J. COMBIN. MATH. COMBIN. COMPUT. 127a (2025) 851–869

Journal of Combinatorial Mathematics
and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Adoption Decision-making and the Evolution of Consumer Rights Protection Behaviour in Sharing Economy Platforms Based on Blockchain Technology

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ABSTRACT
This paper constructs a two-party evolutionary game model based on the perspectives of sharing platforms and consumers, exploring the dynamics of platforms' decisions to actively operate with blockchain technology and the evolution of consumer rights protection behaviors. It is discovered from analysis that certain variables exert considerable influence on the stability of the strategies of both parties. From the consumer perspective, the improvements in the performance of the blockchain technology significantly increase the consumers' willingness to protect their rights: the consumers with initially high levels of rights protection activation intensified their actions when their rights were violated. Thus, with the effective reduction of the cost of safeguarding rights, this trend has been additionally strengthened. As for the platform side, the performance of the blockchain technology exerts positive incentives on the operation of the platforms, although the marginal impact gradually declines with the developing blockchain technology, which in return reveals that platforms need to pay attention to a range of aspects including technology maturity. Measures of dual constraints including heavy fines from government and negative impacts of passive operations help to rein in passive operation among the platforms. Significantly, higher values of fines or negative effects lead to higher tendencies of having proactive operation strategy among the platforms.

Keywords: Sharing economy, Blockchain, Consumer rights protection, Evolutionary game theory

1. Introduction

Globalization is giving way to the sharing economy and the economy is changing dramatically with the help of this model. It is not only in transportation and services, but in every possible area, new sharing platforms are being launched recurrently with increasing numbers of users as the new motor of economic development. But here is one disadvantage of such a fast pace of this process: it is not without difficulties and obstacles. There are questions of deepened information asymmetry, new trust deficits, and weaknesses

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Received 02 April 2024; Revised 21 July 2024; Accepted 11 November 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-050

in the protection of consumer rights, which have emerged gradually and have become major shortcomings that obstruct the healthy development of sharing platforms. Such issues may lead to such threats as prejudice towards consumers, the deterioration of the quality of the services provided, leakage of consumers' personal information, which would significantly influence their satisfaction regarding sharing platforms. Therefore, as to how to overcome these challenges so as to maintain the sustainable development of sharing platforms and continue to meet the needs of consumers' high-quality service experience, this has become a new major issue that conforms to consumers' needs and demands.

According to the conditions of the sharing economy, the protection of consumers' rights remains one of the fundamental pillars that facilitate the stable work of the market. If there is a conflict in sharing platforms, consumers are willing to go out of their way to ensure that their rights are protected through expressing to the platform's customer service, to consumer associations and even to the justice system. Besides these rights protection actions, people have shown a growing awareness of self-protection and delivering platforms play more crucial roles in the constant improvement of services in quality in an unconsciously competitive manner; In other words, consumers, by actively asserting their rights, help sharing platforms get a better picture of the existing problems and deficiencies that exist on the part of consumers and promote the targeted development and growth of trusting and mutually beneficial relationships between market participants.

As a new technology in the digital economy era, blockchain has huge business value and key advantages in supporting and constructing the circulation of healthy sharing economies. Incorporating essential aspects of decentralization, the inability of data change, and high transparency, the blockchain system alters share programs. They also eliminate information asymmetry and make the transactions more transparent and thus improves the trust which forms the basis of users in the market. In addition, through the incorporation and use of features such as smart contracts, blockchain also enables automated contracts, reduces the human interference in contracts and increases on the level of efficiency and security. The obtained benefits help not only to manage the processes of sharing platforms' operation at the highest level but also to bring the general level of services and users' satisfaction to a completely new level. Therefore, in relation to the present calling for creating the healthy model of sharing between different platforms and users, blockchain technology is seen as one of the key technological supports.

As for the two primary elements which are consumer rights protection behaviors and the blockchain to further the prospect and healthy development of sharing platforms, this paper attaches importance to both. Employing evolutionary game theory as an analytical tool, the paper aims to dissect the dual decision-making mechanisms: ask the questions like whether the sharing platforms should employ blockchain technology if not and whether the consumers decide to stand for their rights whenever they are challenged on rights. This will reveal the relationships between consumer rights protection behaviors and blockchain and the pathways they exert on the health of sharing platforms. In addition, aligning with the present course of government policy directions, this paper will present a set of strategic suggestions, including a series of mutually complementing action plans for consistently enhancing the viable development of sharing platforms.

2. Literature Review

2.1. *The sharing economy*

The development of the sharing economy has emerged as a pivotal area of in-depth academic exploration in recent years, attracting widespread research interest. Mahadevan et al. (2018) [1] unveiled the profound motivations influencing user satisfaction on sharing platforms, studying the factors that contribute to this satisfaction and identifying trust deficiency as the primary obstacle. Choi et al. (2019) [2] analyzed the collaborative consumption model of fashion products within the sharing economy, discovering that this model significantly enhances product value and corporate profits. Wirtz et al. (2019) [3] delved into the business models and competitive advantages of peer-to-peer sharing platforms, challenging the prevalent notion of a "winner-takes-all" scenario in the sharing economy. Benjaafar et al. (2019) [4] utilized an equilibrium model to examine issues of ownership and usage rights in the sharing economy, arguing that consumers can reap benefits from this arrangement. He et al. (2021) [5] shifted their research focus to the user experience on peer-to-peer sharing platforms under circular economy strategies, emphasizing the importance of factors such as information transparency and product quality. Lastly, Taleizadeh et al. (2022) [6] explored the application of online peer-to-peer lending platforms within supply chains.

2.2. *Applications of Blockchain Technology*

Blockchain technology is gradually demonstrating its application potential across various sectors. Rijanto et al. (2021) [7], through case studies, confirmed that the application of blockchain technology in supply chain finance can address numerous challenges faced by traditional finance, such as limited financing scope, costs, and risk management. Harwick et al. (2022) [8] delved into the role of blockchain in financial intermediation, proposing a technical integration pathway to achieve genuine blockchain-native applications. Bulut et al. (2022) [9] investigated factors influencing the success probability of Initial Coin Offerings (ICOs), offering practical guidance for the crowdfunding domain. Ning et al. (2023) [10] examined how blockchain reconfigures the business models of supply chain finance platforms, presenting a supportive framework.

In the healthcare sector, Shen et al. (2019) [11] introduced a blockchain-based image protection system to tackle medical data privacy concerns. Chen et al. (2021) [12] explored the integration of 5G and blockchain technologies in drone-based medical services. Liu et al. (2023) [13] proposed a blockchain-powered multi-keyword search scheme, enabling efficient retrieval and privacy protection of encrypted electronic health records. Karmakar et al. (2024) [14] developed MediChain, an efficient blockchain-based storage framework, ensuring secure and adaptive storage of critical health information within the Internet of Medical Things (IoMT). A few scholars have also researched the application of blockchain technology in the sharing economy. Cai et al. (2022) [15] presented a novel two-tiered scalable design framework, addressing scalability issues associated with blockchain in shared economies. Lage et al. (2022) [16] conducted a systematic analysis of emerging blockchain-based platform economies, revealing the characteristics of their decentralized business models.

2.3. *Evolutionary game method*

The evolutionary game approach has been extensively applied in the research of various domain problems, yielding fruitful research outcomes. Jia et al. (2021) [17] analyzed the cooperation mechanism of electronic warehouse receipt pledge financing by constructing an evolutionary game model involving loan enterprises, commercial banks, e-commerce platforms, and logistics alliances. Their study revealed the impact of factors such as credit levels and interest rates on equilibrium strategies. In order to explore the key driving factors of the speed of supplier selection of supply chain finance, under the guidance of organizational motivation theory, Wuttke et al. (2019) [18] build an empirical research model and puts forward corresponding research hypotheses. The research points out that the main driving force for suppliers to adopt supply chain finance comes from the normative requirements of imitation and legitimacy. Zhang et al. (2023) [19] introduced central bank digital currencies into their study and constructed an evolutionary game model for accounts receivable financing. This model analyzed the stable strategies and changes in decision-making paths between SMEs and financial institutions. Jiang et al. (2022) [20] employed the evolutionary game method to explore issues related to enhancing doctors' diagnostic accuracy and protecting patient information security. In a separate study, Wei et al. (2023) [21] constructed an evolutionary game theory framework to simulate the dynamic process of public adoption of non-pharmaceutical interventions during the COVID-19 pandemic. Their work provided insights into the evolutionary trajectories of population behavior, aiding decision-makers. Within the realm of the sharing economy, Li et al. (2022) [22] established an evolutionary game model for the manufacturing industry, examining the issue of resource sharing among enterprises. They proposed suggestions to facilitate rapid development in the manufacturing sector. Furthermore, Xu et al. (2023) [23] explored an evolutionary game model for technology sharing behavior based on organizational bounded rationality. This study investigated the influence of factors such as trust and collaborative benefit distribution on the willingness to share technology.

In summary, while there exists a wealth of research on the sharing economy and blockchain technology, only a minority of scholars have delved into how blockchain technology can be applied within the sharing economy and the business models of the sharing economy based on blockchain technology. Scarce literature has employed the evolutionary game approach to explore the strategic evolution paths of participants in the sharing economy. Therefore, this paper aims to construct an evolutionary game model for sharing platforms and investigate the blockchain adoption strategies of these platforms as well as the consumer rights protection strategies. Ultimately, we propose some recommendations to facilitate the healthy and sustainable development of sharing platforms.

3. The Evolutionary Game Model

The research object of this paper is the sharing economy system consisting of sharing platforms and consumers. In this system, the sharing platforms serve as the core service providers, playing multiple roles such as resource aggregation, information dissemination, transaction facilitation, and trust building. Consumers, on the other hand, access resources and services through these platforms to satisfy their individual needs.

3.1. Model assumptions

Both the shared platforms and consumers are constrained by bounded rationality. Consequently, at the initial stage, their strategic are not optimal. However, through continuous learning, and adjustment, both parties will gradually optimize their strategies until reaching a relatively stable equilibrium state. The platform tasks with the decision to adopt blockchain technology and has responsibility for compensating consumers when their rights are infringed. It is assumed that platforms will adopt blockchain technology when they operate with great care. Consumers weigh whether to safeguard their rights based on the traceability of the product and the cost of safeguarding those rights. To facilitate modeling, the following assumptions are made in this study:

Assumption 1. The probability of decision-making by both parties. When both parties make decisions, the probability of the shared platform choosing proactive operations is $x(0 \le x \le 1)$, and the probability of choosing passive operations is $1-x$; the probability of consumers choosing to safeguard their rights is $y(0 \le y \le 1)$, and the probability of choosing not to safeguard their rights is $1-y$.

Assumption 2. Benefits and costs of the sharing platform and consumers in the context of blockchain technology.

When the sharing platform operates proactively and consumers safeguard their rights, the following dynamics occur: Firstly, the platform adopts blockchain technology to oversee sharing enterprises and individuals, offering traceability services to consumers. At the same time, the operational cost and blockchain adoption cost of the sharing platform are denoted as $(1-T)C_1$ and TC respectively (Wan et al., 2022) [24], where $T(0 \le T < 1)$ represents the performance of the blockchain. This is because as blockchain performance improves, the cost of adoption for the sharing platform increases, yet the overall operational efficiency of the platform also rises, leading to lower operational costs. Secondly, to incentivize technological innovation, the government grants a subsidy G to enterprises that actively adopt blockchain technology. From the consumers' perspective, they can leverage the traceability services of blockchain to safeguard their rights. The utility derived from sharing products and the cost of safeguarding rights for consumers are denoted as $(1+\alpha)L$ and $(1-T)C_2$, where $\alpha(0 < \alpha < 1)$ signifies the transparency of product information. This is because when consumers safeguard their rights, if the sharing product service offers traceability (i.e., the more transparent the product information is), the perceived value of the product by consumers increases (Liu et al., 2022) [25]. Moreover, in the blockchain environment, the cost of safeguarding rights for consumers is relatively low due to the swift identification of responsible parties facilitated by the traceability feature of blockchain, thereby reducing time costs, evidence costs, and other expenses during the rights safeguarding process.

When the sharing platform operates actively, and consumers choose not to safeguard their rights, consumers can only derive a basic utility L from the sharing products and pay a price P for them.

Assumption 3. Benefits and costs of the sharing platform and consumers in a non-blockchain environment.

When the sharing platform operates negatively, and consumers take action to safeguard their rights, the platforms' failure to ensure the quality of sharing products results in the infringement of consumer rights. In response, consumers choose to make complain to supervision authorities to protect their interests. This action exposes the platform to severe penalties F from the government and suffer negative effects N. Additionally, the platform is required to offer economic compensation to consumers, with the compensation amount set at K. From the consumer's standpoint, the utility they derive from using the product and the loss incurred due to product quality issues are denoted as $(1-\alpha)L$ and S respectively. During the consumers' rights safeguarding process, the lack of blockchain technology for effective product traceability (i.e., insufficient product information transparency) leads to a corresponding decrease in their perceived value of the product. Simultaneously, the decline in product quality directly contributes to a reduction in consumer utility.

When the sharing platform operates negatively, and consumers choose not to safeguard their rights, the government penalties and negative effects faced by the platform are βF and βN respectively (Tan et al., 2023), where $\beta(0<\beta<1)$ represents the degree of impact of penalties and negative effects on the sharing platform. Compared to a scenario where consumers actively safeguard their rights and platform issues are widely exposed, when consumers choose not to do so, the platforms' issues tend to attract less attention and severe reactions from the government and various sectors of society. As a result, in this scenario, the government penalties and negative effects borne by the platform are relatively minor. For consumers, besides obtaining the basic utility L from the product and paying the price P, they will also incur a certain level of utility loss S due to product quality issues.

The main parameter settings based on the above assumptions are presented in Table 1.

Table 1. Symbol Descriptions

Symbol form	Descriptions
x	Probability of the sharing platform operating positively
y	Probability of consumers safeguarding their rights
R	Profit of the sharing platform under normal operation
T	Performance of blockchain $(0 \le T < 1)$
C_1	Base cost of the sharing platform's negative operation
C	Base cost of the sharing platform adopting blockchain technology
G	Financial subsidy provided by the government for blockchain technology
F	Penalty paid by the sharing platform for negative operation
K	Compensation for consumers' rights protection efforts
L	Basic utility obtained by consumers from using the product
S	Loss incurred by consumers due to the platform's negative operation
C_2	Base cost of consumers safeguarding their rights
N	Negative effects caused by the platform's negative operation
α	Product information transparency $(0<\alpha<1)$
β	Degree of impact of penalties and negative effects on the sharing platform $(0<\beta<1)$

3.2. *The payment matrix*

Based on the assumptions above, an evolutionary game payment matrix is constructed, as shown in Table 2.

Table 2. Payoff matrix between the sharing platforms and consumers

		Consumers	
		Protect rights (y)	Not protecting rights $(1-y)$
Sharing platforms	Actively operate (x)	$R+G-(1-T)C_1-TC$	$R+G-(1-T)C_1-TC$
		$(1+\alpha)L-P-(1-T)C_2$	$L-P$
	Negatively operate $(1-x)$	$R-C_1-K-F-N$	$R-C_1-\beta F-\beta N$
		$(1-\alpha)L+K-P-S-C_2$	$L-S-P$

4. Stability Analysis

4.1. *Analysis of strategy stability for sharing platforms*

Based on the payoff matrix in Table 2, the expected revenues for sharing platforms when choosing proactive operation and passive operation can be derived as E_{p1} and E_{p2}, respectively.

$$\begin{aligned} E_{p1} &= y(R+G-(1-T)C_1-TC)+(1-y)(R+G-(1-T)C_1-TC) \\ E_{p2} &= y(R-C_1-K-F-N)+(1-y)(R-C_1-\beta F-\beta N) \end{aligned} \tag{1}$$

Therefore, the average expected revenue ($\overline{E_p}$) for the sharing platforms is

$$\overline{E_p} = xE_{p1}+(1-x)E_{p2} \tag{2}$$

Using the Malthusian dynamic equation as a framework, the rate of change in the sharing platforms' strategy is equivalent to its fitness, which can be represented through a dynamic differential equation as follows.

$$\begin{aligned} F(x) &= \frac{dx}{dt} = x(E_{p1}-\overline{E_p}) = x(1-x)(E_{p1}-E_{p2}) \\ &= x(1-x)(G+\beta F+\beta N+TC_1-TC+y(F+K+N-\beta F-\beta N)) \end{aligned} \tag{3}$$

By constructing the aforementioned replicator dynamic equation for the sharing platforms' strategy and analyzing its properties, we can identify the Evolutionarily Stable Strategy (ESS) (Smith and Price, 1973; Taylor, 1978) [26-27] for the sharing platform, as presented in Proposition 1.

Proposition 1.

1) When $y = y^* = \dfrac{TC-TC_1-G-\beta F-\beta N}{F+K+N-\beta F-\beta N}$, $F(x) = \dfrac{dx}{dt} \equiv 0$, x is stable in the interval from 0 to 1.

2) When $0 \le y < y^* \le 1$, $x^*=0, x^*=1$ are stable states, and $x^*=0$ being the ESS.

3) When $0 \le y^* < y \le 1$, $x^*=0, x^*=1$ are stable states, and $x^*=1$ being the ESS.

Proof. For point x to be a stable point, it must satisfy two conditions: $F(x)=0$ and $F'(x)<0$. By differentiating the replicator dynamic equation of the sharing platform, we obtain

When $y=y^*$, $F(x)\equiv 0$. The system becomes unstable, and small fluctuations at y^* will cause the system to converge to either 0 or 1. When $0 \le y < y^* \le 1$, $F(x)<0$. x monotonically decreases towards 0, $F'(0)<0$, and $F'(1)>0$. When $0 \le y^* < y \le 1$, $F(x)>0$, x monotonically increases towards 1, $F'(1)<0$, and $F'(0)>0$.

Based on the above analysis, we can depict the replicator dynamic phase diagram of the sharing platform as shown in Figure 1.

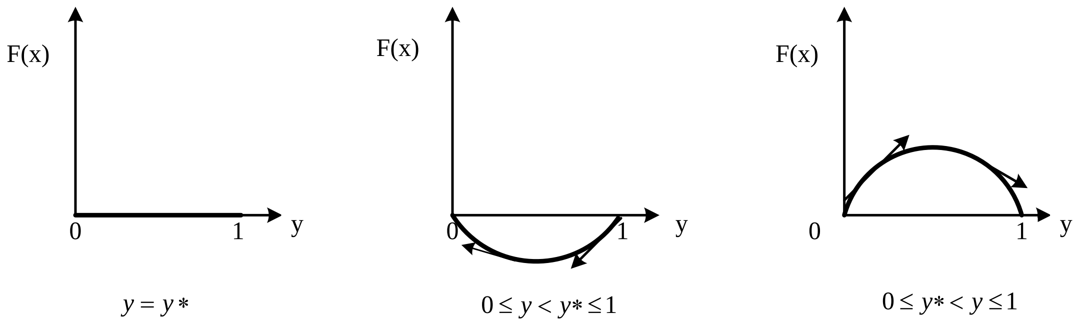

Fig. 1. Replicator dynamic phase graph of the sharing platform

4.2. *Analysis of strategy stability for consumers*

Based on the payoff matrix in Table 2, the expected benefits for consumers when choosing to safeguard their rights and not safeguarding their rights can be derived as E_{c1} and E_{c2}, respectively.

$$\begin{gathered} E_{c1} = x((1+\alpha)L - P - (1-T)C_2) + (1-x)((1-\alpha)L + K - P - S - C_2) \\ E_{c2} = x(L-P) + (1-x)(L-S-P) \end{gathered} \tag{4}$$

Therefore, the average expected benefit ($\overline{E_c}$) for consumers is

$$\overline{E_c} = yE_{c1} + (1-y)E_{c2} \tag{5}$$

According to the *Malthusian* dynamic equation, the rate of change in consumer strategy is equal to its fitness, which can be expressed using a dynamic differential equation. The replicator dynamic equation for consumers can be derived as

$$\begin{aligned} F(y) &= \frac{dy}{dt} = y(E_{c1} - \overline{E_c}) = y(1-y)(E_{c1} - E_{c2}) \\ &= y(1-y)(K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)) \end{aligned} \tag{6}$$

By constructing the aforementioned replicator dynamic equation for consumer strategies, we can derive the stable strategies for consumers, as shown in Proposition 2.

Proposition 2.

1) When $x = x^* = \dfrac{\alpha L + C_2 - K}{TC_2 + 2\alpha L - K}$, $F(y) = \dfrac{dy}{dt} \equiv 0$, and y is stable in the interval from 0 to 1.

2) When $x \ne x*$, the evolutionarily stable states for consumers are either $x* = 1$ or $x* = 0$.

Proof. For point y to be a stable point, it must satisfy two conditions: $F(y) = 0$ and $F'(y) < 0$. By differentiating the replicator dynamic equation for consumers, we obtain

$$F'(y) = (1-2y)(K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)) \tag{7}$$

When $x = x^*$, $F(y) \equiv 0$, and the system is unstable at this point. Any small fluctuation at x^* will cause the system to converge to either 0 or 1.

When $TC_2 + 2\alpha L - K > 0$, $K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)$ is an increasing function of x. Therefore, when $0 \le x < x^* \le 1$, $F(y) < 0$. y monotonically decrease towards 0, $F'(0) < 0$ and $F'(1) > 0$. When $0 \le x^* < x \le 1$, $F(y) > 0$. y monotonically increase towards 1, $F'(1) < 0$, and $F'(0) > 0$.

The replicator dynamic phase diagram for consumers is shown in Figure 2.

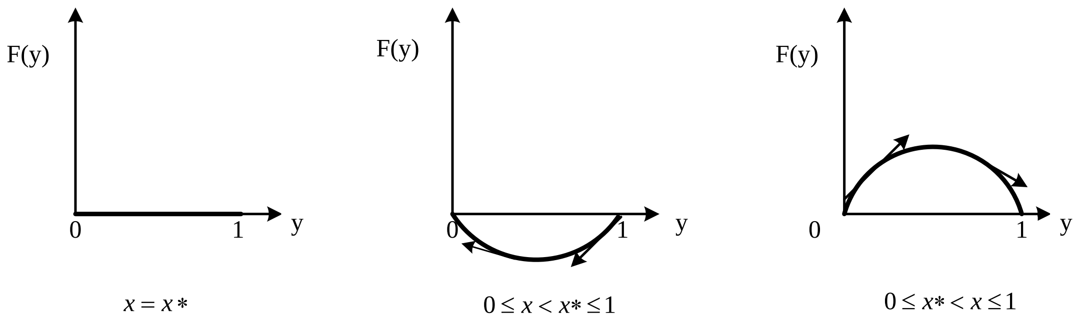

Fig. 2. Replicator dynamic phase graph for consumers $(TC_2 + 2\alpha L - K > 0)$

When $TC_2 + 2\alpha L - K < 0$, $K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)$ is a decreasing function of x. Therefore, when $0 \le x < x^* \le 1$, $F(y) > 0$. y monotonically increase towards 1, $F'(1) < 0$, and $F'(0) > 0$. When $0 \le x^* < x \le 1$, $F(y) < 0$. y monotonically decrease towards 0, $F'(0) < 0$, and $F'(1) > 0$.

The replicator dynamic phase diagram for consumers is shown in Figure 3.

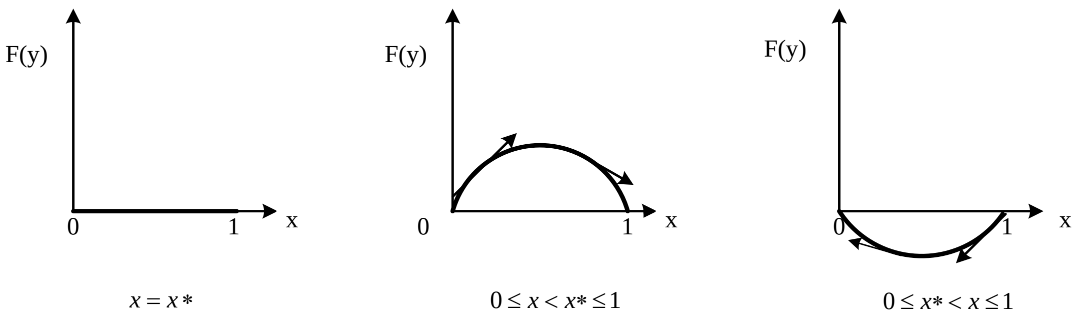

Fig. 3. Replicator dynamic phase graph for consumers $(TC_2 + 2\alpha L - K < 0)$

4.3. *Analysis of strategy stability for evolutionary game systems*

Based on the above analysis, the two-dimensional dynamic system equation consisting of the sharing platform and consumers can be expressed as

$$\begin{cases} F(x) = \dfrac{dx}{dt} = x(1-x)(G + \beta F + \beta N + TC_1 - TC + y(F + K + N - \beta F - \beta N)) \\ F(y) = \dfrac{dy}{dt} = y(1-y)(K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)) \end{cases} \tag{8}$$

Given $F(x) = F(y) = 0$, the equilibrium points of the two-dimensional dynamic system can be obtained as $P_1 = (0,0)$, $P_2 = (1,0)$, $P_3 = (0,1)$, $P_4 = (1,1)$ and $P_5 = (\dfrac{\alpha L + C_2 - K}{TC_2 + 2\alpha L - K}, \dfrac{TC - TC_1 - G - \beta F - \beta N}{F + K + N - \beta F - \beta N})$.

Furthermore, to determine the stability of these equilibrium points, we construct the Jacobi matrix (denoted as J) based on the local stability criteria.

$$J = \begin{bmatrix} \dfrac{\partial F(x)}{\partial x} & \dfrac{\partial F(x)}{\partial y} \\ \dfrac{\partial F(y)}{\partial x} & \dfrac{\partial F(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x)\begin{pmatrix} G + \beta F + \beta N + TC_1 - TC + \\ y(F + K + N - \beta F - \beta N) \end{pmatrix}, & x(1-x)(F + K + N - \beta F - \beta N), \\ y(1-y)(TC_2 + 2\alpha L - K), & (1-2y)(K - C_2 - \alpha L + x(TC_2 + 2\alpha L - K)) \end{bmatrix} \tag{9}$$

The determinants and traces of the Jacobi matrix J at each equilibrium point are presented in Table 3. According to the local stability criteria of the Jacobi matrix, when $\det(J) > 0$ and $tr(J) < 0$ (Friedman, 1991) [28], the corresponding point represents an ESS for the system. Since $tr(J) = 0$ for P_5, it follows that P_5 cannot be an ESS for the system. Therefore, further elaboration on P_5 is omitted, and its corresponding $\det(J)$ and $tr(J)$ are not listed in the Table 3. Based on the results in Table 3, we can derive four propositions.

Table 3. Local stability of system equilibrium points

points	$\det(J)$	$tr(J)$
P_1	$(K-C_2-\alpha L)(G+\beta F+\beta N+TC_1-TC)$	$K-C_2-\alpha L+G+\beta F+\beta N+TC_1-TC$
P_2	$(C_2-TC_2-\alpha L)(G+\beta F+\beta N+TC_1-TC)$	$TC_2-C_2+\alpha L-G-\beta F-\beta N-TC_1+TC$
P_3	$(C_2+\alpha L-K)(F+G+K+N-TC+TC_1)$	$C_2+\alpha L+F+G+N-TC+TC_1$
P_4	$(TC_2-C_2+\alpha L)(F+G+K+N-TC+TC_1)$	$-TC_2+C_2-\alpha L-F-G-K-N+TC-TC_1$

Proposition 3. When $K-C_2-\alpha L<0$ and $G+\beta F+\beta N+TC_1-TC<0$, $\det(P_1)>0$ and $tr(P_1)<0$.

Proof. Because $\det(P_1)=(K-C_2-\alpha L)(G+\beta F+\beta N+TC_1-TC)$, there are two situations in which $\det(P_1)>0$.

1) When $K-C_2-\alpha L>0$ and $G+\beta F+\beta N+TC_1-TC>0$, $tr(P_1)=K-C_2-\alpha L+G+\beta F+\beta N+TC_1-TC>0$. Therefore, P_1 is not an equilibrium point in this situation.

2) When $K-C_2-\alpha L<0$ and $G+\beta F+\beta N+TC_1-TC<0$, $tr(P_1)=K-C_2-\alpha L+G+\beta F+\beta N+TC_1-TC<0$. So, P_1 is an equilibrium point in this situation.

Proposition 4. When $C_2-TC_2-\alpha L>0$ and $G+\beta F+\beta N+TC_1-TC>0$, $\det(P_2)>0$, and $tr(P_2)<0$.

Proof. Because $\det(P_2)=(C_2-TC_2-\alpha L)(G+\beta F+\beta N+TC_1-TC)$, there are two situations in which $\det(P_2)>0$.

1) When $C_2-TC_2-\alpha L<0$ and $G+\beta F+\beta N+TC_1-TC<0$, $tr(P_2)=TC_2-C_2+\alpha L-G-\beta F-\beta N-TC_1+TC>0$. Therefore, P_2 is not an equilibrium point in this situation.

2) When $C_2-TC_2-\alpha L>0$ and $G+\beta F+\beta N+TC_1-TC>0$, $tr(P_2)=TC_2-C_2+\alpha L-G-\beta F-\beta N-TC_1+TC<0$. So P_2 is an equilibrium point in this situation.

Proposition 5. When $C_2+\alpha L-K<0$ and $F+G+K+N-TC+TC_1<0$, $\det(P_3)>0$, and $tr(P_3)<0$.

Proof. Because $\det(P_3)=(C_2+\alpha L-K)(F+G+K+N-TC+TC_1)$, there are two situations in which $\det(P_3)>0$.

1) When $C_2+\alpha L-K>0$ and $F+G+K+N-TC+TC_1>0$, $tr(P_3)=C_2+\alpha L+F+G+N-TC+TC_1>0$. Therefore, P_3 is not an equilibrium point in this situation.

2) When $C_2+\alpha L-K<0$ and $F+G+K+N-TC+TC_1<0$, $tr(P_3)=C_2+\alpha L+F+G+N-TC+TC_1<0$. So P_3 is an equilibrium point in this situation.

Proposition 6. When $TC_2-C_2+\alpha L>0$ and $F+G+K+N-TC+TC_1>0$, $\det(P_4)>0$, and $tr(P_4)<0$.

Proof. The proof follows a similar approach as that of Proposition 3, Proposition 4, and Proposition 5, and therefore, the detailed proof is omitted here for brevity.

Based on the above propositions, we can derive the following inferences.

Inference 1. When $K-C_2-\alpha L<0$, $TC_2-C_2+\alpha L>0$, $G+\beta F+\beta N+TC_1-TC<0$, and $F+G+K+N-TC+TC_1>0$, the system has two equilibrium points, $P_1=(0,0)$ and $P_4=(1,1)$ respectively.

Proof. According to Proposition 5, we can induce that when $K-C_2-\alpha L<0$, P_3 cannot be an equilibrium point. Furthermore, Proposition 4 indicates that when $G+\beta F+\beta N+TC_1-TC<0$, P_2 is not an equilibrium point. Therefore, there are two equilibrium points $P_1=(0,0)$ and $P_4=(1,1)$. The evolutionary diagram is depicted in Figure 4. P_5 divides the rectangle $P_1P_2P_4P_3$ into two parts, $S_A=P_2P_5P_3P_4$ and $S_B=P_2P_5P_3P_1$ respectively. When P_5 approaches P_1, the area of S_A gradually becomes larger than S_B, and the system will evolve towards $P_4=(1,1)$. Conversely, the system will evolve towards $P_1=(0,0)$.

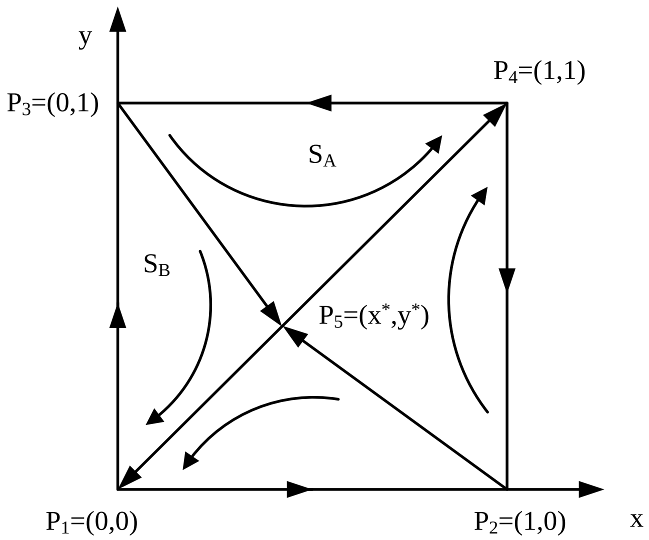

Fig. 4. Evolutionary graph for inference 1

Inference 2. When $K-C_2-\alpha L<0$, $G+\beta F+\beta N+TC_1-TC<0$, and either $TC_2-C_2+\alpha L<0$ or $F+G+K+N-TC+TC_1<0$, the system has only one equilibrium point, which is $P_1=(0,0)$.

Proof. According to Proposition 5, we can induce that when $K-C_2-\alpha L<0$, P_3 cannot be an equilibrium point. Furthermore, Proposition 4 indicates that when $G+\beta F+\beta N+TC_1-TC<0$, P_2 is not an equilibrium point. Additionally, when either $TC_2-C_2+\alpha L<0$ or $F+G+K+N-TC+TC_1<0$ occurs, P_4 cannot be an equilibrium point. Therefore, in this case, the system has only one equilibrium point, which is $P_1=(0,0)$.

Inference 3. When $TC_2-C_2+\alpha L>0$, $F+G+K+N-TC+TC_1>0$ and either $K-C_2-\alpha L>0$ or $G+\beta F+\beta N+TC_1-TC>0$, the system has only one equilibrium point, which is $P_4=(1,1)$.

Proof. According to Proposition 4, we can induce that when $TC_2-C_2+\alpha L>0$, P_2 cannot be an equilibrium point. Furthermore, Proposition 5 indicates that when $F+G+K+N-TC+TC_1>0$, P_3 is not an equilibrium point. Additionally, when either $K-C_2-\alpha L>0$ or $G+\beta F+\beta N+TC_1-TC>0$ occurs, P_1 cannot be an equilibrium point. Therefore, in this case, the system has only one equilibrium point, which is $P_4=(1,1)$.

Inference 4. When $C_2-TC_2-\alpha L>0$ and $G+\beta F+\beta N+TC_1-TC>0$, the system has only one equilibrium point, which is $P_2=(1,0)$.

Proof. According to Proposition 6, we can know that when $C_2-TC_2-\alpha L>0$, P_4 cannot an equilibrium point. Furthermore, Proposition 3 indicates that when $G+\beta F+\beta N+TC_1-TC>0$, P_2 is not an equilibrium point. Since $F+G+K+N-TC+TC_1>G+\beta F+\beta N+TC_1-TC>0$, and in this case P_3 is not an equilibrium point. Therefore, $P_2=(1,0)$ is the only equilibrium point of the system under these conditions.

Inference 5. When $C_2+\alpha L-K<0$ and $F+G+K+N-TC+TC_1<0$, the system has only one equilibrium point, which is $P_3=(0,1)$.

Proof. According to Proposition 3, we can induce that when $C_2+\alpha L-K<0$, P_1 cannot be an equilibrium point. Furthermore, Proposition 6 indicates that when $F+G+K+N-TC+TC_1<0$, P_4 is not an equilibrium point. Since $G+\beta F+\beta N+TC_1-TC<F+G+K+N-TC+TC_1<0$, and in this case P_2 is not an equilibrium point. Therefore, $P_3=(0,1)$ is the only equilibrium point of the system under these conditions.

5. Numerical Simulation Analysis

This section primarily analyzes the impact of changes in key parameters on the evolution of the game. The basic parameter settings are shown in Table 4.

Table 4. Basic parameter settings (a)

Parameters	Parameters values	Parameters	Parameters values	Parameters	Parameters values
T	0.5	G	20	C_1	40
C_2	50	β	0.5	C	80
α	0.5	F	30	K	20
L	40	N	40		

Figure 5 shows the influence of blockchain performance on consumer rights protection strategies. Firstly, as the performance of blockchain technology steadily improves, consumers' behavioral strategies shift notably from a passive, non-advocacy stance to an active one. This transition stems from the fact that traditional advocacy routes are often burdened with high costs and complex procedures, such as expensive product quality testing fees, legal service fees, and litigation expenses, prompting many consumers to abandon their rights due to cost-benefit considerations. However, blockchain technology, with its exceptional traceability and tracking capabilities, significantly reduces these advocacy costs, thereby stimulating consumers' willingness to advocate for their rights. In other words, the optimization of blockchain performance is directly proportional to the reduction in advocacy costs, prompting more consumers to take action to safeguard their rights. Secondly, it is also revealed in Figure 5 that consumers' initial willingness to advocate (i.e., the initial probability) is closely related to the acceleration trend of their subsequent advocacy behaviors. Specifically, if consumers exhibit a high level of rights protection awareness from the outset, their advocacy probability curve will converge faster towards 1, while those with lower initial awareness will converge more slowly towards 0. This phenomenon profoundly reflects a universal truth in real life: consumers who are highly sensitive and attentive to the protection of their rights will take more resolute actions to defend their legitimate rights when they encounter infringements.

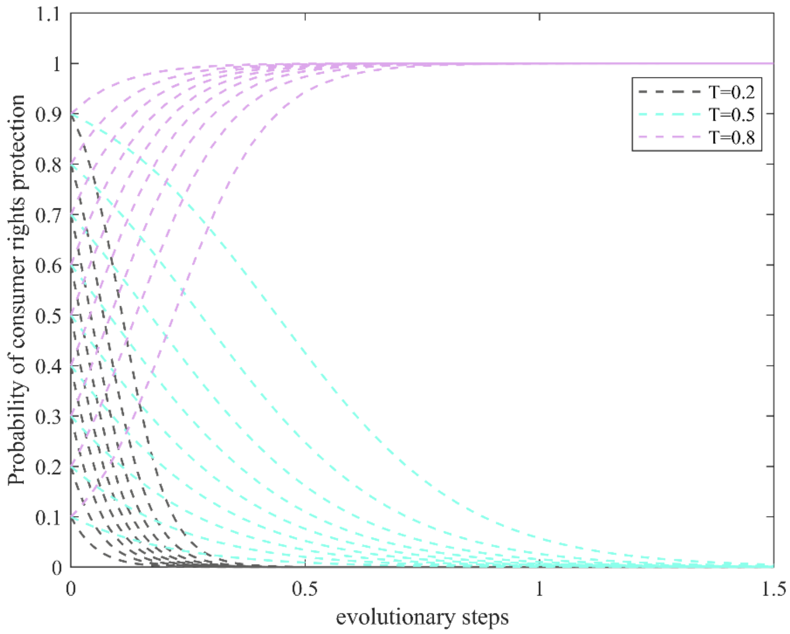

Fig. 5. The influence of blockchain performance on consumer rights protection strategies

Subsequently, we set $C_2 = 50$, $\alpha = 0.2$, $L = 30$, $C_1 = 100$, and $C = 20$. The corresponding evolution trends are illustrated in Figure 6. By observing Figure 6, as the performance of blockchain technology significantly improves, the curve converges towards 1 at a notably faster pace, indicating that sharing platforms are increasingly inclined to adopt proactive operational strategies. The advantages of blockchain effectively reduce platform operational costs and optimize resource allocation, even if the high adoption costs associated with blockchain technology. Therefore, the higher the blockchain performance, the more likely platforms are to embrace this technology in pursuit of more efficient and secure operations. Moreover, once blockchain performance reaches a certain high level, its marginal effect on prompting platforms to adopt proactive operational strategies begins to diminish. This suggests that, while continuous optimization of blockchain technology continues to have a positive impact on platform operations, the growth rate of this impact gradually slows down, revealing that after reaching a certain technological maturity, platforms may encounter new considerations or bottlenecks when adjusting their operational strategies.

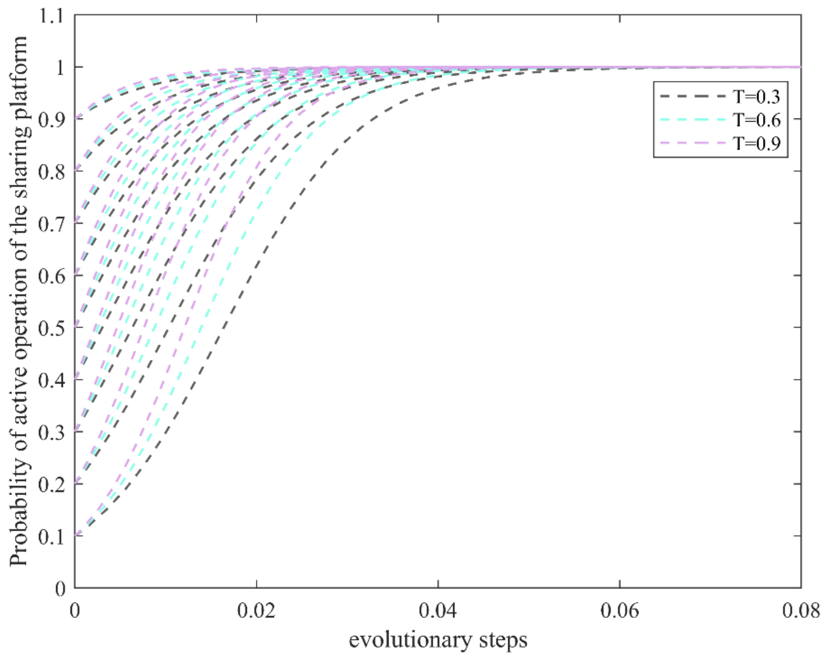

Fig. 6. The influence of blockchain performance on the operation strategies of sharing platforms

As depicted in Figure 7, a notable shift in consumers' coping strategies is evident as the cost of safeguarding their rights rises, transitioning from actively pursuing redress to a greater tendency to abandon their rights claims. This transformation stems fundamentally from consumers' profound deliberation of the cost-benefit relationship when deciding whether to engage in rights protection.

In the process of determining whether to uphold their rights, consumers engage in a comprehensive cost-benefit analysis. They meticulously evaluate the various expenses that may arise during the course of rights protection, encompassing but not limited to product quality inspection fees, legal representation costs, and potential litigation expenses. These costs are then juxtaposed against the potential compensation that might be secured upon successful resolution. When the perceived cost of rights protection far outweighs the anticipated benefit, where the compensation amount appears insignificant, consumers often opt to forgo rights protection actions based on the principle of maximizing cost-effectiveness, thereby avoiding unnecessary financial burdens.

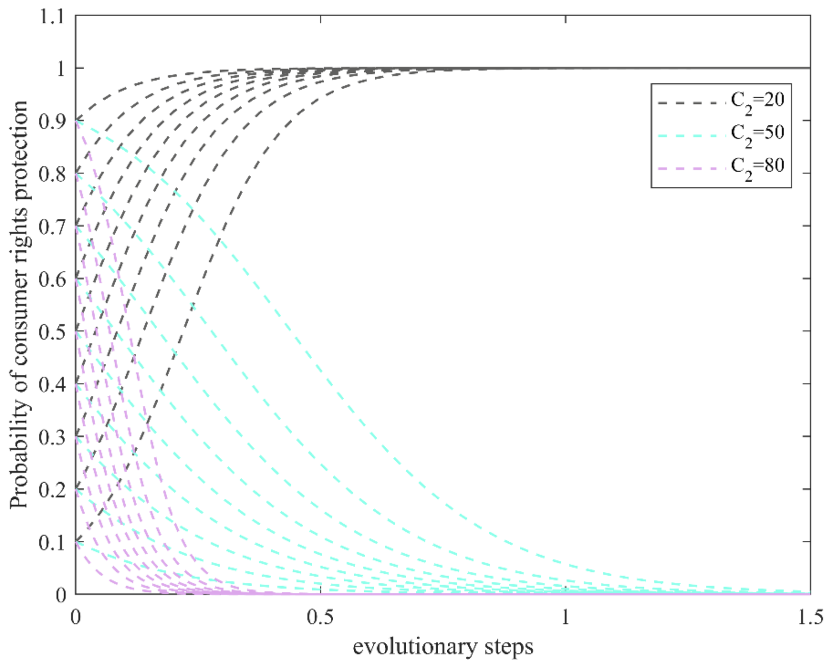

Fig. 7. The influence of the cost of rights protection on consumer rights protection strategies

Based on the parameter settings in Table 5, Figure 8 has been generated. It illustrates the impact of negative effects on the operational strategy of the sharing platform. From the figure, it can be seen that, when $N=10$, the platform tends to adopt a passive operational strategy. When $N=40$, the platform shifts to an active operational mode, albeit with a relatively slower convergence rate towards 1. When $N=70$, the platform continues with an active operational strategy, but the convergence speed significantly accelerates under this scenario. The simulation results reveal that during the gradual stabilization of the evolutionary game system, the negative effects of passive operation by the sharing platform emerge as a pivotal factor. As these negative effects intensify, external pressures propel the sharing platform to transition from passive to active operations. The influence of these negative effects transcends mere economic losses, deeply impacting the platform's credibility and quality foundation. Specifically, once consumers discern the platform's passive operational practices, their trust in product quality immediately erodes. This mistrust swiftly disseminates throughout the supply chain, triggering a reputational crisis. Furthermore, passive operations directly contribute to a decline in platform user numbers, fundamentally weakening demand for platform services and fostering a vicious cycle. Under the immense pressure of these negative effects, the platform wisely adopts an active operational strategy, aiming to restore and enhance market competitiveness by improving service quality and bolstering consumer trust. This approach facilitates long-term stable development.

Table 5. Basic parameter settings (b)

Parameters	Parameters values	Parameters	Parameters values	Parameters	Parameters values
T	0.6	G	20	C_1	20
C_2	50	β	0.5	C	100
α	0.2	F	30	K	20
L	30	N	40		

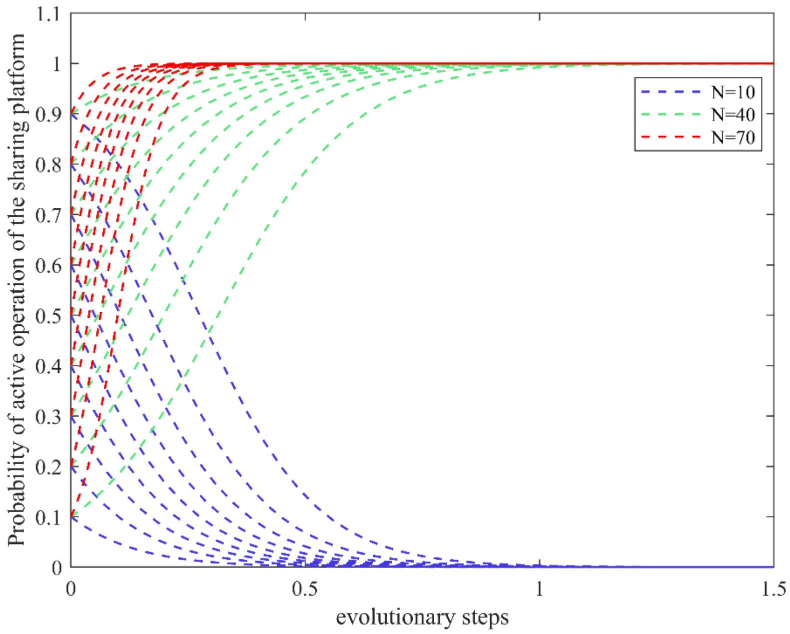

Fig. 8. The influence of negative effects on the operation strategies of sharing platforms

As can be seen from Figure 9, when $F = 10$, the platform tends to adopt a passive operational strategy. When $F = 30$, the platform shifts to an active operational mode, albeit with a relatively slower convergence rate towards 1. When $F = 50$, the platform continues with an active operational strategy, experiencing a notably faster convergence rate under this scenario. The simulation results indicate that the government's imposition of steep penalty policies can effectively deter shared platforms from engaging in passive operational practices. Specifically, as the severity of penalties gradually increases and surpasses a threshold that outweighs the benefits gained from passive operations, the platform, based on cost-benefit analysis, is compelled to reassess its operational strategies. This leads to a gradual shift away from passivity towards more proactive and efficient operational methods. This process underscores the positive role of policy interventions in guiding the healthy development of sharing economy platforms.

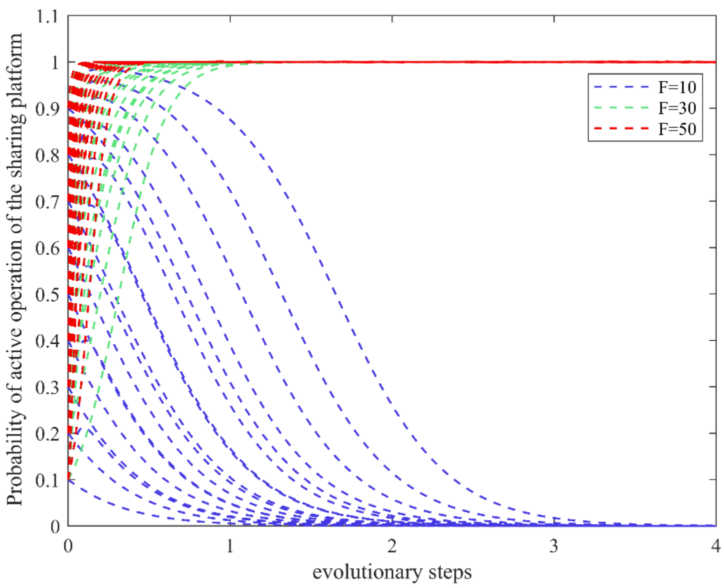

Fig. 9. The influence of penalty on the operation strategies of sharing platforms

6. Conclusions, Implications, and Limitations

This paper establishes a two-party evolutionary game model from the perspectives of shared platforms and consumers. It explores the dynamic evolutionary process of whether platforms adopt blockchain technology for active operations and whether consumers safeguard their rights. Furthermore, the study analyzes and verifies the impact of key factors on the stability of strategies adopted by each participant in the evolutionary game. The research conclusions are as follows.

From the sharing platform perspective, the performance of blockchain technology positively drives the operational strategies of sharing platforms. Specifically, the higher the performance of blockchain technology, the more inclined platforms are to adopt active operational strategies. However, this positive effect does not grow unlimitedly; once technology performance reaches a certain level, its marginal effect on promoting platforms to adopt active operational strategies begins to diminish, indicating that platforms need to comprehensively consider technology maturity and other potential factors in adjusting their operational strategies. Secondly, the government's punishment policies and the negative effects arising from platforms' passive operations form a dual restraint mechanism on shared platform behavior. The synergistic effect of these two factors effectively curbs platforms' tendency towards passive operations, prompting them to adopt more active operational strategies under the dual pressures of high non-compliance costs and widespread negative impacts. Notably, both penalties and negative effects have critical thresholds; once these thresholds are surpassed, they significantly facilitate the shift of platforms' operational strategies from passive to active.

From the consumer perspective, the enhancement of blockchain technology's performance can significantly boost consumers' willingness to safeguard their rights, addressing high costs and difficulties in pursuing legal redress. Moreover, consumers' initial willingness to protect their rights plays a crucial role in accelerating their subsequent rights-defending behaviors, manifested in the fact that consumers who are highly sensitive and value their rights tend to defend them more resolutely when they are infringed upon. Secondly, the cost of consumer rights protection has a strong inhibitory effect on consumers' willingness to safeguard their rights. In other words, the higher the cost of consumer rights protection, the less likely consumers are to pursue their rights.

This study offers some implication for both sharing platforms and governments. Firstly, for sharing platforms, technological innovation holds the key to driving proactive operations and enhancing service quality. The incorporation of blockchain technology can not only address traditional consumer rights protection challenges effectively, bolstering consumer trust and satisfaction, but also ignite consumers' awareness and actions in safeguarding their rights by reducing the cost of rights protection. Consequently, platforms ought to continually invest resources in optimizing blockchain technology's performance while emphasizing transparency in technology application and user experience, thereby leveraging technology to empower service upgrades and foster a more equitable and transparent market environment. Furthermore, the restriction from policy on fines and the effect of negative operation can force platforms not to take short-term actions that could lead to costly compliance violations and brand damage. Additionally, platforms should establish robust internal management mechanisms to enhance self-examination and self-correction capabilities against negative operational practices to navigate increasingly intense market competition and diverse consumer demands.

For governments, the core of their managerial wisdom lies in constructing an efficient and just consumer protection system. The primary and crucial step is to expand and optimize consumer complaint channels, such as establishing additional online complaint platforms, promoting mobile applications and mini-programs, and setting up complaint service stations, thereby significantly lowering the thresholds and costs for consumers to safeguard their rights and effectively stimulating their enthusiasm for consumer rights protection. On this basis, governments should take a long-term perspective and establish a sound and scientific reward and punishment system, guiding the healthy development of sharing platforms through a combination of positive incentives and negative constraints. For platforms that are courageous in innovation and actively adopt cutting-edge technologies like blockchain, governments should generously provide technological innovation subsidies to promote healthy competition and mutual progress throughout the industry. On the other hand, governments should impose strict and targeted punishment measures on platforms with lax management and negative responses to consumer complaints. The amount of fines should precisely reflect the severity of the seller's violations and the actual harm caused to consumer rights, ensuring that violators pay a heavy price and serving as a strong warning to prevent similar issues from recurring. At the same time, it is essential to ensure that this measure does not unfairly affect platforms that actively fulfill their social responsibilities and strive to improve service quality, thereby maintaining the fairness and vitality of the market environment and promoting the sustained prosperity of the sharing economy ecosystem.

This paper also has certain limitations. Firstly, this study explores the relationship between sharing platforms and consumers solely from an evolutionary game theory perspective. As a next step, research could investigate the impact of decision-making leadership and competition among stakeholders on the outcomes of the game. Secondly, by simplifying the government's role as an exogenous variable, this study overlooks its pivotal role in platform governance and consumer rights protection. In reality, the government's strategic choices also influence sharing platforms' operational decisions and consumers' rights protection behaviors. Therefore, future research could consider establishing a tripartite evolutionary game model that includes the government as a participant, exploring the strategic equilibrium among platforms, consumers, and the government under different strategy combinations, as well as its implications on social welfare.

Funding

This research was supported by Young Scientists Fund of the National Natural Science Foundation of China (72101002), Anhui Natural Science Foundation (2108085QG301), Key Re-search Foundation of the Education Department of the Province Anhui (SK2021A0282).

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