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The impact of geographic indication recognition on farmers' intentions for green production behavior: a case study of Gannan navel oranges in China

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Geographical indication of agricultural products is not only a distinct symbol of local characteristic agriculture, but also a powerful engine for promoting high-quality agricultural development and facilitating rural revitalization. Exploring the mechanism by which farmers' cognition of geographical indications affects their willingness for green production can help identify the fundamental path to maintaining the unique qualities of geographical indication agricultural products at the farmer level. Drawing upon the theory of planned behavior, this study establishes a theoretical framework of the impact of farmers' geographical indication cognition on their willingness to engage in green production. Using the survey data collected from farmers in Xinfeng and Anyuan counties of Jiangxi Province, China, and the structural equation modeling to test the theoretical model, the conclusions are as follows: (1) Farmers' attitudes towards green production, perceived behavioral control, and subjective norms significantly affect their intentions to adopt green production practices. Among these, the attitude towards green production has the most substantial impact, followed by subjective norms and perceived behavioral control. (2) Additionally, farmers' geographical indication cognition directly positively influences their willingness to implement green production. (3) This cognition also positively influences their behavioral attitude, behavioral control, and subjective norm regarding green production, thereby indirectly shaping their green production behavioral intention, and the influence is ranked as follows: behavioral attitude, subjective norm, and behavioral control.

KEYWORDS

geographical indication cognition, green production behavioral intention, the theory of planned behavior, structural equation modeling, China

1 Introduction

As the characteristic agricultural products of a speci c region, geographical indication agricultural products (GIAP) not only carry the regional brand and cultural symbols, but also signi cantly contribute to rural economic and high-quality development of agriculture. As global consumers' concerns about food safety and the ecological environment increase, green production of GIAP not only enhances quality and safety to meet market demands but also aids in soil environment protection ensure the product quality characteristics. Farmers' green production behavior means that farmers adopt eco-friendly and resource-saving production methods to minimize environmental harm and promote sustainable agricultural development.

In recent years, the Chinese government has issued and implemented documents such as the "14th Five-Year Plan for Green Agricultural Development" to promote green production technologies. However, encouraging farmers to adopt these practices remains a challenge. The behavior still encounters the challenge of inadequate endogenous motivation (Wen et al., 2024).

GIAP, recognized for their significant brand value (Kong et al., 2008), can command a premium from consumers. This premium, in turn, can contribute to increase farmers' income (Li et al., 2024), as evidenced by the promotion of local farmers' income through brand premium and the stimulation of agricultural industry agglomeration and related industries development, as well as the regional heterogeneity in the impact due to varying government support and market conditions. However, at the same time, GIAP are governed by strict regulations on the environmental conditions, production quality and safety technical specifications. They also exhibit characteristics such as regional monopoly, unique quality, shared property rights, and shared usage (Liu, 2024). Due to the great economic value brought by the geographical indication (GI) brand and the public goods attribute of GIAP, farmers frequently overuse land resources during the production process in order to enhance product yields. In the long run, this will lead to the destruction of land resources, the disappearance of regional advantages, and the deterioration of the unique qualities of GIAP. Since farmers are not only rational economic beings but also have social attributes, It is crucial to explore the factors affecting the green production behavioral intention (GPBI), as empirical studies have shown that farmers' green production behavior is influenced by a range of factors including individual characteristics, household characteristics, policy factors, and economic factors.

The Theory of Planned Behavior (TPB), proposed by Ajzen (1991) is a psychological framework used to understand decision-making and explain individuals' actions in specific situations (Shi et al., 2020). It is rooted in the Theory of Reasoned Action (TRA), introduced by Ajzen and Fishbein. Ajzen identified that people's behavior is not completely voluntary and is influenced by external factors. As a result, TPB proposed that individual behavior is governed by three main factors: attitude toward the behavior, perceived behavioral control and subjective norm (Ajzen, 1991). While TPB accounts for much of behavior, it falls short in analyzing green production by GIAP. GIAP are distinguished from ordinary agricultural products by factors such as market value, brand image, development prospects, and product quality, farmers' geographical indication cognition (GIC) in these aspects may have an impact on their production decisions. Moreover, the failure of many countries to achieve the expected results in protecting geographical indications (GIs) can be largely attributed to the lack of GIC among producers, especially small farmers (Zhao and Luan, 2021). Hence, incorporating GIC factors into the Theory of Planned Behavior (TPB) is essential to investigate the GPBI of farmers producing geographical indication agricultural products (GIAP).

Regarding farmers' GPBI, scholars have yielded significant research findings in areas like individual differentiation (Sun and Li, 2024), ecological cognition (Yu et al., 2024; Hair et al., 2019), government oversight (Wang and Zhang, 2024), risk awareness (Yin et al., 2022), and cooperative involvement (Jiang and Zhao, 2024). On the basis of TPB, some studies have also integrated Norm Activation Model (NAM) (Zhang et al., 2023; Xu et al., 2024) economic rationality (Shi et al., 2020), health concept (Ataei et al., 2021), pesticide knowledge (Bagheri et al., 2019), environmental values (Shi et al., 2020) and other factors. GI is widely recognized for its potential to encourage green production among farmers. For example, Zhang and Huang (2022) argued that GI brand construction can effectively communicate market information about agricultural products, promote farmers' adoption of green production practices, and affect product quality and safety mainly through brand premium and brand maintenance. The study conducted by Baoerjiang et al. (2024) and Du et al. (2023) demonstrated that product quality certification can markedly enhance farmers' adoption of green production technology. Belletti et al. (2015) and Marescotti et al. (2020) believed that the introduction of GI can improve producers' awareness of the interrelationship between their products and the local environment, as evidenced by the success of GI in enhancing product value and protecting unique characteristics, such as those seen in the renowned French Charolais Beef and Italian Vitellone Bianco dell'Appennino Centrale, which leverage their specific natural environments. Li et al. (2021) suggested that farmers' involvement in e-commerce within GI-protected areas could accelerate the integration into the development process of modern agriculture, promote a shift in agricultural management strategies, and heighten their sensitivety to green production practices; Li et al. (2021) believed that the production of GIAP should jointly abide by production standards and behavioral norms, which will encourage farmers to adopt green production behaviors. Nonetheless, current academic research predominantly focuses on external factors like production regulations and market incentives, with scant exploration of green production in GIAP from the farmers' internal perspective.

This paper introduces cognitive factors influencing farmers' attitudes toward GIAP based on TPB. It develops a theoretical model to examine internal factors affecting farmers' GPBI, using the research data of Gannan navel orange in Xinfeng and Anyuan counties of Jiangxi Province, verified through structural equation modeling (SEM). This paper aims to explore the underlying logic of enhancing the GPBI in GIAP, focusing on strategies to maintain the unique soil environment and product quality through the implementation of soil protection measures.

2 Theoretical framework and research hypothesis

2.1 Green production behavioral attitude (GPBA) and GPBI

GPBA reflects farmers' subjective view on green production behaviors. The more positively farmers evaluate green production behaviors, the stronger their intention to engage in green production behaviors (GPBI) is, and vice versa (Cheng et al., 2021). Based on the rational smallholder theory, farmers' attitudes towards GPBA are closely tied to personal motives and interests. When farmers anticipate that green production practices can bring about compounding benefits, such as ecological improvement, improved product quality, and enhanced market competitiveness, they will develop a positive attitude and foster the intention to engage in green production. Based on this, hypothesis H1 is proposed.

> *H1*: GPBA has a positive impact on GPBI.

2.2 Green production behavioral control (GPBC) and GPBI

Perceived behavioral control reflects farmers' self-assessment of their ability to adopt green production behavior and the extent of their resource control. According to the Self-Efficacy Theory, the greater the farmers' abilities and access to opportunities, the stronger their positive self-efficacy will be (Chen et al., 2024). That is, when farmers believe they have the technical capabilities, production conditions and easy access to the necessary resources for implementing green production practices, their confidence will increase, and their behavioral control beliefs will be effectively transformed into Green Production Behavior Intention (GPBI). Based on this, hypothesis H2 is proposed.

> *H2*: GPBC has a positive effect on GPBI.

2.3 Green production subjective norm (GPSN) and GPBI

GPSN reflects the policy constraints and social pressures imposed by both the government and society when farmers implement green production. Farmers are inclined to develop a favorable GPBI when they observe heightened government support and broader societal acceptance of green production. Additionally, rural areas are typical "acquaintance societies," and the network resources of farmers are mainly formed based on kinship and geography (Chen and Zhu, 2022), so the suggestions of relatives, neighbors, and the practices of those around them significantly influence farmers' decision-making. When farmers perceive widespread green production, they tend to converge their behaviors to gain group recognition and support. Therefore, GPSN will have a positive impact on GPBI. Based on this, hypothesis H3 is proposed.

> *H3*: GPSN has a positive impact on GPBI.

2.4 GIC and GPBI

According to the Cognition and Behavior Theory (CBT), an individual's cognition affects his or her emotions and behaviors. GI is a regional quality certification mark that reflects the uniqueness of products produced in a specific geographical area in terms of quality, reputation, nature and humanity. When farmers possess a higher level of GIC, they will be more able to better comprehend and appreciate the value, encompassing product quality, development potential, and brand reputation. At this point, farmers may realize the importance of green production to maintain the soil environment, ensure product quality, preserve brand advantages, and thereby foster positive attitudes and expectations, ultimately enhancing their GPBI. At the same time, Farmers with a higher GIC are more likely to recognize the importance of green production for the sustainability of GIAP, so they are more motivated to proactively learn about green production technologies and assess their own resources and capabilities, thereby contributing to the enhancement of GPBI. In addition, GI serves as a quasi-public property right, shared and developed collectively by all regional members. Collective actions are needed to ensure the product quality of GIAP (Huang and Geng, 2022). Aware of this, farmers will pay more attention to others' expectations and norms regarding green production practices, and be socially constrained to uphold the reputation of GIAP (Figure 1).

Based on the preceding arguments, this paper presents the following research hypotheses:

> *H4*: GIC has a positive impact on the GPBI.
>
> *H5*: GIC has a positive impact on the GPBA, GPBC, and GPSN.
>
> *H6*: GIC indirectly affects GPBI through GPBA, GPBC and GPSN.

3 Methods

3.1 Data and descriptive statistics

3.1.1 Data

Located in the southern part of Jiangxi, Ganzhou, also known as South Jiangxi, governs 18 counties and boasts an expansive mountainous area of 45.6 million acres, of which about one-tenth is suitable for fruit tree cultivation. As a result, it has earned the title of 'World Orange Town' and 'China Navel Orange Hometown'. Xinfeng County and Anyuan County, situated in the middle and southeast of Ganzhou, respectively, are key producing areas of navel orange in southern Jiangxi. As of 2023, Xinfeng County, with a navel orange planting area of 280,000 mu, contributes 260,000 tons to China's production, ranking it as the second-largest producer in Ganzhou City. Anyuan County, with 270,000 mu, follows closely with 210,000 tons, securing the third position in the city's production hierarchy. Xinfeng County, renowned as the birthplace of Gannan navel orange, is acclaimed as the world's premier navel orange production hub and China's sole demonstration area for navel orange standardization. Anyuan County serves as the core producing area in southern Jiangxi and the largest distribution center of navel orange in China (Figure 2).

The data are based on a questionnaire survey of navel orange growers in Xinfeng and Anyuan counties of Ganzhou City, Jiangxi

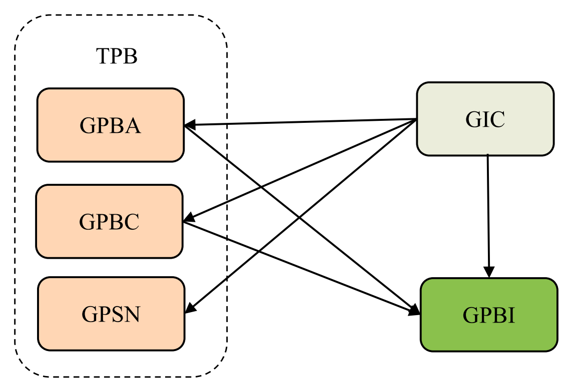

FIGURE 1
Frame diagram of the hypothesis for farmers' GPBI of GIAP.

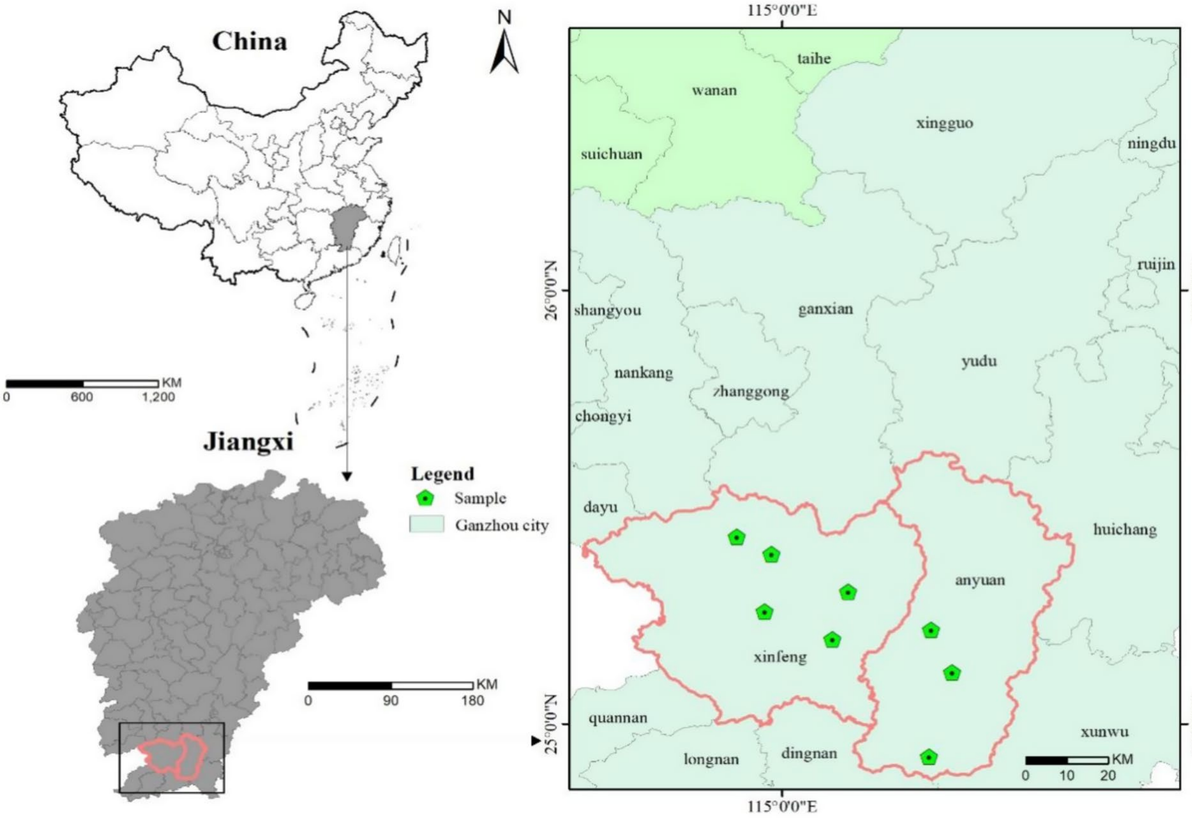

FIGURE 2
Regional map of the research area.

Province from July to September 2023. The survey assessed the planting areas, acreage, and yield of navel oranges in two locations by combining systematic sampling with random sampling. In each county, four to five townships were selected, followed by three to four sample villages within each township and about 15–20 navel orange growers were randomly selected as the survey participants. The questionnaire gathered data on individual family characteristics, farming situations, GIC, GPBI, and other relevant factors of the farmers. A total of 588 questionnaires were distributed, yielding 571 valid responses after excluding invalid ones, resulting in an effective response rate of 97.11%.

3.1.2 Descriptive statistics

In the sample, at the individual level, the production decision-makers of rural households were mainly male. e average age of farmers was 54.09 years, indicating that the local navel orange cultivation was mainly undertaken by older individuals. e mean value of education level was 2.99, suggesting that most respondents were at the junior high school literacy level. e average health condition score was 1.15, re ecting overall good health. e mean value for village cadre involvement was 0.14, indicating that the majority of farmers had not served as village cadres. e mean value for receiveing agricultural training was 0.73, suggesting that most respondents had participated in agricultural training, with local technical training being relatively widesread. Furthermore, 56% of farmers in the sample reported using geographical indications, indicating that most people have used the "Gannan Navel Orange" geographical indication. At the household level, the average number of family members engaged in farming was 2.49, implying that quite a few households had two generations involved in farming simultaneously. e average planting scale of navel oranges was 34.22 mu, with a large standard deviation, indicating the survey sample covered small, medium and large-scale growers. Farmers had an average of 13.95 years of planting experience, suggesting that the development of navel oranges in southern Gannan is relatively stable, with continuous cultivation practices among farmers. e average soil quality score was 3.65, indicating generally good soil conditions, while the average planting terrain score was 3.82, suggesting favorable planting terrain, and these results further demonstrate that the southern Gannan region of Jiangxi Province is well-suited for navel orange cultivation. Detailed information is provided in the Table 1.

3.2 Variable selection

In this paper, green production refers to the adoption of environmentally friendly and sustainable production methods in the cultivation of GIAP, with the core objectives of protecting the ecological environment, conserving resources, and enhancing the quality and safety of agricultural products. It aims to promote the

TABLE 1 Basic characteristics of sample households and statistical description.

Variable		Variable definition and assignment	Total	
			Mean	SD
Personal characteristic	Gender	Male = 1, Female = 0	0.90	0.31
	Age	Actual age (year-old)	54.09	9.15
	Health condition	Good = 1, Moderate = 2, Bad = 3	1.15	0.39
	Educational level	Never attended any school = 1, Elementary school = 2, Junior high school = 3, Senior high school = 4, College or higher = 5	2.99	0.96
	Village cadre or not	Yes = 1, No = 0	0.14	0.35
	Received agricultural training or not	Yes = 1, No = 0	0.73	0.44
	Used geographical indication of "Gannan Navel Orange" or Not	Used directly or indirectly = 1, Not used = 0	0.56	0.50
Family Characteristic	Number of farmers	Number of farmers in the family (people)	2.49	1.23
	Planting scale	Planting area of navel orange (mu)	34.22	62.38
	Planting years	Planting years of navel orange (years)	13.95	9.28
	Soil quality	Very bad = 1, Relatively bad = 2, General = 3, Relatively good = 4, Very Good = 5	3.65	0.81
	Planting Terrain	Flat = 1, Relatively at = 2, Average = 3, Slope = 4, Steep slope = 5	3.82	0.86

simultaneous improvement of both ecological and social benefits in agricultural production. In the cultivation of navel oranges, green production encompasses various practices. In soil, fertilizer and water management, "farmyard manure, straw soil ripening," "intercropping or grass planting," "straw mulching," "organic fertilizers," "soil testing and targeted fertilization" and "clean water irrigation" are included. In tree management, practices such as "regular pruning and shaping," "flower thinning and fruit retention," "manual fruit thinning" and "bagging fruit." In pest and disease control, methods involve "agricultural control," "physical treatment control," "biological control," "biological pesticides" and "farmyard manure for weed control" and so on.

According to the above theoretical analysis, considering the actual circumstances of navel orange farmers in the study area, the questionnaire was formulated by referring to Liu et al. (2021), encompassing five latent variables: GIC, GPBA, GPBC, GPSN, and GPBI, alongside 19 observational variables (Liu et al., 2021), GIC includes five aspects: brand image, brand competitiveness, development prospect, market price and quality cognition. GPBA includes four aspects: improving the quality of navel oranges enhances their price, optimizes the soil environment, and benefits physical health. GPBC encompasses three aspects: cognition of green production technology, suitable production conditions, and ease of use. The GPSN comprises suggestions from relatives, friends, and neighbors, the demonstration effect, and advice from experts. GPBI covers four aspects: learning green production techniques, participating in training sessions, increasing investments, and adopting green production technology. The questionnaire utilized a five-point Likert Scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). The specific meanings and definitions of measurement variables are detailed in Table 2, providing a comprehensive understanding of each variable's role and measurement method.

3.3 Model and design

3.3.1 Model

is paper used a SEM to verify the factors in uencing GPBI. Structural equation modelings are designed to explore causal relationships and latent structures between variables. It can simultaneously consider both observed and latent variables, and describe their relationships by establishing multiple equations. With the help of SEM, one can assess the model t, parameter estimation, and hypothesis testing, thereby verifying the relationships between variables. e matrix equation expression of the SEM is as follows:

$$X = \wedge_x \xi + \delta \quad (1)$$

$$Y = \wedge_y \eta + \varepsilon \quad (2)$$

$$\eta = \beta\eta + \Gamma\xi + \zeta \quad (3)$$

Equations 1–3 represent the measurement models, which illustrate the relationships between exogenous latent variables and their corresponding observable variables, as well as between endogenous latent variables and observable variables. ξ denotes the exogenous latent variables, which refer to GIC, GPBA, GPBC and GPSN; X represents the observed variables corresponding to ξ, which re ect the GIC, GPBA, GPBC and GPSN. $\ddot{E}_x$ is the coe cient matrix of the strength of the relation between X and ξ, δ is the measurement error of X. η represents

TABLE 2 Meanings of measurement variables.

Latent variable	Observational variable	Question item	Variable coding	Mean	SD
GIC	Brand image	I think Gannan navel orange has an excellent brand image	GIC1	4.39	0.71
	Brand competitiveness	I think Gannan navel orange has strong competitiveness and influence	GIC2	4.42	0.64
	Development prospect	I think Gannan navel orange has a bright development prospect	GIC3	4.51	0.61
	Market price	I think the market price of Gannan navel orange with geographical indication certification is higher	GIC4	4.31	0.75
	Quality cognition	I think the quality of Gannan navel orange with geographical indication certification should be better	GIC5	4.32	0.74
GPBA	Improving the quality of navel orange	Green production is helpful to improve the quality of Gannan navel orange	GPBA1	4.23	0.72
	Obtaining higher price	Green production of Gannan navel orange can sell for a higher price	GPBA2	4.24	0.78
	Optimizing soil environment	Green production can protect soil and improve soil quality	GPBA3	4.29	0.70
	Benefiting physical health	Green production of Gannan navel orange is more beneficial to health	GPBA4	4.29	0.75
GPBC	Cognition of green production technology	I know what green production techniques are used in navel orange cultivation	GPBC1	3.20	1.06
	Production conditions	The soil where I grow Gannan Navel Oranges is of good quality	GPBC2	3.65	0.82
	Convenience of use	I can conveniently purchase and use green production technologies	GPBC3	3.56	1.00
GPSN	Suggestions from relatives, friends and neighbors	I have been advised by some of my relatives, friends and neighbors to adopt green production	GPSN1	3.55	0.82
	Demonstration effect	People around me who have adopted green production have good harvests and profits	GPSN2	3.79	0.85
	Advice from experts	I have been advised by agricultural experts to adopted green production	GPSN3	3.68	1.12
GPBI	Learning green production techniques	I am willing to learn about green production techniques and methods	GPBI1	4.12	0.77
	Participating in training	I am willing to take the initiative to participate in the green production training of Gannan navel orange	GPBI2	4.08	0.84
	Increasing investment	I am willing to invest time, energy and money in green production	GPBI3	3.92	0.85
	Adopting green production technology	I am willing to adopt green technology for green production	GPBI4	3.95	0.74

the endogenous latent variable, indicating the GPBI; Y is the observed variable corresponding to η, which is an indicator of GPBI; Λ_y is the coefficient matrix of the strength of the relationship between Y and η, ε is the measurement error of Y. (3) is a structural model, and β represents the coefficient matrix of endogenous latent variables, Γ represents the coefficient matrix of exogenous latent variables, ζ is the random error term of the structural model.

3.3.2 Design

The collected data were processed and analyzed using SPSS 26.0 and AMOS 26.0. Before applying the SEM model, it is essential to assess the effectiveness and consistency of the scale to verify its validity and reliability. The higher the reliability and validity of the questionnaire, the smaller the measurement error. First, Cronbach's alpha was used to measure the reliability of items across different dimensions. Next, factor analysis was conducted to perform the KMO (Kaiser-Meyer-Olkin) test and Bartlett's test of sphericity, which were used to analyze the validity of the questionnaire, and determine the number and distribution of the observed variables' factors. Additionally, in order to ensure the good fit between the model and the data, and to ensure the reliability and accuracy of the validity tests, the suitability of the constructed model was examined. Confirmatory factor analysis (CFA) was used to evaluate the structural validity of the questionnaire. Following this, discriminative validity analysis was performed to examine the distinctions between the factors. Finally, SEM was employed to evaluate the model's fit, parameter estimation, and hypothesis testing, thereby verifying the relationships and underlying mechanisms between the variables.

4 Results

4.1 Reliability analysis

In the reliability test of projects with different dimensions, the determined reliability values were as follows: GIC exhibited a reliability value of 0.829, GPBA reached 0.842, GPBC had a value of 0.726, GPSN scored 0.769, and GPBI achieved a reliability value of 0.866. These reliability coefficients, indicating the internal consistency of the measurement tool, were deemed acceptable as they were at or above the commonly accepted threshold of 0.7 (Table 3).

TABLE 3 Reliability analysis table.

Dimensionality	Designation	Corrected item-total correlation (CITC)	α Coefficient with deleted items	Cronbach α coefficient
GIC	GIC1	0.614	0.768	0.829
	GIC2	0.602	0.772	
	GIC3	0.684	0.753	
	GIC4	0.623	0.765	
	GIC5	0.562	0.779	
GPBA	GPBA1	0.724	0.780	0.842
	GPBA2	0.635	0.818	
	GPBA3	0.684	0.797	
	GPBA4	0.666	0.805	
GPBC	GPBC1	0.561	0.512	0.726
	GPBC2	0.409	0.611	
	GPBC3	0.555	0.516	
GPSN	GPSN1	0.631	0.636	0.769
	GPSN2	0.556	0.666	
	GPSN3	0.589	0.637	
GPBI	GPBI1	0.770	0.807	0.866
	GPBI2	0.757	0.812	
	GPBI3	0.719	0.828	
	GPBI4	0.621	0.865	

4.2 Factor analysis

4.2.1 Explore factor analysis

After importing the data into SPSS, we conducted a validity analysis using the KMO and Bartlett's Spherical Test. The KMO value of 0.848 and the chi-square value of 4,380.560 from Bartlett's test, with 171 degrees of freedom and a significance level of 0.000, suggest that the data is suitable for factor analysis, meeting the validity criteria. After performing factor rotation using the maximum variance method on the variable items and excluding those with factor loading coefficients below 0.5, the final factor distribution is presented in Table 4. According to the distribution interval characteristics of factors, the five factors can be labeled as GIC, GPBA, GPBC, GPSN, and GPBI (Liang et al., 2007).

4.2.2 Confirmatory factor analysis

Confirmatory Factor Analysis (CFA) was performed to evaluate the structural validity of the questionnaire. To assess the goodness-of-fit of the proposed model, the fitting index suggested by Marsh et al. (2004) was adopted in this study.

The χ^2/df value of the validation factor model was 2.527, along with other fit indices such as GFI at 0.923, AGFI at 0.903, RMSEA at 0.052, NFI at 0.895, RFI at 0.901, CFI at 0.933, and PNFI at 0.771. The PGFI was 0.726, suggesting all items' fit values were within an acceptable range. According to the confirmatory factor analysis on the questionnaire of this survey, the AVE values of the five dimensions of this survey were above 0.4, and the CR values of variables were above 0.7. The factor loading coefficients of different variables were all above 0.5, and the significance level of the items reached the standard below 0.05. In line with the established practice in the field, all items measured in this scale underwent rigorous testing through confirmatory factor analysis (CFA), a method widely recognized for its role in validating theoretical models and ensuring the accuracy of measurement tools (Table 5) (Beckett et al., 2018).

4.3 Discriminant validity

After conducting the discriminant validity analysis, the square root of the AVE value for the GIC factor was 0.704, exceeded the highest absolute value of the inter-factor correlation coefficients at 0.332, indicating good discriminant validity. Similarly, the square root of the AVE for the GPBA factor was 0.758, higher than the maximum absolute value of the inter-factor correlation coefficient, 0.384, suggesting strong discriminant validity. For the GPBC factor, the square root of the AVE was 0.690, which was greater than the highest absolute value of the inter-factor correlation coefficients, 0.289, confirming good discriminant validity. The square root of the AVE for the GPSN factor was 0.735, which surpassed the maximum absolute value of the inter-factor correlation coefficients, 0.306, indicating good discriminant validity. Finally, the square root of the AVE for the GPBI factor was 0.791, exceeding the highest absolute value of the inter-factor correlation coefficients, 0.384, demonstrating its strong discriminant validity (Table 6).

4.4 Structural equation model analysis

After analysis, the fitting indicators of the variables were determined, and a revised model was obtained with a χ^2/df value of 2.522. Other adaptation indicators include were 0.935 for GFI, 0.914 for AGFI, 0.052 for RMSEA, 0.917 for NFI, 0.901 for RFI, 0.948 for

TABLE 4 The component matrix following rotation.

Item	Component				
	1	2	3	4	5
GIC3	0.818				
GIC1	0.751				
GIC2	0.744				
GIC4	0.739				
GIC5	0.704				
GPBI2		0.854			
GPBI1		0.850			
GPBI3		0.797			
GPBI4		0.706			
GPBA1			0.820		
GPBA4			0.799		
GPBA3			0.787		
GPBA2			0.767		
GPSN1				0.843	
GPSN2				0.815	
GPSN3				0.763	
GPBC3					0.830
GPBC1					0.800
GPBC2					0.729

Extraction method: Principal Component Analysis (PCA).
Rotation method: Kaiser normalized maximum variance method.
Rotation has converged a er 5 iterations.

TABLE 5 Confirmatory factor analysis.

Factor	Measured item	Standard load factor	Standard error	CR value	*p*	AVE	CR
GIC	GIC1	0.691	–	–	–	0.496	0.831
	GIC2	0.692	0.064	14.280	0.000		
	GIC3	0.777	0.069	15.631	0.000		
	GIC4	0.704	0.073	14.481	0.000		
	GIC5	0.651	0.068	13.533	0.000		
GPBA	GPBA1	0.822	–	–	–	0.575	0.844
	GPBA2	0.700	0.052	16.883	0.000		
	GPBA3	0.779	0.050	18.928	0.000		
	GPBA4	0.727	0.053	17.623	0.000		
GPBC	GPBC1	0.737	–	–	–	0.476	0.730
	GPBC2	0.585	0.064	10.878	0.000		
	GPBC3	0.737	0.087	11.517	0.000		
GPSN	GPSN1	0.732	–	–	–	0.540	0.779
	GPSN2	0.749	0.078	14.007	0.000		
	GPSN3	0.723	0.094	13.856	0.000		
GPBI	GPBI1	0.842	–	–	–	0.625	0.869
	GPBI2	0.838	0.045	22.590	0.000		
	GPBI3	0.793	0.044	21.155	0.000		
	GPBI4	0.678	0.045	17.293	0.000		

TABLE 6 Discriminant validity: Pearson correlation and AVE square root values.

Factor	GIC	GPBA	GPBC	GPSN	GPBI
GIC	0.704				
GPBA	0.323	0.758			
GPBC	0.112	0.186	0.690		
GPSN	0.270	0.273	0.127	0.735	
GPBI	0.332	0.384	0.289	0.306	0.791

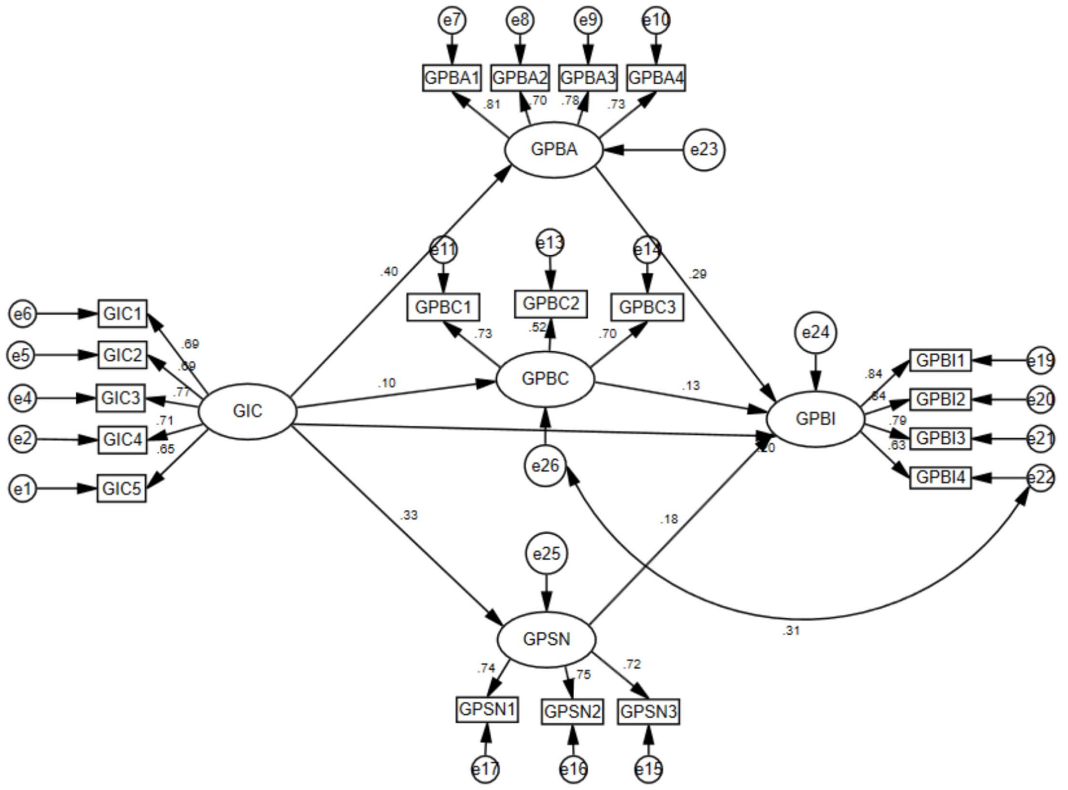

FIGURE 3
Modified model diagram.

CFI, 0.772 for PNFI, and 0.709 for PGFI. Given that all model fitting values were above 0.9, it indicates a strong model fit, as values closer to 1 suggest a better fit according to statistical standards (Figure 3).

Path analysis indicated that the influence coefficients of GPBA, GPBC, and GPSN on GPBI were 0.290, 0.126, and 0.184, respectively. This means that when GPBA, GPBC, and GPSN each increase by one unit, GPBI correspondingly increases by 0.290, 0.126, and 0.184 units, respectively. Therefore, GPBA, GPBC, and GPSN have a significant positive impact on GPBI, assuming that Hypotheses 1, 2, and 3 are all valid. The impact coefficient of GIC on GPBI was 0.204, indicating that GIC has a significant impact on GPBI and hypothesis 4 is valid. The standardization coefficients of GIC for GPBA, GPBC, and GPSN were 0.402, 0.105, and 0.334, respectively. Therefore, GIC has a significant positive impact on GPBA, GPBC, and GPSN, making Hypothesis 5 valid.

From the perspective of specific factors, the factor loading coefficients for GIC were ranked as follows: development prospect (0.772), market price (0.705), brand image (0.692), brand competitiveness (0.691), and quality cognition (0.651). This suggests that farmers' GIC hinges on their expectations for the future development and potential market price increase of the GIAP. For GPBA, the coefficients were ranked as follows: improving the quality of navel orange (0.815), optimizing soil environment (0.785), benefiting physical health (0.733) and achieving a higher price (0.696), thereby highlighting farmers' GPBA focus on green production to enhance product quality and soil protection. The reason why obtaining higher price was ranked last may be that farmers do not have an obvious perception that green production can make Gannan navel oranges sell at a higher price. In terms of GPBC, cognition of green production technology (0.727), convenience of use (0.697) and production conditions (0.525) were ranked in order by coefficient, which indicates that farmers' GPBC should focus on strengthening farmers' training on green production technology and making it easy to obtain and use. In the GPSN, the coefficients were ranked as follows: demonstration effect (0.749), suggestions from relatives, friends, and neighbors (0.736), and advice from experts (0.720), which suggests that farmers attach greater importance to the demonstration effect of those around them and their suggestions from relatives, friends and neighbors (Table 7).

4.5 Indirect effect analysis

In the analysis of the mediating effect of variables, AMOS23.0 was used to analyze the indirect effects. The syntax was set up as follows: M1: GIC → GPBA → GPBI, M2: GIC → GPBC → GPBI, M3: GIC → GPSN → GPBI. Bootstrap method was used to analyze the path for 5,000 iterations, and a 95% variable confidence interval was extracted. The analysis showed that the confidence interval of M1: GIC → GPBA → GPBI was [0.074–0.332]. M2: the confidence interval of GIC → GPBC → GPBI was [0.003–0.070]. M3: the confidence interval of GIC → GPSN → GPBI was [0.023–0.189]. Therefore, the mediating effects of the three paths have been confirmed, and a partial mediating relationship is shown in the analysis. The ranking of the mediating effects is M1 > M3 > M2, indicating that the path from GIC to GPBI through GPBA is the most significant. Therefore, hypothesis 6 is established (Table 8).

5 Discussion

This paper introduced GIC based on the Theory of Planned Behavior (TPB), constructed a theoretical framework and

TABLE 7 Path coefficient analysis.

Factor	Path	Factor	Unstandardized coefficients	S.E.	C.R.	*p*	Standardized coefficients
GPBI	<---	GPBA	0.314	0.054	5.784	***	0.290
GPBI	<---	GPBC	0.132	0.051	2.577	0.010	0.126
GPBI	<---	GPSN	0.178	0.048	3.682	***	0.184
GPBI	<---	GIC	0.311	0.083	3.761	***	0.204
GPBA	<---	GIC	0.565	0.074	7.667	***	0.402
GPBC	<---	GIC	0.152	0.078	1.964	0.049	0.105
GPSN	<---	GIC	0.527	0.086	6.093	***	0.334
GIC1	<---	GIC	1.093	0.081	13.542	***	0.692
GIC2	<---	GIC	0.996	0.074	13.528	***	0.691
GIC3	<---	GIC	1.169	0.080	14.649	***	0.772
GIC4	<---	GIC	1.151	0.084	13.744	***	0.705
GIC5	<---	GIC	1.000				0.651
GPBA1	<---	GPBA	1.000				0.815
GPBA2	<---	GPBA	0.879	0.053	16.599	***	0.696
GPBA3	<---	GPBA	0.953	0.051	18.828	***	0.785
GPBA4	<---	GPBA	0.943	0.054	17.580	***	0.733
GPBC1	<---	GPBC	1.000				0.727
GPBC2	<---	GPBC	0.623	0.067	9.273	***	0.525
GPBC3	<---	GPBC	0.961	0.096	9.970	***	0.697
GPSN1	<---	GPSN	0.776	0.057	13.732	***	0.736
GPSN2	<---	GPSN	0.843	0.061	13.780	***	0.749
GPSN3	<---	GPSN	1.000				0.720
GPBI1	<---	GPBI	1.000				0.841
GPBI2	<---	GPBI	1.012	0.045	22.302	***	0.838
GPBI3	<---	GPBI	0.938	0.045	20.806	***	0.788
GPBI4	<---	GPBI	0.720	0.045	16.155	***	0.631

TABLE 8 Indirect effect analysis.

Path	Indirect effect value	Lower bound of confidence interval	Upper limit of confidence interval	*p*
M1	0.178	0.074	0.332	0.001
M2	0.020	0.003	0.070	0.098
M3	0.094	0.023	0.189	0.015

discussed the influencing factors of GPBI with GIAP from the internal level of farmers. The results confirmed the beneficial effect of GIC on GPBI involving GIAP, demonstrating the applicability of TPB to this research area. To enhance GPBI through GIAP and promote green production among farmers, thereby ensuring product quality and maintaining market competitiveness, interventions are necessary. These should be carried out in the following aspects:

The publicity for GIAP should be increased to improve farmers' GIC. According to the research results, the core of GIC is influenced by farmers' anticipation of the future growth of GIAP and the potential for GIAP to yield increased market prices. Therefore, in the process of government publicity, special attention should be paid to letting farmers fully aware of the value and importance of GIAP, so that they have a good expectation for the future development of GIAP, which can also bring better economic benefits for them.

The GPBA of farmers holds a crucial position in the GPBI, necessitating the reinforcement of farmers' GPBA via education and training programs. Research results indicate that within the GPBA, farmers are primarily concerned with how green production can enhance product quality and benefit soil protection. Hence, in the process of education and guidance, the government ought to emphasize the correlation between green production of GIAP and improved product quality. Green production not only contributes to the protection of soil quality and the reduction of chemical pollution but also ensures the sustainable production of GIAP with unique quality. Additionally, considering the varying education levels of farmers in different counties and regions, tailored educational efforts should be made we can increase educational investment for farmer with lower levels of formal education and further popularize knowledge and technical training on sustainable agricultural practices and green production methods.

Establish models and demonstration projects to foster interactions and collaboration among farmers. Rural areas are "acquaintance society," which is also confirmed in the research results of this paper. Within the GPSN framework, farmers prioritize the demonstrative impact of green production practices adopted by their peers, as well as advice from relatives, friends, and neighbors. Therefore, in regions producing GIAP, efforts should focus on establishing demonstration households and exemplary models to form a supportive environment for the adoption of green production technologies. Organizing experience-sharing activities among farmers can further enhance their awareness and ability of green production. For older farmers in particular, exemplary projects and recommendations from friends and family can help overcome their resistance to new technologies.

Strengthen the formulation and implementation of agricultural policies and provide farmers with necessary resources and technical support. According to the research results, in the GPBC, farmers place greater emphasis on the cognition and convenient access to green production technology. Therefore, it is essential to formulate corresponding agricultural policies to provide farmers with continuous training and guidance on green production technology, as well as ensuring convenient access to green production tools and techniques and green production inputs through agricultural social services. Especially for small-scale farmers, increased technical support should be provided to help them overcome scale constraints and promote their green production behavior.

Compared with other similar research results (Liu et al., 2021), the total effect of GI cognition on green production in this study is relatively low. A possible reason for this may be the low proportion of farmers in the survey sample who have experience with GI use, and the farmers' understanding of GI has not been fully developed. Furthermore, when designing the model in this study, technical capability indicators should have been incorporated into the GPBC to obtain more accurate evaluation results. Due to the limited length of this article, there are certain limitations in this research. Firstly, the model design did not include a subgroup analysis of the specific situation in the two counties, which prevented an understanding of the differences between farmers in the two counties, thus hindering the formulation of localized policies. Secondly, the data sample in this study was based on Gannan navel oranges, which is more applicable to crop-based GI agricultural products, but may have limited reference for livestock and poultry-based GI products. Moreover, due to the constraints of the survey conditions, the data were only collected from Xinfeng and Anyuan counties in Ganzhou. Although these two counties are somewhat representative, the sample size remains small compared to the production of Gannan navel oranges across all counties in Ganzhou. In the future, expanding the survey scope would enhance the generalizability and persuasiveness of the results. Additionally, future research could incorporate more GI-related indicators, such as production regulations and government governance of GIs, into the research framework, in order to better identify beneficial measures that promote the sustainable development of GIAP.

6 Conclusion

Drawing upon the Theory of Planned Behavior (TPB), this article introduces cognitive factors and analyzes survey data collected from farmers in Xinfeng and Anyuan counties of Ganzhou, Jiangxi Province. Through the use of AMOS software and SEM, it explores the influencing factors of the willingness to engage in green production (GPBI). The results indicated that: (1) Farmers' attitudes towards green production (GPBA), perceived behavioral control (GPBC), and subjective norm of green production (GPSN) all have a positive impact on their intention to green production (GPBI), with GPBA having the largest effect, followed by GPSN, and then GPBC. (2) Farmers' cognition of geographical indication (GIC) positively impacts their willingness to implement green production (GPBI). (3) GIC can positively promote farmers' attitudes towards green production (GPBA), perceived behavioral control (GPBC), and social norms regarding green production (GPSN), and indirectly affect their intention to adopt green production practices (GPBI). The order of the effects, based on these three factors, is as follows: GPBA, GPSN, and GPBC.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contributions

QL: Writing – original dra . HL: Writing – review & editing, Funding acquisition. XS: Data curation, Methodology, Writing – review & editing.

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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.

Generative AI statement

e authors declare that no Gen AI was used in the creation of this manuscript.

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