105, which was significant at the 10% level, proving that the quality of the innovation output of enterprises that implement equity incentives for core employees will also be improved. In addition, the coefficient of executives' psychological capital affecting the quality of innovation output is positive, 0.122. The improvement of innovation quality will inevitably cope with more uncertainty and higher risk. The positive psychological state of senior executives is an important resource capability for enterprise innovation. Synthesize the regression values in the following table, it can be seen that employee equity incentives and senior executives' psychological capital have a significant positive effect on enterprise innovation output. Therefore, Hypotheses H1a, H1b, H2a, and H2b are tested.

The study conducts a further analysis according to the results of Models (1) and (2). On the whole, although senior managers' psychological capital and employee equity incentives positively affect the quantity and quality of enterprise innovation output, it is clear that senior managers' psychological capital (0.163 > 0.158) and employee equity incentives (0.217 > 0.105) have stronger positive effects on the quantity of enterprise innovation output. The launch of high-quality innovation activities has a higher failure rate (Ederer and Manso, 2013) and greater risks. For executives, on the one hand, there is a tendency to avoid risks due to the consideration of private rights and interests, so they are unwilling to carry out high-quality innovation. On the other hand, although some research shows that executives with high

TABLE 5 Senior executives' psychological capital, employee equity incentive, and enterprise innovation.

Variables	Model (1)	Model (2)	IV-2SLS(1)	IV-2SLS(2)
	T_Innovation	*Q_Innovation*	*T_Innovation*	*Q_Innovation*
Esop	0.217** (4.726)	0.105* (2.278)	0.279* (2.117)	0.148* (1.700)
Pyc	0.163* (2.564)	0.158* (1.729)	0.144* (1.758)	0.178* (1.757)
R&D	0.208*** (4.074)	0.032*** (6.332)	0.217*** (4.216)	0.030*** (5.905)
Size	0.676*** (13.450)	0.700*** (12.514)	0.682*** (13.537)	0.720*** (12.847)
Tangibility	0.014 (0.036)	0.194 (0.458)	0.064 (0.165)	0.223 (0.521)
Age	−0.071 (−0.583)	−0.127 (−1.007)	−0.089 (−0.729)	−0.138 (−1.104)
ROA	1.567** (1.826)	2.124** (2.285)	1.595* (1.860)	2.207** (2.386)
Lev	0.236 (0.688)	0.515 (1.416)	0.017 (0.044)	0.304 (0.767)
Inlc	−0.506 (−0.515)	−1.665 (−1.180)	−0.601 (−1.180)	−1.613 (−1.142)
Vrd	0.008** (2.657)	0.005 (1.517)	0.008*** (2.656)	0.005 (1.517)
Constant	−13.736*** (−6.271)	−13.796*** (−5.918)	−12.651*** (−5.840)	−13.235*** (−11.244)
LM	–	–	53.165 [0.000]	63.844 [0.000]
Wald F	–	–	77.539 {16.40}	83.818 {17.37}
Year & Ind	Yes	Yes	Yes	Yes
N	669	567	669	567
Adj.R^2	0.326	0.358	0.328	0.369

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

psychological capital may be more willing to innovate (Newman et al., 2014), there are many "obstacles" to enterprise innovation, including resource shortages and talent limitations. These constraints must be considered when executives make innovation decisions. For core employees, first of all, employee equity incentives link personal rights and interests with the innovation and development of the company. In this regard, the greater the value of innovation output, the more rights and interests employees obtain. Second, employee equity plans have a high tolerance for short-term enterprise innovation failure. The classified incentive effect generated by the employee equity plans incentivize employees to enhance their ability to bear innovation risks (Hall and Murphy, 2003). Thus, they become more inclined to high value, high-quality innovation. Finally, equity incentives encourage enterprises to create an environment conducive to innovation success, enabling core employees to share knowledge, resources, and technology with each other, and to collaborate as much as possible to improve the value of innovative products (Hochberg and Lindsey, 2010).

From the perspective of quantity and quality, the positive effect of employee equity incentives on the quantity of enterprise innovation output is greater ($Esop = 0.217 > 0.158 = Pyc$), while the positive effect of executive psychological capital on the quality of enterprise innovation output is clearly higher ($Esop = 0.105 < 0.158 = Pyc$). Senior executives are not only the decision-makers of innovation activities, but also the decision-makers of R&D capital investment, while core employees execute and participate in innovation activities. Enterprises must tolerate more failure, bear more risks, and invest more resources to improve the quality of innovation output, which depends on senior executives' innovation decisions. Research shows that enterprise managers who possess higher psychological capital have better insight and creativity, and are more likely to implement breakthrough innovation with significant technological progress (Newman et al., 2014).

5.3. Endogenous treatment

According to the relevant theories and empirical findings mentioned above, whether to the quantity or quality of enterprise innovation, employee equity incentive plays a positive role. However, the integration of existing literature shows that both may have a cause and effect on each other. Companies that attach importance to innovation also tend to implement equity incentives to improve employees' motivation to engage in innovation activities to produce more high-quality innovation results. This paper selects the appropriate instrumental variables, and then uses the two-stage least squares method to test the endogenous problems that may be caused by employee equity incentives and enterprise innovation. we reference existing practices (Hochberg and Lindsey, 2010; Chen et al., 2016), and select the natural logarithm of the number of employees [*Ln* (*Em*)] as the tool variable of this paper, The selected tool variables meet:

1. There is a correlation between the number of employees and the intensity of employee equity incentive.
2. The number of employees has nothing to do with the innovation output of the enterprise. These two points were verified in the first stage of regression.

The results of endogenous test are shown in Table 5 (showing the results of the model in the second stage, and Wald F statistics and LM statistics). The Wald F statistics in the first stage are significantly greater than the critical value under the 10% bias, indicating that the selected instrumental variables have a strong explanation for endogenous variables. The Kleibergen-Paap rk LM statistical results show that the value of p is 0.000, indicating that the problem of unrecognizability does not exist. In addition, the estimation results of the second stage are shown in Table 5, which are consistent with the

benchmark regression results, indicating that the above research conclusions have strong robustness and reliability.

5.4. Robustness test

This paper tests the robustness of the empirical results by re-selecting alternative indicators for the explained variables, explanatory variables, and control variables as follows:

1. Replace the interpreted variables — Re-measure the quantity and quality of enterprise innovation output. The number of patent authorizations and patent applications can reflect the innovation output of enterprises. Compared with patent applications, patent authorizations certified by the National Patent Office can more accurately represent the effective innovation output of enterprises (Chang et al., 2015). However, their shortcomings are also obvious, and patent authorization often lags behind. Therefore, this paper uses the natural logarithm of the number of patent authorizations lagging behind one period as a substitute variable for the number of innovation outputs (*T_Innovation*). Similarly, it uses the natural logarithm of the number of patent authorizations lagging behind one period as a substitute variable for the quality of innovation outputs (*Q_Innovation*).
2. Replace explanatory variables — Re select the strength of employee equity incentive and the psychological capital of senior executives. In the usual regression analysis, the intensity of the employee equity incentives is judged by the proportion of equity incentives given to core employees from the company's total equity. However, this method ignores the impact of per employee. Even if two companies with the same equity may have different incentive numbers, the *per capita* difference may be large. Therefore, this paper uses *per capita* employee equity incentive intensity as a substitute variable for employee equity incentive intensity (*Esop*).
3. Add control variables —Add two variables that affect enterprise innovation. Enterprises with high profitability and strong growth may invest more resources in R&D and innovation (Jugend et al., 2018). Therefore, this paper adds the growth rate of operating income as a new control variable that represents the growth of enterprises (*Growth*). Regardless of managers' decisions, they will first weigh private interests. Enterprise innovation performance will change with the change of managers' shareholding ratio (Morck et al., 1988). Therefore, this paper adds the management shareholding ratio (*MngHold*) as a new control variable (Table 6).

From Table 7, after the relevant indicators, such as explained variables, explanatory variables, and control variables are replaced, the relevant symbols in the robustness test results are consistent with the previous regression values, indicating that the research conclusions above are highly reliable.

5.5. Further study

5.5.1. Verification of the intermediary effect of senior executives' psychological capital on employee equity incentive and enterprise innovation

Table 8 mainly applies the recursive model constructed above to conduct a regression analysis on the intermediary effect of executive psychological capital on employee equity incentive and enterprise innovation. From the regression results of model 1 alone, the impact coefficient of employee equity incentives on the number of innovation outputs is $\gamma = 0.139$, passing the test at the 10% significance level. According to the regression coefficient of model 2 in Table 7, the

TABLE 6 Definition of alternative variables.

Variable properties	Variable names	Symbol	Variable calculation
Interpreted variables	Quantity of innovation outputs	*T_Innovation*	Ln(1 + The total number of patent authorizations lags behind by one phase)
	Quality of innovation output	*Q_Innovation*	Ln(1 + The number of invention patents granted lags behind one phase)
Explanatory variable	Staff equity incentive intensity	*Esop*	(Total number of shares granted to key employees/Total number of company shares)/Number of core staff incentives
Control variables	Enterprise growth	*Growth*	Growth rate of operating income: (Current year - Last year)/Last year
	Management shareholding ratio	*MngHold*	Number of shares held by management/Number of corporate equity

TABLE 7 Robustness test results.

Variables	Replace interpreted variables		Replace explanatory variables		Replace control variables	
	T_In	*Q_In*	*T_In*	*Q_In*	*T_In*	*Q_In*
Esop	0.168*** (2.278)	0.154*** (2.278)	26.201** (3.297)	13.073* (2.126)	1.595* (1.860)	0.706*** (12.651)
Pyc	0.064* (1.573)	0.044** (2.687)	0.104* (2.034)	0.167* (2.826)	0.022*** (4.216)	0.031*** (6.192)
Constant	−7.827*** (−7.171)	−10.516*** (−10.292)	1.004 (1.318)	−11.542*** (−9.619)	−10.372*** (−9.583)	−11.458*** (−9.632)
N	581	488	669	567	669	567
Adj.R²	0.298	0.365	0.343	0.360	0.328	0.355

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

impact coefficient of employee equity incentives on senior executives' psychological capital is $\alpha = 0.279$, passing the test at the 1% significance level. According to the empirical results of Model 3, the impact of employee equity incentives and senior executives' psychological capital on the number of innovation output is statistically tested at a 10% significance level, with a regression coefficient of $\gamma' = 0.217$, $\delta = 0.163$. Regression results based on models 1–3 in Table 7, and according to the intermediary effect test process, senior managers' psychological capital contributes to an intermediary effect between employee equity incentive and the number of enterprise innovations [refer to the calculation method of mediating effect by existing scholars (α·δ)]. The mediating effect of available executives' psychological capital is about 0.045, accounting for 17.176% of the total effect.

Similarly, according to the empirical results of Model 4, the impact coefficient of employee equity incentives on innovation output quality is $\gamma = 0.111$, passing the test at the 10% significance level. Look at the regression value of model 5 alone, the impact coefficient of employee equity incentive on senior executives' psychological capital is $\alpha = 0.264$, passing the test at the 1% significance level. Analysis by regression value of model 6 alone, the impact of employee equity incentives and senior executives' psychological capital on the quality of innovation output has passed the statistical test at the 10% significance level, and the regression coefficient si $\gamma' = 0.105$, $\delta = 0.158$. The regression values of models 4, 5 and 6 can be analyzed that senior executives' psychological capital also has a partial mediating effect between employee equity incentives and enterprise innovation quality. The intermediary effect of executive psychological capital is about 0.042, accounting for 28.571% of the total effect. To sum up, the psychological capital of senior executives has a mediating effect between employee equity incentive and enterprise innovation. Therefore, Hypothesis H3a and H3b is verified.

According to the analysis of the results of Models 1–6, although the intermediary effect of executive psychological capital between employee equity incentive and innovation quality is small, it accounts for a slightly higher proportion of the total effect (28.571% > 17.176%). Risk bearing is an important driving force for enterprise innovation (Boubakri et al., 2013). High quality innovation activities tend to have longer cycles, are more affected by external uncertainties, and carry higher risk. As organizers of innovation activities and decision-makers of investment strategies, such as on human capital, executives have a risk aversion tendency for the sake of private interests. Some studies have pointed out that leaders with higher levels of psychological capital have stronger tenacity and motivation to implement breakthrough innovation (Newman et al., 2014; Russo and Stoykova, 2015), and they often achieve their goals by influencing employees' innovation behavior. As an important incentive for enterprise innovation, equity incentives not only connect core employees, executivess and enterprises (Hochberg and Lindsey, 2010) and improves the risk-bearing level of core employees and executives but also helps stimulate executives' willingness to carry out high-quality and high-risk innovation.

5.5.2. The moderating effect of R&D investment on employee equity incentives, senior executives' psychological capital, and enterprise innovation

Table 9 mainly applies the hierarchical adjustment regression model constructed above to conduct a regression analysis on the moderating effect of R&D investment on employee equity incentives

TABLE 8 Verification of the intermediary effect of senior executives' psychological capital.

Variables	*T_Innovation*			*Q_Innovation*		
	Model 1:*T_In*	Model 2:*Pyc*	Model 3:*T_In*	Model 4:Q_*In*	Model 5:*Pyc*	Model 6:Q_*In*
$Esop_m$	0.139* (3.693)	0.279*** (5.446)	0.217** (4.726)	0.111* (2.593)	0.264*** (4.587)	0.105* (2.278)
Pyc_m			0.163* (2.564)			0.158* (1.729)
Constant	−10.868*** (−10.671)	4.177*** (9.632)	−13.736*** (−6.271)	−12.221*** (−10.873)	4.275*** (8.202)	−13.796*** (−5.918)
N	669	669	669	567	567	567
$Adj.R^2$	0.318	0.100	0.326	0.357	0.085	0.358
Intermediary effect	$\alpha \cdot \delta = 0.045$			$\alpha \cdot \delta = 0.042$		
Proportion of effects	$\alpha \cdot \delta / (\alpha \cdot \delta + \gamma') \times 100 = 17.176\%$			$\alpha \cdot \delta / (\alpha \cdot \delta + \gamma') \times 100 = 28.571$		

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

TABLE 9 The moderating effect of R&D investment on employee equity incentives and enterprise innovation.

Variables	*T_Innovation*		*Q_Innovation*	
	T_1	*T_2*	*Q_3*	*Q_4*
$Esop_e$	0.217** (4.726)	0.127** (2.339)	0.105* (2.278)	0.137* (2.018)
R&D	0.208*** (4.074)	0.150* (2.652)	0.032*** (6.332)	0.022*** (3.088)
$Esop_e \times R\&D$		0.361*** (3.102)		0.422*** (2.306)
Constant	−13.736*** (−6.271)	−10.352*** (−9.627)	−13.796*** (−5.918)	−11.537*** (−9.713)
Year & Ind	Yes	Yes	Yes	Yes
N	669	669	567	567
$Adj.R^2$	0.326	0.338	0.358	0.367

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

and enterprise innovation. Based on the regression results of Models *T*_1 and *T*_2, it can be seen tha the cross projects of employee equity incentivel and R&D investment have a positive impact on the innovation output at the quantitative level, as well as the quality level (0.334,0.422), indicating that R&D investment positively regulates the connection between employee equity incentives and enterprise innovation. When combined with the four stages of the innovation process, the efforts of core employees determine the transformation effect of "R&D input into innovation output," and sufficient R&D input can support employees in transforming more knowledge and technology into the desired innovation output (Kuo et al., 2017).

Similarly, Table 10 shows the regression value of the test on the moderating effect of R&D investment between senior executives' psychological capital and enterprise innovation. Based on the regression results of Models *Q*_3 and *Q*_4, the cross projects of senior executives' psychological capital and R&D investment have a positive impact on the innovation output at the quantitative level, as well as the quality level (0.043 and 0.071), indicating that R&D investment positively regulates the connection between senior executives' psychological capital and enterprise innovation. As a decision-making group of innovation activities, senior executives bear the responsibility of frustration and failure in innovation in response to innovation projects with long cycles, high risk, and high cost. At this time, senior executives' psychological capital may become the key factor affecting innovation decisions. As a necessary resource for innovation, increased R&D investment undoubtedly enhances the innovation motivation and psychological capital of senior executives and encourages them to invest in innovative activities with high risks to maximize their returns and improve innovation performance.

5.5.3. Employee equity incentive forms, senior executives' psychological capital, and enterprise innovation

This paper explores the positive effect of employee equity incentive and executive psychological capital on enterprise innovation, by regrouping and regressing the data according to the forms of equity incentives, based on whether there are differences due to different forms of employee equity incentive. Table 11 below shows the regression results. In the grouping of stock option form (O), reviewing the regression results of model, it can be seen that the impact coefficient of employee equity incentive on enterprise innovation output is 0.299 on the quantitative level and 0.253 on the quality level, respectively, passing the statistical test. Similarly, the regression coefficients of senior executives' psychological capital are 0.153 and 0.057, respectively, also passing the statistical test, thereby indicating that the implementation of stock options can significantly promote enterprise innovation, and also enable the psychological capital of executives to maintain a positive role in enterprise innovation and development.

In the restricted stock form (R) grouping, the comprehensive results of models show that the positive effect of employee equity incentives on innovation output is limited, and the regression coefficient is only 0.020. Employee equity incentive has nothing to do with the quality of innovation output, and the correlation coefficient has not passed the statistical test. In addition, executives' psychological capital negatively affects the quality of innovation output, with a regression coefficient of 0.204, which passes the significance test. Regression results in the comprehensive table, when compared to the implementation of stock options, the implementation of restricted stocks not only reduces the

TABLE 10 The moderating effect of R&D investment on executives' psychological capital and enterprise innovation.

Variables	*T_Innovation*		*Q_Innovation*	
	T_1	*T_2*	*Q_3*	*Q_4*
Pyc_e	0.163* (2.564)	0.141* (1.754)	0.158* (1.729)	0.108* (2.160)
R&D	0.208*** (4.074)	0.163* (1.893)	0.032*** (6.332)	0.016* (1.366)
$Pyc_e \times R\&D$		0.043* (1.116)		0.071* (1.489)
Constant	−13.736*** (−6.271)	−10.135*** (−9.012)	−13.796*** (−5.918)	4.275*** (8.202)
Year & Ind	Yes	Yes	Yes	Yes
N	669	669	567	567
$Adj.R^2$	0.326	0.328	0.358	0.364

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

TABLE 11 Employee equity incentive forms, senior executives' psychological capital, and enterprise innovation.

Variables	Stock option(O)		Restricted stock(R)	
	T_Innovation	*Q_Innovation*	*T_Innovation*	*Q_Innovation*
Esop	0.229** (2.217)	0.253* (2.574)	0.020*** (3.772)	0.280 (0.122)
Pyc	0.153** (1.307)	0.057* (1.760)	−0.163 (−1.626)	−0.204** (−2.137)
Constant	−11.640*** (−6.641)	−13.491*** (−6.327)	−9.582*** (−7.511)	−10.336*** (−7.650)
Year & Ind	Yes	Yes	Yes	Yes
N	216	167	534	466
$Adj.R^2$	0.411	0.438	0.298	0.336

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

TABLE 12 The innovation effectiveness of employee equity incentive and executives' psychological capital is affected by the nature of property rights.

Variables	State-owned enterprise		Non-state-owned enterprises	
	T_Innovation	*Q_Innovation*	*T_Innovation*	*Q_Innovation*
Esop	0.030** (2.539)	8.689 (0.607)	0.179** (2.817)	0.148* (2.216)
Pyc	0.081** (2.041)	0.092 (0.166)	0.122** (2.247)	0.156*** (3.648)
Constant	−11.949*** (−3.385)	2.515 (0.568)	−10.693*** (−8.475)	−11.043*** (−8.541)
Year & Ind	Yes	Yes	Yes	Yes
N	62	35	607	531
Adj.R²	0.526	0.562	0.302	0.328

t inspection value display. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

incentive effect on enterprise innovation but also makes senior executives' psychological capital negatively impact enterprise innovation. Thus, Hypothesis H4a and H4b is verified.

5.5.4. The innovation effectiveness of employee equity incentive and executives' psychological capital is affected by the nature of property rights

In order to judge whether the effectiveness of employee equity incentive and senior executives' psychological capital have a positive effect on enterprise innovation and is affected by different property rights, this paper groups and regresses the sample data according to the property rights and also considers the characteristics of China's relevant systems. Based on the above grouped regression results of state-owned enterprises (as shown in Table 12), it can be seen that employee equity incentive and senior managers' psychological capital have little positive effect on the number of innovative outputs of enterprises, and their regression coefficients are 0.081 and 0.030, respectively, passing the test at the 5% significance level. At this time, although the impact of employee equity incentive and executive psychological capital on the quality of innovation output is positive, it has not passed the statistical test.

Based on the above results of grouping regression for non-state-owned enterprises, both employee equity incentives and senior executives' psychological capital can effectively promote the number of innovative outputs of enterprises, with regression coefficients of 0.179 and 0.122, which pass the statistical test. Similarly, both pages can positively affect the quality of enterprise innovation output, with regression coefficients of 0.148 and 0.156, both of which pass the statistical test. To sum up, it is found that the nature of property rights affects the promotion of executives' psychological capital and employee equity incentives on enterprise innovation. Comparing the regression results in the table, state-owned enterprises will reduce the positive effects of executives' psychological capital and employee equity incentive. Thus, Hypothesis H5 is verified.

6. Conclusion and policy enlightenment

This paper takes listed companies that implemented equity incentives in the A-share market from 2010 to 2021 as research samples to empirically examines the difference between the impact of executive psychological capital and employee equity incentives on enterprise innovation, and discusses the intermediary effect of executive psychological capital between the latter two. The research shows that employee equity incentives and executives' psychology can effectively promote the increase in the number of innovative outputs of enterprises and significantly bring about the enhancement of output quality. Moreover, it also finds that employee equity incentives has a more significant positive effect in terms of quantity, while the psychological capital of senior executives has a better positive effect on innovation in terms of quality. Further research shows that there is an intermediary effect between employee equity incentive and enterprise innovation. However, this intermediary effect has a more significant impact on innovation output at the quality level. In addition, R&D investment positively regulates the relationship between employee equity incentive, executive psychological capital, and enterprise innovation. This study also found that the nature of property rights and the form of employee equity incentive affect the effectiveness of the positive role of employee equity incentive and executives' psychological capital. Moreover, the implementation of restricted stocks will reduce the positive role of both on enterprise innovation, while the positive effect of both in state-owned enterprises is not high.

This paper provides a new basis for enterprises to promote the reform of employee equity incentive mechanism, enhance senior executives' psychological capital, and then achieve innovation-driven development from the theoretical and practical aspects. According to the previous research results, the following policy suggestions can be advanced.

Starting from employee equity incentive:

1. Employee equity incentive system can positively affect enterprise innovation, but still needs to improve the design of the government mechanism. For example, at this stage, there is a lack of legal systems that match the equity incentives and that can protect employees' rights and interests from injury, which makes the incentive effect of employee stock ownership of enterprises insufficient. In addition, the government's existing relevant laws and regulations focus more on interest binding.
2. In order to give full play to the innovation-oriented effectiveness of employee equity incentives, we should ensure the effectiveness and scientific of the incentive plan. For example, according to the above empirical evidence, the proportion of stock options should be increased in the form of employee equity incentive to maintain a greater effect of equity incentives.

3. The design of employee equity incentive policy system should not only consider the changes in China's stock market environment, but also pay attention to whether the sustainable development of enterprise innovation is affected by the proportion of state-owned property rights.

From the perspective of senior executives' psychological capital:

4. The psychological capital of senior executives can enhance the innovation willingness of the organization as a whole. Enterprises should hire or increase the cultivation of managers with strong psychological capital to provide impetus for the growth of long-term value of enterprises.
5. Enterprises actively pursuing innovation should build a corresponding mechanism environment to give play to the innovation effect of senior executives' psychological capital; for example, optimize the incentive mechanism for senior executives, improve the tolerance for senior executives' innovation failure, promote the creation of innovation remedy effect, and then reduce the problem of myopia, establish a cultivation mechanism that can enhance senior executives' long-term strategic vision, and urge them to focus on the future value brought by high-quality innovation of enterprises.
6. The government should play the role of strategic guidance, encourage enterprises to actively explore innovative projects, and then provide an external environment for giving play to the enterprise managers' adventurous spirits.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

LY contributed to the generation of research concepts and the arrangement of theoretical frameworks. JH wrote the paper after completing data collection and analysis. All authors contributed to the article and approved the submitted version.

Funding

The completion of this paper is thanks to the support of the National Bureau of Statistics Preferred Project (2021LY087), Key Program of Natural Science Foundation of Zhejiang Province (Z21G030004) and the characteristic & preponderant discipline of key construction universities in Zhejiang province (Zhejiang Gongshang University-Statistics).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aghion, P., Van Reenen, J., and Zingales, L. (2013). Innovation and institutional ownership. *Am. Econ. Rev.* 103, 277–304. doi: 10.1257/aer.103.1.277

Baron, A.and Armstrong, M. (2007). *Human Capital Managemnt: Achieving Added Value Through People*. London: Kogan page Ltd.

Baron, R. M., and Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* 51, 1173–1182. doi: 10.1037/0022-3514.51.6.1173

Bernstein, S. (2015). Does going public affect innovation? *J. Financ.* 70, 1365–1403. doi: 10.1111/jofi.12275

Boubakri, N., Mansi, S. A., and Saffar, W. (2013). Political institutions, connectedness, and corporate risk – taking. *J. Int. Bus. Stud.* 3, 195–215. doi: 10.1057/jibs.2013.2

Bradley, D., Kim, I., and Tian, X. (2016). Do unions affect innovation? *Manag. Sci.* 63, 2251–2271.

Brander, J. A., and Zhang, W. (2017). Employee relations and innovation: an empirical analysis using patent data. *Econ. Innov. New Technol.* 26, 368–384. doi: 10.1080/10438599.2016.1202523

Burns, N., Minnick, K., and Starks, L. T. (2013). CEO tournaments: a cross-country analysis of causes, cultural influences and conse-quences. *J. Financial Quant. Anal.* 52, 519–551.

Call, A. C., Campbell, J. L., Dhaliwal, D. S., and Moon, J. R. Jr. (2017). Employee quality and financial repoting outcomes. *J. Account. Econ.* 64, 123–149. doi: 10.1016/j.jacceco.2017.06.003

Chang, X., Fu, K., Low, A., and Zhang, W. (2015). Non-executive employee stock options and corporate innovation. *J. Financ. Econ.* 115, 168–188. doi: 10.1016/j.jfineco.2014.09.002

Chen, C., Chen, Y., Hsu, P. H., and Podolski, E. J. (2016). Be nice to your innovators: employee treatment and corporate Innovation performance. *J. Corp. Finan.* 39, 78–98. doi: 10.1016/j.jcorpfin.2016.06.001

Cho, C., Halford, J. T., Hsu, S., and Ng, L. (2016). Do managers matter for corporate innovation? *J. Corp. Finan.* 36, 206–229. doi: 10.1016/j.jcorpfin.2015.12.004

Cornaggia, J., Mao, Y., Tian, X., and Wolfe, B. (2015). Does banking competition affect innovation? *J. Financ. Econ.* 115, 189–209. doi: 10.1016/j.jfineco.2014.09.001

Den Hartigh, R. J. R., and Hill, Y. (2022). Conceptualizing and measuring psychological resilience: what can we learn from physics? *New Ideas Psychol.* 66:100934. doi: 10.1016/j.newideapsych.2022.100934

Ding, D. Z., Akhtar, S., and Ge, G. L. (2009). Effects of inter-and intra-hierarchy wage dispersions on firm performance in Chinese enterprise. *Int. J. Hum. Resour. Manag.* 20, 2370–2381. doi: 10.1080/09585190903239716

Ederer, F., and Manso, G. (2013). Is pay for performance detrimental to innovation? *Manag. Sci.* 59, 1496–1513. doi: 10.1287/mnsc.1120.1683

Edmans, A., Fang, V. W., and Lewellen, K. A. (2017). Equity vesting and investment. *Rev. Financ. Stud.* 30, 2229–2271. doi: 10.1093/rfs/hhx018

Fang, H., Nofsinger, J. R., and Quan, J. (2015). The effect of employee stock option plans on operating performance in Chinese firms. *J. Bank. Financ.* 54, 141–159. doi: 10.1016/j.jbankfin.2015.01.010

Fang, V. W., Tian, X., and Tice, S. (2014). Does stock liquidity enhance or impede firm innovation? *J. Financ.* 69, 2085–2125. doi: 10.1111/jofi.12187

Fatoki, O. (2018). The impact of entrepreneurial resilience on the success of small and medium enterprises in South Africa. *Sustainability* 32:2527. doi: 10.3390/su10072527

Francis, B., Hasan, I., and Wu, Q. (2015). Professors in the boardroom and their impact on corporate governance and firm performance. *Financial Mang.* 3, 547–581. doi: 10.1111/fima.12069

Gao, Q. Y., Wu, C. S., Wang, L. C., and Zhao, X. Y. (2020). The entrepreneur's psychological capital, creative innovation behavior, and enterprise performance. *Front. Psychol.* 11:1651. doi: 10.3389/fpsyg.2020.01651

Griliches, Z. (1990). Patent statistics as economic indicators: a survey. *J. Econ. Lit.* 28, 1661–1707.

Hall, B. J., and Murphy, K. J. (2003). The trouble with stock options. *J. Econ. Perspect.* 17, 49–70. doi: 10.1257/089533003769204353

Hallak, R., Assaker, G., O'Connor, P., and Lee, C. (2018). Firm performance in the upscale restaurant sector: the effects of resilience, creative self-efficacy, innovation and industry experience. *J. Retail. Consum. Serv.* 40, 229–240. doi: 10.1016/j.jretconser.2017.10.014

Hambrick, D. C., and Mason, P. A. (1984). Upper echelons: the organization as a reflection of its top managers. *Acad. Manag. Rev.* 9, 193–206. doi: 10.2307/258434

Hattori, R. A., and Lapidus, T. (2004). Collaboration, trust and innovative change. *J. Chang. Manag.* 4, 97–104. doi: 10.1080/14697010320001549197

Hirshleifer, D., Low, A., and Teoh, S. H. (2012). Are overconfident CEOs better innovators? *J. Financ.* 67, 1457–1498. doi: 10.1111/j.1540-6261.2012.01753.x

Hochberg, Y. V., and Lindsey, L. (2010). Incentives, targeting, and firm performance: an analysis of non - executive stock options. *Rev. Financ. Stud.* 23, 4148–4186. doi: 10.1093/rfs/hhq093

Huang, J., and Sheng, M. (2013). Do top management background characteristics have information content? *Manage. World* 9, 144–153.

Jefferson, G. H., Bai, H. M., Guan, X. J., and Yu, X. Y. (2006). R&D performance in Chinese industry. *Econ. Innov. New Technol.* 15, 345–366. doi: 10.1080/10438590500512851

Jugend, D., Jabbour, C. J. C., Scaliza, J. A. A., Rocha, R. S., Junior, J. A. G., Latan, H., et al. (2018). Relationships among open innovation, innovative performance, government support and firm size: comparing Brazilian firms embracing different levels of radicalismin innovation. *Technovation* 74, 54–65. doi: 10.1016/j.technovation.2018.02.004

Kuo, C. I., Wu, C. H., and Lin, B. W. (2017). Gaining from scientific knowledge: the role of knowledge accumulation and knowledge combination. *Acad. Manag. Annu. Meet. Proc.* 1:15029. doi: 10.1111/radm.12322

Lafuente, E., Vaillant, Y., Vendrell-Herrero, F., and Gomes, E. (2019). Bouncing Back from failure: entrepreneurial resilience and the internationalisation of subsequent ventures created by serial entrepreneurs. *Appl. Psychol.* 68, 658–694. doi: 10.1111/apps.12175

Li, T. Y., Ling, W., Yu, Z. J., and Dang, X. (2020). Analysis of the influence of entrepreneur's psychological capital on employee's innovation behavior under leader-member exchange relationship. *Front. Psychol.* 11:1853. doi: 10.3389/fpsyg.2020.01853

Luthans, F., Avollio, J., Avey, J. B., and Norman, S. M. (2007). Positive psychological capital: measurement and relationship with performance and satisfaction. *Pers. Psychol.* 60, 541–572. doi: 10.1111/j.1744-6570.2007.00083.x

Manso, G. (2011). Motivating innovation. *J. Financ.* 66, 1823–1860. doi: 10.1111/j.1540-6261.2011.01688.x

Mao, C. X., and Weathers, J. (2019). Employee treatment and firm innovation. *J. Bus. Financ. Acc.* 46, 977–1002. doi: 10.1111/jbfa.12393

Mao, C. X., and Zhang, C. (2018). Managerial risk-taking incentive and firm innovation: evidence from FAS 123R. *J. Financ. Quant. Anal.* 53, 867–898. doi: 10.1017/S002210901700120X

Mehta, R., Dahl, D. W., and Zhu, R. J. (2017). Socialrecognition versus financial incentives? Exploring the effects of creativity-contingent external rewards on creative performance. *J. Consum. Res.* 44, 536–553. doi: 10.1093/jcr/ucx062

Minnick, K., and Noga, T. (2010). Do corporate governance characteristics influence tax management. *J. Corp. Finan.* 16, 703–718. doi: 10.1016/j.jcorpfin.2010.08.005

Morck, R., Shleifer, A., and Vishny, R. W. (1988). Management ownership and market valuation: an empirical analysis. *J. Financ. Econ.* 20, 293–315. doi: 10.1016/0304-405X(88)90048-7

Muller, A., and Whiteman, G. (2015). Corporate philanthropic responses to emergent human needs: the role of organizational attention focus. *J. Bus. Ethics* 137, 1–16. doi: 10.1007/s10551-015-2556-x

Newman, A., Ucbasaran, D., Zhu, F., and Hirst, G. (2014). Psychological capital: a review and synthesis. *J. Organ. Behav.* 35, 120–138. doi: 10.1002/job.1916

Oyer, P., and Schaefer, S. (2005). Why do some firms give stock options to all employees? An empirical examination of alternative theories. *J. Financ. Econ.* 76, 99–133. doi: 10.1016/j.jfineco.2004.03.004

Rego, A., Cavazotte, F., Cunha, M. P. E., Valverde, C., Meyer, M., and Giustiniano, L. (2021). Gritty leaders promoting employees' thriving at work. *J. Manag.* 47, 1155–1184. doi: 10.1177/0149206320904765

Russo, S. D., and Stoykova, P. (2015). Psychological capital intervention (PCI): a replication and extension. *Hum. Resour. Dev. Q.* 26, 329–347. doi: 10.1002/hrdq.21212

Santoro, G., Bertoldi, B., Giachino, C., and Candelo, E. (2020). Exploring the relationship between entrepreneurial resilience and success: the moderating role of stakeholders' engagement. *J. Bus. Res.* 119, 142–150. doi: 10.1016/j.jbusres.2018.11.052

Siegel, P. A., and Hambrick, D. C. (2005). Pay disparities within top management groups: evidence of harmful effects on performance of high-technology firms. *Organ. Sci.* 16, 259–274. doi: 10.1287/orsc.1050.0128

Sihvola, S., Kvist, T., and Nurmeksela, A. (2022). Nurse leaders' resilience and their role in supporting nurses' resilience during the COVID-19 pandemic: a scoping review. *J. Nurs. Manag.* 30, 1869–1880. doi: 10.1111/jonm.13640

Torp, S., and Nielsen, B. B. (2018). Psychological ownership and financial firm performance: the interplay of employee stock ownership and participative leadership. *Aust. J. Manag.* 43, 476–492. doi: 10.1177/0312896218755517

Tsang, A., Wang, K. T., Liu, S., and Yu, L. (2021). Integrating corporate social responsibility criteria into executive compensation and firm innovation: international evidence. *J. Corp. Finan.* 70:102070. doi: 10.1016/j.jcorpfin.2021.102070

Van Knippenberg, B., and Van Knippenberg, D. (2005). Leader self-sacrifice and leadership effectiveness: the moderating role of leader prototypicality. *J. Appl. Psychol.* 90, 25–37. doi: 10.1037/0021-9010.90.1.25

Wang, Y. F., Chen, Y., and Zhu, Y. (2021). Promoting innovative behavior in employees: the mechanism of leader psychological capital. *Front. Psychol.* 11:598090. doi: 10.3389/fpsyg.2020.598090

Wu, J., and Tu, R. (2007). CEO stock option pay and R&D spending: a behavioral agency explanation. *J. Bus. Res.* 60, 482–492. doi: 10.1016/j.jbusres.2006.12.006

Zaltman, G., Duncan, R., and Holbek, J. (1973). *Innovations and organizations.* New York: John Wiley & Sons.

frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 March 2023
DOI 10.3389/fpsyg.2023.1133270

OPEN ACCESS

EDITED BY
Yu Liping,
Zhejiang Gongshang University, China

REVIEWED BY
Xianping Yuan,
Xi'an University of Science and Technology, China
Xiao Yao,
Zhejiang Gongshang University, China

*CORRESPONDENCE
Jing Xue
✉ xuejing2002@163.com
Junran Shi
✉ 915031694@qq.com

SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 December 2022
ACCEPTED 20 February 2023
PUBLISHED 13 March 2023

CITATION
Chen M, Mi X, Xue J, Li Y and Shi J (2023) The impact of entrepreneurial team psychological capital on innovation performance: The mediating role of knowledge sharing and knowledge hiding.
Front. Psychol. 14:1133270.
doi: 10.3389/fpsyg.2023.1133270

The impact of entrepreneurial team psychological capital on innovation performance: The mediating role of knowledge sharing and knowledge hiding

Minling Chen[1], XueMei Mi[1], Jing Xue[1]*, Yi Li[1] and Junran Shi[2]*

[1]School of Economics and Management, Xi'an Shiyou University, Xi'an, China, [2]School of Finance and Public Administration, Yunnan University of Finance and Economics, Kunming, China

Introduction: The important role of psychological capital on corporate innovation has attracted the attention of academics, more and more scholars have conducted related studies. Although most scholars have explored the mechanisms and paths of psychological capital on innovation performance, few scholars have explored the inner relationship between them from the perspective of knowledge management. Based on the knowledge management perspective, We explore the influence effect of the psychological capital of entrepreneurial teams on the innovation performance of startups in the entrepreneurial situation.

Methods: We conducted hypothesis testing using data from 113 Chinese entrepreneurial teams, and conducted reliability analysis, correlation analysis, and regression analysis on the questionnaire data with the help of SPSS software and AMOS software.

Results: The results showed that (1) entrepreneurial team psychological capital has a significant positive effect on innovation performance of startups; (2) entrepreneurial team psychological capital positively promotes their knowledge sharing behavior and reduces knowledge hiding behavior; (3) entrepreneurial team knowledge sharing and knowledge hiding play a partially mediating role between entrepreneurial team psychological capital and innovation performance of startups; (4)organizational innovation climate plays a moderating role in the influence of entrepreneurial team knowledge sharing and knowledge hiding on the innovation performance of startups.

Discussion: The findings are consistent with the hypothesis model proposed in this paper, indicating that as the psychological capital of entrepreneurial teams increases, the innovation performance of startups can benefit from higher levels of knowledge sharing and lower levels of knowledge hiding.

KEYWORDS

entrepreneurial team, psychological capital, knowledge sharing, knowledge hiding, organizational innovation climate, innovation performance

Abbreviations: SPSS, Statistical Product Service Solutions; AMOS, Advanced Mortar System; SME, Structure Equation Modeling; CMIN, Chi-Square Minimum Method; DF, Degree of Freedom; GFI, Goodness of Fit Index; RMSEA, Root Mean Square Error of Approximation; RMR, Root Mean Square Residual; AGFI, Adjusted Goodness of Fit Index; CFI, Comparative Fit Index; NFI, Normed Fit Index; IFI, Incremental Fit Index.

1. Introduction

Driven by the severe employment situation and the strong entrepreneurial atmosphere, enterprises and individuals are increasingly willing to start their own businesses and are actively engaged in entrepreneurial activities. At the same time, with the introduction of the "mass entrepreneurship and innovation" policy, the competitive environment has changed, and enterprises must consider how to improve their own innovation performance. At the macro level, the improvement of innovation performance of entrepreneurial enterprises can greatly promote the dynamic development of regional and national economies, provide more and newer employment opportunities for the society, and become the engine of national economic growth (Wang R. et al., 2022); at the micro level, enterprises with excellent performance in innovation performance usually have a strong atmosphere of organizational innovation, which in turn motivates employees to engage in positive innovation behaviors. Therefore, how to improve the innovation performance of startups has become a hot topic at present, and scholars have conducted research based on internal and external factors affecting enterprise development, and found that psychological capital (PsyCap), as a positive psychological state shown by people in the process of work-life development, can effectively promote the rapid improvement of enterprise innovation behavior and performance. Given the importance of psychological capital in business development, more scholars have conducted research around the correlation between psychological capital and business performance, and the number of related literature published in high-level international journals is not few (Gao et al., 2020b; Grözinger et al., 2022). Although many scholars have continued to focus on psychological capital and business performance, after adding the element of "innovation," the focus of scholars has been more on innovation ability and innovation behavior, and few scholars have directly focused on the relationship between psychological capital and innovation performance, which greatly affects people's perception of the relationship between the two and creates some resistance to the innovation development of enterprises. At the same time, most scholars study psychological capital at the individual level, and few scholars raise the study of psychological capital to the team level, especially the lack of research on the psychological capital of entrepreneurial teams in entrepreneurial contexts. Therefore, this paper will investigate the process of "how psychological capital of entrepreneurial teams affects innovation performance of entrepreneurial firms in entrepreneurial scenarios."

Psychological capital plays an important role in the process of business development, influence business performance directly or indirectly through various factors (Ngo, 2021; Jiao et al., 2022), task performance (Udin and Yuniawan, 2020; Al Kahtani and Sulphey, 2022), project performance (Zhang et al., 2022), safety performance (Peng et al., 2022), entrepreneurial performance (Gao et al., 2020a), and business performance (Chen and Tao, 2021) of the firm. With the increasing importance of innovation-driven strategy in enterprise development, the path to improve enterprise innovation performance has become a hot spot for scholars' research, and psychological capital as a variable affecting innovation performance has been included in scholars' analytical models (Guo et al., 2020), mediated by the intrinsic motivation of the transformational educational environment, and shown through empirical studies that workers' psychological capital is positively related to innovation performance (Tran et al., 2021). Numerous scholars have focused on the impact of psychological capital on the performance of work, tasks, and innovation in firms, but few scholars have paid attention to the impact of team psychological capital on the innovation performance of firms, especially the impact of entrepreneurial team psychological capital on the innovation performance of startups based on entrepreneurial scenarios needs to be studied in depth.

How psychological capital affects firm innovation performance, in addition to considering factors such as intrinsic motivation, personal creativity, and readiness for change. As a new management idea and method emerging in the era of knowledge economy, knowledge management integrates modern information technology, business management ideas and modern management concepts, and plays an important role in the development of enterprises. Previous studies have shown that a significant relationship between team psychological capital and knowledge management (Zhang et al., 2022) and there is also a significant relationship between knowledge management and innovation performance (Jing and Cisheng, 2021; Chang et al., 2022; Ge, 2022). Knowledge sharing and knowledge hiding as an important part of knowledge management, it is representative to study the relationship between them and psychological capital and innovation performance. Scholars have used psychological capital as a mediating variable in their models when examining the relationship between the role of abusive supervision, ethical leadership, and knowledge sharing, empirical results showed that psychological capital was positively related to knowledge sharing (Agarwal and Anantatmula, 2021; Goswami and Agrawal, 2022); Zhu used psychological capital as a mediating variable when exploring the relationship between perceived overqualification and knowledge hiding behavior, and the results showed that psychological capital has a negative effect on knowledge hiding (Zhu et al., 2022). By combing through the relevant literature, Dongling et al. (2022) found that knowledge sharing has a positive impact on firm innovation performance, and the empirical results show that member knowledge sharing in the era of big data significantly impact the innovation performance of eSports industry knowledge alliances (Yue et al., 2022); scholars have shown through their research that knowledge hiding as an independent or mediating variable has a negative effect on task performance (Tian et al., 2022), team performance (Miao et al., 2022), organizational performance (Wen and Ma, 2021), and innovation performance (Rong and Liu, 2021) of firms. In summary, psychological capital has a correlation with knowledge sharing and knowledge hiding, and at the same time, knowledge sharing, knowledge hiding and innovation performance also have a correlation, but the existing literature lacks an overall study of the above four variables, and the inner connection between the four needs to be explored in depth.

Amabile et al. (1996) believes that organizational innovation climate is not only perceived by organizational members, but also influences their creative behavior. Organizational innovation climate is a typical extrinsic motivation that can affect employees' performance. In layman's terms, organizational innovation climate represents the extent to which the organization supports and encourages employees to actively participate in innovation

activities (Bock et al., 2005). most scholars consider organizational innovation climate as a theoretical framework at the organizational level, a psychological climate that indirectly affects innovation performance of firms, Organizational innovation climate has been found to be an effective predictor of employee creativity and organizational innovation (Hsu and Chen, 2017). Scholars have shown that organizational innovation climate can positively moderate the impact of perceived benefits and perceived risks on digital transformation (Tsai and Su, 2022). The higher the organizational innovation climate, the greater the positive impact of positive emotional climate on innovation performance, and conversely the weaker the positive impact of negative emotional climate on innovation performance (Dou et al., 2022). The moderating role of organizational innovation climate in the process of firm development is more significant, but little literature has focused directly on its role as a moderating variable affecting knowledge management activities and innovation performance.

Based on the above analysis, this paper studies the correlation between the psychological capital of entrepreneurial teams and the innovation performance of startups in the entrepreneurial context by referring to theories such as positive organizational behavior. Knowledge sharing and knowledge hiding are selected as the mediating variables, and organizational innovation climate is introduced as the moderating variable to form the research model of this paper. In the process of investigation and data analysis, online and offline questionnaires were used to obtain relevant data, Likert scale was used to measure the data, confirmatory factor analysis was carried out on the measurement items, and SPSS and AMOS were used to test the reliability and validity of variables. The empirical results show that psychological capital of entrepreneurial teams affects the innovation performance of startups, Knowledge sharing and knowledge hiding play a partial mediating role in the two, Organizational innovation climate positively moderates the effect of knowledge sharing on innovation performance of startups and negatively moderates the effect of knowledge hiding on innovation performance of startups.

This study attempts to make some contributions in the following points: first, the article investigates the influence of psychological capital of entrepreneurial teams on innovation performance of entrepreneurial enterprises under entrepreneurial scenarios, completes the research on psychological capital and innovation performance at the team level, enriches the relevant theories, laying the foundation for scholars to later study the psychological capital of entrepreneurial teams and the improvement of corporate innovation performance under entrepreneurial scenarios; second, partial mediating role of knowledge sharing and knowledge hiding in the relationship between psychological capital of entrepreneurial teams and innovation performance of startups verified, this study clarifies the inner connection between the four through empirical research, it is beneficial to promote scholars to continue to explore the relationship between psychological capital and innovation performance along the knowledge management perspective in subsequent studies; third, the moderating role of organizational innovation climate in knowledge sharing, knowledge hiding and innovation performance of startups is verified, which facilitates the participation of other moderating variables in the study of knowledge management and innovation performance.

2. Theoretical background and hypotheses development

2.1. PsyCap of entrepreneurial team and innovation performance

As a global socio-economic phenomenon, entrepreneurship and innovation activities have received widespread attention at both the theoretical and practical levels (Singh and Gaur, 2018). In previous studies, scholars have placed high emphasis on the individualism and heroism of entrepreneurs and leaders, however, the highly complex and changing nature of today's innovation and entrepreneurship environment makes innovation and entrepreneurial activities increasingly dependent on the joint efforts of team members, and the vast majority of successful businesses today are built on collaboration and frequently outperform than they would alone, this means that the entrepreneurial team plays a key role in the development of startups (Bolzani et al., 2019). The importance of entrepreneurial teams in entrepreneurial ventures cannot be overlooked: almost 95% of entrepreneurial individuals choose to collaborate with others or intend to do so in the future (Ruef et al., 2003). In addition, the high degree of uncertainty and risk associated with innovative entrepreneurial activity means that a variety of external and internal factors need to be supported in the process of innovation and entrepreneurship. Scholars currently consider the impact of external factors such as new product development coordination (Zhang and Min, 2022), value modularity (Wang J. et al., 2022), and knowledge search (Wang and Wang, 2022) on innovation performance, and similarly internal factors such as personality, psychological empowerment (Zhang, 2022), psychological contract (Zhang, 2022), psychological capital (Waters et al., 2020; Dimas et al., 2022), and other factors on innovation activities and innovation performance have also gradually received attention from scholars.

Psychological capital refers to the positive inner traits and positive psychological states that individuals possess and exhibit, and its concept originates from positive psychology and positive organizational behavior (POB). Luthans first classified psychological capital into four dimensions: self-confidence, hope, resilience and optimism, and it has been widely accepted by academics (Luthans et al., 2003). At the individual level, individuals with high psychological capital have stronger beliefs about innovation, are full of enthusiasm, energy, curiosity, have a spirit of exploration, are more willing to think and accept new ideas, and more likely to have the willingness to innovate and conditions to improve their overall innovation capacity (Luthans et al., 2011). Individuals with high psychological capital have higher hope and self-efficacy (Luthans et al., 2007) and are more likely to see the positive side of innovation when faced with innovation risks and setbacks, and are more likely to regain confidence and actively seek solutions to problems (Luthans et al., 2003; Andersson et al., 2020). At the team level, psychological capital increases work engagement behaviors and levels in a supportive learning climate to promote team innovation (Peng and Chen, 2022). At the organizational level, psychological capital, as an intangible asset for startups and SMEs, can help organizations generate more innovative activities in the face of

exogenous crises (Grözinger et al., 2022). Psychological capital has a positive and significant contribution to both innovation activities and innovation performance: according to McKenny et al. (2013) psychological capital is particularly important for innovation performance, business growth in SMEs. Abbas et al. found that psychological capital is positively related to innovation job performance and negatively related to job stress in a study of employees in various organizations in Pakistan (Abbas and Raja, 2015). All four dimensions of entrepreneurial psychological capital, including self-confidence, hope, resilience, and optimism promote technological innovation, business innovation, and thus improve business performance (Gao et al., 2020a). Leader psychological capital positively contributes to team psychological capital, which in turn improves team innovation (Tho, 2020; Waters et al., 2020). When studying the effect of supervisor's supervisory style on graduate students' innovation performance in a Chinese educational context, Yang et al. (2022) found that graduate students' psychological capital played a fully mediating role between the two, indicating that graduate students' psychological capital is positively correlated with their innovation performance. Based on psychological theory, Ge et al. (2022) found that the psychological capital of knowledge employees in Shihezi region of Xinjiang had a significant contribution to their innovation performance based on a study of knowledge employees. To sum up, in previous studies, the psychological capital of entrepreneurs and employees at the individual level has been widely concerned by scholars, but little literature has studied team-level psychological capital, especially the psychological capital of entrepreneurial teams, however, in the new competitive environment, the complexity of innovation and entrepreneurial activities is increasing, and the importance of entrepreneurial teams is subsequently highlighted, this paper argues that in the entrepreneurial context, the psychological capital of entrepreneurial teams capital has a significant contribution to the innovation performance of startups, whereby hypothesis 1 is proposed:

> H1: Psychological capital of entrepreneurial teams has a positive impact on innovation performance of startups.

2.2. The mediating role of knowledge sharing

Knowledge is an individual's knowledge of things and is defined in Wechsler's dictionary as the information, understanding, or skills that a person acquires from education or experience. Knowledge sharing is the willingness and behavior of individuals to share information about the learning process and new knowledge. Research has shown that psychological capital is an important factor in promoting knowledge sharing among employees (Qiu et al., 2015; Wu and Lee, 2017; Zhang et al., 2017). Maitlo et al. (2017) used public university researchers as respondents and the study proved that all four dimensions of psychological capital efficacy, hope, optimism, and resilience are related to knowledge sharing behavior of researchers in a university setting. Goswami and Agrawal (2022) confirmed that psychological capital has a positive contribution to knowledge sharing. In addition, collective psychological capital, based on individual psychological capital, describes collective members' positive evaluation of the group's environment and their expectations of collective development and success, including four dimensions of collective efficacy, hope, optimism, and resilience (Walumbwa et al., 2011). First, collective efficacy is the positive beliefs that collective members have in their work, which can help collective members overcome barriers to knowledge sharing and thus achieve knowledge sharing (Gully et al., 2002); collective hope is the collective members' expectation of the organization's plan to achieve a common goal, and collective hope can enhance collective members' intrinsic motivation and promote their knowledge sharing behavior; optimism is the collective's favorable evaluation of things in the work process, the members of a collective with optimism have a strong belief that the organization can achieve its desired goals, and rarely considers the adverse effects of communication and cooperation with others in its work, which is conducive to knowledge sharing (Peterson, 2000). A collective with high resilience can act quickly to find solutions to problems and is willing to help other collective members, making knowledge sharing among individuals sustainable (Coutu, 2002). Based on this, this paper argues that in an entrepreneurial environment, the psychological capital of entrepreneurial teams affects their willingness to share knowledge and behavior. That is, the psychological capital of the entrepreneurial team has the same positive contribution to its knowledge sharing, according to which, this paper proposes hypothesis 2.

> H2: Psychological capital of entrepreneurial teams promotes knowledge sharing of entrepreneurial teams.

The psychological capital of an entrepreneurial team is a positive psychological state that affects the performance of the entire team when team members translate it into action. That is, the innovation performance of an entrepreneurial team requires team members to take the initiative to transform their positive psychological capital into concrete actions that are conducive to improving the team's innovation performance in order to drive that team to achieve innovation performance in the end. Innovation is an activity in which knowledge is involved in a series of complex processes such as generation, transformation, and integration, and knowledge sharing promotes innovative behavior (Vandavasi, 2020; Derin et al., 2022; Xu and Suntrayuth, 2022). Knowledge sharing is the key to improve the innovation capability of a company (Saenz et al., 2009) and knowledge sharing behavior is a prerequisite for organizations to innovate (Del Giudice and Della Peruta, 2016). Moreover, knowledge sharing behavior leads to the generation of organizational innovation performance (Donate and de Pablo, 2015; Giampaoli et al., 2017). The generation of innovation performance inherently relies on tacit knowledge, and knowledge sharing facilitates the dissemination and flow of tacit knowledge in organizations (Nonaka, 1994; Del Giudice and Della Peruta, 2016). When studying the impact of new product development coordination on firms' innovation performance, Zhang and Min (2022) suggested that knowledge sharing plays a mediating role between the two, it proved that knowledge sharing can promote enterprise innovation performance. Ritala et al. (2015) suggest that external knowledge sharing has a positive effect on innovation performance based on the results of a survey of 150 Finnish

technology-intensive firms. Accordingly, this paper argues that teams with high levels of psychological capital are able to maintain the willingness to share knowledge with team members in the face of frustration and difficulties, thus obtaining the knowledge resources and key elements needed for team innovation and improving the overall innovation performance of the team. This paper proposes hypothesis 3.

> H3: Knowledge sharing in entrepreneurial teams mediates the relationship between the psychological capital of entrepreneurial teams and the innovation performance of startups.

2.3. The mediating role of knowledge hiding

Knowledge management plays an important role in every organization, and it affects the performance of the whole organization, teams and individuals. Knowledge hiding is a separate concept that is in opposition to knowledge sharing (Zhao et al., 2019). The existence of "knowledge hiding" behavior makes it difficult to implement knowledge collection and integration in organizations. Previous studies have shown that employees are reluctant to share knowledge with others mainly out of defensive consciousness, trying to protect and control their knowledge ownership (Huo et al., 2016). According to the survey, about 50% of employees in organizations have the intention to retain, mislead, or conceal knowledge that others need when interacting with other members (Peng, 2013). Through scholars' research on the antecedent variables of knowledge hiding, it was found that mainly the characteristics of knowledge, organizational-level factors, team and interpersonal factors and individual-level factors influence workers' knowledge hiding behaviors, among which, the characteristics of knowledge include the complexity of knowledge itself and task relevance among colleagues; organizational-level factors include organizational rules, policies, knowledge management systems, knowledge sharing culture, etc.; team and interpersonal factors include team motivational climate, top management constraints, interpersonal equity, etc.; and individual factors include personality, self-efficacy, and goal orientation (He et al., 2021). Employees with high emotional intelligence are less likely to develop knowledge hiding behaviors because employees or team members with high emotional intelligence focus on teamwork and are more likely to build trusting relationships with partners in that team or organization than others (Xiong et al., 2021). Zhu et al. (2022) believe that individuals' knowledge hiding behaviors may cause huge economic losses to organizations, and their research proves that the improvement of individuals' psychological capital will reduce their knowledge hiding behaviors, thus bringing positive effects to organizations. This paper argues that in entrepreneurial teams, knowledge hiding behaviors among team members can hinder the benign development of the whole team, and the psychological capital of team members is a key factor affecting their knowledge hiding behaviors, i.e., the psychological capital of entrepreneurial teams reduces the knowledge hiding behaviors of team members. Accordingly, hypothesis 4 is proposed.

> H4: Psychological capital of entrepreneurial team has a negative effect on knowledge hiding of entrepreneurial team.

Rong and Liu (2021) investigated the impact of knowledge hiding behavior on corporate innovation performance by using executive teams, and found that team knowledge hiding behavior is more complex than individual because, in addition to the psychological and cognitive factors of team members, interpersonal factors such as collaborative interactions of team members also affect team members' knowledge hiding. In the long run, knowledge hiding at the team level can lead to a decrease in firm innovation performance (Chatterjee et al., 2021). Based on cultural dimension theory and social information processing theory, a multilevel linear model was used to analyze the data of university innovation teams, and the empirical results showed that knowledge hiding has a significant negative impact on the knowledge innovation behavior of university innovation teams (Zhang and Wang, 2021). Accordingly, this paper argues that in entrepreneurial teams, team members with high levels of psychological capital are able to collaborate more actively with team members in the cooperation process, which naturally reduces knowledge hiding behavior and thus improves the overall innovation performance of the team. This paper proposes hypothesis 5.

> H5: Knowledge hiding in entrepreneurial teams mediates the relationship between the psychological capital of entrepreneurial teams and the innovation performance of startups.

2.4. The moderating effect of organizational innovation climate

Organizational innovation climate refers to the perception of organizational members on norms and behaviors that can promote the generation, development and realization of new ideas (Anderson et al., 2020). The interactive perspective argues that an individual's environment changes his or her behavior. The innovation climate is a key factor for organizations to remain innovative and is the perception of organizational members about whether the organization encourages innovation and risk-taking; organizations with a strong innovation climate, organizational members possess openness and divergent thinking, and employees working in this climate are more willing to share knowledge (Munir and Beh, 2019). An organization that provides employees with a sense of security and creates an atmosphere where employees are not criticized for no reason is conducive to employees' ability to think innovatively (Cabrera and Cabrera, 2005). An organizational environment in which employees feel comfortable encourages them to create and share knowledge (Fu et al., 2007). An innovative climate also empowers employees to think independently, and contribute to innovative performance by creatively reshaping their cognitive, motivational, emotional, and intellectual resources (Waheed et al., 2019). Empirical studies

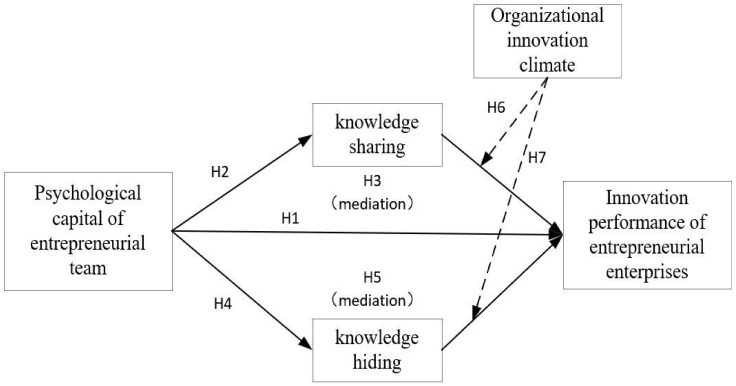


FIGURE 1
Theoretical model and research hypothesis.

have examined the moderating effect of organizational innovation climate on different models. For example, Yu et al. (2013) have shown that organizational innovation climate not only directly affects innovation behavior but also increases the positive contribution of knowledge sharing to innovation behavior. Sung and Choi (2014) found that the positive relationship between interpersonal and organizational learning practices and innovation performance is stronger when the organizational innovation climate is higher. On this basis, we argue that organizational innovation climate provides a psychologically safe environment for organizational members to face challenges, exchange ideas, and encourage each other to learn and collaborate, and in the practice of team interest-oriented and more willing to share knowledge with team members, the frequency of knowledge sharing among members will increase, while the knowledge hiding behavior will subsequently decrease, and the overall innovation performance of the team is improved. Accordingly, this paper proposes the following hypothesis:

> H6: Organizational innovation climate positively moderates the impact of knowledge sharing in entrepreneurial teams on innovation performance of entrepreneurial firms.

> H7: Organizational innovation climate negatively regulates the influence of entrepreneurial team knowledge hiding on innovation performance of startups.

In summary, the theoretical model of this article is shown in **Figure 1**.

3. Data and methods

In order to test whether the above hypotheses are valid and thus judge the rationality of the theoretical model, this study follows the scientific research paradigm and conducts empirical analysis according to the following steps: firstly, the questionnaire is designed with reference to the existing maturity scale, and the data are collected by distributing and collecting questionnaires; secondly, the reliability and validity tests are conducted by SPSS and Amos software to ensure the reliability and validity of the study; finally, SPSS 22.0 was used to conduct descriptive statistical analysis, correlation analysis and cascade regression analysis to complete the hypothesis validation and thus judge the rationality of the theoretical model.

3.1. Samples, data and processing methods

In this paper, a questionnaire was used, and the questionnaire was formed by translating and back-translating from foreign scales. An anonymous questionnaire designed with existing mature scales was used, and three discussions were held within the team to form the preliminary questionnaire. To ensure the accuracy of the questionnaire, three senior experts in related fields were invited to carefully check the content of the survey items. The questionnaire was collected from August to October 2022, 50 paper questionnaires and 100 electronic questionnaires were distributed, 137 questionnaires were returned, excluding invalid questionnaires that did not pass the reverse test set in the questionnaire, fixed answer multiple choice test questions, less than 300 s to fill in and scribble, 113 valid questionnaires were finally returned. Among them, 50 paper questionnaires were distributed in field research, 50 were collected, 50 valid questionnaires, with 100% efficiency; 100 electronic questionnaires were distributed, 87 were collected, 63 valid questionnaires, with 63% efficiency, and the total sample of valid questionnaires covered seven provinces such as Shaanxi, Sichuan, and Hebei.

The sample consisted of 113 entrepreneurial teams. The years of entrepreneurship ranged from 3 to 20 years, and most of them were in the range of 3–5 years (42.5%). Our selected survey respondents mainly include the initial founders (14.6%), board members (28.5%), professional advisors (22.4%), and core members (34.5%) of the startup. The size of the startups was indicated by the number of people in the business, ranging from 20 to 200. Among them, 58.5% are male and their age ranges from 21 to 58 years old. The majority had an educational background of bachelor's degree or higher (76.9%). Specific basic information is shown in **Table 1**.

3.2. Measure of main variable

The psychological capital of entrepreneurial teams, innovation performance of startups, organizational innovation climate, knowledge sharing and knowledge hiding research variables involved in this paper were measured using a 5-point Likert scale (completely disagree = 1; completely agree = 5). Measures of psychological capital were first heavily applied at the individual level, and beginning around 2011, many scholars began to focus on psychological capital at the team and organizational levels (Walumbwa et al., 2011; McKenny et al., 2013) developed a Collective psychological capital measure. Based on previous research, we will use a revised team psychological capital questionnaire designed to assess the collective PsyCap of teams (Mathe-Soulek et al., 2014), and this study will measure four dimensions of entrepreneurial team psychological capital in an entrepreneurial context, namely team effectiveness, team hope, team optimism, and team resilience, with the final scale consisting of eight items. Each dimension is assessed by two items. Innovation Performance of Startups was measured using four indicators according to Fischer et al. (2001) and Zeng et al. (2010), and respondents were asked to indicate the extent to which they agreed with various statements about their firm's innovation performance over the past 3 years when compared with competitors (see Table 2). Organizational innovation climate was measured using a 15-item innovation climate scale developed by Siegel and Kaemmerer (1978), modified by Scott and Bruce (1994), and well validated. Team knowledge sharing was measured using a questionnaire developed by Chuang et al. (2016), and the scale consists of seven items. We used two items developed by Serenko and Bontis (2016) and another two items developed by Connelly et al. (2012) to assess specific knowledge hiding behaviors. The specific measured entries for the five variables are shown in Table 2.

TABLE 1 Sample descriptive statistics.

Characteristic	Category	Percentage
Gender	Male	58.5%
	Female	41.5%
Age	<25	11.5%
	25–30	29.4%
	31–35	23.8%
	36–40	21.6%
	>40	13.7%
Educational background	Junior high school and below	5.7%
	High school	17.4%
	Junior college	24.6%
	Undergraduate	37.8%
	Master or above	14.5%
Years of entrepreneurship	<3	23.7%
	3–5	42.5%
	6–10	15.8%
	11–20	9.7%
	>20	8.2%
Team size	<20	31.8%
	21–50	27.1%
	51–100	15.9%
	101–200	16.3%
	>200	8.9%
Survey respondents' positions in start-up companies	Initial founders	14.6%
	Board members	28.5%
	Professional advisors	22.4%
	Core members	34.5%

3.3. Control variables

We used these demographic characteristics as control variables, i.e., gender, age, and education, and in addition we added two control variables, years of entrepreneurship and team size, considering that this study is in an entrepreneurial context, for which we obtained relevant data in the survey items.

4. Data analysis

4.1. Test of common method deviation

In view of the possible problem of homogeneous bias caused by using the questionnaire form of data collection, this paper used Harman's single factor analysis method to extract common factors for all entries of the five variables, and a total of five common factors were extracted with a cumulative explanatory power of 71.435%, and the explanatory power of the first factor was 24.198%, which was lower than the critical standard value of 40%. Therefore, it can be concluded that there is no serious problem of common method bias in this paper.

4.2. Reliability and validity test

First, this paper conducted validated factor analysis on the measured entries of all variables, and the results showed a KMO value of 0.945 and Bartlett test results passed the 0.000 significance level. Secondly, this paper conducted reliability and validity tests by SPSS and Amos software. According to the reliability test results in Table 2, the Cronbach's α values of the reliability analysis of the four variables were higher than 0.8, and the combined reliability (CR) values of the latent variables were greater than 0.8 and greater than the critical value of 0.7, so it can be considered that the scale used in this paper has relatively good reliability and internal consistency. The results of the discriminant validity indicate a good five-factor model fit of the measurement model (CMIN/DF = 2.253 < 3, GFI = 0.914 > 0.9, RMSEA = 0.028 < 0.08, RMR = 0.031 < 0.05, AGFI = 0.933 > 0.9, CFI = 0.928 > 0.9, NFI = 0.924 > 0.9, and IFI = 0.917 > 0.9), the standard factor loadings obtained from the validation factor analysis were all greater than the critical value of 0.6, so the scale designed in this paper can be considered to have good discriminant validity. Finally, as the data in Table 2

10.3389/fpsyg.2023.1133270

TABLE 2 Sample validity and reliability assessment of the measures.

Variable	Construct and measuring items	SFL
Psychological capital of entrepreneurial team: α = 0.923; AVE = 0.705; CR = 0.950		
PCET1	We are confident that we can solve the problems and difficulties that occur in the process of starting a business.	0.805
PCET2	We are very confident that we can achieve our goals in our own entrepreneurial field.	0.817
PCET3	Our team members can come up with many ways to achieve their goals.	0.792
PCET4	We feel we have achieved success in our work.	0.903
PCET5	We always see the positive side of the future development of the company.	0.891
PCET6	We always have an optimistic attitude toward our work.	0.782
PCET7	We are usually able to handle the stress at work with ease.	0.834
PCET8	We can get through the hard times at work.	0.882
Knowledge sharing: α = 0.875; AVE = 0.626; CR = 0.921		
KS1	Members of our team share their special knowledge and expertise with one another.	0.837
KS2	If a member in our team has some special knowledge about how to perform the team task, he/she will tell other members about it.	0.804
KS3	There is virtually no exchange of information, knowledge, or sharing of skills among members of the team (Reversed).	0.835
KS4	More knowledgeable team members freely provide other members with hard-to-find knowledge or specialized skills.	0.753
KS5	Members of our team provide a lot of work-related suggestions to each other.	0.747
KS6	There is a lot of constructive discussion during team meetings.	0.783
KS7	Members in our team provide their experience and knowledge to help other members find solutions to their problems.	0.774
Knowledge hiding: α = 0.947; AVE = 0.668; CR = 0.889		
KH1	In my project team, I often pretended that I did not know the information.	0.786
KH2	In my project team, I agreed to help my colleagues but never really intended to offer the knowledge they wanted.	0.791
KH3	I often communicated only part of the whole story to other project team members.	0.883
KH4	I often twisted the facts to suit my needs when communicating with other team members.	0.805
Innovation performance of startups: α = 0.906; AVE = 0.584; CR = 0.848		
IPS1	Proportion of annual turnover of new products.	0.801
IPS2	New products index.	0.674
IPS3	Modified products index.	0.739
IPS4	Patent growth rate.	0.832
Organizational innovation climate: α = 0.897; AVE = 0.503; CR = 0.938		
OIC1	Creativity is encouraged here.	0.747
OIC2	Our ability to function creatively is respected by the supervisor.	0.736
OIC3	Around here, people are allowed to try to solve the same problems in different ways.	0.705
OIC4	The main function of members in this organization is to follow orders, which come down through channels (Reversed).	0.725
OIC5	Around here, a person can get in a lot of trouble by being different (Reversed).	0.682
OIC6	This organization can be described as flexible and continually adapting to change	0.748
OIC7	A person cannot do things that are too different around here without provoking anger (Reversed).	0.646
OIC8	The best way to get along in this organization is to think the way the rest of the group does (Reversed).	0.765
OIC9	People around here are expected to deal with problems in the same way (Reversed).	0.634
OIC10	This organization is open and responsive to change.	0.628
OIC11	The people in charge around here usually get credit for others' ideas.	0.757
OIC12	In this organization, we tend to stick to tried and true ways.	0.643
OIC13	This place seems to be more concerned with the *status quo* than with change.	0.672
OIC14	The reward system here encourages innovation.	0.787
OIC15	This organization publicly recognizes those who are innovative.	0.731

TABLE 3 Descriptive statistical analysis and correlation coefficients.

Variables	Mean value	Standard deviation	1	2	3	4	5
Psychological capital of entrepreneurial team	4.013	0.644	1				
Knowledge sharing	4.134	0.519	0.298**	1			
Knowledge hiding	3.969	0.783	−0.254*	−0.459**	1		
Innovation performance of startups	3.768	0.607	0.323***	0.283**	−0.261**	1	
Organizational innovation climate	4.189	0.724	0.253***	0.304**	−0.247*	0.277***	1

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

show, the average variance extracted (AVE) values of all latent variables are greater than 0.5, and the flat square root of AVE is greater than the corresponding correlation coefficient between variables, so the scale can be considered to have good convergent validity.

4.3. Descriptive statistics and correlation analysis

The main variables in this paper include five. The means and standard deviations of the five variables and the correlation coefficients between the variables are shown in Table 3. The CFA results in Table 2 show that all standard factor loadings (SFL) values exceed 0.5, AVE values exceed the 0.5 threshold, and CR values for each construct exceed 0.6. Thus, the scale has good convergent reliability. As can be seen from Table 3, the square root of AVE of each construct exceeds the absolute value of the correlation coefficient between that construct and other constructs, indicating that the scale has good discriminant validity. From Table 3, it can be found that there are significant positive correlations among psychological capital of entrepreneurial team, organizational innovation climate, knowledge sharing and innovation performance of startups, and significant negative correlations between knowledge hiding and other variables, and the correlation coefficients are all below 0.5, indicating that there is no potential multiple co-linearity problem, and also providing a preliminary verification of the hypotheses.

5. Hypothesis tests

5.1. Regression analysis on PsyCap of venture teams and innovation performance

Hierarchical regression was used to test the research hypotheses proposed in this paper, and the results of the hierarchical regression are shown in Table 4. Model 5 in Table 4 is the result of regressing the control variables of this paper-entrepreneur's gender, age, entrepreneur's education, years of startup founding and startup team size as independent variables on the innovation performance of startups, and Model 6 is the result of regressing the innovation performance of startups after adding the psychological capital of startup team to Model 5 Model 6 is the result of adding the psychological capital of the entrepreneurial team to model 5. Model 5 and model 6 show that the R2 of the model increases significantly after adding the independent variables, and the regression coefficient of psychological capital of entrepreneurial team on innovation performance of startups is 0.268, which is significantly positive at the 0.01 level, indicating that there is a significant positive effect of psychological capital of entrepreneurial team on innovation performance of startups, and hypothesis H1 is confirmed.

5.2. A test of intermediary effect of knowledge sharing

To verify the mediating effect of knowledge sharing, Model 1 in Table 4 is the result of regressing the control variables of this paper-entrepreneur's gender, age, entrepreneur's education, years of startup founding and startup team size-on knowledge sharing as independent variables, and Model 2 is the result of adding the psychological capital of the startup team to Model 1 on startup Model 2 is the result of adding the psychological capital of entrepreneurial team to Model 1 and regressing the knowledge sharing. It can be found from model 1 and model 2 that the R2 of the model increases significantly after adding the independent variables, and the regression coefficient of entrepreneurial team psychological capital on knowledge sharing is 0.368 and significantly positive at the 0.01 level, indicating that there is a significant positive effect of entrepreneurial team psychological capital on knowledge sharing, and hypothesis H2 is verified.

Model 7 in Table 4 shows the results of regressing entrepreneurial team psychological capital and knowledge sharing into model 5 simultaneously on the innovation performance of startups. It can be found that the absolute value of the regression coefficient of entrepreneurial team psychological capital becomes smaller (from 0.268 to 0.208) and the significance level becomes lower relative to model 6 after the introduction of the mediating variable knowledge sharing, indicating that the mediating effect of knowledge sharing exists and is partially mediated the hypothesis H3 was verified.

5.3. The test of intermediary effect of knowledge hiding

To verify the mediating effect of knowledge hiding, Model 3 in Table 4 is the result of regressing the control variables of this

TABLE 4 Sample regression analysis of the impact of entrepreneurial team PsyCap on innovation performance.

Variable	Knowledge sharing		Knowledge hiding		Innovation performance of startups					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Gender	−0.133	−0.156	0.109	0.143	−0.145	−0.132	−0.138	−0.133	−0.141	−0.131
Age	0.134	0.164	0.198*	0.157*	0.176	0.168	0.137	0.201	0.168	0.173
Educational background	0.113	0.134	0.141	0.137	0.129	0.124	0.125	0.109	0.121	0.125
Years of entrepreneurship	0.144	0.182	0.197	0.168	0.187	0.178	0.157	0.103	0.201	0.179
Team size	0.132	0.155	0.178	0.165	0.132	0.134	0.125	0.145	0.143	0.129
Psychological capital of entrepreneurial team		0.368***		−0.415**		0.268***	0.208**	0.237**	0.263**	0.257**
Knowledge sharing							0.329***		0.302**	
Knowledge hiding								−0.401**		−0.386**
Organizational innovation climate									0.304**	
Knowledge sharing × organizational innovation climate									0.267**	
Knowledge hiding × organizational innovation climate										−0.253**
*R*2	0.034	0.267	0.089	0.341	0.046	0.297	0.369	0.378	0.403	0.398
Adjusted *R*2	0.026	0.251	0.080	0.315	0.037	0.299	0.329	0.347	0.361	0.372
F	1.689	10.605	2.013	9.787	1.981	10.312	13.115	14.017	15.819	14.899

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

10.3389/fpsyg.2023.1133270

paper-entrepreneur's gender, age, entrepreneur's education, years of startup establishment and startup team size on knowledge hiding as independent variables, and Model 4 is the result of regressing knowledge hiding by adding the psychological capital of the startup team to Model 3. Model 4 is the result of regressing knowledge hiding by adding entrepreneurial team psychological capital to model 3. Model 3 and model 4 show that the R2 of the model increases significantly after adding the independent variables, and the regression coefficient of entrepreneurial team psychological capital on knowledge hiding is 0.415 and significantly negative at the 0.05 level, indicating that there is a significant negative effect of entrepreneurial team psychological capital on knowledge hiding, and hypothesis H4 is verified.

Model 8 in Table 4 shows the results of regressing entrepreneurial team psychological capital and knowledge hiding into model 5 simultaneously on the innovation performance of startups. It can be found that the absolute value of the regression coefficient of entrepreneurial team psychological capital becomes smaller (from 0.268 to 0.237) and the significance level becomes lower relative to model 6 after the introduction of the mediating variable knowledge hiding, indicating that the mediating effect of knowledge hiding exists, and it is partially mediated effect, and hypothesis H5 was verified.

5.4. The moderating effect of organizational innovation climate

To test the moderating effect of organizational innovation climate on the relationship between knowledge sharing and innovation performance of startups and knowledge hiding and innovation performance of startups, respectively, two pairs of variables, knowledge sharing and organizational innovation climate, and knowledge hiding and organizational innovation climate, were firstly centered to reduce the effect of multicollinearity, and then regression tests were conducted, and the results are shown in Table 4. According to model 9 in Table 4, the regression coefficient of the interaction term between knowledge sharing and organizational innovation climate is 0.267 and significant at the 0.05 level, indicating that organizational innovation climate positively regulates the relationship between knowledge sharing and innovation performance of startups, and hypothesis H6 is verified. According to model 10 in Table 4, the regression coefficient of the interaction term between knowledge hiding and organizational innovation climate is −0.253 and significant at the 0.05 level, indicating that organizational innovation climate negatively regulates the relationship between knowledge hiding and innovation performance of startups, and hypothesis H7 is verified.

6. Conclusion and discussion

6.1. Research conclusion

This study aims to answer the question of whether and how psychological capital of entrepreneurial teams affects innovation performance of entrepreneurial firms. From the perspective of knowledge management, based on the survey data of 113 entrepreneurial teams in China's provinces, this paper explores the relationship between team psychological capital and innovation performance, as well as the mediating role of knowledge sharing and knowledge hiding and the moderating role of organizational innovation climate.

Our research results show that entrepreneurial team psychological capital has a positive and significant role in promoting the innovation performance of entrepreneurial enterprises. This implies that managers should pay attention to the important role played by psychological capital in organizational innovation.

The conclusion that entrepreneurial team psychological capital is positively related to their knowledge sharing behavior and negatively related to their knowledge hiding behavior is consistent with the hypothesis, which enriches our understanding of psychological capital and knowledge management. In addition, the study confirms that knowledge sharing and knowledge hiding play a partially mediating role in the relationship between entrepreneurial team psychological capital and innovation performance of entrepreneurial firms, which suggests that in innovation management practice, the importance managers attach to the psychological capital of their teams facilitates the smooth implementation of organizational knowledge management activities, and ultimately contributes to the achievement of overall organizational goals. Finally, the moderating role of organizational innovation climate in knowledge management and innovation performance is verified, that is, the higher the organizational innovation climate is, the stronger the positive influence of entrepreneurial team knowledge sharing behavior on innovation performance of entrepreneurial enterprises, while the negative influence of entrepreneurial team knowledge hiding behavior on innovation performance of entrepreneurial enterprises is weakened.

6.2. Theoretical contributions

First, this paper investigates the psychological capital of entrepreneurial teams, which makes up for the deficiencies of previous studies that only focus on the psychological capital of employees, leaders, followers and entrepreneurs, and enriches the research on team psychological capital in the context of entrepreneurship. Secondly, this paper constructs a systematic research framework on the relationship between psychological capital, knowledge sharing, knowledge hiding, organizational innovation climate and innovation performance of entrepreneurial enterprises, analyzes the theoretical relationship among them, and reveals the mechanism of the role of entrepreneurial team psychological capital on innovation performance of startups. Finally, from the perspective of knowledge management, this paper discusses the impact path of psychological capital on innovation performance, and explores the mediating effects of knowledge sharing and knowledge hiding in it, which enriches the intersection research in the field of organizational psychology and knowledge management.

6.3. Managerial implications

Our study provides practical management insights for enterprises. On the one hand, our study shows that psychological capital of entrepreneurial teams can trigger knowledge sharing and knowledge hiding behaviors in the field of knowledge management, which provides new ideas for improving innovation performance of firms. Therefore, we suggest that enterprises should pay attention to psychological capital and clarify the role of psychological capital in innovation performance. Specifically, while focusing on individual psychological capital, enterprises should also pay attention to team psychological capital and team members' mental health.

On the other hand, the role of the influence brought by knowledge management on innovation activities has been widely recognized by the academic community. We suggest that enterprises should conduct regular training in knowledge management, cultivate an open and mutually supportive cooperation atmosphere, encourage employees to actively participate in team cooperation, focus on collective interests, improve team members' sense of belonging, stimulate team members' willingness to share knowledge. Moreover, let team members understand that knowledge hiding behavior is a manifestation of mistrust among organization members, that knowledge hiding is not conducive to the realization of the overall goals of the organization, team members should trust each other and not blindly pursue the maximization of personal interests.

6.4. Limitations and future research direction

The research limitations of this paper are mainly reflected in three aspects: first, due to the limited number of surveyed startups and startup teams sample size, the limited sample size may have a certain degree of influence on the research results, so we hope to expand the geographical distribution and business scope of the data and samples in the future. For example, the samples of entrepreneurial enterprises and entrepreneurial teams should reasonably select entrepreneurial enterprises in eastern, central and western China. In addition, traditional industries and high-tech industries should be reasonably selected to make them broad and representative.

Second, the model in this paper only considers the moderating role of the variable "organizational innovation climate" in the influence of knowledge sharing and knowledge hiding behaviors of entrepreneurial teams on innovation performance of entrepreneurial enterprises, ignoring the role of other factors. For example, the application of digital technology can promote the flow of resources and knowledge among internal and external members of an organization, which in turn promotes the renewal of organizational knowledge and the construction of organizational capabilities. Therefore, in the context of digital competition, the influence of digital technology and other factors on innovation activities cannot be ignored, and future research can focus on the role of digital economy, digital technology, digital empowerment and other factors in the relationship between knowledge management and innovation.

Finally, the research model in this paper reveals the mechanism of the impact of team-level psychological capital on innovation performance from the perspective of knowledge management, and lacks research on the impact of different innovation types. Future research can consider the following questions: such as whether team psychological capital can promote organizational process innovation, product innovation, service innovation, business model innovation, and knowledge innovation? Are there differences in the impact of team psychological capital on different types of innovation? These problems will be the future research direction.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MC was responsible for the writing—original draft, formal analysis, methodology, and conceptualization of this study. XM contributed to the manuscript writing and hypothesis model design. JX collected and screened literature, contacted channels to issue questionnaires, and communicated with participants. YL and JS participated in the manuscript writing and analyzed the data. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the following fund projects, namely Key Research Base of Philosophy and Social Sciences of Shaanxi Provincial Department of Education (20JZ078), the Soft Science Project of Shaanxi Provincial Department of Science and Technology (2021KRM202), the Youth Fund for Humanities and Social Sciences of the Ministry of Education (18YJC630046), and the Key Think Tank Project of Shaanxi Provincial Department of Education (20JT057).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abbas, M., and Raja, U. (2015). Impact of psychological capital on innovative performance and job stress. *Can. J. Adm. Sci.* 32, 128–138. doi: 10.1002/cjas.1314

Agarwal, U. A., and Anantatmula, V. (2021). "Psychological safety effects on knowledge sharing in project teams," in *Proceedings of the IEEE transactions on engineering management*, (Piscataway, NJ: IEEE), 1–11. doi: 10.1109/TEM.2021.3087313

Al Kahtani, N. S., and Sulphey, M. M. (2022). A study on how psychological capital, social capital, workplace wellbeing, and employee engagement relate to task performance. *SAGE Open* 12:21582440221095010. doi: 10.1177/21582440221095010

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., and Herron, M. (1996). Assessing the work environment for creativity. *Acad. Manag. J.* 39, 1154–1184. doi: 10.2307/256995

Anderson, M., Moen, O., and Brett, P. O. (2020). Organizational climate of psychological security: Its relevance to innovation capability and innovation performance in small and medium-sized enterprises. *J. Eng. Technol. Manag.* 55:101554.

Andersson, M., Moen, O., and Brett, P. O. (2020). The organizational climate for psychological safety: Associations with SMEs' innovation capabilities and innovation performance. *J. Eng. Technol. Manag.* 55:101554. doi: 10.1016/j.jengtecman.2020.101554

Bock, G.-W., Zmud, R.-W., Kim, Y.-G., and Lee, J.-N. (2005). Behavioral intention formation in knowledge sharing: Examining the roles of extrinsic motivators? social-psychological forces, and organizational climate. *MIS Quarterly* 29, 87–111. doi: 10.2307/25148669

Bolzani, D., Fini, R., Napolitano, S., and Toschi, L. (2019). Entrepreneurial teams: An input-process-outcome framework. *Found. Trends Entrep.* 15, 56–258. doi: 10.1561/0300000077

Cabrera, E. F., and Cabrera, A. (2005). Fostering knowledge sharing through people management practices. *Inter. J. Hum. Resour. Manag.* 16, 720–735. doi: 10.1080/09585190500083020

Chang, H. C., Lee, C. C., Yeh, W. C., and Chang, I. (2022). The influence of real estate brokers' personalities, psychological empowerment, social capital, and knowledge sharing on their innovation performance: The moderating effect of moral hazard. *Front. Psychol.* 13:971339. doi: 10.3389/fpsyg.2022.971339

Chatterjee, S., Chaudhuri, R., Thrassou, A., and Vrontis, D. (2021). Antecedents and consequences of knowledge hiding: The moderating role of knowledge hiders and knowledge seekers in organizations. *J. Bus. Res.* 128, 303–313. doi: 10.1016/j.jbusres.2021.02.033

Chen, H., and Tao, Y. (2021). Efficacy of entrepreneurs' psychological capital on the performance of new ventures in the development of regional economy in the greater bay area. *Front. Psychol.* 12:705095. doi: 10.3389/fpsyg.2021.705095

Chuang, C. H., Jackson, S. E., and Jiang, Y. (2016). Can knowledge-intensive teamwork be managed? Examining the roles of HRM systems, leadership, and tacit knowledge. *J. Manage.* 42, 524–554. doi: 10.1177/0149206313478189

Connelly, C. E., Zweig, D., Webster, J., and Trougakos, J. P. (2012). Knowledge hiding in organizations. *J. Organ. Behav.* 33, 64–88. doi: 10.1002/job.737

Coutu, D. L. (2002). How resilience works. *Harv. Bus. Rev.* 80, 46–56.

Del Giudice, M., and Della Peruta, M. R. (2016). The impact of IT-based knowledge management systems on internal venturing and innovation: A structural equation modeling approach to corporate performance. *J. Knowl. Manag.* 20, 484–498. doi: 10.1108/JKM-07-2015-0257

Derin, O. B., Toker, K., and Gorener, A. (2022). The relationship between knowledge sharing and innovative work behaviour: The mediating role of ethical climate. *Knowl. Manag. Res. Pract.* 20, 557–570. doi: 10.1080/14778238.2020.1860666

Dimas, I. D., Assunção, M., Rebelo, T., Lourenço, P. R., and Alves, M. (2022). Innovation in teams: The role of psychological capital and team learning. *J. Psychol.* 156, 133–146. doi: 10.1080/00223980.2021.2014391

Donate, M. J., and de Pablo, J. D. S. (2015). The role of knowledge-oriented leadership in knowledge management practices and innovation. *J. Bus. Res.* 68, 360–370. doi: 10.1016/j.jbusres.2014.06.022

Dongling, W., Yuming, Z., Xinmin, L., Chen, J., XiaoYi, Z., and Chang, H. (2022). Can inter-organizational knowledge-sharing improve enterprise innovation performance? The mediator effect of innovation capability and the moderator effect of network characteristics. *Front. Commun.* 7:856301. doi: 10.3389/fcomm.2022.856301

Dou, G., Yang, J., Yang, L., Liu, B., and Yuan, Y. (2022). Where there is pressure, there is motivation? The impact of challenge-hindrance stressors on employees' innovation performance. *Front. Psychol.* 13:1020764. doi: 10.3389/fpsyg.2022.1020764

Fischer, M. M., Diez, J. R., and Snickars, F. (2001). *Metropolitan innovation systems: Theory and evidence from three metropolitan regions in Europe*. Berlin: Springer Science and Business Media. doi: 10.1007/978-3-662-04630-2

Fu, H. Y., Yu, K. D., Cheng, Y. P., and Chou, C. H. (2007). The study on the relationship among organizational culture, knowledge sharing and organizational innovation knowledge types as moderator in the shipping industry. *Chin. Marit. Res. Inst.* 16, 1–16.

Gao, Q., Wu, C., Wang, L., and Zhao, X. (2020a). The entrepreneur's psychological capital, creative innovation behavior, and enterprise performance. *Front. Psychol.* 11:1651. doi: 10.3389/fpsyg.2020.01651

Gao, Q., Xu, J., Tao, Z., Liu, L., and Wu, C. (2020b). Exploration and analysis on the psychological capital of entrepreneurship and the deviant innovation behavior of employees. *Front. Psychol.* 11:1880. doi: 10.3389/fpsyg.2020.01880

Ge, Y. (2022). The impact of dynamic knowledge management capability on enterprise innovation performance. *Oper. Manage. Res.* 15, 1048–1059. doi: 10.1007/s12063-021-00251-7

Ge, Y., He, Y., Huang, Z., and Sun, X. (2022). Influence of knowledge-based employee incentive construction on innovation performance using psychological capital. *J. Environ. Public Health* 2022:9424068. doi: 10.1155/2022/9424068

Giampaoli, D., Ciambotti, M., and Bontis, N. (2017). Knowledge management, problem solving and performance in top Italian firms. *J. Knowl. Manag.* 21, 355–375. doi: 10.1108/JKM-03-2016-0113

Goswami, A. K., and Agrawal, R. K. (2022). It's a knowledge centric world! Does ethical leadership promote knowledge sharing and knowledge creation? Psychological capital as mediator and shared goals as moderator. *J. Knowl. Manag.* doi: 10.1108/JKM-09-2021-0669 [Epub ahead of print].

Grözinger, A. C., Wolff, S., Ruf, P. J., and Moog, P. (2022). The power of shared positivity: Organizational psychological capital and firm performance during exogenous crises. *Small Bus. Econ.* 58, 689–716. doi: 10.1007/s11187-021-00506-4

Gully, S. M., Incalcaterra, K. A., Joshi, A., and Beauien, J. M. (2002). A meta-analysis of team-efficacy, potency, and performance: Interdependence and level of analysis as moderators of observed relationships. *J. Appl. Psychol.* 87, 819–832. doi: 10.1037/0021-9010.87.5.819

Guo, L. X., Liu, C. F., and Yain, Y. S. (2020). Social entrepreneur's psychological capital, political skills, social networks and new venture performance. *Front. Psychol.* 11:925. doi: 10.3389/fpsyg.2020.00925

He, P., Jiang, C., Xu, Z., and Shen, C. (2021). Knowledge hiding: Current research status and future research directions. *Front. Psychol.* 12:748237. doi: 10.3389/fpsyg.2021.748237

Hsu, M., and Chen, F. H. (2017). The cross-level mediating effect of psychological capital on the organizational innovation climate–employee innovative behavior relationship. *J. Creat. Behav.* 51, 128–139. doi: 10.1002/jocb.90

Huo, W., Cai, Z., Luo, J., Men, C., and Jia, R. (2016). Antecedents and intervention mechanisms: A multi-level study of RandD team's knowledge hiding behavior. *J. Knowl. Manag.* 20, 880–897. doi: 10.1108/JKM-11-2015-0451

Jiao, Y., Xioaman, Z., Lu, S., Wu, Z., and Deng, Y. (2022). Research on the influence of team psychological capital on team members' work performance. *Front. Psychol.* 13:1072158. doi: 10.3389/fpsyg.2022.1072158

Jing, Z., and Cisheng, W. (2021). Cross-level impact of employees' knowledge management competence and team innovation atmosphere on innovation performance. *Ann. Oper. Res.* 310, 49–87. doi: 10.1007/s10479-021-04328-1

Luthans, F., Avolio, B. J., Avey, J. B., and Norman, S. M. (2007). Positive psychological capital: Measurement and relationship with performance and satisfaction. *Pers. Psychol.* 60, 541–572. doi: 10.1111/j.1744-6570.2007.00083.x

Luthans, F., Luthans, K. W., and Luthans, B. C. (2003). Positive psychological capital:beyond human and social capital. *Bus. Horiz.* 47, 45–50. doi: 10.1016/j.bushor.2003.11.007

Luthans, F., Youssef, C. M., and Rawski, S. L. (2011). A tale of two paradigms: The impact of psychological capital and reinforcing feedback on problem solving and innovation. *J. Organ. Behav. Manag* 31, 333–350. doi: 10.1080/01608061.2011.619421

Maitlo, A. A., Memon, S. B., and Syed, S. (2017). Influence of psychological capital on knowledge sharing behaviour in research fellows of public sector universities. *J. Bus. Strategy* 11, 1–20.

Mathe-Soulek, K., Scott-Halsell, S., Kim, S., and Krawczyk, M. (2014). Psychological capital in the quick service restaurant industry: A study of unit-level performance. *J. Hosp. Tour. Res.* 41, 823–845. doi: 10.1177/1096348014550923

McKenny, A. F., Short, J. C., and Payne, G. T. (2013). Using computer-aided text analysis to elevate constructs: An illustration using psychological capital. *Organ. Res. Methods* 16, 152–184. doi: 10.1177/1094428112459910

Miao, Y., Qi, N., Liu, E., and Zhai, P. (2022). Temporary team performance and knowledge hiding: Mediated by interpersonal mistrust. *Front. Psychol.* 13:876710. doi: 10.3389/fpsyg.2022.876710

Munir, R., and Beh, L. S. (2019). Measuring and enhancing organisational creative climate, knowledge sharing, and innovative work behavior in startups development. *Bottom Line* 4, 269–289. doi: 10.1108/BL-03-2019-0076

Ngo, T. T. (2021). Impact of psychological capital on job performance and job satisfaction: A case study in Vietnam. *J. Asian Financ. Econ.* 8, 495–503.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organ. Sci.* 5, 14–37. doi: 10.1287/orsc.5.1.14

Peng, C., Xue, K., Tian, Y., Zhang, X., Jing, X., and Luo, H. (2022). Organizational emotional capability perspective: Research on the impact of psychological capital on enterprise safety performance. *Front. Psychol.* 13:854620. doi: 10.3389/fpsyg.2022.854620

Peng, H. (2013). Why and when do people hide knowledge? *J. Knowl. Manage.* 3, 398–415. doi: 10.1108/JKM-12-2012-0380

Peng, J. C., and Chen, S. W. (2022). Learning climate and innovative creative performance: Exploring the multi-level mediating mechanism of team psychological capital and work engagement. *Curr. Psychol.* 6, 1–19. doi: 10.1007/s12144-021-02617-3

Peterson, C. (2000). The future of optimism. *Am. Psychol.* 55, 44–55. doi: 10.1037/0003-066X.55.1.44

Qiu, X., Yan, X., and Lv, Y. (2015). The effect of psychological capital and knowledge sharing on innovation performance for professional technical employees. *J. Serv. Sci. Manag.* 8:545. doi: 10.4236/jssm.2015.84055

Ritala, P., Olander, H., Michailova, S., and Husted, K. (2015). Knowledge sharing, knowledge leaking and relative innovation performance: An empirical study. *Technovation* 35, 22–31. doi: 10.1016/j.technovation.2014.07.011

Rong, P., and Liu, S. (2021). Top management team knowledge hiding and enterprise innovation performance: A moderated mediation model. *Front. Psychol.* 12:783147. doi: 10.3389/fpsyg.2021.783147

Ruef, M., Aldrich, H. E., and Carter, N. M. (2003). The structure of founding teams: Homophily, strong ties, and isolation among US entrepreneurs. *Am. Sociol. Rev.* 68, 195–222. doi: 10.2307/1519766

Saenz, J., Aramburu, N., and Rivera, O. (2009). Knowledge sharing and innovation performance: A comparison between high-tech and low-tech companies. *J. Intellect. Cap.* 1, 22–36. doi: 10.1108/14691930910922879

Scott, S., and Bruce, R. (1994). Determinants of innovative behaviour: A path model of individual innovation in the workplace. *Acad. Manage. J.* 37, 580–607. doi: 10.5465/256701

Serenko, A., and Bontis, N. (2016). Understanding counterproductive knowledge behavior: Antecedents and consequences of intra-organizational knowledge hiding. *J. Knowl. Manag.* 20, 1199–1224. doi: 10.1108/JKM-05-2016-0203

Siegel, S., and Kaemmerer, W. (1978). Measuring the perceived support for innovation in organizations. *J. Appl. Psychnol.* 63, 553–562. doi: 10.1037/0021-9010.63.5.553

Singh, S. K., and Gaur, S. S. (2018). Entrepreneurship and innovation management in emerging economies. *Manage. Decis.* 56, 2–5. doi: 10.1108/MD-11-2017-1131

Sung, S. Y., and Choi, J. N. (2014). Do organizations spend wisely on employees? Effects of training and development investments on learning and innovation in organizations. *J. Organ. Behav.* 35, 393–412. doi: 10.1002/job.1897

Tho, N. D. (2020). Team psychological capital and innovation: The mediating of team exploratory and exploitative learning. *J. Knowl. Manag.* 25, 1745–1759. doi: 10.1108/JKM-06-2020-0475

Tian, Z., Tang, C., and Akram, F. (2022). Negative work attitudes and task performance: Mediating role of knowledge hiding and moderating role of servant leadership. *Front. Psychol.* 13:963696. doi: 10.3389/fpsyg.2022.963696

Tran, P. T., Nguyen, T. D. T., Pham, L. M., Phan, P. T. T., and Do, P. T. (2021). The role of intrinsic motivation in the relationship between psychological capital and innovative performance: Empirical evidence from Vietnam. *J. Asian Financ. Econ.* 8, 1067–1078.

Tsai, W. Y., and Su, C. J. (2022). Digital transformation of business model innovation. *Front. Psychol.* 13:1017750. doi: 10.3389/fpsyg.2022.1017750

Udin, U., and Yuniawan, A. (2020). Psychological capital, personality traits of big-five, organizational citizenship behavior, and task performance: Testing their relationships. *J. Asian Financ. Econ.* 7, 781–790. doi: 10.13106/jafeb.2020.vol7.no9.781

Vandavasi, R. K. K. (2020). Knowledge sharing, shared leadership and innovative behaviour: A cross-level analysis. *Int. J. Manpower* 41, 1221–1233. doi: 10.1108/IJM-04-2019-0180

Waheed, A., Miao, X., Waheed, S., Ahmad, N., and Majeed, A. (2019). How new HRM practices, organizational innovation, and innovative climate affect the innovation performance in the IT industry: A moderated-mediation analysis. *Basel* 11:621. doi: 10.3390/su11030621

Walumbwa, F. O., Luthans, F., Avey, J. B., and Oke, A. (2011). Authentically leading groups: The mediating role of collective psychological capital and trust. *J. Organ. Behav.* 32, 4–24. doi: 10.1002/job.653

Wang, J., Zhao, Y., Han, X., Li, L., and Rasool, S. F. (2022). Exploring the relationship between value modularity, knowledge transfer, and firm innovation performance: Evidence from China. *Front Psychol.* 12:772231. doi: 10.3389/fpsyg.2021.772231

Wang, M., and Wang, H. (2022). Knowledge exploration and innovation performance: The mediating role of absorptive capacity. *Oper. Manage. Res.* 15, 1–11. doi: 10.1007/s12063-022-00279-3

Wang, R., Zhou, H., and Wang, L. (2022). The influence of psychological capital and social capital on the entrepreneurial performance of the new generation of entrepreneurs. *Front. Psychol.* 13:832682. doi: 10.3389/fpsyg.2022.832682

Waters, L., Strauss, G., Somech, A., Haslam, N., and Dussert, D. (2020). Does team psychological capital predict team outcomes at work? *Int. J. Wellbeing* 10, 1–25. doi: 10.5502/ijw.v10i1.923

Wen, J., and Ma, R. (2021). Antecedents of knowledge hiding and their impact on organizational performance. *Front. Psychol.* 12:796976. doi: 10.3389/fpsyg.2021.796976

Wu, W. L., and Lee, Y. C. (2017). Empowering group leaders encourages knowledge sharing: Integrating the social exchange theory and positive organizational behavior perspective. *J. Knowl. Manag.* 21, 474–491. doi: 10.1108/JKM-08-2016-0318

Xiong, C., Chang, V., Scuotto, V., Shi, Y., and Paoloni, N. (2021). The social-psychological approach in understanding knowledge hiding within international R&D teams: An inductive analysis. *J. Bus. Res.* 128, 799–811. doi: 10.1016/j.jbusres.2019.04.009

Xu, Z., and Suntrayuth, S. (2022). Innovation behavior in high-tech firms: The interlocking mediating Effect of psychological security and knowledge Sharing. *Front. Psychol.* 13:1017121. doi: 10.3389/fpsyg.2022.1017121

Yang, B., Bao, S., and Xu, J. (2022). Supervision style and innovative performance of graduate students: The mediating Role of psychological Capital and the moderating role of harmonious academic Passion. *Front. Psychol.* 13:1034216. doi: 10.3389/fpsyg.2022.1034216

Yu, Q., Yu, C., and Yu, J. (2013). Knowledge sharing, organizational climate and innovation behavior: A cross-level analysis of effectiveness. *SBP J.* 41, 143–156. doi: 10.2224/sbp.2013.41.1.143

Yue, L., Zheng, Y., and Ye, M. (2022). The impact of eSports industry knowledge alliances on innovation performance: A mediation model based on knowledge sharing. *Front. Psychol.* 13:902473. doi: 10.3389/fpsyg.2022.902473

Zeng, S. X., Xie, X. M., and Tam, C. M. (2010). Relationship between cooperation networks and innovation performance of SMEs. *Technovation* 30, 181–194. doi: 10.1016/j.technovation.2009.08.003

Zhang, D., Zhang, F., Lin, M., and Du, H. S. (2017). Knowledge sharing among innovative customers in a virtual innovation community: The roles of psychological capital, material reward and reciprocal relationship. *Online Inform. Rev.* 41, 691–709. doi: 10.1108/OIR-08-2016-0226

Zhang, J., Raza, M., and Khalid, R. (2022). Impact of team knowledge management, problem solving competence, interpersonal conflicts, organizational trust on project performance, a mediating role of psychological capital. *Ann. Oper. Res.* Available online at: https://www.webofscience.com/wos/woscc/summary/00221299-53bd-444a-8b15-471ef1a9cf6a-64a513a5/relevance/1 (accessed December 10, 2022).

Zhang, L. (2022). Impact of psychological contract breach on firm's innovative performance: A moderated mediation model. *Front. Psychol.* 13:970622. doi: 10.3389/fpsyg.2022.970622

Zhang, S., and Wang, X. (2021). The influence of knowledge hiding on knowledge innovation behavior of innovation team members. *Scientometrics* 126, 6423–6442. doi: 10.1007/s11192-021-04047-1

Zhang, Z., and Min, M. (2022). Research on project NPD coordination, knowledge transfer process and innovation performance among chinese enterprises. *Asia Pac. J. Manag.* 39, 1161–1186. doi: 10.1007/s10490-021-09755-z

Zhao, H., Liu, W., Li, J., and Yu, X. (2019). Leader-member exchange, organizational identity and knowledge hiding: The moderating role of leader-member communication. *J. Organ. Behav.* 40, 834–848. doi: 10.1002/job.2359

Zhu, J., Lin, F., and Zhang, Y. (2022). Exploring the effect of perceived over qualification on knowledge hiding: The role of psychological capital and person-organization fit. *Front. Psychol. J.* 13:955661. doi: 10.3389/fpsyg.2022.955661

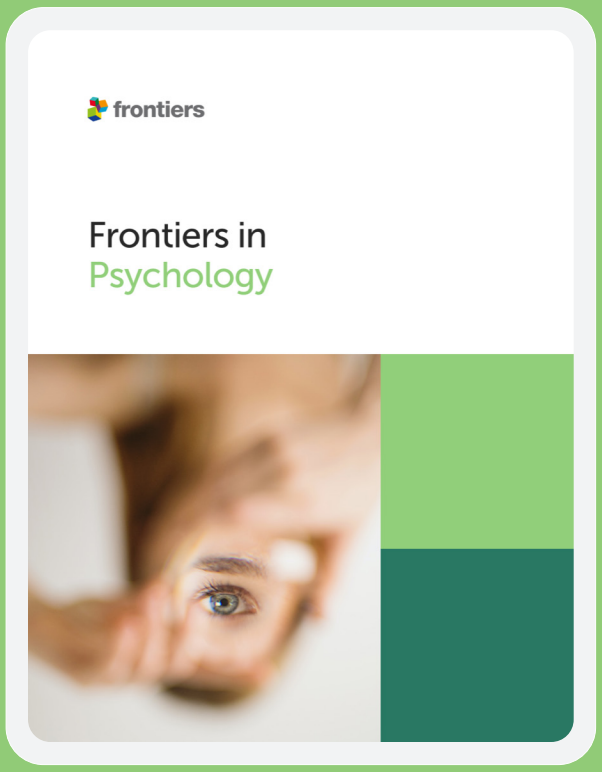
Frontiers in Psychology

Paving the way for a greater understanding of human behavior

The most cited journal in its field, exploring psychological sciences - from clinical research to cognitive science, from imaging studies to human factors, and from animal cognition to social psychology.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact