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Analysis of tripartite evolutionary game in the digital transformation of China's rural industries

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Introduction: Promoting the digital transformation of rural industry is a necessary path for the modernization and development of agriculture and rural areas.

Methods: Based on the evolutionary game theory, this study constructs a tripartite evolutionary game model of the government, digital technology suppliers, and rural industry subjects. It analyzes the evolutionary stability strategies and influencing factors of each subject and carries out numerical simulation analysis using MATLAB.

Results: The study found that: (1) The strategy choices of each game subject affect each other. The probability of the government's "encourage" strategy decreases with the increase of the probability of the digital technology supplier's active "supply" or the probability of the rural industry subject's active "adopt." Similarly, a higher "encourage" probability by the government and a higher "adopt" probability by the rural industrial entities showed a higher "supply" probability by the digital technology providers. (2) The size of the initial probability and the change of each parameter have an important impact on the choice of behavioral strategy in the main body of the game. The evolutionary stability strategy eventually converges to the government choosing "encourage," digital technology suppliers choosing "supply," and rural industry subjects choosing "adopt."

Discussion: This study biggest difference from previous research is that found that the evolutionary stability strategy ultimately converges to encourage the government, supply digital technology suppliers, and adopt rural industry entities. However, there are also shortcomings in the article, such as neglecting other stakeholders. this study finally proposes relevant suggestions from the government, digital technology suppliers, and rural industrial subjects.

KEYWORDS

rural industry, digital transformation, tripartite evolutionary game, China, QCA

1 Introduction

Rural industries are the basis for promoting farmers' income and rural development, and persisting in the sustainable development of rural industries is an intrinsic requirement of China's strategy of comprehensively promoting rural revitalization (Peng et al., 2023). Throughout the development history of other countries in the world, countries have generally faced the problem of rural decline in the process of urbanization (Cheng et al., 2019). The most important reason for this problem is the lack of effective support from rural industries, which is manifested in a short rural industrial chain, low efficiency, and a single structure (Tan, 2019). With the rapid development of information technology, digital transformation has become an inevitable trend in the development of global rural industry

(Haefner and Sternberg, 2020). Digital empowerment plays an important role in achieving rural revitalization and promoting rural modernization (Cao et al., 2023). Digital economy takes data as the core element, accelerating the integration of modern industrial elements and traditional industries in the countryside (Hu et al., 2023). New-generation information technology, such as artificial intelligence, supports data collection of multiple agricultural processes through devices promoted under the "Internet of Things," promoting the intelligent and sustainable development of agriculture (De Alwis et al., 2022). However, many new issues have emerged in the process of digital transformation. For example, the digital divide in rural areas continues to widen (Shao, 2022), and the more remote the countryside, the less digital connection it has with the outside world (Tranos, 2012). According to the "China Enterprise Digital Transformation Index (2021)"[1] only 16% of Chinese enterprises had significant digital transformation in 2021, which is still a gap compared with developed countries. Therefore, the problem of effectively promoting the digital transformation of rural industries in China, such that it increases adoption of digital technologies and consequently rural revitalization, is among the state's top strategic priorities.[2]

Nadkarni and Prügl (2021) argued that the study of digital transformation should start from both technology and participant dimensions, and with the increasing maturity of technology, the participant dimension should be given more attention. Existing literature on digital transformation of rural industries mainly focuses on the connotative features (Liu et al., 2020), the driving mechanism (Lapuz, 2023), and the realization path (Bryant and Higgins, 2021). In the research on the realization path, scholars mainly proposed countermeasures and suggestions from the perspectives of the government, villagers, enterprises, and other participants, which provides a basis for this article. However, there are fewer existing studies focusing on the interaction of subjects' behaviors. The digital transformation of China's rural industry not only requires the guidance of top-level design but also depends on the first exploratory practice of rural industrial subjects. It is the result of the joint action of various internal and external forces, such as the government, the external technology market, and rural industrial subjects (Hu, 2023).

Thus, the digital transformation of China's rural industry depends on the joint actions by the government, the external technology market, and rural industrial subjects. For the development of China's rural industry, technology suppliers are the source of technology for digital transformation, the subjects of the rural industry itself are the main body of digital transformation, and the government provides the necessary institutional environment. Therefore, the digital transformation of China's rural industry needs the support, cooperation, and coordination of the government, digital technology suppliers, rural industry subjects, and other participants. This process involves a behavioral game among the subjects of interest, which is also the focus of this study—that is, to analyze the game of the evolution of the behavior of the subjects of interest in the digital transformation of China's rural industry.

1 Data sourced from: https://m.thepaper.cn/baijiahao_14626542.

2 http://en.cppcc.gov.cn/2023-03/03/c_865754.htm

The behavior of the subjects of interest is an important factor affecting the effective empowerment of digital technology for the high-quality development of rural industry, and the study of the evolutionary game of the subjects of interest's behavior is of great significance in guiding the government to promote the high-quality development of rural industry in the real situation. Evolutionary game theory combines game theory and dynamic evolutionary process together, using the game of limited rationality as the analytical framework, which is more in line with the reality that decision makers are not completely rational, and believes that in reality, the decision-making behavior of individuals is to achieve dynamic equilibrium through the process of imitation, learning, and mutation among each other. Participants in the digital transformation of China's rural industries usually have limited rationality, and they must continuously learn by trial and error through the game process to find better strategic choices.

Based on the above, we use evolutionary game theory to construct a three-party (government, digital technology suppliers, and rural industry subjects) evolutionary game model to analyze the evolutionary stability of each party's strategy. We use MATLAB to represent and simulate the evolutionary process of the three parties' behavioral strategies to discover the key factors affecting their respective strategic choices, equilibrium, and stability strategies, thereby providing a theoretical basis for state actions aimed at promoting the digital transformation of China's rural industries. The main structure of the article is as follows: first, it reviews the related literature on digital transformation of rural industry, evolutionary game theory, and its application and proposes the research questions; second, it presents the research hypotheses and constructs the model; third, it analyzes the subject's evolutionary stabilization strategy to find out the key factors affecting the subject's strategy choice and the equilibrium stabilization strategy; fourth, it conducts the numerical simulation analysis on the model to validate the model; and finally, it summarizes the conclusions of the research and provides countermeasure suggestions and future research prospects. The innovation of this study lies in the application of evolutionary game theory, for the first time, to study the digital transformation of rural industries. The study finds that the evolutionary stability strategy eventually converges to the government choosing "encourage," digital technology suppliers choosing "supply," and rural industry subjects choosing "adopt".

2 Literature review

2.1 Digital transformation of rural industries

In recent years, academics have carried out a lot of research on the digital transformation of rural industries, with related topics focusing on connotation characteristics, driving mechanisms, realization paths, and other aspects.

First, the connotation of the digital transformation of rural industries. The process of digital transformation is essentially a process in which "digital technology" drives changes in the business activities of the "target" (Vial, 2019). The digitalization of industry is the use of digital technology to upgrade and transform traditional industries to enhance the process of production efficiency, while the rural industry has its own specificity: the rural areas around the resource endowment and the development of the situation presents a big difference and has a different connotation of features (Qiu et al., 2023). Therefore, at present, there is no uniform conclusion in the academic community about the connotation of the digital transformation of rural industries. Liu et al. (2020) believed that the digital transformation of rural industry is the process of integrating data elements into all aspects of the traditional rural industry chain, with data as key production factors and modern information networks as the carrier. This involves transforming the traditional production and operation methods, promoting the digital transformation of rural industry, upgrading the value chain, integrating the primary, secondary, and tertiary industries, optimizing the structure of the rural industry, upgrading the quality of the development of the rural industry, and promoting the three-dimensional process of realizing the overall benefits of the rural industry. Jantti and Aho (2023) consider the digital transformation of the rural industry as a new way of thinking to promote high-quality and integrated development, which benefits its stakeholders by reducing costs, increasing productivity, and establishing new operating models. Qiu et al. (2023) point out that, in terms of industry types, the digital transformation of rural industries in general exhibits hierarchical and staged characteristics of development. This study draws on the definition of Wang and Li (2022) and considers that the digital transformation of rural industries is the process of digitally transforming all elements of the rural industrial chain using "digital technology".

Second, the driving mechanism of the digital transformation of rural industries. It has been widely recognized that the wide application of digital technology promotes its deep integration with rural industries and drives the transformation and upgrading of rural industries. Lapuz (2023) points out that digital technology is a key factor in the digital transformation of the rural tourism model. Westerman (2016) found that digital platforms promote the productivity of rural industries. Reina-Usuga et al. (2022) argued that the digitization of the whole chain of agriculture promotes the improvement of the production efficiency of the whole industrial chain, the industrial structure, the new market of products, and the synergistic division of labor of the main bodies and promotes and leads the transformation of agriculture to digital agriculture or agriculture 4.0 (Han et al., 2023). Jakku et al. (2022) found that the digital transformation of agriculture involves advances in information and communication technologies (ICTs) that drive productivity and efficiency while reducing risks and negative impacts. Ahmed et al. (2022) also found that technological advances have an important moderating role in the digital transformation model. Anderson et al. (2016) noted that broadband technology facilitates the development of rural creative enterprises. Xue et al. (2022) pointed out that the digital economy is profoundly changing human production and lifestyle due to the benefits of digital technological progress, promoting the dual digital transformation of both the supply and demand side of industries.

Third, the realization path of digital transformation of rural industries. Scholars believe that the realization of digital transformation of rural industry requires both rational allocation of resource elements and coordination of the behavior of the main body of interests. On the one hand, it involves coordinated allocation of labor, technology, policy, and other resource elements. Douglass (2018) believes that the intrinsic thrust of the development of digital transformation of rural industries is intersected with the external radiation diffusion force of the city through a series of factor flows. Liu S. et al. (2023) pointed out that the degree of human capital of the rural labor force affects the construction of digital countryside in China, which not only restricts the development potential of digital countryside but also affects the development of the digital rural pension service industry. Liu B. et al. (2023) pointed out that green low-carbon rural development (GLRD) has become an important way to explore sustainable development in China's rural areas, which requires the support of green technologies. Zhang et al. (2023) pointed out that digital inclusive financial policies are found to be effective in promoting the prosperity of rural industries and facilitating the digital development of Chinese rural industries.

On the other hand, it involves coordinating the behaviors of industry digital development stakeholders. Bryant and Higgins (2021) found that farm advisors and agronomists play a key role in the adoption of smart agricultural technologies, and more attention should be given to these subjects. Cloete and Doens (2008) pointed out that with the advancement of information technology, more and more decision makers in agriculture are inclined to participate in e-commerce and promote the development of rural e-commerce. Mei et al. (2022) pointed out that the entrepreneurial activity of the digital industry is an important mechanism for digital village construction to promote the high-quality development of the rural economy, and it is necessary to stimulate and protect the entrepreneurial enthusiasm of farmers.

2.2 Evolutionary game theory and its application

Maynard and Price's article "The Logic of Animal Conflict" (Smith and Price, 1973), published in *Nature*, *first* introduced the idea of evolutionary games. The theory originated from academic explanations of ecological phenomena and is a theory based on Darwinian ideas of biological evolution. The evolutionarily stable strategy and the replicator dynamic equation are two core concepts of evolutionary game theory. The so-called evolutionarily stable strategy means that if the vast majority of individuals in a group choose this strategy, then groups with other strategies will not invade this group (Smith, 1974). The replication dynamic equation further promotes the development of evolutionary game theory, which is a dynamic strategy adjustment mechanism that describes the equilibrium of finite rational parties to the game by learning and imitating the superior strategy through differential equations (Taylor and Jonker, 1978). Evolutionary game theory combines game theory and dynamic evolutionary process (Smith, 1974), using the game of limited rationality as the analytical framework, which is more in line with the reality that decision makers are not completely rational, and believes that in reality, the decision-making behavior of individuals is to achieve dynamic equilibrium through the process of imitation, learning, and mutation among each other (Weibull, 1997). Since the twenty-first century, evolutionary game theory has been widely applied and developed. The related topics are more scattered. For example, Zhu and Dou (2007) analyzed the costs and benefits of the government and core enterprises in green supply chains by establishing an evolutionary game model and pointed out the factors affecting the

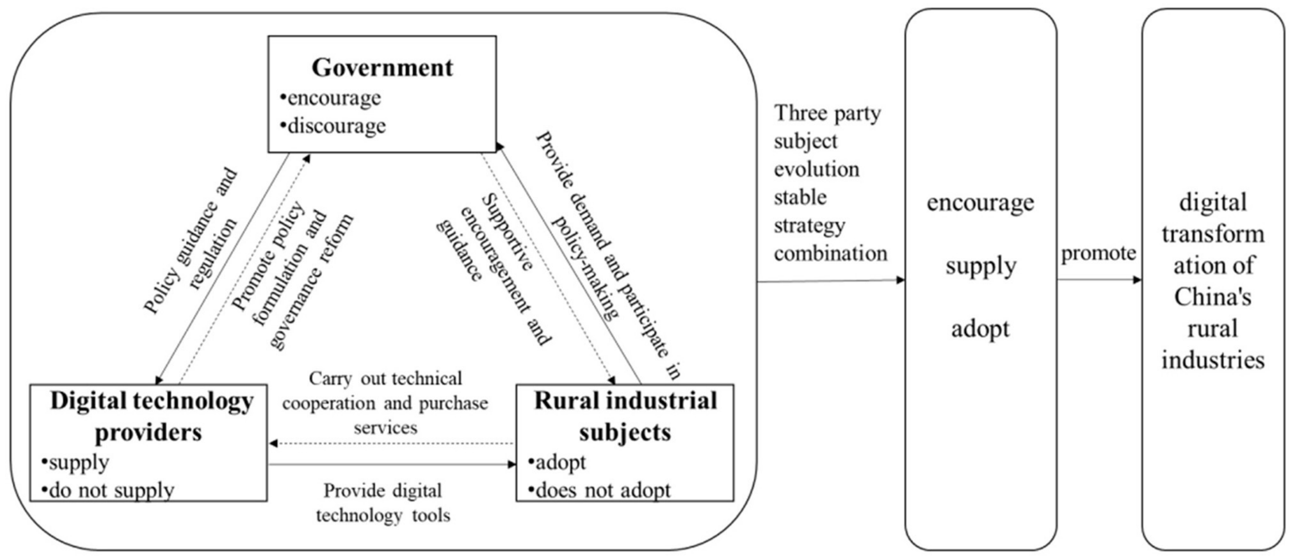

FIGURE 1
The mechanism of action of the subjects of the three-way evolutionary game.

outcome of the game. Xiao et al. (2021), based on the evolutionary game model, studied the preventive and control behaviors of online users and the government in the process of data sharing and information disclosure. Arifovic and Ledyard (2004) used evolutionary games to analyze the differences in human behavior under specific conditions and the reasons for them. Chong and Sun (2020) used an evolutionary game to analyze the relationship between polluting firms and local governments and argued that increasing environmental penalties for local governments alone does not provide incentives for local governments to perform their regulatory duties.

In summary, existing research has deeply analyzed the connotation characteristics, driving mechanisms, and implementation paths of digital transformation of rural industries from both qualitative and quantitative perspectives, laying the foundation for this study. However, there are certain differences between domestic and foreign research. In China, qualitative research is the main focus, empirical research is scarce, and the research perspective tends to be macro; whereas, in foreign countries, quantitative experimental research is emphasized, and the research perspective tends to be micro. In terms of research content, domestic research focuses on analyzing the impact of digital technology on rural tourism and agriculture, while foreign research mainly focuses on the impact of technology on agriculture, rural areas, farmers, and other aspects. At present, there is relatively little discussion on the behavior of stakeholders in the digital transformation of rural industries both domestically and internationally, and there is a lack of in-depth analysis of the interactive patterns among stakeholders. What are the patterns of behavior among various stakeholders in the digital transformation of rural industries? Participants in the digital transformation of China's rural industries usually have limited rationality, and they must continuously learn by trial and error through the game process to find better strategic choices. Based on the evolutionary game theory, this study analyzes the evolutionary stabilization strategies of the government, digital technology suppliers, and rural industry subjects, and it explores the role of the subject's behavioral strategy choices to provide a theoretical basis for the government's decision-making.

3 Assumptions and modeling

3.1 Definition of participating subjects

High-quality development of digital technology for rural industries is a complex, systematic project involving multiple subjects of interest, of which the three main types of subjects are the government, digital technology providers, and rural industry subjects. They depend on each other and cooperate to jointly promote the digital transformation and innovative development of rural industries and realize the goal of high-quality development, as shown in Figure 1.

3.1.1 Government

The government plays an important role in digital technology-enabled high-quality development of rural industries, serving as a bridge to promote cooperation between rural industrial entities and digital technology providers. On the one hand, the government encourages rural industrial entities to actively adopt digital technologies to improve the efficiency and quality of agricultural production by providing financial subsidies, preferential policies, training and technical guidance, and Internet access. On the other hand, the government guides and supports the development of digital technology suppliers and incentivizes them to provide digital technology through public procurement and cooperation, price subsidies, building digital infrastructure, and organizing training and promotional activities. At the same time, the government also plays the role of regulating the compliance and data security of digital technologies, ensuring the sustainability of digital development and fair competition. The government's interests lie in promoting the upgrading of rural industries, fostering rural economic growth, and improving the quality of life of rural residents.

3.1.2 Digital technology providers

Digital technology suppliers are enterprises or organizations that provide various digital technology tools, platforms, solutions, and services. They are the main supplying body of digital technology and the supporter of digital transformation of rural industries, including Internet technology companies, software developers, and data analysis companies. They play an indispensable role in the digital technology trading market. On the one hand, they can provide rural industrial entities with digital technology tools, customized digital technology solutions, etc., to help them improve production efficiency, product quality, and market competitiveness and promote the digital transformation of rural industries. On the other hand, the innovations and practices of digital technology providers can also provide an important basis and reference for the government to formulate relevant policies and promote changes in governance. Through actual cases and data, they demonstrate to the government the potential and effect of digital technology to empower the development of rural industries, provide technical support and professional advice, promote the implementation of policies, and advance digital governance, thus promoting the high-quality development of rural industries. The interest of digital technology suppliers lies in providing technical solutions, products, and services to rural industrial subjects to realize business value and profitable growth.

3.1.3 Rural industrial subjects

Rural industry subjects refer to the application subjects of digital technology, the actual operators, and participants of rural industries, including farmers, rural cooperatives, and agricultural enterprises. They are the demand side of the digital technology trading market. On the one hand, rural industrial subjects need to choose suitable digital technology suppliers, carry out technical cooperation, or purchase related technical products and services. Through cooperation with digital technology suppliers, they can obtain the support of innovative technology, improve production efficiency, expand market channels, and achieve the goal of digital transformation. On the other hand, rural industrial subjects need to establish effective communication channels with the government, provide demand and feedback, and participate in the process of rural industrial policy making and development planning. They can leverage government support for financial support, policy concessions, and market expansion opportunities. The interests of rural industrial subjects lie in enhancing industrial competitiveness, creating value, and providing better services through digital technology.

3.2 Assumptions

3.2.1 Behavioral strategies of game subjects

This study puts forward assumption 1: under the "natural" conditions without considering other constraints, the government, digital technology suppliers, rural industry subjects as a complete system, assuming that each subject in the system is a finite rationality subject, the information mastered by each subject has incomplete asymmetry, and each party is in the initial stage of the game in the evolution game. Initial stage, the game process does not take into account other subjects that may affect the three parties of the game.

Assumption 2: Strategy space. The set of government's behavioral strategies is $A_1 = \{U_1$ encourage, U_0 discourage$\}$, "encourage" means that the government encourages rural industrial subjects to adopt digital technology for production and encourages digital technology suppliers to provide digital technology by introducing policies, improving public infrastructure construction, and granting financial subsidies, and "discourage" means that the government has a wait-and-see, negative attitude toward the adoption of digital technology by rural industrial subjects and the provision of digital technology by digital technology suppliers, and it does not mean that the government opposes these behaviors.[3] The set of behavioral strategies of digital technology suppliers is $A_2 = \{V_1$ supply, V_0 do not supply$\}$, "supply" means that digital technology suppliers provide digital technology to rural industrial subjects, "do not supply" means that digital technology suppliers do not provide digital technology to rural industrial subjects. The set of behavioral strategies of the rural industrial entity is $A_3 = \{W_1$ adopt, W_0 does not adopt$\}$, "adopt" means that the rural industrial subjects adopt digital technology to engage in production activities, and "does not adopt" means that the rural industrial subjects engage in production activities traditionally.

3.2.2 Probability of behavioral strategy choice

Assumption 3: Strategy selection probability. In the initial stage of the tripartite game among the government, digital technology suppliers, and rural industrial subjects, the probability that the government chooses the strategy of "encourage" is x, and the probability that the government chooses the strategy of "discourage" is $1 - x$; the probability that the digital technology supplier chooses the "supply" strategy is y, and the probability that the supplier chooses the "do not supply" strategy is $1 - y$; and the probability that the rural industry subjects chooses the "adopt" strategy is z, and the probability that the rural industry subjects chooses the "does not adopt" strategy is $1 - z$, where, $0 \leq x \leq 1$, $0 \leq y \leq 1$, and $0 \leq z \leq 1$.

3.2.3 Model parameter setting

Assumption 4: Strategic gains. Using R_1 represents the reward of the government's "encourage" strategy in terms of rural economic growth, increased employment opportunities, and improved resource utilization efficiency. Using R_2 represents the

3 Discouragement includes wait-and-see, passivity and opposition. When the government opposes, digital technology suppliers may face administrative penalties for supplying digital technology strategies and rural industrial entities may face penalties for choosing to adopt digital technology strategies, while the government does not impose penalties when it is passive and wait-and-see. This paper mainly refers to the government's negative treatment and wait-and-see attitude.

reward of the digital technology supplier's "supply" strategy in terms of sales revenues, expanded market share, and technological feedback and improvement. Neither the government nor the digital technology supplier has alternative rewards for "does not encourage" and "does not supply," because they can only benefit from the initiative—it can't get worse. Using R_3 represents the reward of the rural industrial subjects' "adopt" strategy in terms of improved production efficiency and product quality and quantity, expanded product sales channels, and increased revenues. Using R_4 represents the reward of the rural industrial subjects' "does not adopt" strategy, which benefits from production in the traditional way, where $0 < R_4 < R_3$. The reason is that digital technology can improve production efficiency and bring greater rewards to the rural industrial subjects. If the rewards R_3 are not higher than R_4, they will not adopt digital technology.

Assumption 5: Strategy costs. The government generally encourages rural industrial subjects to adopt digital technology for production and encourages digital technology suppliers to provide digital technology through technical guidance, infrastructure construction, education and training, policy formulation, management and supervision, and so on, and the cost of the digital technology suppliers to rural industrial subjects is C_1 ($0 < C_1 < R_1$). The cost of "supply" of digital technology to rural industrial subjects is C_2 ($0 < C_2 < R_2$), which mainly includes technology research and development, production and operation, marketing, and after-sales service. Rural industrial subjects "adopt" digital technology for production need to pay for technical equipment and supporting products purchase and equipment maintenance costs, network access costs, training and learning and technical consulting costs and other costs, set to C_3 ($0 < C_3 < R_3$), while "does not adopt" digital technology will need to pay the cost of C_4, that is, in accordance with the traditional way of production of human resources, materials and other resources invested in the cost of production. Where, $0 < C_3 < C_4$, $0 < R_4 - C_4 < R_3 - C_3$.

Assumption 6: External rewards. When digital technology suppliers "supply" digital technology for rural industrial subjects, the potential reward of the government is the transformation of governance, agricultural digital efficiency, agricultural product safety and security, and other external gains, which is set as S_1; when rural industrial subjects "adopt" digital technology to engage in production activities, the potential reward of the government is resource saving, stable income security of agricultural products, and so on, which is set as M_1; When the government adopts the strategy of "encourage," the potential reward of digital technology suppliers is price subsidies and special funds for digital technology suppliers, which is set as G_1; when digital technology suppliers "supply" digital technology, the potential reward of rural industrial subjects is more development opportunities and customized services, which is set as S_2; when the government adopts the strategy of "encourage," the potential reward of rural industrial entities is subsidies for the purchase of technological equipment, technological guidance, and educational resources, which is set as G_2.

According to the stakeholder theory, the government is the defender and representative of the public interest in the tripartite evolutionary game, and its ultimate goal is to promote the high-quality development of the rural economic and social society, which includes the promotion of win–win situation for the main players to achieve the common governance of the stakeholders. The government provides subsidies and technical guidance to digital technology suppliers and rural industrial subjects, which, on the one hand, can motivate digital technology suppliers to increase technology research and development, encourage technology to sink into grassroots rural areas, and improve technological innovation and radiation capacity, and on the other hand, it can help rural industrial subjects to master and use digital technology, promote the wide application of digital technology in rural areas, and promote the digital development of rural industries, and then realize the development of the rural economy. From an overall perspective, the benefits gained by the government are far greater than the costs it pays (including the subsidies given to each subject). Therefore, there are $0 < G_1 + G_2 + C_1 < R_1$.

Assumption 7: External costs and losses. The external costs or losses of digital technology suppliers are that when the government adopts the strategy of "discourage," it will lead to digital technology suppliers' intellectual property rights not being guaranteed by the system, a lack of motivation for technological innovation, and a reduction of R&D investment, which is set as G_3. When rural industrial subjects choose "does not adopt" strategy, it will bring external costs and losses such as an increase in inventory cost, a decrease in market share, and a decrease in R&D motivation, which is set as M_2. Potential costs or losses of the government, as well as the rural industrial entity's choice of "does not adopt" strategy, may lead to the government's decrease in tax revenue and inefficient resource utilization, which is set as M_3. The assumptions and meanings of the relevant parameters in the evolutionary game model are shown in Table 1.

3.3 Evolutionary game model construction

3.3.1 Strategy combination and payment matrix for government, digital technology providers, and rural industry subjects

Based on the behavioral strategies of the government, digital technology suppliers, and rural industry subjects, eight combinations of strategies between the three can be derived, namely (U_1 encouraged, V_1 supplied, W_1 adopted), (U_1 encouraged, V_1 supplied, W_0 did not adopt), (U_1 encouraged, V_0 did not supply, W_1 adopted), (U_1 encouraged, V_0 did not supply, W_0 did not adopt), (U_0 discouraged, V_1 supplied, W_1 adopted), (U_0 discouraged, V_1 supplied, W_0 did not adopt), (U_0 discouraged, V_0 did not supply, W_1 adopted), and (U_0 discouraged, V_0 did not supply, W_0 did not adopt).

From the parameter assumptions and meanings in Table 1, it can be seen that when the combination of strategies is (U_1 encouraged, V_1 supplied, W_1 adopted), the government obtains the benefit R_1, the external benefit S_1 brought by the digital technology supplier's supply of digital technology, as well as the potential benefit M_1 brought by the rural industrial entity's choice of the "adoption" strategy, and at the same time, it needs to pay certain costs C_1 and the incentives G_1 and G_2 given to the digital technology supplier and the rural industrial subjects; the digital technology supplier receives the benefits R_2 and the government's incentives G_1 and needs to pay a certain cost C_2; the rural industrial

TABLE 1 Model parameters and meanings.

Parametric	Meaning
R_1	The Government's adopt "encourage" strategy has yielded benefits in terms of rural economic growth, increased employment opportunities and more efficient use of resources.
R_2	The benefits of a "supply" strategy by digital technology vendors in terms of sales revenues, market share gains, technology feedback and improvements.
R_3	Rural industrial subjects adopt the "adopt" strategy to gain benefits such as increased productivity and product quality, expanded sales channels and increased income.
R_4	Gains from the "does not adopt" strategy of rural industrial agents (that is gains from producing in the traditional way).
C_1	Costs of technical guidance, infrastructure development, education and training, policy formulation, regulatory oversight, etc., of the "encourage" strategy adopted by the Government.
C_2	Costs of technology development, production and operation, marketing, after-sales service, etc. for digital technology suppliers adopting a "supply" strategy.
C_3	The "adoption" strategy adopted by rural industrial entities brings with it costs for the purchase and maintenance of technical equipment and ancillary products, network access fees, training and learning, and technical advice.
C_4	The cost of "does not adopt" (i.e., the cost of human, material and other resources invested in production in the traditional way) by rural industrial subjects.
G_1	The Government adopts an "encourage" strategy by granting price subsidies, special funds, etc., to digital technology providers.
G_2	The Government has adopted an "encourage" strategy to subsidize the purchase of technical equipment, technical guidance and educational resources for rural industrialists.
G_3	As a result of the Government's "discourage" strategy, intellectual property rights of digital technology suppliers are not protected by the system, and there is a lack of incentive for technological innovation and a reduction in research and development R&D investment.
S_1	The "supply" strategy adopted by digital technology vendors brings potential benefits to governments in terms of transforming governance, digitizing and making agriculture more efficient, and ensuring the safety and security of agricultural products.
S_2	The "supply" strategy adopted by digital technology providers brings external benefits such as increased development opportunities and customized services to rural industry players.
M_1	Adoption of the "adoption" strategy by rural industrial entities brings potential benefits to the government in terms of resource savings, stable income and security of agricultural products.
M_2	Indirectly, the "does not adopt" strategy adopted by rural industry players has resulted in higher inventory costs, lower market share and reduced incentives for research and development for digital technology suppliers.
M_3	The adoption of a "does not adopt" strategy by rural industrialists has resulted in reduced tax revenues and inefficient use of resources by the government.

All parameters are proposed by the author based on experience and rural industrial development practice, and parameter symbols only serve for identification purposes and do not affect the research results.

entity receives the benefits R_3, the government's incentives G_2, and the external benefits S_2 brought by the digital technology supplier's supply of digital technology and needs to pay a certain cost C_3.

When the strategy combination is (U_1 encouraged, V_1 supplied, W_0 did not adopt), the government obtains the benefit R_1 and the external benefit S_1 from the supply of digital technology by the digital technology supplier, while paying a certain cost C_1 as well as the incentives G_1 to the digital technology supplier, and the loss M_3 caused by the non-adoption of the rural industrial subjects; the digital technology supplier obtains the benefit R_2 and the government's incentives G_1, and the cost C_2 and the inventory cost caused by the non-adoption of digital technology by the rural industrial subjects M_2; farmers gain R_4 and need to pay a certain cost C_4.

When the combination of strategies is (U_1 encouraged, V_0 did not supply, W_1 adopted), the government receives the benefit R_1 and the potential benefit M_1 of the rural industrial entity choosing the "adopt" strategy, and at the same time, it needs to pay a certain cost C_1 and the incentives for the rural industrial entity to adopt the digital technology G_2; the digital technology supplier has no gain in the game because it does not supply digital technology, but incurs an inventory cost, which is the same as the increase in inventory caused by the rural industrial subjects' non-adoption of digital technology and is M_2. Because the digital technology supplier does not supply digital technology, the rural industrial subjects can only produce in the traditional way, obtaining a gain R_4 and paying a cost C_4.

When the combination of strategies is (U_1 encouraged, V_0 did not supply, W_0 did not adopt), the government receives a gain R_1 with a cost C_1 and a loss M_3 caused by the rural industrial subjects does not adopt digital technology; the digital technology supplier has no gain but incurs a cost M_2, and the rural industrial entity can only produce according to the traditional way and receives a gain R_4 and incurs a cost C_4.

When the strategy combination is (U_0 discouraged, V_1 supplied, W_1 adopted), the strategy adopted by the government does not generate benefits and costs due to discouragement, but it can obtain the external benefits S_1 from the supply of digital technology by the digital technology supplier, and the potential benefits M_1 from the rural industrial entity's choice of the "adoption" strategy; the digital technology supplier obtains the benefits R_2 with costs C_2 and losses G_3 due to government disincentives; Rural industrialists receive benefits R_3 and external benefits S_2 from the supply of digital technologies by digital technology suppliers, with costs C_3.

When the strategy combination is (U_0 discouraged, V_1 supplied, W_0 did not adopt), the government can obtain the external gain S_1 from the supply of digital technology by the digital technology supplier, but the non-adoption of digital technology by the rural industrial entity will also cause the external loss M_3 of the government; the digital technology supplier obtains the gain R_2, and at the same time, it needs to pay a certain cost C_2, and the increase in the cost of inventory caused by the non-adoption of digital technology by the rural industrial entity M_2 and the loss G_3 caused by the government; the rural industrial entity receives a gain R_4 and pays a cost C_4.

TABLE 2 Behavioral strategy combinations and game payment matrices of the three subjects.

Strategic combination	Government revenue	Digital technology supplier revenue	Rural industrial subjects revenue
(U_1, V_1, W_1)	$R_1 + S_1 + M_1 - C_1 - G_1 - G_2$	$R_2 + G_1 - C_2$	$R_3 + G_2 + S_2 - C_3$
(U_1, V_1, W_0)	$R_1 + S_1 - C_1 - G_1 - M_3$	$R_2 + G_1 - C_2 - M_2$	$R_4 - C_4$
(U_1, V_0, W_1)	$R_1 + M_1 - C_1 - G_2$	$-M_2$	$R_4 - C_4$
(U_1, V_0, W_0)	$R_1 - C_1 - M_3$	$- M_2$	$R_4 - C_4$
(U_0, V_1, W_1)	$S_1 + M_1$	$R_2 - C_2 - G_3$	$R_3 + S_2 - C_3$
(U_0, V_1, W_0)	$S_1 - M_3$	$R_2 - C_2 - M_2 - G_3$	$R_4 - C_4$
(U_0, V_0, W_1)	M_1	$-M_2$	$R_4 - C_4$
(U_0, V_0, W_0)	$-M_3$	$-M_2$	$R_4 - C_4$

Author's own production.

When the combination of strategies is (U_0 discouraged, V_0 did not supply, W_1 adopted), the government adopts a strategy that generates no benefits or costs of its own, but receives a potential benefit M_1 from the rural sector's choice to 'adopt' the strategy; the digital technology supplier receives no benefit but incurs a cost M_2, and the rural sector receives a benefit R_4 at a cost of C_4.

When the strategy combination is (U_0 discouraged, V_0 did not supply, W_0 did not adopt), the government adopts a strategy that does not generate benefits and costs by itself, but because the rural industrial entity does not adopt digital technology, this results in an external loss M_3 to the government, such as reduced tax revenues and inefficient use of resources; the digital technology supplier has no benefit but incurs costs M_2; the rural industrial entity receives a benefit R_4 and pays a cost C_4. The strategy combinations of the behaviors and the evolutionary game payment matrices are shown in Table 2.

3.3.2 Replicated dynamic equations for tripartite evolutionary game

"Replication dynamics" is one of the core categories of evolutionary game theory, which is a dynamic description and analysis of the process of adjusting the behavioral strategies of a finite rational game subject (Sun and Sun, 2016). It is a dynamic description and analysis of the adjustment process of the behavioral strategies of limited rationality game subjects. In the following, we construct the replication dynamics equations for the behavioral strategies of the government, digital technology suppliers, and rural industry subjects, respectively.

Assuming that the expected benefit to the government of encouraging digital technology suppliers to supply digital technology vs. encouraging rural industry players to adopt digital technology is E_g, the expected benefit of "discourage" is $\sim E_g$, and the average expected benefit to the government is E_1. Let x be the probability that the government chooses the strategy of "encourage," and y and z be the probabilities of the supplier and subjects encouraging and adopting the digital technology, respectively, then we have the following:

$$E_1 = x\, E_g + (1 - x) \sim E_g \tag{1}$$

$$\begin{aligned} E_g &= yz(R_1 + S_1 + M_1 - C_1 - G_1 - G_2) + y(1-z)(R_1 + S_1 - C_1 \\ &- G_1 - M_3) + (1-y)z(R_1 + M_1 - C_1 - G_2) + (1-y)(1-z)(R_1 \\ &- C_1 - M_3) \\ &= yS_1 - yG_1 + zM_1 + zM_3 - zG_2 + R_1 - C_1 - M_3 \end{aligned} \tag{2}$$

$$\begin{aligned} \sim E_g &= yz(S_1 + M_1) + y(1-z)(S_1 - M_3) + (1-y)z(M_1) + (1-y)(1-z) \\ &- (M_3) \\ &= yS_1 + zM_1 + zM_3 - M_3 \end{aligned} \tag{3}$$

The replicated dynamic equation for the constructed government behavioral strategy is as follows:

$$\begin{aligned} F(x) &= dx/dt = (xE_g - E_1) = x(1-x)(E_g - \sim E_g) \\ &= x(1-x)\left[yS_1 - yG_1 + zM_1 + zM_3 - zG_2 + R_1 - C_1 \right. \\ &- \left. M_3 - (yS_1 + zM_1 + zM_3 - M_3)\right] \\ &= x(1-x)(R_1 - C_1 - yG_1 - zG_2) \end{aligned} \tag{4}$$

Similarly, assuming that the expected return on the strategy of digital technology suppliers choosing to "supply" digital technology to rural industrial entities is E_b, the expected return on the strategy of "do not supply" is $\sim E_b$, and the average expected return on the digital technology suppliers is E_2, we have the following:

$$E_2 = yE_b + (1-y) \sim E_b \tag{5}$$

$$\begin{aligned} E_b &= xz(R_2 + G_1 - C_2) + x(1-z)(R_2 + G_1 - C_2 - M_2) + (1-x) \\ &- z(R_2 - C_2 - G_3) + (1-x)(1-z)(R_2 - C_2 - M_2 - G_3) \\ &= xG_1 + xG_3 + zM_2 + R_2 - C_2 - M_2 - G_3 \end{aligned} \tag{6}$$

$$\begin{aligned} \sim E_b &= xz - (M_2) + x(1-z) - (M_2) + (1-x)z - (M_2) + (1-x)(1-z) \\ &- (M_2) = (-M_2) \end{aligned} \tag{7}$$

The constructed replication dynamic equation for the behavioral strategies of digital technology suppliers is as follows:

$$\begin{aligned} F(y) &= dy/dt = (yE_b - E_2) = y(1-y)(E_b - \sim E_b) \\ &= y(1-y)\left[xG_1 + xG_3 + zM_2 + R_2 - C_2 - M_2 - G_3 - (-M_2)\right] \\ &= y(1-y)(xG_1 + xG_3 + zM_2 + R_2 - C_2 - G_3) \end{aligned} \tag{8}$$

Similarly, assuming that the expected return of the rural industrial entity choosing the strategy of "adopt" digital technology

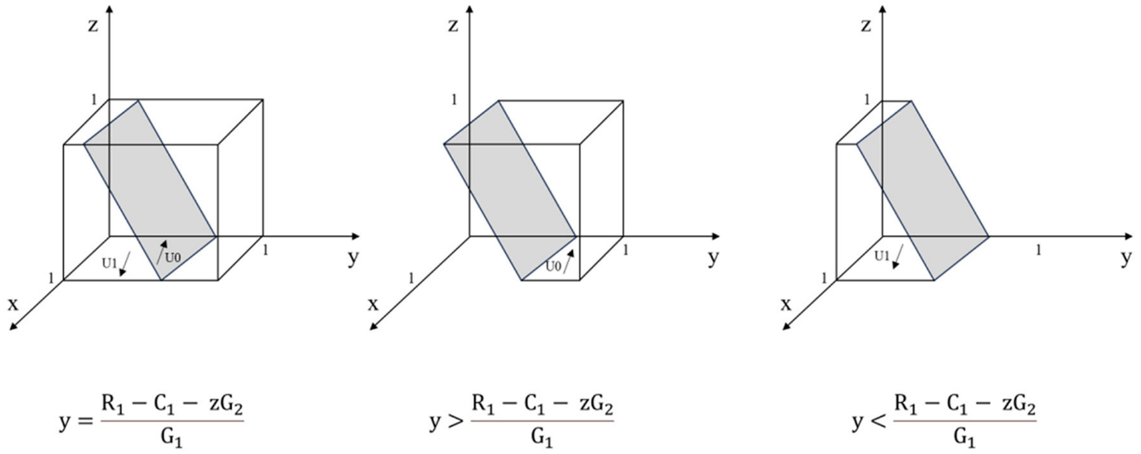

FIGURE 2
Dynamic replication phase diagram of the evolution of government strategy choices.

is E_p, the expected return of "does not adopt" digital technology is $\sim E_p$, and the average expected return of the rural industrial entity is E_3, then we have the following:

$$E_3 = zE_p + (1 - z) \sim E_p \tag{9}$$

$$\begin{aligned} E_p &= xy(R_3 + G_2 + S_2 - C_3) + x(1-y)(R_4 - C_4) + (1-x)y(R_3 + S_2 - C_3) \\ &+ (1-x)(1-y)(R_4 - C_4) \\ &= xyG_2 + (R_4 - C_4) - yR_4 + yC_4 + yR_3 - yC_3 \end{aligned} \tag{10}$$

$$\begin{aligned} \sim E_p &= xy(R_4 - C_4) + x(1-y)(R_4 - C_4) + (1-x)y(R_4 - C_4) \\ &+ (1-x)(1-y)(R_4 - C_4) = (R_4 - C_4) \end{aligned} \tag{11}$$

The constructed replication dynamic equation for the behavioral strategies of rural industrial agents is as follows:

$$\begin{aligned} F(z) &= dz/dt = z(E_p - E_3) = z(1-z)(E_p - \sim E_p) \\ &= z(1-z) \\ &\left[xyG_2 + R_4 - C_4 - yR_4 + yC_4 + yR_3 - yC_3 - (R_4 - C_4)\right] \end{aligned} \tag{12}$$

The associative replication dynamic equations F(x), F(y), and F(z) can be formed into a three-dimensional dynamical system for the dynamic evolution of the government, the digital technology provider, and the rural industry subjects. The set of replicated dynamic equations of the dynamical system is as follows:

$$\begin{cases} Fx = (x)(1-x)(R_1 - C_1 - yG_1 - zG_2) \\ F(y) = y(1-y)(xG_1 + xG_3 + zM_2 + R_2 - C_2 - G_3) \\ F(z) = z(1-z)\left[xyG_2 - yR_4 + yC_4 + yR_3 - yC_3\right] \end{cases}$$

4 Analysis of the tripartite evolutionary game model

4.1 Government's evolutionary stabilization strategy

Based on the replicated dynamic equation constructed in the previous section, let $G(y, z) = R_1 - C_1 - yG_1 - zG_2$, which can be obtained by taking the partial derivative of x for F(x):

$$\frac{\partial F(x)}{\partial x} = (1-2x)(R_1 - C_1 - yG_1 - zG_2) = (1-2x)G(y,z) \tag{13}$$

(1) When$y = \frac{R1-C1-zG2}{G1}$, G (y, z) = 0, this moment F(x) = 0, and it means that whatever strategy the government adopts for digital technology suppliers and rural industry subjects is a stable strategy, and the strategy will not change over time. When$y \neq \frac{R1-C1-zG2}{G1}$, taking x = 0 and x = 1 as evolutionary stability points can make F(x) = 0. According to the stability theorem of replicated dynamic differential equations and evolutionary stability (Lou et al., 2022), if a certain strategy adopted by the government is a stable strategy, it needs to satisfy F(x) = 0 and $\partial F(x)/\partial x < 0$. Therefore, make the following distinction:

(2) When $y > \frac{R1-C1-zG2}{G1}$, G (y, z) < 0, and thus, we have $\frac{\partial F(x)}{\partial x}|x = 0 < 0$, and $\frac{\partial F(x)}{\partial x}|x = 1 > 0$, then the equilibrium point of the government strategy is x=0, the government adopts the strategy of "discourage" as the only evolutionary stable strategy.

(3) When $y < \frac{R1-C1-zG2}{G1}$, G (y, z) > 0, and thus, we have $\frac{\partial F(x)}{\partial x}|x = 0 > 0$, and $\frac{\partial F(x)}{\partial x}|x = 1 < 0$, then the equilibrium point of the government strategy is x = 1, the government adopts the "encourage" strategy as the only evolutionary stable strategy.

In summary, the dynamic replication phase diagram of the evolution of government strategy choices is shown in Figure 2.

In Figure 2, the probability of the government "encourage" a digital technology supplier to supply digital technology and "encourage" a rural industrial subject to adopt digital technology is calculated as the volume V_{U1} of U_1:

$$V_{U1} = \int_0^1 \int_0^1 \frac{R_1 - C_1 - zG_2}{G_1} dzdx = \frac{2(R_1 - C_1) - G_2}{2G_1} \tag{14}$$

Corollary 1: The probability that the government encourages digital technology suppliers to supply digital technology and encourages rural industrial entities to adopt digital technology is positively related to the benefits they receive when adopting the encouragement strategy and negatively related to the costs they pay for adopting the encouragement strategy, such as price subsidies and specialized funds given to digital technology suppliers, and subsidies given to rural industrial entities for the purchase of technological equipment, technological guidance, and educational resources.

Proof: Taking the first-order partial derivatives of each element of V_{U1} separately, we get $\partial V_{U1}/\partial R_1 > 0$, $\partial V_{U1}/\partial C_1 < 0$, $\partial V_{U1}/\partial G_1 < 0$, $\partial V_{U1}/\partial G_2 < 0$. Thus, when R_1 rises or C_1, G_1, and G_2 fall, both increase the probability that the government will encourage digital technology suppliers to supply digital technology and encourage rural industrial subjects to adopt digital technology.

Corollary 1 shows that, on the one hand, the higher the benefit of the government's strategy, the more it can encourage the government to encourage digital technology suppliers to supply digital technology and rural industrial entities to adopt digital technology by means of price subsidies and technical guidance; on the other hand, when the cost of government incentives is high, and when it gives too many economic incentives to the digital technology suppliers and rural industrial entities, the pressure on the government's fiscal expenditures will increase, which can promote the market transaction behaviors of both parties but also inhibit the evolution of the government strategy to stabilize over the "encourage" strategy.

Corollary 2: The probability that the government will encourage digital technology suppliers to supply digital technology and encourage rural industrial entities to adopt digital technology decreases as the probability of digital technology suppliers actively "supply" or rural industrial entities actively "adopt" increases.

Proof: From the previous section, when $y > \frac{R1-C1-zG2}{G1}$ or ,[4] $G(y,z) < 0$, and thus, we have $\frac{\partial F(x)}{\partial x}|x = 0 < 0$, and $F(x)|x = 0 = 0$, that is an evolutionary stable strategy policy, or else, x = 1 is an evolutionary stable strategy policy.

Corollary 2 shows that when the probability of digital technology suppliers take the initiative to "supply" and the probability of rural industry bodies take the initiative to "adopt" decreases, market activity may be lower, then the government needs to actively intervene, increase policy support, encourage and guide all parties to adopt positive strategies to promote the market transactions, which generally occurs in the rural industry in the primary stage of digitalization or the early stage of the commercialization and popularization of digital technology. When the probability of the digital technology suppliers taking the initiative to "supply" and the probability of the rural industry subjects taking the initiative to "adopt" are higher, the market may be more active. At this time, the government should simplify and decentralize the government, minimize intervention in the market, and play the role of "night watchman."

4.2 Evolutionary stabilization strategies for digital technology providers

As above, let $G(x, z) = (xG_1 + xG_3 + zM_2 + R_2 - C_2 - G_3)$, which can be obtained by taking the partial derivative of y for F(y):

$$\frac{\partial F(y)}{\partial y} = (1 - 2y)(xG_1 + xG_3 + zM_2 + R_2 - C_2 - G_3) \tag{15}$$

(1) When$z = \frac{C2+G3-R2-x(G1+G3)}{M2}$, G(x, z) = 0 and F(y) = 0, at this time, whatever strategy the digital technology provider chooses is a stable strategy and the strategy does not change over time. When$z \neq \frac{C2+G3-R2-x(G1+G3)}{M2}$, taking y = 0 or y = 1 as evolutionary stable points can make F(y) = 0. As mentioned before, if the strategy adopted by the digital technology provider is a stable strategy, it needs to satisfy F(y) = 0 and $\frac{\partial F(y)}{\partial y} < 0$. Therefore, the following distinction is made:

(2) When $z > \frac{C2+G3-R2-x(G1+G3)}{M2}$, G(x, z) > 0, and thus, we have $\frac{\partial F(y)}{\partial y}|y = 1 < 0$, $\frac{\partial F(y)}{\partial y}|y = 0 > 0$, the equilibrium point of the digital technology supplier's strategy at this time is y = 1, that is the digital technology supplier adopts the "supply" strategy as the only globally stable evolutionary strategy.

(3) When $z < \frac{C2+G3-R2-x(G1+G3)}{M2}$, G(x, z) < 0, and thus, we have $\frac{\partial F(y)}{\partial y}|y = 1 > 0$, $\frac{\partial F(y)}{\partial y}|y = 0 < 0$, the equilibrium point of the digital technology supplier's strategy at this time is y = 0, that is the digital technology supplier adopts the "do not supply" strategy as the only globally stable evolutionary strategy.

In summary, the dynamic replication phase diagram of the evolution of digital technology vendor strategy selection is shown in Figure 3.

In Figure 3, the probability that a digital technology supplier adopts a "do not supply" strategy is calculated as the volume V_{V0} of V_0, and the probability of "supply" digital technology to a rural industrial entity is calculated as the volume V_{V1} of V_1:

$$\begin{aligned} V_{V0} &= \int_0^1 \int_0^1 \frac{C_2 + G_3 - R_2 - x(G_1 + G_3)}{M_2} dxdy \\ &= \frac{2(C_2 - R_2) - G_1}{2M_2} \end{aligned} \tag{16}$$

$$V_{V1} = 1 - V_{V0} = 1 - \frac{2(C_2 - R_2) - G_1}{2M_2} \tag{17}$$

Corollary 3: The probability that a digital technology supplier will "supply" digital technology to a rural industrial entity is positively related to the benefits of its active "supply" strategy, government subsidies, inventory costs, etc., and negatively related to the costs of its active "supply" strategy.

Proof: Similar to the proof of Corollary 1, the first-order partial derivatives are obtained for each element of V_{V1} separately, we

4 G (y, z) = $R_1 - C_1 - yG_1 - zG_2$, when or $z > \frac{R1-C1-yG1}{G2}$, G (y, z) < 0, then $\frac{\partial F(x)}{\partial x} = (1-2x)(R_1 - C_1 - yG_1 - zG_2) < 0$.

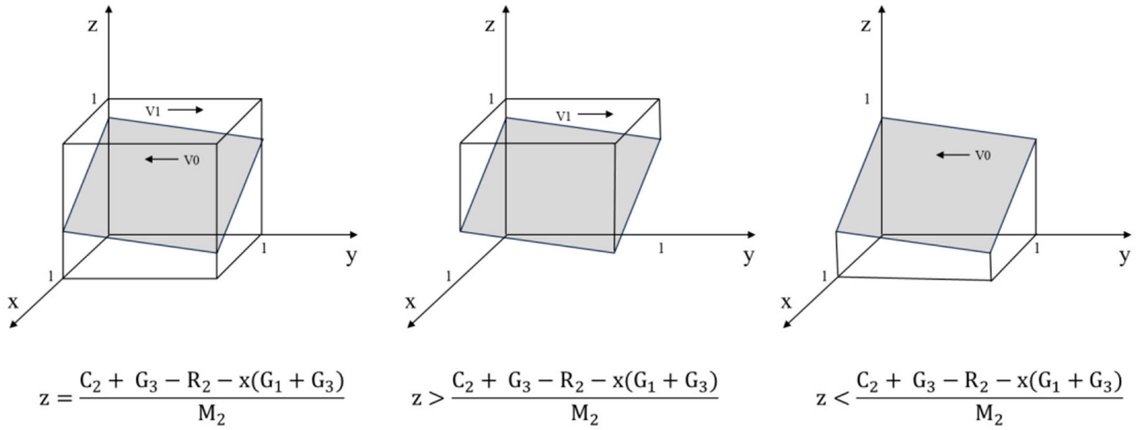

FIGURE 3
Dynamic replication phase diagram of the evolution of digital technology vendor strategy selection.

get: $\partial V_{V1}/\partial R_2 > 0$, $\partial V_{V1}/\partial G_1 > 0$, $\partial V_{V1}/\partial M_2 > 0$, $\partial V_{V1}/\partial C_2 < 0$. Thus, when R_2, G_1, M_2 go up or C_2 goes down, the probability of a digital technology supplier "supply" digital technology goes up.

Inference 3 shows that, on the one hand, the rise in inventory costs and the decline in market share of digital technology suppliers will increase the risk and pressure of the enterprises, thus prompting them to strive to expand sales channels and increase sales revenue, and the higher the probability that they will actively supply digital technology to rural industrial entities; on the other hand, digital technology suppliers are profit-oriented organizations, and the more sales revenue and subsidies they receive from supplying digital technology to rural industrial entities, the more likely they are to take the initiative to strengthen cooperation with rural industrial entities and actively supply digital technology; or else, the higher the cost and lower the profit of supplying digital technology will inhibit the evolution and stabilization of digital technology suppliers' strategy toward the "supply" strategy.

Corollary 4: The probability that a digital technology do not supply a rural industrial subject with a digital technology decreases as the probability of government encouragement and the probability of adoption by the rural industrial entity increase, that is the higher the probability of government encouragement and the probability of adoption by the rural industrial entity, the higher the digital technology adopts the strategy of "supply."

Proof: Similar to the proof of Corollary 2, when $z > \frac{C2+G3-R2-x(G1+G3)}{M2}$ or $x > \frac{C2+G3-R2-zM2}{G1+G3}$, G(y, z) > 0, and thus, we have $\frac{\partial F(y)}{\partial y}|y = 1 < 0$, and$F(y)|y = 1 = 0$, that is, x = 1 is an evolutionarily stable policy strategy, or else, x = 0 is an evolutionarily stable policy strategy.

Corollary 4 suggests that the choice of digital technology suppliers' strategies is constrained by both market demand and government policies. The institutional environment positively regulates both the direct and indirect benefits of digital technology to enable the high-quality development of rural industries. Market demand and government policies belong to the institutional environment, while digital technology suppliers are one of the rural industry interest subjects, which means that the institutional environment also influences the strategic choices of digital technology suppliers and even other rural industry interest subjects. Therefore, on the one hand, digital technology suppliers should actively develop demand-oriented "pull supply chain" model innovation, focus on the rural industry subjects "provide whatever technology they need," strengthen market research, deeply understand the market demand, and continuously create consumption scenarios to stimulate the rural industry subjects to develop their own technology. On the other hand, digital technology suppliers also need to coordinate with the government, actively strive for various policies, tax incentives, and financial subsidies, and strive to create a good institutional environment.

4.3 Evolutionary stabilization strategies for rural industrial subjects

As above, let , which can be obtained by taking the partial derivative of z for F(z):

$$\frac{\partial F(z)}{\partial z} = (1 - 2z)y(xG_2 + R_3 + C_4 - R_4 - C_3) \tag{18}$$

Since 0 ≤ y ≤ 1, when y = 0, G(x, y) = 0, F(z) = 0, then the rural industrial entity can only choose the "do not adopt" strategy. This is because, when the digital technology supplier does not supply digital technology, the rural industrial entity cannot obtain the technology and, therefore, can only follow the traditional way of production. When y ≠ 0, that is, under the premise of a certain probability of the digital technology supplier supplying digital technology, the rural industrial subjects have the following evolutionary strategies:

(1) When $x = \frac{R4+C3-R3-C4}{G2}$, G(x, y) = 0, F(z) = 0, at this time, no matter what strategy the rural industrial entity chooses is a stable strategy, and the strategy will not change over time. When $x \neq \frac{R4+C3-R3-C4}{G2}$, taking z = 0 or z = 1 as evolutionary stable point can make F(z) = 0. As mentioned earlier, if the strategy adopted by

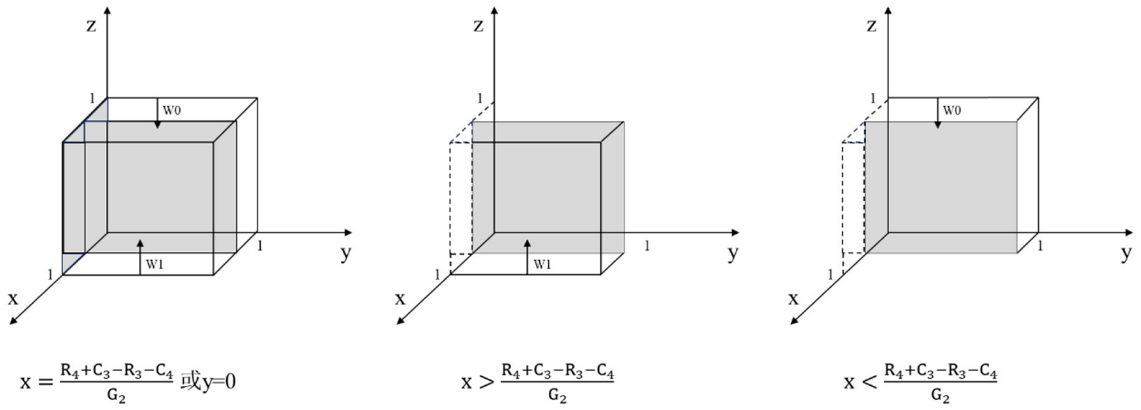

FIGURE 4
Dynamic replication phase diagram of the evolution of strategic choices of rural industrial subjects.

the rural industrial subjects is a stable strategy, it needs to satisfy F(z) = 0 and $\frac{\partial F(z)}{\partial z} < 0$. Therefore, the following distinction is made:

(2) When $x > \frac{R4+C3-R3-C4}{G2}$, G(x, y) >0, and thus, we have $\frac{\partial F(z)}{\partial z}|z = 1 < 0, \frac{\partial F(z)}{\partial z}|z = 0 > 0$, the equilibrium point of the strategy of the rural industrial subjects is z = 1, that is, the rural industrial subjects adopt the "adoption" strategy as the only global evolutionary stability strategy.

(3) When $x < \frac{R4+C3-R3-C4}{G2}$, G(x, y) < 0, and thus, we have $\frac{\partial F(z)}{\partial z}|z = 1 > 0, \frac{\partial F(z)}{\partial z}|z = 0 < 0$, at this time, the equilibrium point of the strategy of the rural industrial body is z = 0, that is, the rural industrial body adopts the "does not adopt" strategy as the only global strategy.

In summary, the dynamic replication phase diagram for the evolution of strategy selection of rural industrial subjects is shown in Figure 4.

In Figure 4, the probability that a rural industrial subject adopts the strategy of "does not adopt" digital technology is calculated as the volume V_{W0} of W_0, while the probability of "adopt" digital technology is calculated as the volume V_{W1} of W_1:

$$V_{W0} = \int_0^1 \int_0^1 \frac{R_4 + C_3 - R_3 - C_4}{G_2} dydz = \frac{R_4 + C_3 - R_3 - C_4}{G_2} \tag{19}$$

$$V_{W1} = 1 - V_{W0} = 1 - \frac{R_4 + C_3 - R_3 - C_4}{G_2} \tag{20}$$

Corollary 5: The adoption of digital technologies by rural industrial agents is conditional on a certain probability of supply by digital technology suppliers, and the probability of their choosing to "adopt" digital technologies is positively related to the benefits of adoption, government subsidies, and the costs of non-adoption and negatively related to the costs of adoption and the benefits of non-adoption.

Proof: Similar to the proof of Corollary 1, the first-order partial derivatives are obtained for each element of V_{W1} separately, we get: $\partial V_{W1}/\partial R_3 > 0$, $\partial V_{W1}/\partial G_2 > 0$, $\partial V_{W1}/\partial C_4 > 0$, $\partial V_{W1}/\partial C_3 < 0$, $\partial V_{W1}/\partial R_4 < 0$. Thus, when R_3, G_2, and C_4 rise or C_3 and R_4 fall, the probability of "adopt" digital technologies by rural industrial agents rises.

Corollary 5 shows that the more subsidies and technical guidance the government gives to rural industrial entities, the more rural industrial entities will be motivated to adopt digital technology. At the same time, the higher the income gained from the adoption of digital technology or the higher the cost of production in accordance with the traditional way, the easier it is to adopt digital technology for production, and vice versa, if the cost of adopting digital technology or the income gained from production in accordance with the traditional way is higher, the less likely to adopt digital technology. Therefore, on the one hand, the government should increase policy support and appropriately give financial subsidies and technical guidance to rural industrial subjects; on the other hand, according to the type and nature of rural industrial production, it should classify and apply policies and promote the integration of digital technology and industry in a targeted manner. The effect of digital technology adoption is obvious when the traditional methods of production for rural industrial subjects are more expensive, which accelerates the digital transformation of the rural industry. The effect of digital technology is not obvious when these traditional methods are comparatively inexpensive for lower rural industries, which suggests the adoption is overly hasty. Moreover, the three parties should not "march in unison" as if "one size fits all."

4.4 Stability analysis of the equilibrium point of the tripartite evolutionary game model

Friedman (1991) pointed out that the evolutionary stable equilibrium solution of the replication dynamics system can be obtained by solving the local stability of the Jacobian matrix of the replication dynamics system. On the basis of the previous stability analysis of the evolutionary strategies of individual subjects of the government, digital technology suppliers, and rural industry subjects, this study will also analyze the tripartite system as a whole.

TABLE 3 Eigenvalues for each equilibrium point.

Balance point	Eigenvalue 1	Eigenvalue 2	Eigenvalue 3
E_1 (0, 0, 0)	$R_1 - C_1$	$R_2 - C_2 - G_3$	0
E_2 (0, 0, 1)	$R_1 - C_1 - G_2$	$M_2 + R_2 - C_2 - G_3$	0
E_3 (0, 1, 0)	$R_1 - C_1 - G_1$	$C_2 + G_3 - R_2$	$R_3 + C_4 - R_4 - C_3$
E_4 (0, 1, 1)	$R_1 - C_1 - G_1 - G_2$	$-(M_2 + R_2 - C_2 - G_3)$	$-(R_3 + C_4 - R_4 - C_3)$
E_5 (1, 0, 0)	$(R_1 - C_1)$	$G_1 + R_2 - C_2$	0
E_6 (1, 0, 1)	$(R_1 - C_1 - G_2)$	$G_1 + M_2 + R_2 - C_2$	0
E_7 (1, 1, 0)	$(R_1 - C_1 - G_1)$	$-(G_1 + R_2 - C_2)$	$G_2 + R_3 + C_4 - R_4 - C_3$
E_8 (1, 1, 1)	$-(R_1 - C_1 - G_1 - G_2)$	$-(G_1 + M_2 + R_2 - C_2)$	$-(G_2 + R_3 + C_4 - R_4 - C_3)$

Author's own production.

According to the basic assumptions, it can be known that the feasible domain of the replication dynamics system in this study is [0, 1] X [0, 1] X [0, 1], respectively, so that F(x) = 0, F(y) = 0, F(z) = 0, you can get multiple equilibrium points of the system's dynamic evolution, which includes eight special equilibrium points: $E_1(0, 0, 0)$, $E_2(0, 0, 1)$, $E_3(0, 1, 0)$, $E_4(0, 1, 1)$, $E_5(1, 0, 0)$, $E_6(1, 0, 1)$, $E_7(1, 1, 0)$, $E_8(1, 1, 1)$. This is because the evolutionary stable strategy of multigroup evolutionary game is necessarily a strict Nash equilibrium, and the strict Nash equilibrium is a pure strategy equilibrium, that is to say, the mixed strategy equilibrium in the asymmetric game must not be an evolutionary stable equilibrium, it is only necessary to consider the asymptotic stability of the pure strategy equilibrium (Selten, 1988; Xiao et al., 2020), that is the asymptotic stability of the above eight special equilibria is discussed.

It is generally believed that the asymptotic stability of the equilibrium point can be discerned by the positivity and negativity of the determinant det(J) and trace tr(J) of the equilibrium point Jacobi matrix J. However, this method is not applicable to analyzing the asymptotic stability of the three-party evolution game, so this study draws on the results of the existing research (Zhao et al., 2020), which adopts an indirect method to judge the asymptotic stability of equilibrium points, that is, Lyapunov stability theory. Lyapunov discriminant method is mainly the eigenvalue sign of the Jacobi matrix of the dynamical system to assist the judgment, that is when the sign of all the eigenvalues is negative, the corresponding equilibrium point is the asymptotically stable equilibrium point of ESS of the system, and the equilibrium point is unstable if it has a positive real part, and the rest of the cases cannot be judged. According to the above system of dynamic equations for the replicated dynamics of the dynamical system, it is known that the Jacobi matrix of the system is as follows:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix}$$

Among other things:

$$\frac{\partial F(x)}{\partial x} = (1 - 2x)(R_1 - C_1 - yG_1 - zG_2) \quad (21)$$

$$\frac{\partial F(x)}{\partial y} = x(1 - x)(-G_1) \quad (22)$$

$$\frac{\partial F(x)}{\partial z} = x(1 - x)(-G_2) \quad (23)$$

$$\frac{\partial F(y)}{\partial x} = y(1 - y)(G_1 + G_3) \quad (24)$$

$$\frac{\partial F(y)}{\partial y} = (1 - 2y)(xG_1 + xG_3 + zM_2 + R_2 - C_2 - G_3) \quad (25)$$

$$\frac{\partial F(y)}{\partial z} = y(1 - y)M_2 \quad (26)$$

$$\frac{\partial F(z)}{\partial x} = z(1 - z)yG_2 \quad (27)$$

$$\frac{\partial F(z)}{\partial y} = z(1 - z)(xG_2 + R_3 + C_4 - R_4 - C_3) \quad (28)$$

$$\frac{\partial F(z)}{\partial z} = (1 - 2z)y(xG_2 + R_3 + C_4 - R_4 - C_3) \quad (29)$$

The values of each equilibrium point are substituted into the Jacobi matrix J, respectively, the corresponding eigenvalue of each equilibrium point can be obtained, and the direction of the sign of the eigenvalue is judged according to the assumptions, according to which the asymptotic stability of each equilibrium point can be identified, and the eigenvalues of each equilibrium point are shown in Table 3.

Corollary 6: There exists a stabilization point $E_8(1, 1, 1)$ of the replica dynamical system when $R_1 > C_1 + G_1 + G_2$, $R_2 > C_2$, $R_3 - C_3 > R_4 - C_4$.

Proof: According to Table 3, it can be seen that $E_1 - E_7$ all have positive real part, only the sign of the eigenvalue of E_8 is all negative, so $E_8(1, 1, 1)$ is an asymptotically stable equilibrium ESS, and the rest of the equilibriums are unstable, the sign of the eigenvalues of the equilibriums and asymptotically stability is shown in Table 4.

Corollary 6 suggests that for the government, it will adopt an "encourage" strategy when the benefits of government incentives are greater than the sum of its costs and the subsidies it gives to digital technology suppliers and rural industrial agents. For digital technology suppliers, they will also adopt a "supply" strategy when the benefits they receive from supplying digital technology

TABLE 4 Sign and asymptotic stability of eigenvalues at each equilibrium point.

Balance point	Eigenvalue 1	Eigenvalue 2	Eigenvalue 3	Progressive stability
E_1 (0, 0, 0)	+	Inconclusive	0	Point of instability
E_2 (0, 0, 1)	+	Inconclusive	0	Point of instability
E_3 (0, 1, 0)	+	Inconclusive	+	Point of instability
E_4 (0, 1, 1)	+	Inconclusive	-	Point of instability
E_5 (1, 0, 0)	-	+	0	Point of instability
E_6 (1, 0, 1)	-	+	0	Point of instability
E_7 (1, 1, 0)	-	-	+	Point of instability
E_8 (1, 1, 1)	-	-	-	ESS

Author's own production.

are greater than the costs of supplying it. For the rural industrial subjects, it will also "adopt" digital technology for production when the profit it makes from adopting digital technology for production is greater than the profit it makes from traditional production methods, which is the benefit-cost difference after adopting digital technology minus the benefit-cost difference before adopting digital technology is >0. Therefore, it is important for all three parties to endeavor to increase the benefits of digital technology and enhance its empowering effect.

5 Numerical simulation results

Owing to the bounded rationality of each subject and the incomplete symmetry of the information they possess, the absence of some information may require game players to consider uncertainty when formulating strategies, thereby increasing the complexity of strategy selection. This requires participants to predict the opponent's behavior based on possible probability distributions and respond accordingly. According to the previous analysis, under the condition of finite rationality, the most ideal development state of the government, digital technology suppliers, and rural industry subjects, and also the one most consistent with the real situation of the stability strategy choice, is (U_1 encouraged, V_1 supplied, W_1 adopted). To verify the validity of the evolutionary stability analysis, this study combines the assignment of values to the model parameters with numerical simulation using MATLAB 2018b. Owing to the limited conditions, the relevant data are very difficult to obtain. Referring to Shen et al. (2024); Li et al. (2024a,b) in the literature on the setting of the initial values of the system, combined with the opinions of relevant experts, this study sets the initial probability of the government, digital technology suppliers, and rural industrial subjects to choose positive strategies (U_1 encouraged, V_1 supplied, W_1 adopted) as low, medium, and high levels, respectively, that is, x_0, y_0, z_0 ε Ω (0.2, 0.5, 0.8), and formulates the initial values of the other parameters as $R_1 = 12$, $R_2 = 6$, $R_3 = 6$, and $R_4 = 4$, $C_1 = 2$, $C_2 = 2$, $C_3 = 1$, $C_4 = 2$, $G_1 = 2$, $G_2 = 2$, $G_3 = 2$, $M_2 = 1$, and study the effect of the change of each parameter on the strategy choice of the participating subjects separately, to induce the strategy choice of each participating subject to be close to the (U_1 encouraged, V_1 supplied, W_1 adopted).

5.1 Impact of changes in government subsidies on the evolution of equilibrium strategies of tripartite agents

We evaluate the evolution of the equilibrium strategies of the three parties in response to the change in the numerical value associated with the government's "encourage" decision. Here, $G_1 = 2, 3, 4$; $G_2 = 2, 3, 4$.

As can be seen from Figures 5a–c, the government's subsidy behavior has a significant impact on the strategy evolution of digital technology suppliers and rural industrial subjects, and different initial probabilities have a significant impact on the convergence speed of the three subjects. On the one hand, the greater the government subsidy, the faster the digital technology supplier converges to the "supply" digital technology strategy, and the faster the rural industrial subjects converge to the "adopt" digital technology strategy. This is because government subsidies provide positive incentives to both digital technology suppliers and rural industrial entities. As stated in Corollary 3 and Corollary 5, government subsidies are positively correlated with the probability of digital technology suppliers "supply" digital technology and the probability of rural industrial entities "adopt" digital technology.

On the other hand, different initial probabilities have significant effects on the convergence speed of the three subjects. When the initial probability of each subject choosing a positive strategy is 0.2, the convergence speed of each subject is relatively slow, and when the probability rises to 0.5 and 0.8, the convergence speed of each subject is faster, especially with the increase of the government subsidy, the convergence speed of the digital technology supplier and the rural industry subjects exceeds that of the government. This indicates that the strategic behavior of each game subject is largely influenced by the initial subsidies offered when the government decides to "encourage" adoption.

According to the theory of planned behavior, it is known that behavioral intention is a direct factor in determining behavior. Generally speaking, the stronger the behavioral intention, the greater the possibility of taking action, and behavioral intention is influenced by behavioral attitude and subjective norms (Xu and Li, 2017). We should, therefore, start with the attitude, by improving the digital literacy and skills of government officials, entrepreneurs, and villagers, to strengthen their interest in and preference for the use of digital technology; second, we should

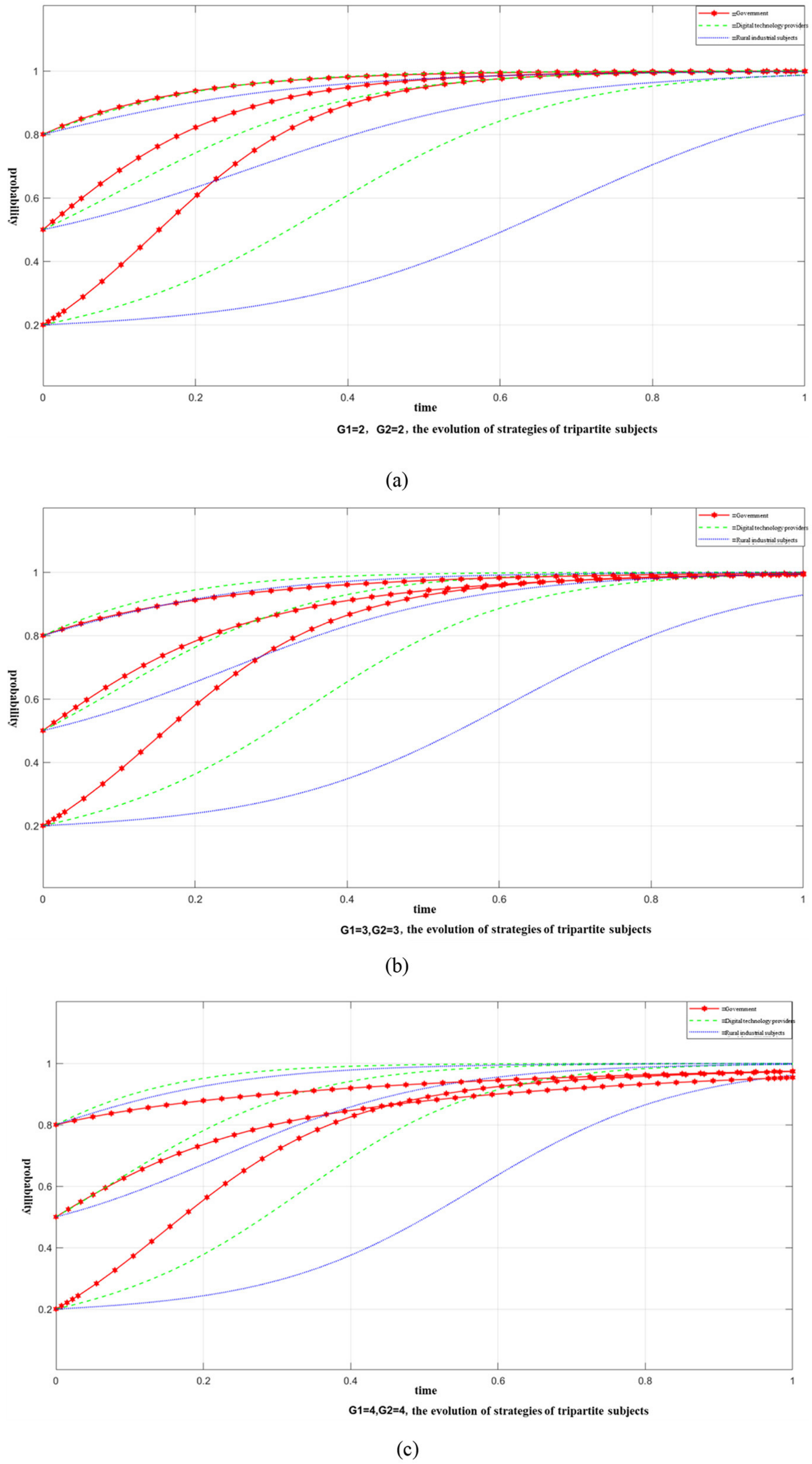

FIGURE 5
Impact of changes in government subsidies on the evolution of strategies of tripartite agents.

start from the institutional norms, to strengthen the top-level design of digital technology, to create a favorable social atmosphere, which will motivate the three-party subjects to adopt a positive gaming strategy.

5.2 Impact of changes in strategy costs on the evolution of strategies of tripartite subjects

Assuming $C_1 = 1, 2, 3$; $C_2 = 1, 2, 3$; and $C_3 = 1, 2, 3$, that is, the evolution of the equilibrium strategies of the three types of subjects after the cost of adopting an active strategy changes.

As can be seen from Figures 6a–c, the cost of adopting active strategies by each game subject has a significant impact on its strategy evolution. As the cost of the positive strategy for each subject increases, its probability of adopting the positive strategy decreases continuously. Take the rural industry subjects as an example, assuming that the initial probability is 0.2, when the cost of adopting digital technology is 1, over time the probability of its final choice of “adopt” will be >0.8, when the cost increases to 2, over time the probability of its final choice of “adopt” $= 0.8$, while when the cost increases to 3, the probability of “adopting” over time is <0.6. This verifies part of the conclusions of Corollary 1, Corollary 3, and Corollary 5 in the previous section. Therefore, the game players should endeavor to reduce the cost of their respective strategies.

According to the literature review, digital technology has the role of cost reduction, which can empower the rural industry to develop with high quality by reducing all kinds of costs in the industry. For the digital technology suppliers, they can improve the level of technological innovation by improving the capacity of technological research and development innovation, and reduce the production cost through technological feedback; for the rural industry subjects, they should introduce digital technology appropriately according to the reality of production, accurately assess the cost of use, and actively introduce digital technology for production in the fields and sectors in urgent need of transformation and upgrading; for the government, it is necessary to formulate the relevant policies and systems to escort other subjects to choose positive strategies, but also to optimize the allocation of resources, try to avoid the waste of resources and reduce the cost of encouragement.

5.3 Impact of changes in strategy returns on the evolution of tripartite principal strategies

Assuming $R_1 = 12, 10, 8$; $R_2 = 6, 5, 4$; and $R_3 = 6, 5, 4$, that is the evolution of the equilibrium strategies of the three types of subjects after a change in their returns from adopting an active strategy.

As can be seen from Figures 7a–c, the change in the return of each game subject to adopt an active strategy has a significant impact on its strategy evolution. With the increase of the strategy gain, the probability of each subject adopting a positive strategy increases. Again, using the rural industry subjects as an example, assuming that the initial probability is 0.2, when the gain of adopting digital technology is 4, the probability of its final choice of “adopt” will be between 0.4 and 0.5 over time. When the gain increases to 5, the probability of “adopt” is between 0.6 and 0.7, while the probability of “adopt” over time is >0.8 when the revenue increases to 6. This also verifies the conclusions of Corollary 1, Corollary 3, Corollary 5, and Corollary 6 in the previous section. The process of promoting high-quality development of rural industry should therefore, on the one hand, accurately identify the effect of digital technology empowerment and strive to improve the benefits of positive strategies adopted by the main body; on the other hand, for the rural industry subjects that do not have significant benefits from the adoption of digital technology, we should analyze the reasons in-depth and prescribe the right medication to suspend the project if necessary, to avoid the increase in costs due to the blind application of digital technology.

5.4 Impact of changes in inventory costs of digital technology suppliers on the evolution of strategies of the three main parties

It is assumed that $M_2 = 1, 2, 3$, that is, the evolution of the equilibrium strategies of the three types of subjects after the change in the inventory costs of the digital technology suppliers caused by the non-adoption of digital technology by the rural industrial subjects.

As can be seen in Figures 8a–c, changes in the inventory costs of digital technology suppliers have a significant impact on the evolution of their strategies. As the inventory cost increases, digital technology suppliers converge to the “supply” digital technology strategy faster. With an initial probability of 0.8, for example, when the inventory cost is 1, the convergence curve of the digital technology supplier is synchronized with that of the government; when the inventory cost increases to 2, the convergence curve of the digital technology supplier is slightly higher than that of the government; and when the inventory cost increases to 3, the convergence curve of the digital technology supplier is significantly higher than that of the government, so that the speed of convergence is accelerated gradually. This may be because an increase in the inventory cost of digital technology supporting products will lead to a large amount of liquidity being tied up by the digital technology suppliers, affecting capital turnover, and will also contribute to the rise in management costs and manpower costs, the possibility of potential losses, and an increase in business risks. Therefore, the higher the inventory cost, the more the digital technology tends to provide digital technology to the rural industrial body and reduce the inventory pressure by expanding sales. For digital technology suppliers, it is important to adhere to market demand-oriented and strengthen customized services.

In summary, it can be found that the strategic choices between the subjects of the game are interconnected, with mutual promotion and mutual influence. When a certain or some parameters change, it will lead to a change in the strategy choice of a subject, the other two participating subjects' strategy changes in the same direction, evolutionary stability strategy eventually converges to (1, 1, 1).

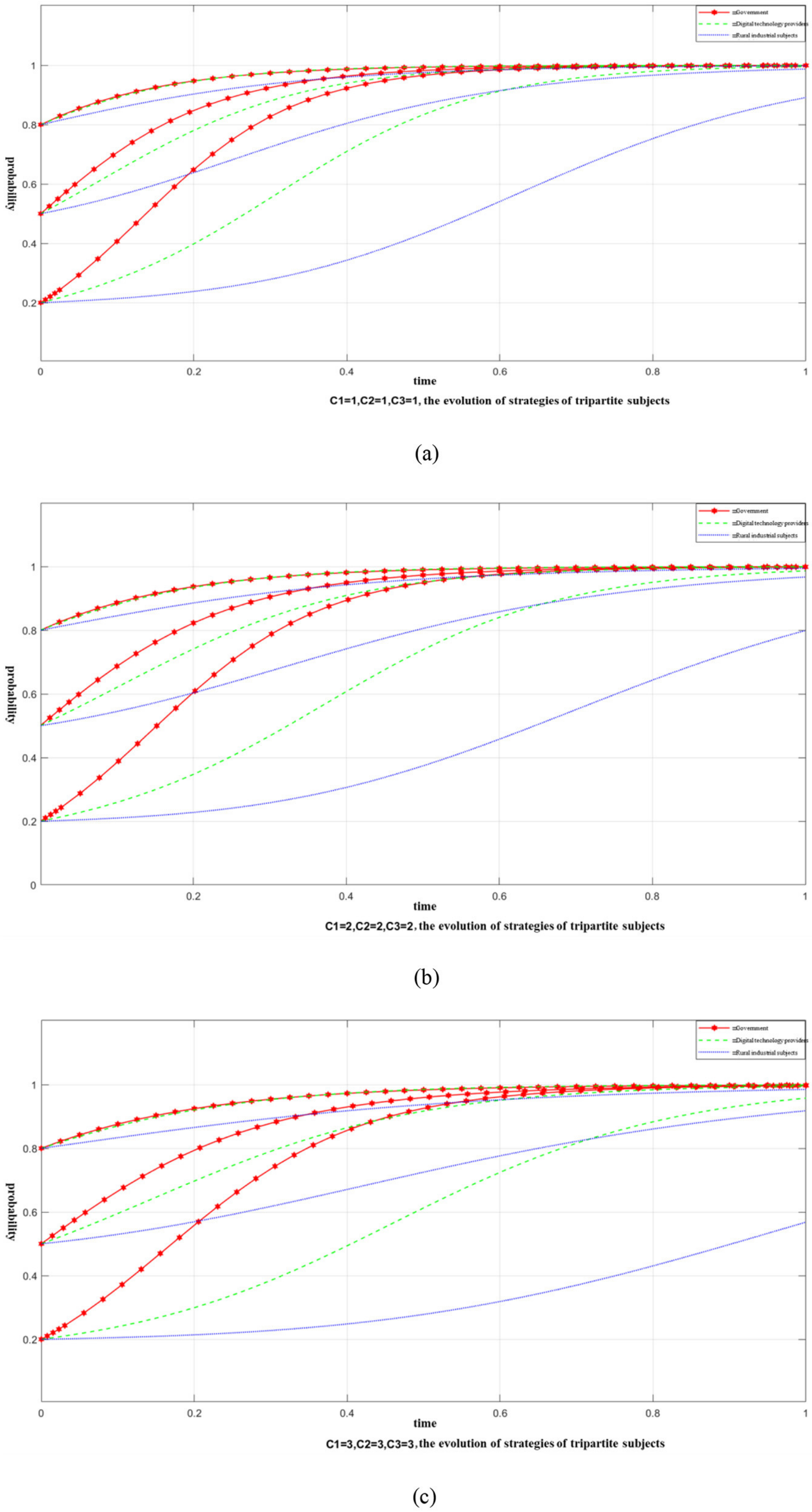

FIGURE 6
Impact of cost changes on the evolution of strategies of tripartite subjects.

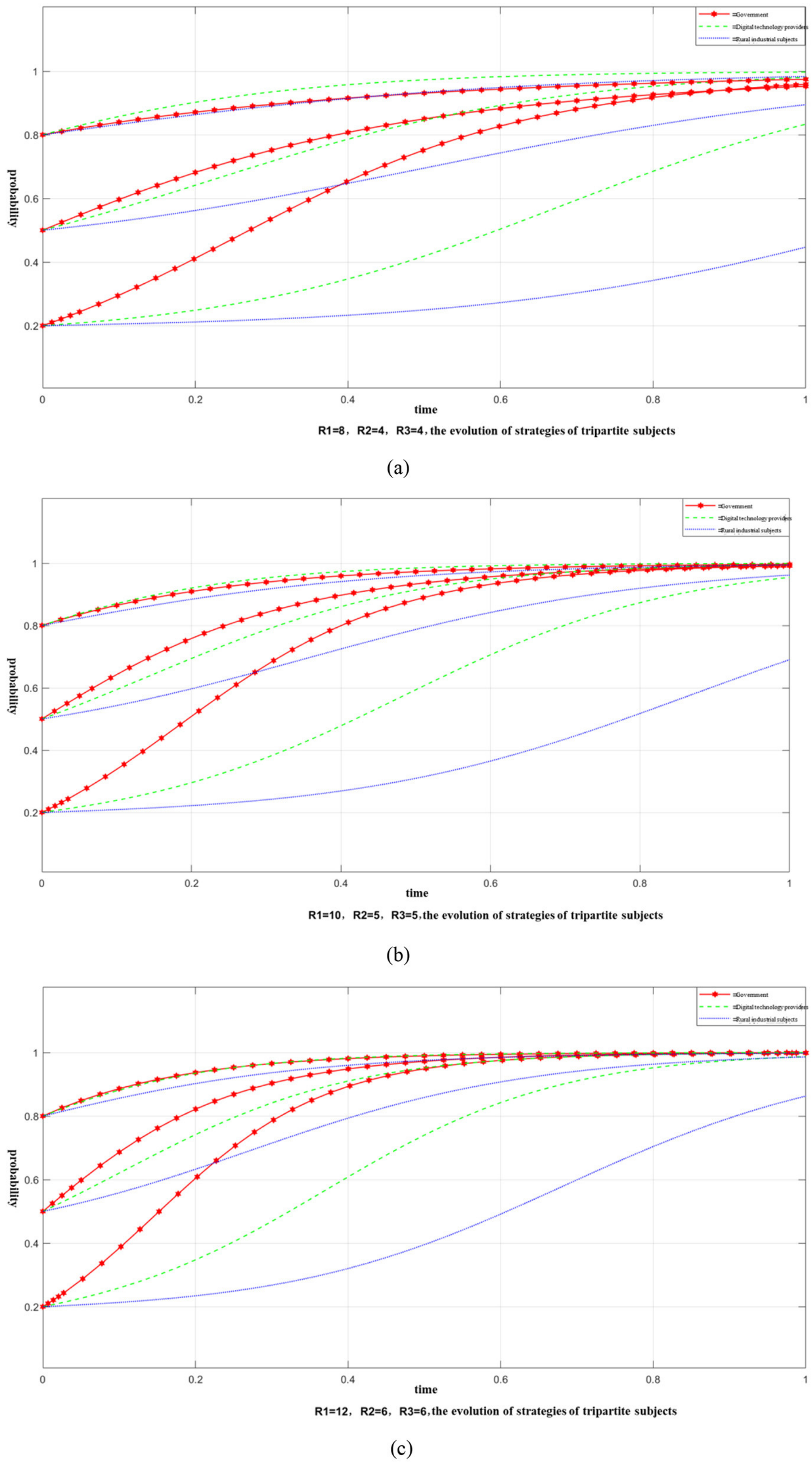

FIGURE 7
Impact of changes in returns on the evolution of strategies of tripartite subjects.

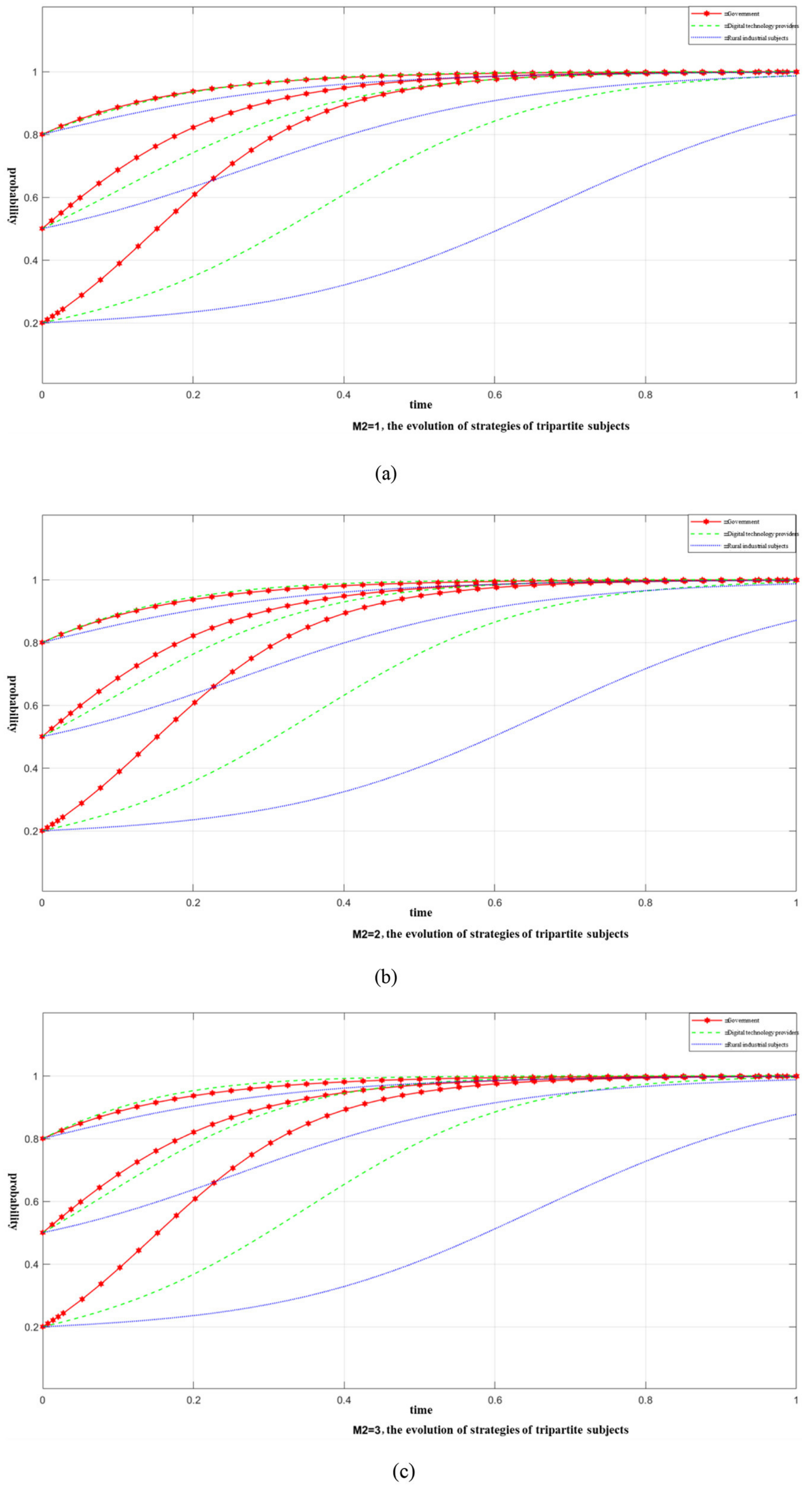

FIGURE 8
Impact of changes in inventory costs of digital technology suppliers on the evolution of strategies of triadic subjects.

Different initial probabilities will also affect the convergence speed of the participating subjects; the larger the initial probability, the faster the convergence speed. In practice, the Chinese government has issued the "National Action Plan for Smart Agriculture (2024–2028)" to encourage the development of smart agriculture; the digital technology suppliers also actively provide technical support, such as China Unicom's continuous increase in network investment in rural areas, with a mobile network coverage rate of over 99% in administrative villages in China; and the rural industry subjects such as farmers also actively adopt digital technology in their production and daily life. As of December 2024, the number of rural Internet users in China reached 313 million, accounting for 28.2% of the national Internet users.[5]

6 Shortcomings and prospects

This study mainly analyzes the evolutionary game among the government, digital technology suppliers, and rural industry subjects in the process of digital transformation of China's rural industries; however, the model oversimplifies decision-making processes, ignores other subjects of interest, and applies evolutionary game theory in a setting that is typically not tripartite. In practice, digital technology empowerment involves many subjects of interest, for example, the government can be divided into the central government and local governments, and to simplify the research problem, this study does not make a breakdown. Therefore, the evolutionary game between more subjects of interest can be explored later and overcome the difficulty of obtaining data and the challenges of defining a proper rationality function.

7 Conclusion, discussion, and suggestions

7.1 Conclusion

This study focuses on discussing and analyzing the behaviors of the interested parties in the high-quality development of rural industries empowered by digital technology. The study finds the following:

1) Whether the government encourages digital technology suppliers to supply digital technology and rural industrial entities to adopt digital technology is positively correlated with the benefits of encouragement and negatively correlated with the costs of encouragement, price subsidies, and special funds given to digital technology suppliers, as well as subsidies for the purchase of technical equipment, technical guidance, and educational resources given to rural industrial entities.
2) Whether or not a digital technology supplier supplies digital technology is positively related to the revenue it receives from supplying digital technology, government subsidies, and inventory costs and negatively related to the cost of supply.
3) The adoption of digital technology by rural industrial entities is predicated on a certain probability that the digital technology supplier will supply digital technology, and their probability of adopting digital technology is positively related to government subsidies, pre-adoption costs, and post-adoption benefits and negatively related to pre-adoption benefits and post-adoption costs.
4) The strategic choices of each game subject interact with each other. The probability of the government encouraging the strategy will decrease as the probability of the digital technology supplier's active "supply" or the probability of the rural industrial subject's active "adopt" increases. Similarly, the higher the probability of the government encouraging the strategy and the probability of the rural industrial subject's adoption, the higher the probability of the digital technology adopting the strategy of "supply."
5) The magnitude of the initial probability and the variation of each parameter will have an important impact on the choice of behavioral strategies of the game subjects, and the evolutionary stabilization strategies eventually converge to (encourage, supply, adopt).

7.2 Discussion

The main purpose of this article is to analyze the game mechanism of relevant stakeholders and promote the digital transformation of rural industries in China. The article constructs a tripartite evolutionary game model among the government, digital technology suppliers, and rural industry entities, analyzes the evolutionary stability strategies and influencing factors of each entity, and uses MATLAB for numerical simulation analysis, providing a theoretical basis for promoting the digital transformation and development of rural industries. Research has found that: (1) The strategy choices of each game subject influence each other. The probability of the government's "encouragement" strategy decreases as the probability of digital technology suppliers actively "supplying" or rural industry entities actively "adopting" increases. Similarly, the higher the probability of government "encouragement," the greater the probability of rural industrial entities "adoption," and the higher the probability of digital technology provider "supply." (2) The size of the initial probability and the variation of each parameter have a significant impact on the choice of behavioral strategies for game players. The evolutionary stability strategy ultimately converges toward the government adopting "encouragement," digital technology suppliers adopting "supply," and rural industrial entities adopting "adoption." In the past, domestic research mainly focused on qualitative analysis, focusing on the impact of digital technology on rural tourism and agriculture, while foreign research focused on quantitative micro analysis, focusing on the impact of technology on agriculture, rural areas, farmers, and other aspects. However, there has been relatively little discussion on the behavior of stakeholders in the digital transformation of rural industries, and there is a lack of in-depth analysis on the interaction patterns between stakeholders. Compared with previous research, the innovation of this article lies in the first use of evolutionary game

5 https://baijiahao.baidu.com/s?id=1821476846190915076&wfr=spider&for=pc

theory to study the digital transformation of rural industries. It was found that the evolutionary stability strategy ultimately converges to encourage the government, supply digital technology suppliers, and adopt rural industry entities. This is also the biggest difference from previous research. However, there are also shortcomings in the article, such as neglecting other stakeholders. In practice, the empowerment of digital technology involves numerous stakeholders, such as the Chinese government, which can be divided into central and local governments. However, to simplify the research problem, this article does not provide a detailed breakdown. Further detailed research can be conducted in the future.

7.3 Suggestions

This study mainly puts forward countermeasures and suggestions to promote digital technology to effectively enable the high-quality development of rural industries from three aspects: the government, digital technology suppliers, and rural industry subjects.

1) First, from the government's perspective, it is necessary to optimize the institutional environment for digital technology to enable the high-quality development of rural industries, improve the construction of digital infrastructure, strengthen the cultivation and introduction of digital technology talents, and enhance the training and guidance of digital skills for rural industrial subjects. Especially, when the market transactions are inactive, that is, when the willingness of digital technology suppliers to actively supply technology products and rural industrial entities to actively adopt them decreases, the government should increase incentives.
2) Second, from the perspective of digital technology suppliers, it is necessary to improve technological innovation capability, enhance ethics and social responsibility, and tap and create the digital consumption demand of rural industrial subjects. The digital technology suppliers should strengthen research, be guided by market demand, adopt differentiated market entry strategies, and establish core competitiveness.
3) Third, from the perspective of rural industrial entities, it is necessary to establish the concept of high-quality development, improve digital literacy and skills, and strengthen technical exchanges and cooperation with other rural industrial entities.

Data availability statement

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

Author contributions

XWW: Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares 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

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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