Study on Evolutionary Game of Rural E-Commerce Entrepreneurship Ecosystem with Governmental Participation

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Abstract: Rural e-commerce has become an effective measure for rural economic development under the background of digital transformation. Governmental participation is an important driving force to encourage the formation of rural e-commerce entrepreneurial ecosystems. From the perspective of bounded rationality, this paper establishes a tripartite evolutionary game model of a rural e-commerce entrepreneurial ecosystem among e-commerce platform, entrepreneurs and government, and systematically analyzes the evolutionary stability of each participant’s strategic choice. The initial intention of the three parties and the coefficient of governmental reward and punishment are introduced into the model design. Through numerical simulation, the influence of different parameters on the strategic selection of the three parties and the evolution path are analyzed, further implying the complexity of the strategic selection process in the reality. The results show that subsidies for e-commerce platforms are more conducive to the evolution of entrepreneurs and e-commerce platforms in a positive direction than direct subsidies for entrepreneurs by the government. In the early stage of development of the rural e-commerce entrepreneurial ecosystem, the government behavior strategy evolved to be one of active participation. After the system matured, the government behavior turned toward the negative direction. Compared with governmental reward and punishment, the initial willingness of each subject has more significant influence on the evolution of the tripartite behavior strategy. Finally, this paper proposes some countermeasures and suggestions to optimize the game relationship among the main bodies in the rural e-commerce entrepreneurial ecosystem from the perspective of a government subsidy mode, effective government intervention and the promotion of the initial willingness of the three parties. The research ideas and conclusions of this paper are enlightening to the academic research and corporate practice related to rural e-commerce.

Keywords: rural e-commerce; entrepreneurial ecosystem; government rewards and punishments; evolutionary game; simulation analysis

1. Introduction

The rapid development of digital agriculture promotes the cultivation and development of new rural industries and new business models. With the popularization of information technology in rural areas, the traditional business model has been urged to be transformed [1]. The whole-network precision agriculture model in the United States has become the main force in the application of agricultural Internet technology; Japan has vigorously developed moderate-scale precision agriculture and Australia develops efficient ecological agriculture based on the construction of a high-speed broadband network [2–4]. As a representative agricultural country, e-commerce is changing the industrial pattern of rural China, creating new job/income opportunities, reducing rural poverty and promoting rural revitalization. There are currently 7023 administrative villages with annual e-commerce sales of more than CNY 10 million in China (Ministry of Commerce of China, 2021). In the first half of 2022, China’s rural online retail sales reached CNY 975.93 billion,
up to 2.5% annually; the online retail sales of agricultural products reached CNY 250.67 billion, up to 11.2% annually. With the support and encouragement of the government and the active participation of entrepreneurs, the innovative business mode of e-commerce platforms in rural China can provide references for the world’s poor populations to eradicate poverty and foster the sustainable development of rural areas [5]. Largely, rural e-commerce has played a positive role in boosting the growth of the agricultural economy. However, a range of challenges need to be addressed as well, such as deficient quality control, insufficient logistics and supply chain capability, talent shortage, irregular service and insufficient policy coordination, which result in a low success rate and performance. Developing an efficient rural e-commerce ecosystem can be critical to address the issue of resource constraints and improve the performance of e-commerce in rural areas.

The rural e-commerce entrepreneurship ecosystem is composed of major players such as entrepreneurs, e-commerce platforms, governments and other factors such as policies and external environments, which influence and depend on each other in the process of forming a dynamic equilibrium system. Among them, e-commerce platforms, entrepreneurs and governments are the core participants of the rural e-commerce entrepreneurship ecosystem [6]. E-commerce platform refers to the website platform that showcases the products or services for sale, processes purchases, electronic payments and other business transactions for rural e-commerce, allowing entrepreneurs to take advantage of modern information technology. Entrepreneurs refer to the individuals of production and operation engaged in rural e-commerce entrepreneurship. Government refers to the regulatory department that conducts administrative intervention through state rights and acts against the violations of enterprises. The best direction for the evolution of the entrepreneurial system is the formation of mutually beneficial and stable cooperative relationships between various subjects [7].

Due to information asymmetry, in the development process of the rural e-commerce entrepreneurship ecosystem, the e-commerce platforms, entrepreneurs and the government will all have opportunistic behaviors, and the three parties are faced with different strategic choices. In order to avoid costs, the e-commerce platform has the moral hazard problems of malicious speculation, illegal price marketing and false transactions, which is called the e-commerce platform “passive participation”; correspondingly, when the e-commerce platform provides quality services to the entrepreneurs, it is called the e-commerce platform “active participation”. Entrepreneurs use the e-commerce platform to start a business, obtain quality service and improve their success rate. However, entrepreneurs also face the moral hazard of passive participation of the e-commerce platform, and entrepreneurs may choose a more conservative retention of income with higher uncertainty, rather than choose to earn more entrepreneurial income through the e-commerce platform. There are two kinds of strategies for the government to participate in the development of rural e-commerce entrepreneurship: the first is the government choosing “passive participation” to avoid costs, that is, the government simply provides financial subsidies to e-commerce platforms and entrepreneurial entities. The second is “active participation”. In addition to the subsidy policies, the government will also punish the passive participation of the e-commerce platforms, so as to force the e-commerce platforms to provide quality services to entrepreneurs and improve the success rate of entrepreneurship.

No matter whether the government adopts the active participation strategy or the passive participation strategy, the government is the main game subject in the development process of the rural e-commerce entrepreneurship ecosystem. How to promote e-commerce platforms to provide quality services through government participation and encourage entrepreneurs to achieve entrepreneurial success through e-commerce platforms, is an important issue of great practical significance and innovation in the field of rural e-commerce. This paper mainly explores the following three questions:
(1) Is there a stable strategy in the evolutionary game among the three players, namely e-commerce platform, entrepreneurs and the government?

(2) What is the relationship between the equilibrium convergence of the three players, namely e-commerce platform, entrepreneurs and the government, and the initial intention of their respective groups in the evolutionary process? How does the initial intention affect policy stability?

(3) Can the sustainable development of the rural e-commerce entrepreneurship ecosystem be achieved by adjusting the government’s subsidies and penalties on e-commerce platforms and entrepreneurs?

Based on the bounded rational evolutionary game theory, this paper establishes a tripartite evolutionary game model in the development process of the rural e-commerce entrepreneurship ecosystem to identify the most stable strategy for system evolution, and describes the evolution trajectory of the behavioral strategies of each player by introducing the initial intention of the entrepreneurs, the e-commerce platforms and the government into the model and provides a scientific basis for the healthy development of the rural e-commerce entrepreneurship ecosystem. This paper’s contributions are the three that follow:

(1) An asymmetric model has been built based on e-commerce platform, entrepreneurs and the government, and the evolutionary game theory has been applied to analyze the behavioral decisions of players, thereby achieving the optimal returns under bounded rationality.

(2) At present, studies on rural e-commerce entrepreneurship mainly focus on single player or typical cases, and no mathematical modeling analysis on the behavioral strategies evolution of multiple players in the rural e-commerce entrepreneurship ecosystem has been found.

(3) We concluded that the final equilibrium strategy among the three players can be changed by adjusting the initial parameters. Among them, the initial intention of the three players and government rewards as well as punishments are the decisive factors to promote the efficient development of the rural e-commerce entrepreneurship ecosystem, which provides a scientific basis for the government to formulate relevant policies.

The structure of this paper is as follows. The first part is an introduction, which raises the background and research questions. The second part is a literature review. The third part is model hypothesis and game model construction. The fourth part is the model stability analysis, discussing the evolution stability of each player’s strategy choice in the development process of the rural e-commerce entrepreneurship ecosystem. The fifth part is a numerical simulation analysis, depicting the evolution of each player’s behavioral strategies with the changes in different parameters. The sixth part presents the conclusions, management inspirations and further directions.

2. Literature Review

2.1. Study on Entrepreneurship Ecosystem

The concept of entrepreneurship ecosystem was developed early by Cohen, which is defined as a community formed by interacting players in a specific area to achieve sustainable development and create social and economic value by helping and promoting the creation and growth of new enterprises [8]. At present, studies on entrepreneurship ecosystem mainly focus on two aspects: one is to explore the core elements and construction of entrepreneurship ecosystem; the other is to pay attention to the dynamic evolution of the entrepreneurship ecosystem. For the entrepreneurship ecosystem, new enterprises are the main players [9], the government, investment institutions and technical support platforms are the indirect players [10–12]; while the natural environment, cultural atmosphere and market are the external environmental elements [13,14]. In addition, the number of players, service quality of technical support platforms and member network are also crucial to the entrepreneurship ecosystem [15]. In view of the intricate interaction between elements, scholars specify entrepreneurship ecosystems in specific fields such as digital entrepreneurship, graduate innovation entrepreneurship and rural household entrepreneurship [16–18].
The evolution of an entrepreneurship ecosystem is not only affected by the strategic choices of players in the system, but also by the selective behavior of the external environment itself [19]. Cantner et al. [20] believes that the evolutionary game is the essential feature of the development of an entrepreneurship ecosystem. The players in the system can consistently improve their own structure and function through constant competition, strategy adjustment and cooperation. At present, academia pays more attention to the entrepreneurship ecosystem of the whole and specific players, but there is still a lack of relevant studies on the entrepreneurship ecosystem in the field of rural e-commerce, implying the significance of this study.

2.2. Study on Rural E-Commerce Entrepreneurship

The development of rural e-commerce has recently become an innovative strategy for farmers to increase their incomes. Studies on rural e-commerce entrepreneurship are increasingly enriched, mainly focusing on three aspects: (1) Typical mode for rural e-commerce entrepreneurship. Cunha et al. [21] proposes the frugal entrepreneurship mode. Mei et al. [22] takes the typical entrepreneurship model of Taobao village in China as the starting point and reveals the influence mechanism of the Taobao village mode on farmers’ entrepreneurial behavior. (2) Farmers’ intention for rural e-commerce entrepreneurship. The study mainly focuses on the impact of social capital, perceived risk, subjective experience and other factors of farmers’ intention for rural e-commerce entrepreneurship, revealing that the more sufficient the social capital, the richer the subjective experience, while the higher the risk perception certainty, the higher the enthusiasm of farmers to participate in entrepreneurship [23–25]. (3) E-commerce entrepreneurship performance. This paper mainly discusses the impact of venture capital, industrial agglomeration and social network on the farmers’ e-commerce entrepreneurial performance in the process of entrepreneurship. George et al. [26] finds that the development of rural e-commerce can promote entrepreneurial activities and then affect industrial and commercial outcomes. Gao et al. [27] shows that the development of rural e-commerce can provide new employment opportunities and affect wage incomes. However, rural e-commerce is evolving and has shown the characteristics of ecological agglomeration [28], and there is inevitably a complex game relationship among entrepreneurs, the government and e-commerce platforms. Therefore, the behavioral game of multiple players in rural e-commerce entrepreneurship ecosystems is worth studying from the perspective of an ecosystem.

2.3. Study on Evolutionary Game

The evolutionary game theory is a favorable analytical tool to study the interaction behaviors of different players in system decision. Based on bounded rationality, players gradually achieve dynamic equilibrium in the self-adaptive adjustment of their own behavioral strategies through the perception of local information [29]. Due to the influence of self-conditions and local ecological chains, the players in the system weigh the pros and cons according to their own resource advantages and play multi-party games with players in different ecological niches [30]. Akaka et al. [31] discusses the stability strategy and behavioral decision of each player in the process of system value co-creation through the evolutionary game model. Zhuang et al. [32] uses the evolutionary game theory to establish a game model for production recovery and epidemic prevention in the health event decision-making system. Soundarrajan et al. [33] believes that grasping the evolution law of government behavior is important to cultivate a healthy crowd-innovation ecological environment. Audretsch et al. [34] embeds the symbiotic state into the network at each level of the ecosystem and analyzes the evolution process of each player in the entrepreneurship ecosystem. In view of this, the evolutionary game model can effectively represent the expected gains and losses of the players in the system under different strategy choices, and plays an important role in the optimal strategy choice and system equilibrium.
Through the analysis of the literature review, along with the continuous penetration of Internet technology into rural areas, rural e-commerce entrepreneurship has become a hot topic in academic studies, which lays a good theoretical foundation for this study. However, the existing studies of rural e-commerce entrepreneurship mainly focus on a single player or typical cases, and neither does the research study rural e-commerce entrepreneurship from the perspective of an ecosystem, nor does it make explicit the evolutionary mechanism of the behavioral strategies of the players in the system. It should be noted that the development of the rural e-commerce entrepreneurship ecosystem requires the mutual cooperation of all the players. A healthy multi-party cooperative relationship can enhance the strength of the system network, improve the aggregation ability of rural e-commerce entrepreneurship elements and give full play to the advantages of system resources and symbiosis. Therefore, based on the evolutionary game theory, this paper constructs a tripartite evolutionary game model of e-commerce platform, entrepreneurs and government, discusses the evolutionary mechanism of a rural e-commerce entrepreneurship ecosystem with governmental participation and provides instructional suggestions for building an effective rural e-commerce entrepreneurship ecosystem.

3. Model Hypothesis and Construction

3.1. Model Hypothesis

Premise 1: This paper assumes that three types of game players are involved in the rural e-commerce entrepreneurship ecosystem’s evolution: e-commerce platform (EP), enterprise individuals (EIs) and government (G). The three parties contain incomplete symmetrical information, so it is difficult to know the behavior probability of each of them. All parties are bounded to rationality; therefore, the three parties need to learn and adjust repeatedly, constantly revise strategies and repeat the game and then finally obtain a stability strategy. The two strategies of the e-commerce platform are active participation and passive participation, while the behavior strategies of the entrepreneurship individuals are accepting services and not accepting services and the behavior strategies of the government are active participation and passive participation. The probabilities of the EP’s active participation, the EIs accepting services and the G’s active participation are \( \alpha, \beta, \gamma \) respectively, and \( \alpha, \beta, \gamma \in [0, 1] \) are all functions of time \( t \). The initial intentions of the three players are, respectively, marked as \( \alpha_0, \beta_0, \gamma_0 \), and each player dynamically adjusts its game strategy over time \( t \).

Premise 2: EP active participation cost is assumed as \( c_1 \), and the performance income is \( b_1 \); then, the EP’s retained income for passive participation is \( b_0 \). If EIs accept the services provided by the EP, then the EP will obtain additional benefits \( b_2 \).

Premise 3: When G chooses passive participation, G will provide financial subsidy \( s_1 \) to EIs accepting EP services. If the subsidy intensity is \( \lambda_1 \), then the financial subsidy obtained by EI is \( \lambda_1 s_1 \). If the financial subsidy from G for EP is \( s_2 \) and the subsidy intensity is \( \lambda_2 \), then the financial subsidy obtained by the EIs is \( \lambda_1 s_1 \). When G chooses active participation, and the participation cost is \( c_2 \), then in addition to providing subsidy to EP, G’s penalty for the passive participation behavior of EP will be \( p \). If the punishment intensity is \( k \), then the punishment for EP is \( kp \). Moreover, EIs can obtain additional benefits \( (b_3) \) due to the active participation of G.

Premise 4: The obtained income for EIs accepting EP services is \( b_4 \), and the retained income without accepting the services is \( b_5 \).

The parameter symbols and meanings in the above hypotheses are shown in Table 1.
Table 1. Symbols and meanings of model parameters.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
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<th>Meaning</th>
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<tbody>
<tr>
<td>$c_1$</td>
<td>EP active participation cost</td>
<td>$k$</td>
<td>G’s punishment intensity for EP’s passive participation</td>
</tr>
<tr>
<td>$b_1$</td>
<td>EP active participation income</td>
<td>$b_2$</td>
<td>Els’ additional benefits from G’s active participation</td>
</tr>
<tr>
<td>$b_0$</td>
<td>EP retained income for passive participation</td>
<td>$b_4$</td>
<td>Els’ obtained income for accepting EP services</td>
</tr>
<tr>
<td>$b_3$</td>
<td>EP additional benefits from Els accepting the services</td>
<td>$b_5$</td>
<td>Els’ retained income without accepting EP services</td>
</tr>
<tr>
<td>$\lambda_1$</td>
<td>G’s financial subsidy intensity for Els</td>
<td>$c_2$</td>
<td>G’s input costs for active participation</td>
</tr>
<tr>
<td>$\lambda_2$</td>
<td>G’s financial subsidy intensity for EP</td>
<td>$s_1$</td>
<td>G’s financial subsidy to Els accepting EP services in passive participation</td>
</tr>
<tr>
<td>$s_2$</td>
<td>G’s financial subsidy to EP in passive participation</td>
<td>$p$</td>
<td>G’s punishment for EP’s passive participation in active participation</td>
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3.2. Game Payoff Matrix and Replication Dynamic Equation

According to the above premises, the evolutionary game payoff matrix among EP, Els, and G can be constructed, as shown in Tables 2 and 3.

Table 2. Evolutionary game payoff matrix for G active participation ($\gamma$).

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<tbody>
<tr>
<td>Accept ((\beta))</td>
<td>Active participation ((\alpha))</td>
<td>(b_3 + b_4 + \lambda_1 s_1)</td>
<td>(b_1 + b_2 - c_1)</td>
<td>(-\lambda_2 s_2 - \lambda_1 s_1 - c_2)</td>
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<td></td>
<td>Passive participation ((1 - \alpha))</td>
<td>(b_5 + \lambda_1 s_1)</td>
<td>(b_0 - kp)</td>
<td>(kp - \lambda_1 s_1 - c_2)</td>
</tr>
<tr>
<td>Not accept ((1 - \beta))</td>
<td>Active participation ((\alpha))</td>
<td>(b_5)</td>
<td>(b_1 - c_1 - kp)</td>
<td>(kp - \lambda_2 s_2 - c_2)</td>
</tr>
<tr>
<td></td>
<td>Passive participation ((1 - \alpha))</td>
<td>(b_5)</td>
<td>(b_0 - kp)</td>
<td>(kp - \lambda_2 s_2 - c_2)</td>
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Table 3. Evolutionary game payoff matrix for G passive participation (\(1 - \gamma\)).

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<tbody>
<tr>
<td>Accept ((\beta))</td>
<td>Active participation ((\alpha))</td>
<td>(b_4 + \lambda_1 s_1)</td>
<td>(b_1 + b_2 - c_1)</td>
<td>(-\lambda_2 s_2 - \lambda_1 s_1)</td>
</tr>
<tr>
<td></td>
<td>Passive participation ((1 - \alpha))</td>
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<td>(-\lambda_2 s_2)</td>
</tr>
</tbody>
</table>

According to the above premises, the evolutionary game payoff matrix among EP, Els, and G can be constructed, as shown in Tables 2 and 3.

1) Expected income for the EP’s active participation: \(E_\alpha = (b_1 - c_1) + \beta b_2 - (1 - \beta)\gamma kp\)

2) Expected income for the EP’s passive participation: \(E_{1-\alpha} = b_0 - \gamma kp\)

The EP’s average expected income: \(E_{EP} = \alpha E_\alpha + (1 - \alpha)E_{1-\alpha}\)

The EP’s replication dynamic equation:

\[
F(\alpha) = \frac{d_\alpha}{dt} = \alpha (1 - \alpha) [(b_1 - c_1) + \beta \gamma kp + \beta b_2 - b_0]
\]

(1)

(2) Expected income for Els accepting services:

\[
E_\beta = (1 - \alpha) b_5 + \alpha b_4 + [\alpha (1 - \gamma) + \gamma] \lambda_1 s_1 + \alpha \gamma b_3
\]
The expected income for ELs without accepting services: \( E_{1-\beta} = b_5 \)
The ELs’ average expected income: \( E_{\text{EI}} = yE_y + (1 - y)E_{1-y} \)
The ELs’ replication dynamic equation:
\[
F(\beta) = \frac{d\beta}{dt} = \beta(1 - \beta)[a(b_4 - b_5) + (a + \gamma - a\gamma)\lambda_1s_1 + a\gamma b_3]
\] (2)

(3) Expected income for G’s active participation:
\( E_\gamma = kp(1 - \beta\alpha) - (1 - \beta + \beta\gamma)\lambda_2s_2 - \beta\lambda_1s_1 - c_2 \)
The expected income for G’s passive participation: \( E_{1-\gamma} = -\lambda_2s_2 - a\beta\lambda_1s_1 \)
The G’s average expected income: \( E_G = \gamma E_\gamma + (1 - \gamma)E_{1-\gamma} \)
The G’s replication dynamic equation:
\[
F(\gamma) = \frac{d\gamma}{dt} = \gamma(1 - \gamma)[(1 - a\beta)kp + \beta(a - 1)\lambda_1s - \beta(a - 1)\lambda_2s_2 - c_2]
\] (3)

4. Strategy Stability Analysis of Each Game Player

4.1. Solution of Equilibrium Point

According to the evolutionary game theory, if \( F(\alpha) = F(\beta) = F(\gamma) = 0 \), then there are nine equilibrium points in the real number field \( R = \{(a, \beta, \gamma)|a, \beta, \gamma \in [0, 1]\} \), which can satisfy the following conditions:

\[
\begin{align*}
\alpha(b_4 - b_5) + (a - a\gamma + \gamma)\lambda_1s_1 + a\gamma b_3 &= 0 \\
(d_1 - c_1) + \beta b_2 + \beta\gamma kp - b_0 &= 0 \\
(1 - a\beta)kp - \beta(a - 1)\lambda_2s_2 + \beta(a - 1)\lambda_1s_1 - c_2 &= 0
\end{align*}
\] (4)

According to the equilibrium point \( a^*, \beta^*, \gamma^* \), when \( F'(a^*) < 0, F'(\beta^*) < 0, F'(\gamma^*) < 0 \), the stability strategy set among EP, ELs and G is \( \Omega(a^*, \beta^*, \gamma^*) \), and

\[
F'(a^*) = (1 - 2\alpha)[(d_1 - c_1) + \beta\gamma kp + \beta b_2 - b_0]
\] (5)

\[
F'(\beta^*) = (1 - 2\beta)[a(b_4 - b_5) + a\gamma b_3 + (a + \gamma - a\gamma)\lambda_1s_1]
\] (6)

\[
F'(\gamma) = (1 - 2\gamma)[(1 - a\beta)kp + \beta(a - 1)\lambda_1s_1 - \beta(a - 1)\lambda_2s_2 - c_2]
\] (7)

4.2. Stability Analysis

According to the above analysis, when \( F'(a^*) < 0, F'(\beta^*) < 0, F'(\gamma^*) < 0 \), \( a^*, \beta^*, \gamma^* \) is the stability strategy of EP, ELs and G.

(1) EP asymptotic stability analysis. According to Equation (5), the boundary of the EP’s stable state is \( (d_1 - c_1) + \beta\gamma kp + \beta b_2 - b_0 = 0 \). If \( (d_1 - c_1) + \beta\gamma kp + \beta b_2 - b_0 > 0 \), then \( F'(0) > 0 \cap F'(1) < 0 \), thus, the EP’s active participation is regarded as a stable state, while passive participation is regarded as an unstable state. On the contrary, if \( (d_1 - c_1) + \beta\gamma kp + \beta b_2 - b_0 < 0 \), then \( F'(0) < 0 \cap F'(1) > 0 \), at this time, the EP’s active participation is regarded as an unstable state, while passive participation is regarded as a stable state.

(2) EL asymptotic stability analysis. According to Equation (6), the boundary of the ELs’ stable state is \( a(b_4 - b_5) + a\gamma b_3 + (a - a\gamma + \gamma)\lambda_1s_1 = 0 \). If \( a(b_4 - b_5) + a\gamma b_3 + (a - a\gamma + \gamma)\lambda_1s_1 > 0 \), then \( F'(0) > 0 \cap F'(1) < 0 \), thus, ELs accepting the services is regarded as a stable state, while ELs rejecting the services is regarded as an unstable state. On the contrary, if \( a(b_4 - b_5) + a\gamma b_3 + (a - a\gamma + \gamma)\lambda_1s_1 < 0 \), then \( F'(0) < 0 \cap F'(1) > 0 \), thus, ELs accepting services is regarded as an unstable state, while ELs rejecting services is regarded as a stable state.

(3) G asymptotic stability analysis. According to Equation (7), the boundary of G’s stable state is \( (1 - a\beta)kp + \beta(a - 1)\lambda_1s_1 - \beta(a - 1)\lambda_2s_2 - c_2 = 0 \). If \( (1 - a\beta)kp + \beta(a - 1)\lambda_1s_1 - \beta(a - 1)\lambda_2s_2 - c_2 > 0 \), then \( F'(0) > 0 \cap F'(1) < 0 \), thus, the G’s active participation is regarded as a stable state, while the G’s passive participation is regarded as an unstable state.
state. On the contrary, if $(1 - a\beta)kp + \beta(a - 1)\lambda_1s - \beta(a - 1)\lambda_2s_{21} - c_2 < 0$, then $F'(0) < 0 \cap F'(1) > 0$, thus, the G’s active participation is regarded as an unstable state, while the G’s passive participation is regarded as a stable state.

5. Simulation of the Evolution of Tripartite Behavioral Strategies

In order to actively encourage and guide e-commerce entrepreneurship, the government usually provides financial subsidies and support to entrepreneurs and e-commerce platforms and punishes violations of laws and regulations to ensure the healthy and stable operation of the rural e-commerce entrepreneurship ecosystem. In order to intuitively describe the game strategies of the e-commerce platform, entrepreneurs and the government, the MATLAB software is used to simulate the dynamic evolution process of strategy selection of the three players under different initial intentions.

5.1. Parameter Settings

Equations (1)–(3) are discretized, and the time interval is set as $\Delta t = 0.01$. Referring to the initial parameter settings in Zhuang et al. (2021) [32], it is assumed that the initial intentions of the EP’s active participation, the EI’s acceptance of the services and the G’s active participation are identical, i.e., $\alpha_0 = \beta_0 = \gamma_0$, then set 0.2, 0.5 and 0.8 as the low, medium and high intensity, respectively, i.e., $\alpha_0, \beta_0, \gamma_0 = \Omega(0.2, 0.5, 0.8)$ and set $b_1 = 3.1, c_1 = 1.5, c_2 = 1, b_0 = 2.5, b_4 = 3.5, s_1 = s_2 = 1, b_3 = b_2 = p = 1, b_5 = 2$. In reality, the G’s subsidy or punishment intensity for EPs and EIs is different. Therefore, let us set G’s participation intensity (EP subsidy, EI subsidy, EP punishment for passive participation) as low, medium and high, and the parameters are 0.2, 0.5 and 0.8, respectively, i.e., $\lambda_1, \lambda_2, k = \Omega(0.2, 0.5, 0.8)$.

5.2. Simulation Analysis

5.2.1. The Effect of the Initial Intentions of the Three Players and G’s Subsidy Intensity for EIs on the Evolution of Behavioral Strategy of Each Player

We set $\lambda_1 = \Omega(0.2, 0.5, 0.8)$ as low, medium and high G subsidy intensities for EPs, respectively, and fixed the remaining parameters. MATLAB is used to simulate the evolution trajectory of each player’s behavior.

(1) The effect of the initial intentions of the three players and G’s subsidy intensity for EIs on the evolution of EP behavioral strategy. This paper analyzes the effects of the initial intention of the EP’s active participation, the initial intention of the EIs accepting services and the initial intention of the G’s active participation on the evolution of the EP’s behavioral strategy. The results show that the improvement in the intention of the EIs accepting services and the intention of the G’s active participation is conducive to the evolution of an EP behavioral strategy toward active participation, but there are still differences in the effects.

As shown in Figure 1, when the initial intention of the EIs’ acceptance of the services is at a low level $(\beta_0 = 0.2)$, with the improvement in the initial intention of the EIs’ acceptance of the services, the evolution speed of the EP’s game behavior toward active participation is accelerated, and the evolution speed toward passive participation is reduced. When the initial intention of the EIs accepting the services is at a medium–high level $(\beta_0 = 0.5, 0.8)$, with the improvement in the initial intention of the EIs accepting the services, not only the evolution speed of the EP’s game behavior toward active participation is accelerated, but the strategy of participation behavior of the EP with low initial intention $(\alpha_0 = 0.2)$ also evolves from passive participation to active participation. Therefore, the evolution of the Eps’ behavioral strategy is not only affected by their own initial intention, but also significantly affected by the intention of the EIs.
5.2. Simulation Analysis
5.2.1. The Effect of the Initial Intentions of the Three Players and G’s Subsidy Intensity

As shown in Figure 2, when the G’s initial intention of participation is at different levels ($\gamma_0 = 0.2, 0.5, 0.8$), all the EPs will evolve toward active participation. The G’s intention of active participation has a significant impact on the evolution speed of the EPs’ game strategy. The increase in the G’s intention of active participation accelerates the evolution speed of the EPs’ behavior. Therefore, the improvement in initiative of the G’s active participation is conducive to promoting the EPs to actively provide services to the EIs and create a healthy environment for rural e-commerce entrepreneurship.

(2) The effect of the initial intention of the three players and of the G’s subsidy intensity for EIs on the evolution of the EIs’ behavioral strategy. This paper further analyzes the effects of the initial active participation intention of the EPs, the initial intention of the EIs of accepting services and the initial intention of the G of active participation on the evolution of the EIs’ behavioral strategy. The improvement in the initial intention of the EIs accepting EP services has accelerated the evolution speed of the EIs’ game behavior. Compared with the effect of the G’s intention of active participation on the EIs’ behavioral strategy, the intention of active participation of the EPs has a more significant effect on the evolution speed of the EIs’ behavior.

As shown in Figure 3, when the initial intention of the EIs is at a low level ($\beta_0 = 0.2$), the medium- or high-level intention of the EP’s active participation ($\alpha_0 = 0.5, 0.8$) can improve the initial intention of the EIs and promote the evolution of the EIs to actively accept services. When the initial intention of the EIs reaches a medium-high level ($\beta_0 = 0.5, 0.8$), the improvement in the intention of active participation of the EPs can accelerate the evo-
lution speed of the EIs’ behavior. As shown in Figure 4, when the G’s intention of active participation is at different levels ($\gamma_0 = 0.2, 0.5, 0.8$), the EIs’ behavioral strategy will evolve toward the active direction, and the increase in the G’s intention of participation accelerates the evolution speed of the EIs toward accepting services.

![Figure 3. Evolution trajectories of E_{EI} and E_{EP} initial intention and E_{EI} behavioral strategy under different $\lambda_1$.](image)

![Figure 4. Evolution trajectories of E_{EI} and G initial intentions and E_{EI} behavioral strategy under different $\lambda_1$.](image)

(3) The effect of the initial intentions of the three players and the G’s subsidy intensity for EIs on the evolution of the G’s behavioral strategy. This paper analyzes the effects of the initial intention of active participation of the EPs, the initial intention of the EIs of accepting services and the initial intention of active participation of the on the evolution of the G’s game behavioral strategy. As shown in Figures 5 and 6, the evolution of the G’s behavioral strategy is significantly affected by the initial intention of each player in the rural e-commerce entrepreneurship ecosystem and by the G’s subsidy intensity for EIs. The higher the intention of active participation of the EPs, the initial intention of the EIs of accepting services and the intention of active participation of the G, the faster the evolution speed of the G’s behavioral strategy toward active participation. In order to encourage rural e-commerce entrepreneurship, the G provides policy support and financial subsidy to the EIs. However, the G’s financial support is limited. Without considering the social contribution of the EIs, the greater the subsidy intensity for the EIs, the greater the financial pressure on the G, and the slower the evolution speed of the G’s game strategy toward active participation. Only the EIs’ support cannot effectively improve the rural e-commerce entrepreneurship environment. Therefore, the G needs to rely on EPs to build the rural e-commerce entrepreneurship ecosystem, provide high-quality services for the EIs through...
the integration of EP resources and lead to the healthy and orderly development of the rural e-commerce entrepreneurship ecosystem.

**Figure 5.** Evolution trajectories of G and EEP initial intentions and G behavioral strategy under different $\lambda_1$.

**Figure 6.** Evolution trajectories of G and EEI initial intention and G behavioral strategy under different $\lambda_1$.

5.2.2. The Effect of the Initial Intentions of the Three Players and the G’s Subsidy Intensity for EPs on the Evolution of Behavioral Strategy of Each Player

We set $\lambda_2 = \Omega(0.2, 0.5, 0.8)$ as the low, medium and high G subsidy intensities for EIs, respectively, and fixed the remaining parameters. MATLAB is used to simulate the game evolution trajectory of each player.

(1) The effect of the initial intentions of the three players and the G’s subsidy intensity for the EPs on the evolution of the EPs’ behavioral strategy. The EPs’ game strategy is significantly affected by the initial intention of each player in the rural e-commerce entrepreneurship ecosystem and by the G’s subsidy intensity for EPs. The improvement in the intention of the EIs of accepting services and in the G’s active participation significantly accelerated the evolution speed of the EPs’ behavioral strategy toward active participation.

This paper analyzes the effects of the intention of the EIs of accepting services, the initial intention of active participation of the EPs and the simultaneous changes in the G’s subsidy intensity for the EPs on the evolution of the EPs’ game strategy. As shown in Figure 7, when the initial intention of active participation of the EPs and the initial intention of the EIs of accepting services are both at low levels ($\alpha_0 = 0.2, \beta_0 = 0.2$), the G can only increase the subsidy intensity for the EPs to promote the evolution of EPs from passive participation toward active participation. At the same time, the improvement in the intention of the G’s active participation accelerated the evolution of the EPs’ game strategy toward active participation, as shown in Figure 8. In the early stage of the development of a rural e-
commerce entrepreneurship ecosystem, the EP faces many difficulties in survival and development. The G should increase its support for EPs, especially those independently developed by enterprises, guide the rapid growth of EPs and promote EPs to provide professional and standardized services to EIs by active participation.

![Figure 7](image_url)

**Figure 7.** Evolution trajectories of $E_{Ep}$ and $E_{EI}$ initial intentions and $E_{Ep}$ behavioral strategy under different $\lambda_2$.

![Figure 8](image_url)

**Figure 8.** Evolution trajectories of $E_{Ep}$ and G initial intentions and $E_{Ep}$ behavioral strategy under different $\lambda_2$.

(2) The effect of the initial intentions of the three players and of the G’s subsidy intensity for the EPs on the evolution of the EIs’ behavioral strategy. This paper analyzes the effects of the initial intention of the EPs, and the simultaneous changes in the G’s subsidy intensity for the EPs on the evolution of the EIs’ game strategy. As shown in Figure 9, when the initial intention of active participation of the EPs is at a low level ($a_0 = 0.2$), the improvement in the G’s subsidy intensity for the EPs accelerates the evolution of the EIs’ behavioral strategy toward active accepting services. Therefore, in the early stage of the development of a rural e-commerce entrepreneurship ecosystem, the G’s financial subsidy intensity for the EPs is particularly important. This paper analyzes the effect of the initial intention of active participation of the G and the simultaneous changes in the G’s subsidy intensity for the EPs on the evolution of the EIs’ behavioral strategy. The improvement in the intention of active participation of the G accelerates the evolution speed of the EIs toward accepting services, as shown in Figure 10.
Figure 9. Evolution trajectories of $E_{EI}$ and $E_{EP}$ initial intentions and $E_{EI}$ behavioral strategy under different $\lambda_2$.

Figure 10. Evolution trajectories of $E_{EI}$ and $G$ initial intentions and $E_{EI}$ behavioral strategy under different $\lambda_2$.

(3) The effect of the initial intentions of the three players and of the G’s subsidy intensity for the EPs on the evolution of the G’s behavioral strategy. This paper analyzes the effects of the initial intention of each player in the rural e-commerce entrepreneurship ecosystem and the simultaneous changes in the G’s subsidy intensity for the EPs on the evolution of the G’s behavioral strategy, as shown in Figures 11 and 12. When the intention of active participation of the G is at a low level ($\gamma_0 = 0.2$), the improvement of the intention of active participation of the EPs and the initial intention of the EI is conductive to the G’s evolution toward active participation, while the medium–high level ($\alpha_0 = 0.5, 0.8, \beta_0 = 0.5, 0.8$) intention of active participation of the EPs and the initial intention of the EI will reduce the effect on the evolution of the G’s behavior toward active participation, until it turns to the passive direction. In the early stage of the development of the rural e-commerce entrepreneurship ecosystem, due to the unclear positioning of the EI, the information asymmetry between EPs, and the constraints of funds, technology and talents, the EPs are not capable of providing high-quality services to all EI, which also reduces the initial intention of the cooperation between EI and EPs. While increasing the financial support for the EPs, the G must improve its participation and actively participate in the development of the rural e-commerce entrepreneurship ecosystem. However, when the rural e-commerce entrepreneurship ecosystem is mature, the G should reduce its direct intervention, and instead create a fair market competition environment by improving the market access criteria for the EPs, optimizing the whole-chain supervision system and establishing a comprehensive government coordination mechanism, thereby encouraging the EPs’ high-quality development.
Figure 11. Evolution trajectories of G and EEP initial intentions and G behavioral strategy under different $\lambda_2$.

Figure 12. Evolution trajectories of G and EEP initial intentions and G behavioral strategy under different $\lambda_2$.

5.2.3. The Effect of the Initial Intentions of the Three Players and Different Punishment Intensities on the Evolution of Behavioral Strategy of Each Player

The EP is the online market platform that the EIs rely on for their survival. In order to continuously optimize the business environment, the G needs to regulate EP behavior through relevant policies and measures. We set $k = \Omega(0.2, 0.5, 0.8)$ as the low, medium and high G punishment intensities for EPs, respectively, and fixed the remaining parameters. MATLAB is used to simulate the evolution trajectory of each player’s behavior.

(1) The effect of the initial intentions of the three players and of the different punishment intensities on the evolution of the EPs’ behavioral strategy. The improvement of the G’s punishment intensity for the EP’s passive participation accelerated the evolution of the EP’s game strategy toward active participation. This paper analyzes the effects of the synchronous changes of initial intention of the EIs of accepting services, the initial intention of active participation of the EPs on the evolution of the EPs’ game strategy. As shown in Figures 13 and 14, the intention of active participation of the G and the initial intention of active participation of the EPs have a positive effect on the behavior of the EPs’ performance. When the initial intention of the EIs is at a low level ($\alpha_0 = 0.2$), and the intention of active participation of the EPs is also at a low level ($\alpha_0 = 0.2$), then the EPs’ behavioral strategy evolves toward passive participation. When the initial intention of the EIs reaches a medium–high level ($\beta_0 = 0.5, 0.8$), the improvement in the G’s punishment intensity accelerates the evolution speed of the EPs’ behavioral strategy toward active participation. Similar to the initial intention of the EIs of accepting services, the improvement of the G’s intention of active participation is conducive to promoting the EPs’ active participation.
The effect of the initial intentions of the three players and different punishment intensities on the evolution of the EIs’ behavioral strategy. This paper analyzes the effects of the synchronous changes of initial intention of the EIs and of the G’s punishment intensity on the evolution of the EIs’ game strategy. As shown in Figure 15, when the initial participation intention of the EPs is at a low level ($\alpha_0 = 0.2$), even if the G’s punishment intensity for the EPs’ passive participation is high ($k = 0.8$), it is still insensitive to the effect on the EIs’ behavioral strategy. With the prolongation of the G’s active participation, the effect of government intervention gradually emerges, and more and more EIs have evolved their final behavioral strategy toward the active direction. When the initial performance intention of the EPs reaches a medium level ($\beta_0 = 0.5$), if the G’s punishment intensity for the EPs is at a high level ($k = 0.8$), some EIs with a high initial intention ($\beta_0 = 0.8$) will choose to accept the EP’s services first. With more and more EIs joining the rural e-commerce entrepreneurship ecosystem, the “herd effect” appears, and the market expectations of each player are gradually improved. In addition, with the improvement in the intention of active participation of the G, the rural e-commerce entrepreneurial environment has become more standardized, which has enhanced the entrepreneurial confidence of the EIs and promoted the evolution of the EIs’ behavioral strategy toward the active direction, as shown in Figure 16.
Figure 15. Evolution trajectories of $E_{EI}$ and $E_{Ep}$ initial intentions and $E_{EI}$ behavioral strategy under different $k$.

Figure 16. Evolution trajectories of $E_{EI}$ and $G$ initial intentions and $E_{EI}$ behavioral strategy under different $k$.

(3) The effect of the initial intentions of the three players and different punishment intensities on the evolution of the G’s behavioral strategy. This paper analyzes the effects of the synchronous changes of initial performance intention of the EPs, the intention of the EIs accepting services and the G’s punishment intensity on the evolution of the G’s game strategy. From the above analysis (see Figure 14), when the initial performance intention of the EPs is low ($α_0 = 0.2$), the G’s low punishment intensity ($k = 0.2$) can neither effectively promote the evolution of the EIs’ behavioral strategy toward the active direction, nor can it effectively improve the behavior of the EPs’ passive participation. The government should increase the punishment intensity for the EPs’ passive participation so as to boost market confidence. When the initial intention of the EPs performance reaches a medium level ($α_0 = 0.5$), as the initial intention of the EIs increases, the G’s high punishment intensity ($k = 0.2$) can neither effectively promote the evolution of the EIs’ behavioral strategy toward the active direction, nor can it effectively improve the behavior of the EPs’ passive participation. The government should increase the punishment intensity for the EPs’ passive participation so as to boost market confidence. When the initial intention of the EIs performance reaches a high level ($α_0 = 0.8$), the development of the rural e-commerce entrepreneurship ecosystem will be optimal, and the G’s behavioral strategy will evolve toward the passive direction.
Therefore, only by adopting punishment and providing a certain degree of financial subsidy can the government effectively improve the rural e-commerce entrepreneurial environment. When the rural e-commerce entrepreneurship ecosystem is mature, the cooperation between the EPs and EIs will be stable. Due to its diminishing marginal utility, the effect of the G’s active participation on the EPs’ behavioral strategy is gradually weakened, and even inhibits the EPs from providing high-quality services to the EIs. Under this circumstance, the G should reduce any excessive intervention, and instead create a fair market competition environment and standardize the EPs’ operations by improving the market access criteria for EPs, optimizing the whole-chain supervision system and establishing a comprehensive government coordination mechanism, thereby promoting the sustainable and healthy development of the rural e-commerce entrepreneurship ecosystem.

6. Conclusions and Implications

6.1. Conclusions

Based on the complex relationships between EP, EIs and G in the rural e-commerce entrepreneurship ecosystem, this paper constructs an evolutionary model of game strategy...
of the three players, and introduces the initial intentions of the EP, EIs and G as well as the G’s participation, discusses the effect of the initial intentions of the three interest gainers and the G’s participation strategy on the evolution mechanism of the behavioral strategy of the three players. The main study conclusions are summarized as follows:

(1) The means of government subsidies have a significant influence on the direction and speed of the system’s evolution. Compared with the G’s direct subsidy to the EIs, the G’s subsidy to the EPs is more conducive to the evolution of the EPs’ active participation and to EIs’ acceptance of the services. The evolution of the game strategy of e-commerce platforms and entrepreneurial subjects is affected by the initial willingness of the participants. When using punishment means to regulate e-commerce behavior, the government needs to use subsidies to improve the initial willingness of e-commerce platforms and entrepreneurs, so as to better play the effect of government punishment means.

(2) In the early stage of the development of the rural e-commerce entrepreneurship ecosystem, the EPs’ performance deviates from the G’s expectations, and the G’s active participation is helpful for the EPs to provide high-quality services to the EIs. When the development of the rural e-commerce entrepreneurship ecosystem tends to mature, the G’s active participation will weaken its impact on the EPs’ and EIs’ behavioral evolution, and even inhibit the EPs from providing high-quality services to the EIs. Thus, the G’s behavioral strategy will evolve toward the passive direction.

(3) The changes in the initial intentions of the three players have a significant impact on the evolution of the behavioral strategy of each player in the rural e-commerce entrepreneurship ecosystem. When the initial performance intention of the EPs and the initial intention of the EIs of accepting the services are at a low level, the G’s participation has a weak impact on the evolution of the EPs’ and EIs’ game strategy. When the initial performance intention of the EPs and the initial intention of the EIs of accepting the services are at a high level, the G’s participation can, at a low level, achieve the expected goal.

6.2. Managerial Implications

(1) The government, in implementing the policy of rural e-commerce entrepreneurship ecosystem, should reward and punish simultaneously. On one hand, it may be necessary to increase the subsidies for e-commerce platforms and provide appropriate subsidies for entrepreneurs. Research shows that compared to the G’s direct subsidy to the EIs, the G’s subsidy to the EPs is more conducive. Therefore, the limited finance should first subsidize the e-commerce platforms (including tax incentives, loan subsidies and awards instead of punishment, etc.), so as to improve the enthusiasm of the e-commerce platforms to provide quality services. Then, through the moderate introduction of start-up subsidies, social security subsidies and rent subsidies, to reduce the risk for the entrepreneurs, their enthusiasm and the success rate of entrepreneurship. On the other hand, it may be reasonable to strengthen the supervision of the e-commerce platforms, and punish the e-commerce platforms that fail to perform their duties (including fines, warning interviews, orders to exit, etc.).

(2) The government should fully play the role of “leader” based on the features of the different stages of the development of rural e-commerce entrepreneurship ecosystems. In the early stage of the development of the rural e-commerce entrepreneurship ecosystem, it is difficult for the system’s development to rely solely on market forces. The government should actively guide e-commerce platforms to provide quality services for entrepreneurs, take subsidy measures to reduce the entrepreneurial cost and capital pressure on entrepreneurs and then promote the development and evolution of the rural e-commerce entrepreneurship ecosystem. When the development of the rural e-commerce entrepreneurship ecosystem enters a mature stage, the government should gradually reduce its direct intervention on the behavior of e-commerce platforms, and instead regulate the performance behavior of e-commerce platforms by improving the
access standards of e-commerce platforms, improving the supervision system of the whole chain, and establishing a government comprehensive coordination mechanism.

(3) According to the research, the higher the initial willingness of the e-commerce platforms and entrepreneurs, the more conducive it is to the evolution of the game decision in a positive direction. Therefore, a high-quality entrepreneurial environment to enhance the initial intentions of the EI and EP should be created. First, an e-commerce public service center should be established to provide one-stop services such as training and incubation, business consultation and technical guidance for e-commerce platforms and entrepreneurial entities. Second, it may be necessary to further the development of logistics infrastructures in rural areas to create appropriate conditions for the convenient circulation of agricultural products. Third, it may be reasonable to actively cultivate rural e-commerce talents, improve the accuracy of training and incubate multiple types of new e-commerce farmers. Efforts should be made to create a good environment for the development of rural e-commerce to improve the initial willingness of all participants in the development process of the rural e-commerce entrepreneurship ecosystem.

6.3. Study Limitations and Further Directions

There are still some deficiencies in this paper. The rural e-commerce entrepreneurship ecosystem is complex and dynamic, which increases the complexity of the operation process. In addition to the three core participants, including entrepreneurs, e-commerce platform and government, there is still a range of variables for the evolution process of the rural e-commerce entrepreneurship ecosystem. In further studies, external factors such as policy changes, economic environment, new technologies and new scenarios will be used to construct a dynamic and repeated game model with the participation of multiple players.

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