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Blockchain-enabled sharing economy platform adoption decisions and consumer rights protection behavior analysis

Tong Ye[1], Chenchen Liu[1] and Daru Zhang[1,*]
[1] School of Economics and Management, Anhui Polytechnic University, Wuhu, Anhui, 241000, China
Corresponding authors: (e-mail: zdrzdr2024@163.com).

Abstract This paper focuses on the evolutionary game between blockchain adoption decisions and consumer rights protection behavior on sharing economy platforms, aiming to provide support and guidance for platforms to formulate effective policies and measures. It introduces key theories and techniques required for constructing evolutionary game models, including replication dynamics equations and evolutionary stable strategies. By applying evolutionary game theory, an evolutionary game model is constructed for blockchain adoption decisions and consumer rights protection behavior, with corresponding replicating dynamic equations proposed for each. Numerical simulations are conducted to further analyze the factors influencing evolutionary stability. The results show that reducing the cost of blockchain technology investment and reasonably controlling expected returns, alleviating corporate competitive pressure, and lowering the risk coefficient of corporate operations can effectively increase the probability of corporate blockchain adoption decisions. In terms of consumer rights protection behavior, the difficulty of rights protection significantly inhibits consumers from choosing rights protection strategies, and the rights protection compensation coefficient is closely related to consumers' motivation for rights protection.

Index Terms evolutionary game theory, blockchain, replicating dynamic equations, consumer rights protection behavior

I. Introduction

As the economy continues to develop, society has gradually transitioned from a shortage-based economy to a surplus-based economy, resulting in many people owning items that cannot be fully utilized to serve their needs. Therefore, sharing these idle resources is a viable option, and with the support of internet technology, the sharing economy has begun to emerge. The sharing economy is a new economic form that has emerged gradually on the basis of the continuous improvement of information technology and the development of economic mechanisms [1]. The development of the sharing economy relies on credible social platforms as intermediaries to establish transaction platforms for consumers and owners of idle resources, thereby achieving the goal of mutual benefit through sharing [2]-[4]. As such, the “sharing economy” is fundamentally a “sharing economy” that integrates social resources through specific platforms. By achieving resource sharing and maximizing co-created value, it optimizes the allocation of resources between suppliers and demanders, ultimately contributing to the construction of a green and resource-efficient society [5]-[8]. The sharing economy has already begun to transform China's traditional economic development landscape and has provided new opportunities for China's economic growth [9], [10].

There is no denying that while China's sharing economy has been developing rapidly, a series of issues—including the absence of supporting regulations and systems, inadequate information security protection mechanisms, and an incomplete sharing mechanism—have severely hindered the standardized development of the sharing economy, becoming a key factor constraining the growth of China's sharing economy and the overall economic transformation [11]-[14]. Therefore, to further regulate the development of China's sharing economy and achieve the goal of creating economies of scale through the co-creation of value for social and public resources via the network economy, it is necessary to leverage the role of blockchain technology in facilitating the development of the sharing economy [15]-[18].

The sharing economy is a newly emerging economic model that has played a significant role in promoting national economic prosperity. However, it has also posed challenges and pressures on traditional consumer rights protection systems. Numerous scholars have conducted research on methods to safeguard consumer interests in the current sharing economy context. Literature [19] argues that while sharing economy platforms provide quality services and create employment opportunities, they also face challenges in consumer rights protection. By analyzing consumer lawsuits targeting platforms, the study provides decision-making support for platform enterprises and public policy

makers to maintain fairness in the sharing economy. Literature [20] indicates that sharing economy platforms in the digital economy era have exacerbated issues of consumer equality between consumers and sellers, proposing to strengthen regulation and legislation to promote the vision of enterprises fulfilling their obligations to consumers. Literature [21] uses shared housing as a starting point to clarify the relationships and responsibilities among various entities in the sharing economy model, particularly the responsibility to protect human rights, aiming to reduce the public risks users face on sharing economy platforms. Literature [22] attributes the root cause of consumer rights violations on sharing economy platforms to changes brought by digital technology and the resulting unresolved moral and ethical issues, emphasizing that digital enterprises should proactively assume responsibility to address issues such as privacy, discrimination, worker rights, and regulation within the sharing economy. Literature [23] explores the challenges faced by the sharing economy model, pointing out that the sharing economy model under the platform narrative faces labor exploitation issues known as “Uberization.” On one hand, it challenges consumer rights by influencing laws, and on the other hand, it reduces production burdens to achieve direct benefits. Literature [24] proposes that sharing economy platforms should promote social and environmental values while achieving their own economic value, while also introducing government regulation to create a more democratic platform governance model. The above studies have explored the root causes of consumer rights issues. Therefore, in the sharing economy, every effort should be made to ensure that the interests and obligations of merchants, consumer groups, and platforms are distributed evenly. In the digital economy era, blockchain technology is undoubtedly the best means and measure to protect the interests of consumer groups.

Blockchain adoption decisions and consumer rights protection behaviors are indispensable important modules in the sustainable development of sharing economy platforms. This paper focuses on the evolutionary game theory research of the two, providing a brief introduction to the principles of the sharing economy platform, introducing evolutionary game theory, proposing the replication dynamic equation—an important model in evolutionary game theory—and discussing the common linear selection model within it. It also analyzes the concept of evolutionary stable strategies in evolutionary game theory. Subsequently, an evolutionary game model for blockchain adoption decisions and consumer rights protection behavior is constructed, with corresponding replication dynamic equations proposed for blockchain adoption decisions and consumer rights protection behavior. Using MATLAB software, initial probability simulations of the evolutionary game model are conducted, and numerical simulations are employed to conduct an in-depth exploration and analysis of the factors influencing evolutionary stability.

II. Principles of Sharing Economy Platforms

The sharing economy is developing rapidly and has become an important driving force for global economic growth. This chapter will briefly introduce the relevant principles of sharing economy platforms in the context of the sharing economy.

II. A. Definition of the Sharing Economy

The “sharing economy” is a new economic model that disrupts traditional business models. It has reshaped people's understanding of economic concepts. The sharing economy possesses the innovative magic of internet technology, and sharing economy platforms have developed under the umbrella of the sharing economy. The sharing economy encompasses a wide range of activities, making it difficult to establish a unified research object for discussion with other scholars. This has led to the question of how to regulate the sharing economy. In reality, neither sharing economy businesses nor their participants fully understand the concept of sharing; their sole objective is to gain benefits. Therefore, defining the sharing economy as a personal economy or a demand-driven economy better aligns with reality.

II. B. Definition of Sharing Economy Platforms

II. B. 1) Conceptual Principles

The sharing economy has three main components: suppliers, consumers, and sharing economy platforms, as shown in Figure 1. Sharing economy platforms primarily utilize emerging information technologies such as mobile internet, big data, and cloud computing to achieve precise and rapid matching between suppliers and demanders. They serve as intermediaries facilitating transactions between suppliers and demanders. These platforms do not possess the physical assets required to provide services to demanders but instead outsource such services to vast amounts of idle social resources. By integrating these idle social resources, they offer low-cost services to demanders, embodying a typical light-asset business model.

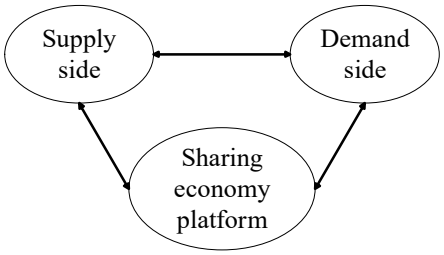

Figure 1: Main body of sharing economy

The sharing economy is based on internet technology, with information integration connecting all participants in the market economy. This creates an interactive platform that connects the demand and supply sides, forming a platform enterprise. The primary driver of the sharing economy's development is the widespread adoption of internet technology and the data processing capabilities of platforms, which have reduced the spatial and temporal distances between demand and supply, thereby lowering transaction costs. This highlights the crucial role of platforms as intermediaries in the sharing economy. The healthy development of sharing economy platforms is the foundation for the growth of the sharing economy, with platforms occupying a central position within the sharing economy [25]. The development of sharing economy platforms also reflects the prospects and current state of the sharing economy. Internally, sharing economy platforms represent both supply and demand sides, while externally they represent the sharing economy itself. Therefore, issues related to sharing economy platforms represent the focal point of contradictions within the sharing economy.

II. B. 2) Platform Classification

The forms of sharing economy platforms not only reflect the operational model of the sharing economy but also embody its development. Regarding the classification of the sharing economy and the categorization of sharing economy platforms, no official standards have been published. Scholars generally classify sharing economy platforms into different categories based on various criteria.

Based on functional classification, sharing economy platforms can be divided into four types:

1) Transaction-based (random matching of transaction relationships), such as shared transportation and shared accommodation;

2) Agreement-based, such as mutual childcare, long-term car rentals, and shared community spaces;

3) Service-based platforms, such as tool rental organizations;

4) Lifestyle service-based platforms, such as shared tools.

Foreign scholars have proposed classifying sharing economy platforms into public welfare platforms and non-public welfare platforms. For example, time banks are public welfare platforms, while Didi Chuxing and Uber are typical non-public welfare platforms.

From the perspective of user needs, sharing economy platforms can be categorized into: transportation sharing economy platforms (Didi Chuxing/Huola), accommodation sharing economy platforms, food and beverage sharing economy platforms, clothing sharing, knowledge sharing (MOOC China), healthcare services, travel, and production (Apple Store/Tao Factory), etc.

Current sharing economy platforms each have their own strengths, unique features, and distinct development directions. The classification of sharing economy platforms should be based on a comprehensive distinction that takes into account the developmental essence of the sharing economy and the differences in platform development.

III. Blockchain Adoption Decision-Making and Consumer Rights Protection Behavior Evolutionary Game Model

Blockchain, as a new generation of information technology, possesses technical characteristics such as decentralization, secure and transparent data storage, and enhanced trust among participants. It can address various issues in shared economy platforms, including information asymmetry, lack of transparency, unreliability, and insecurity. Meanwhile, the convenience and efficiency of shared economy platforms have been widely welcomed by consumers. However, while enjoying the platform's benefits, consumers also face the challenge of rights infringement, and consumer rights protection actions are not uncommon. Both blockchain adoption decisions and consumer rights protection behaviors are crucial to the development of sharing economy platforms. They are indispensable elements in shaping the trust mechanisms, operational efficiency, and sustainable development of such platforms. This chapter will introduce evolutionary game theory to construct an evolutionary game model of

blockchain adoption decisions and consumer rights protection behaviors, analyzing their evolutionary processes and outcomes.

III. A. Evolutionary Game Theory

III. A. 1) Evolutionary Game Theory Principles

Game theory refers to the process by which participants make strategic choices based on established rules and available information to maximize their own interests. The fundamental concepts studied in game theory include games, strategies, and solutions. A game refers to a specific decision-making scenario involving interactions among multiple decision-makers (players); a strategy refers to the possible courses of action available to each player; and a solution refers to the optimal strategy adopted by players in a given game scenario.

Evolutionary game theory is a branch of game theory whose origins can be traced back to the 1970s. It emerged at the intersection of biology and game theory, aiming to explain and understand evolutionary behavior in biological systems [26]. In biological systems, interactions and competition between individuals can be viewed as a game, while various behavioral strategies can be regarded as different survival strategies. Common models in evolutionary game theory include evolutionary stable strategies, repeated games, and kin selection. These models play important roles in evolutionary game theory, enabling the explanation and understanding of behavioral evolutionary mechanisms in biological systems, as well as individual strategy selection and behavioral decision-making in games.

III. A. 2) Copying dynamic equations

The replicator equation is one of the important models in evolutionary game theory, which is used to describe the evolutionary process of different strategies within a population. In the biological world, it is assumed that individuals within a population can compete and cooperate through interactions, and the success or failure of these interactions determines the reproductive rate of the next generation. The replicator equation assumes that an individual's strategy is heritable, thereby enabling biological evolution.

In stakeholder theory, the replicator dynamic equation can describe how the proportions of different strategies chosen by stakeholders change over time. The most common replicator dynamic equation is the linear selection model, as shown below:

$$dx/dt = x\left(f_A - \overline{f}\right) = x(1-x)\left(f_A - f_B\right) \tag{1}$$

Among them, dx/dt is the rate of change of x, where x represents strategy A among stakeholders, f_A is the expected return for stakeholders adopting strategy A, f_B is the expected return for stakeholders adopting strategy B, and $\overline{f}$ is the average expected return for all stakeholders. Equation (1) indicates that the rate of change of strategy A depends on the difference between the expected benefit of strategy A and the overall average expected benefit. That is, when $f_A > \overline{f}$, the proportion of strategy A will increase, and when $f_A < \overline{f}$, the proportion of strategy A will decrease. When generally solving the replicator dynamics equation, it is necessary to set $dx/dt = F(x)$ in the replicator dynamics equation and find x^* when $F(x) = 0$. Here, x^* is the equilibrium point. When x approaches x^* from the left side infinitely, $F(x) < 0$, meaning that as time progresses, x decreases, implying that $F'\left(x^*\right) < 0$. At this point, x^* is also referred to as an evolutionary stable point (ESS).

III. A. 3) Evolutionary stable strategy

Evolutionarily stable strategies (ESS) are a key concept in evolutionary game theory. They describe a situation where, within a population, a specific strategy becomes stable and persists once it reaches a certain proportion, making it unlikely to be replaced by other strategies [27]. It is important to note that an evolutionary stable strategy is not necessarily the optimal strategy; it merely represents a stable state relative to other strategies within the population. Different evolutionary stable strategies may emerge under varying environmental conditions, and during the evolutionary process, new evolutionary stable strategies may replace existing ones.

Against the backdrop of the rapid development of sharing economy platforms, constructing an evolutionary game model of blockchain adoption decisions and consumer rights protection behavior, and analyzing the stability of evolutionary strategies, can provide a deeper understanding of how changes in different parameters affect blockchain adoption decisions and consumer rights protection behavior. This can effectively explore the strategic interactions of stakeholders' consumer rights protection behavior under different scenarios, assist in evaluating various situations in the evolutionary game process, and provide support and guidance for formulating effective policies and measures. Therefore, the application of evolutionary game theory holds significant theoretical and practical significance for the development of sharing economy platforms.

III. B. Evolutionary Game Model Construction

Sharing economy platforms must make decisions regarding the adoption of blockchain technology to ensure product quality and safety and meet consumer needs. Consumers are the ultimate users of products, and their high concern for product quality and safety drives consumer rights protection actions. Without making decisions on blockchain adoption, platforms may face issues of information asymmetry and trust deficits, which could impact consumers' willingness to purchase products. In terms of consumer rights protection, consumers primarily focus on product quality and safety. Their concern over food safety issues is growing, and they seek products with traceability and guarantees. When encountering quality or safety issues during consumption on sharing economy platforms, they often choose to exercise their rights. If blockchain adoption decisions are made, it can enhance product credibility, increase consumer trust in products, and thereby boost their willingness to purchase. However, if blockchain adoption decisions are not made or the application of blockchain technology is ineffective, it may lead to consumer doubts about product quality and safety, resulting in an increase in consumer rights protection actions. In such cases, a dynamic game-theoretic relationship forms between blockchain adoption decisions and consumer rights protection actions.

In summary, the evolutionary game theory relationship between blockchain adoption decisions and consumer rights protection behavior is a dynamic process. In this process, both parties need to continuously adjust their strategies to maximize their respective interests.

In terms of strategy stability, the payoffs for consumers choosing to enforce their rights and not to enforce their rights are π_{31} and π_{32}, respectively, with an average expected payoff of $\bar{\pi}_3$. π_{31}, π_{32}, $\bar{\pi}_3$ respectively:

$$\pi_{31} = y\left(V_c + R_c + \theta S - P\right) + (1-y)\left(V_c - P - L_c\right) \tag{2}$$

$$\pi_{32} = yR_c + (1-y)\left(-L_c\right) \tag{3}$$

$$\bar{\pi}_3 = z\pi_{31} + (1-z)\pi_{32} \tag{4}$$

According to the replication dynamics equation of evolutionary game theory, the rate of change in consumer rights protection behavior strategy selection is shown in the following equation:

$$\frac{dz}{dt} = z\left(\pi_{31} - \bar{\pi}_3\right) = z(1-z)\left[y\theta S + V_c - P\right] \tag{5}$$

Similarly, the involved enterprises can choose to adopt blockchain technology or not, with the corresponding benefits being π_{41}, π_{42} and $\bar{\pi}_4$, respectively. π_{41}, π_{42}, and $\bar{\pi}_4$ are as follows:

$$\pi_{41} = z\left(V + R_2 + \beta I - C\right) + (1-z)\left(\beta I + R_2 - C\right) \tag{6}$$

$$\pi_{42} = z(-\gamma T - U) + (1-z)(-\gamma T) \tag{7}$$

$$\bar{\pi}_4 = y\pi_{41} + (1-y)\pi_{42} \tag{8}$$

According to the replication dynamics equation of evolutionary game theory, the rate of change in blockchain adoption decision-making strategies is shown in the following equation:

$$\frac{dy}{dt} = y\left(\pi_{41} - \bar{\pi}_4\right) = y(1-y)\left[z(U+V) + \beta I + \gamma T + R_2 - C\right] \tag{9}$$

According to the replication dynamic equation of consumer rights protection behavior, if $y = \frac{P - V_c}{\theta s}$, then $\frac{dz}{dt} \equiv 0$, then all z levels are ESS; If $y > \frac{P - V_c}{\theta S}$, then $Z^* = 1$ is ESS; If $y < \frac{P - V_c}{\theta S}$, then $Z^* = 0$ is ESS. According to the replication dynamic equation of the blockchain's adoption decision, if $z = \frac{c - \left(\beta I + R_2 + \gamma T\right)}{U + V}$, then $\frac{dy}{dt} \equiv 0$, then all y levels are ESS; If $z > \frac{c - \left(\beta I + R_2 + \gamma T\right)}{U + V}$, then $y^* = 1$ is ESS, and if $z < \frac{c - \left(\beta I + R_2 + \gamma T\right)}{U + V}$, then $y^* = 0$ is ESS.

III. C. Simulation analysis of initial strategies in evolutionary game models

Based on the evolutionary game model analysis discussed above, we further utilize MATLAB software to simulate the evolutionary trends of blockchain adoption decisions and consumer rights protection behaviors under initial probabilities converging toward the equilibrium point (1,1). Let the initial time be 0 and the end time be 10. The initial probabilities for blockchain adoption decisions and consumer rights protection behavior are set to (0.5, 0.5). The specific parameter settings are shown in Table 1. The specific meanings of the different indicators in the table are as follows:

U_n ——The utility consumers derive from goods;

E_n, T_n ——Increased revenue from blockchain adoption decision strategies;

D_n ——Time and economic costs of blockchain adoption decision strategies;

A_n — Costs incurred by not adopting the blockchain adoption decision strategy;

B_n — Economic, social, and legal liabilities incurred by not adopting the blockchain adoption decision strategy;

C_n — Costs of non-standardization on the sharing economy platform.

Table 1: Parameter setting

Index	Specific assignment
U_n	U_1 =7
	U_2 =3
	U_3 =3
E_n	E_1 =8
D_n	D_1 =2
	D_2 =2
	D_3 =2
T_n	T_1 =4
	T_2 =4
A_n	A_1 =3
	A_2 =3
	A_3 =5
B_n	B_1 =4
C_n	C_1 =4
	C_2 =1
	C_3 =2

The simulation results are shown in Figure 2. The results in the figure indicate that when the benefits of adopting blockchain technology outweigh the costs of not adopting it, the game system composed of blockchain adoption decisions and consumer rights protection behavior will eventually converge to the progressive equilibrium point (1,1).

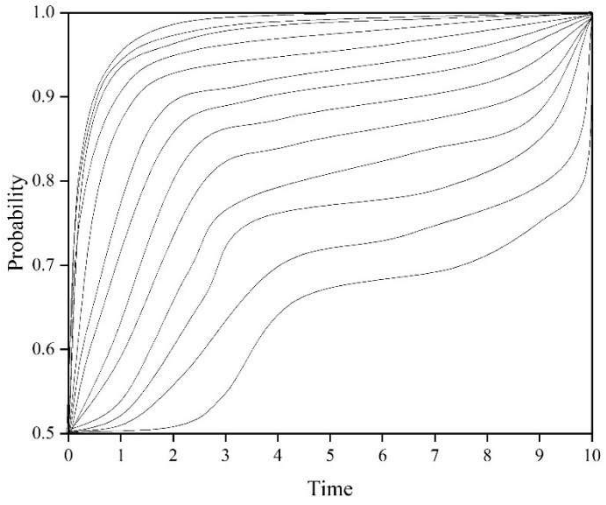

Figure 2: Evolution trend

Under the condition that other circumstances remain unchanged, the probabilities of blockchain adoption decisions and consumer rights protection behaviors are set as [x, y] = {[0.2, 0.2]; [0.4, 0.4]; [0.6, 0.6]}. The evolutionary trends under different initial probabilities are specifically shown in Figure 3. As can be seen from the figure, although the initial strategies are different, they all eventually converge toward the progressive equilibrium point (1, 1).

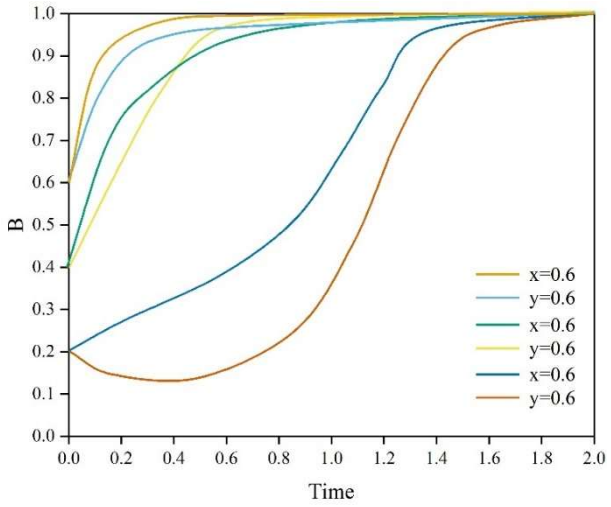

Figure 3: Evolution trend under different initial probabilities

IV. Blockchain Adoption Decisions and Consumer Rights Protection Behavior Evolutionary Game Analysis

This chapter will use the blockchain adoption decision and consumer rights protection behavior evolutionary game model constructed in the previous section as a basis, and utilize MATLAB software to conduct in-depth exploration and analysis of the factors affecting evolutionary stability through numerical simulation.

IV. A. Analysis of Factors Affecting Blockchain Adoption Decisions

IV. A. 1) Blockchain Technology Investment Costs and Expected Returns

The impact of blockchain technology investment costs T and expected returns P on the probability of blockchain adoption decision Y is illustrated in Figure 4. As can be seen, the evolution rate of blockchain adoption decisions accelerates as expected returns P increase, while the evolution rate slows down when blockchain technology investment costs T increase from 10 to 90. Reducing blockchain technology investment costs and reasonably controlling expected returns can effectively increase the probability of enterprises adopting blockchain technology in shared economy platforms.

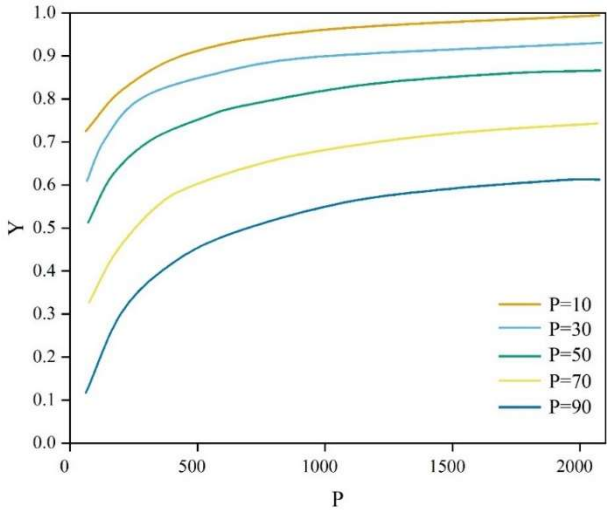

Figure 4: Blockchain technology input cost and expected return

IV. A. 2) Risk Factors and Competitive Pressure

The impact of risk factor R and competitive pressure C on the probability of blockchain adoption decision Y is illustrated in Figure 5. As the risk factor R increases from 0.2 to 1, the probability of blockchain adoption decision Y is suppressed as competitive pressure C increases. Since the sharing economy platform is currently in a period of rapid development, there is significant competitive pressure among enterprises on the platform.

Additionally, the credit system within the platform system is still underdeveloped, which also poses a high risk for enterprises' blockchain adoption decisions. Therefore, within a reasonable range, reducing competitive pressure among enterprises and improving the system's credit system to lower operational risks can effectively increase the probability of enterprises adopting blockchain technology.

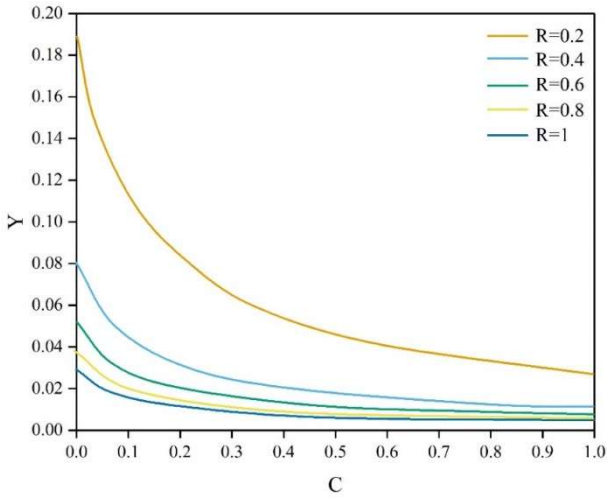

Figure 5: Risk coefficient and competitive pressure

IV. B. Analysis of Factors Affecting Consumer Rights Protection Behavior

To further understand consumer rights protection behavior and its evolutionary stability influencing factors, we first analyze the impact of the initial state on consumer rights protection behavior. In the initial state, the rights protection difficulty coefficient RS = 0.8, and the rights protection compensation coefficient RC = 0.5. The evolutionary dynamics of the system under changing initial conditions are illustrated in Figure 6. As shown in the figure, under a given initial state threshold value x, once the probability of consumers choosing to engage in rights protection exceeds 27%, other consumers whose interests have been harmed will learn and imitate the behavior of rights-protecting consumers, ultimately leading to widespread rights protection behavior throughout the entire group.

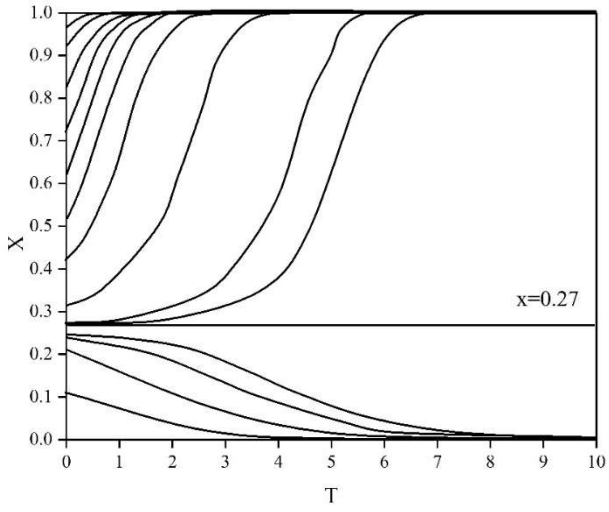

Figure 6: The system evolution when initial state changes

IV. B. 1) Difficulty of consumer rights protection

This section will first explore the impact of the difficulty of consumer rights protection on consumer rights protection behavior and system evolution, with the rights protection difficulty coefficient set to RS =1.6. The numerical simulation results are shown in Figure 7. Compared to the initial state, when the rights protection difficulty coefficient increases from the original 0.8 to 1.6, the difficulty of system evolution increases, and the critical value of system

evolution increases to approximately 36%. Clearly, higher enforcement difficulty significantly inhibits consumers from choosing enforcement behavior strategies.

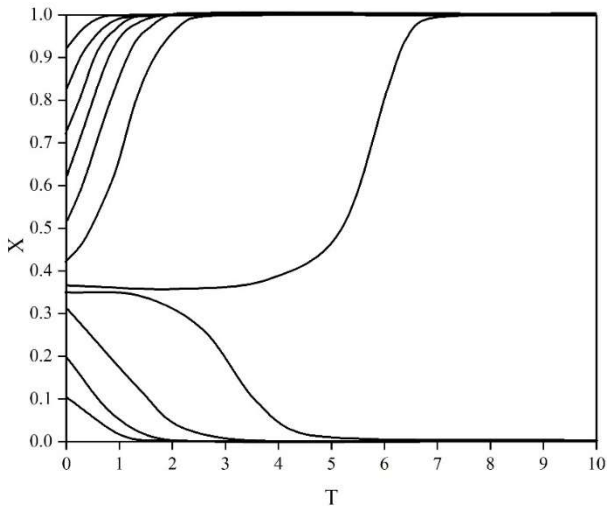

Figure 7: The impact of difficulty of rights protection on system evolution

IV. B. 2) Consumer Rights Protection Compensation Coefficient

To explore the impact of the consumer rights protection compensation coefficient on consumer rights protection behavior and system evolution, we first set RC = 2.5, while keeping other parameters unchanged. The numerical simulation results are shown in Figure 8. Compared with the initial state, the critical value x of evolution decreased to approximately 18.26%, and the probability of rights protection behavior increased.

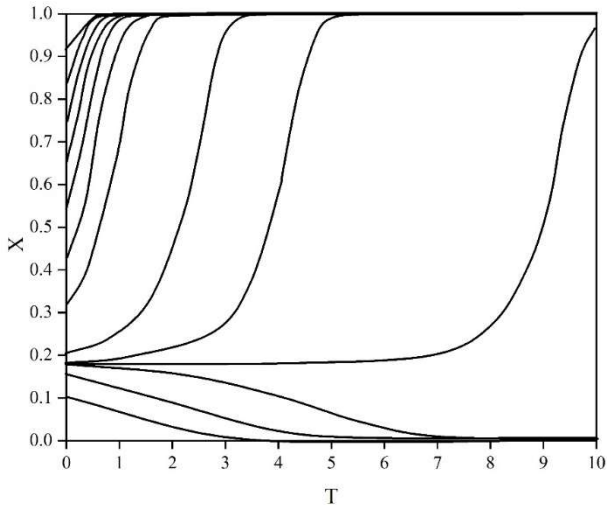

Figure 8: The influence of rights compensation coefficient when RC =2.5

Based on the above, further setting RC = 2, the changes in the numerical simulation results are shown in Figure 9. It can be seen that the critical value x of the system evolution increases sharply to 64.15%, and the difficulty of system evolution increases. At this point, more consumers choose to comply with the strategy of protecting their rights, and the time required for evolution is shortened.

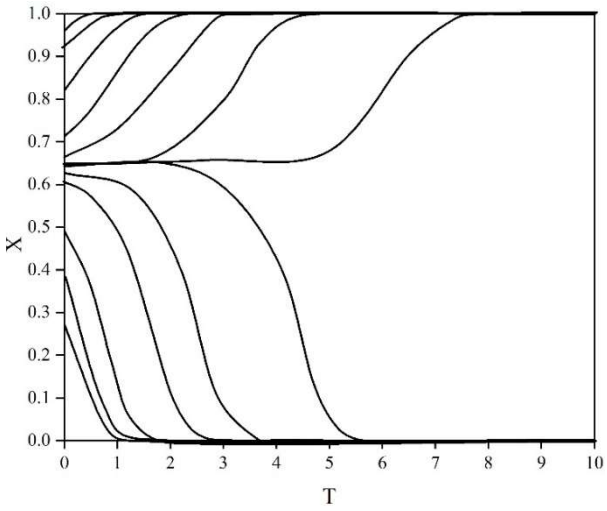

Figure 9: The influence of rights compensation coefficient when RC =2

Further setting RC = 0.5 while keeping other parameters unchanged, the numerical simulation results are shown in Figure 10. Compared with the case where RC = 2, the critical value of evolution increases to 90.05%, and relatively speaking, the probability of consumers choosing to comply in terms of rights protection increases.

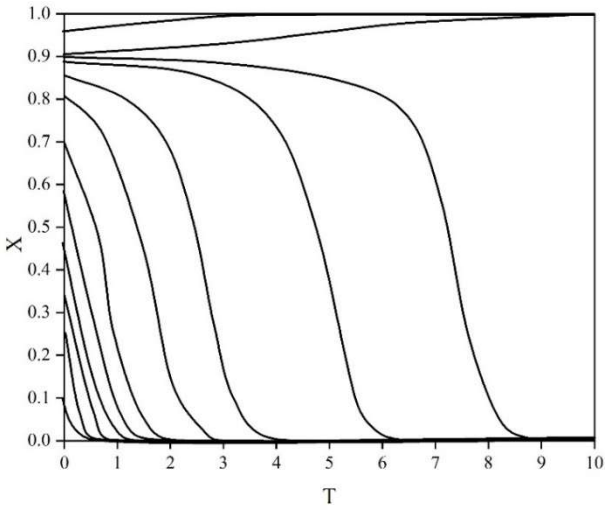

Figure 10: The influence of rights compensation coefficient when RC =0.5

In summary, the compensation obtained through consumer rights protection is the basic motivation for consumers to choose to protect their rights. If the consumer rights protection compensation coefficient decreases, the benefits that consumers can obtain from protecting their rights will also decrease, thereby reducing consumers' motivation to choose a rights protection strategy.

V. Conclusion

This paper introduces evolutionary game theory to construct an evolutionary game model of blockchain adoption decisions and consumer rights protection behavior on a sharing economy platform. Using MATLAB software, we simulate the evolutionary trend process of blockchain adoption decisions and consumer rights protection behavior as they converge toward the equilibrium point (1,1) under initial probabilities. When the initial probabilities of blockchain adoption decisions and consumer rights protection behavior are set to (0.5, 0.5), the resulting game system eventually converges to the progressive stable point (1,1). When the probabilities of blockchain adoption decisions and consumer rights protection behaviors are [x, y] = {[0.2, 0.2]; [0.4, 0.4]; [0.6, 0.6]}, despite differing initial strategies, they all ultimately converge toward the progressive stable point (1,1).

Further, through numerical simulation, we explore the factors influencing the evolutionary stability of blockchain adoption decisions and consumer rights protection behavior. In terms of blockchain adoption decisions, when the blockchain technology investment cost T increases from 10 to 90, the evolutionary rate slows down, while when the expected return P increases, the evolutionary rate accelerates. When the risk coefficient R increases from 0.2 to 1, the probability of blockchain adoption decision Y is suppressed as competition pressure C increases. Clearly, by reducing the cost of blockchain technology investment, reasonably controlling expected returns, and lowering the risk coefficient and competition pressure, the probability of blockchain adoption decisions by enterprises can be effectively enhanced. Regarding consumer rights protection behavior, when the difficulty of rights protection increases from 0.8 to 1.6, the system evolution difficulty increases, and the evolution threshold rises to approximately 36%. The increased difficulty of rights protection significantly inhibits consumers from choosing rights protection behavior strategies. When the consumer rights protection compensation coefficient RC is set to 2.5, the evolution threshold x decreases to approximately 18.26% compared to the initial state. When further setting RC = 2 and RC = 0.5, the critical value of evolution x increases to 64.15% and 90.05%, respectively. This indicates that consumer rights protection compensation serves as the foundation for consumer rights protection behavior. If the consumer rights protection compensation coefficient decreases, the motivation for consumers to choose rights protection strategies also decreases.

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