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# A Study of the Multi-Actor Evolutionary Game of Social Auditing: A Blockchain Technology-Enabled Perspective

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**Abstract**

Private economy is an intrinsic element of China's economic system, and promoting the development of private economy is an important support for the high-quality development of China's economy. Private enterprises are the key subjects of the private economy, and in recent years, the innovation vitality of China's private enterprises has continued to improve, and innovation achievements have emerged one after another, which is an important driving force for cultivating new quality productivity. However, there are still a series of problems such as insufficient domestic demand, intensified involution, and lack of enhancement, which hinder the sustainable development of private enterprises. Based on the perspective of blockchain technology empowerment, this study focuses on the strategic choice of private enterprises, government regulators and accounting firms in social audit regulation, and applies the evolutionary game theory for model construction to analyze the stability conditions for the game system to evolve to a stable state. In deeply grasping the evolutionary trend of all parties' subjects under different strategy choices, this study aims to provide theoretical support for the optimization of China's social audit regulatory system.

**Keywords:** blockchain, social audit, private enterprise, evolutionary game, numerical simulatio

## 1. Introduction

The State Council issued the Government Work Report 2024 and the Decision on Further Comprehensively Deepening Reform and Promoting Chinese-Style Modernization of the Third Plenary Session of the 20th CPC Central Committee mentioned that, to optimize the environment for the development of the private economy, it supports private enterprises to carry out key core technology research and development, creates small and medium-sized enterprises with strong innovation capability and characteristic industrial clusters, supports and guides private enterprises to improve their governance structure and management system, strengthens the private enterprises' compliance building, and standardize the administrative inspection of private enterprises. However, China is at the critical node of the transformation of old and new kinetic energy, the national regulatory system is in urgent need of improvement, and the problem of auditing and supervision of private enterprises is becoming more and more prominent, and it still faces the phenomena of the difficulty of linkage between enterprises and accounting firms, the pain point of the uncoordinated vertical and horizontal integration, and the blockage of the frequent emergence of collusive behaviors. In the process of promoting the high-quality development of enterprises, relying only on the state's efforts to regulate and traditional auditing is not enough to solve the above problems. Due to the transparency and decentralization characteristics of blockchain technology, it can assist the healthy development of enterprises. Blockchain technology can not only improve quality, reduce costs, and increase efficiency for enterprises, but also provide a new type of regulatory system for state supervision. Additionally, it provides a scientific guarantee for accounting firms to innovate dynamic auditing, thereby attracting a diverse range of subjects to participate in enterprise supervision. Therefore, blockchain technology can not only play the core performance for private enterprises in the goal of high-quality development, but also provide technical support for the state to strengthen dynamic supervision in the market.

With the deepening reform of China's economic system and the booming development of the digital era, private enterprises have become an important pillar of the national economy. In corporate governance, government departments are prone to rent-seeking behavior when checking enterprises, at this time, accountants who abide by professional ethics will actively audit. If private enterprises stop at the current technological conditions, they need to bring together the power of technological innovation and other forces to promote the enterprise to achieve the goal of unity of economic and social benefits. Therefore, the strategic choice of blockchain technology-enabled

social auditing and regulatory bodies has a far-reaching impact on optimizing the auditing and regulatory system and improving auditing efficiency and quality. In this paper, we construct an evolutionary game model and use MATLAB 2022a for numerical simulation to analyze the strategic choices of private enterprises and regulators in the face of the application of blockchain technology, so as to provide decision-making references for policymakers. Relying on the blockchain technology empowerment, this paper will deeply explore its application in social audit regulation and its impact on the strategy choice of audit and regulatory bodies, with a view to providing new ideas and methods for the high-quality development of private enterprises and the improvement of national regulatory system in China.

The rest of the paper is organized as follows. Section 2 conducts a literature review. Section 3 constructs the model. Section 4 gives the conclusions and relevant recommendations of this study.

## 2. Literature Review

### *2.1 Private Enterprises*

With the continuous relaxation of national economic policies and the gradual improvement of the market economic system, private enterprises have been given a new historical mission and become the main force to promote the high-quality development of China's economy [1]. Nowadays, a new generation of scientific and technological revolution and industrial change surge, private enterprises increasingly diversified and personalized market demand is increasing, which provides a broad market space and development opportunities for private enterprises[2]. Despite the introduction of a series of policies by the state, private enterprises are still facing the problems of low-end and high-end product structure highlighting, insufficient R&D investment and innovation ability, poor business environment and low economic efficiency [3], and also face risks in the top-level design and other aspects, such as digital technology barriers, digital information security and other issues.

Aiming at the prominent problems of private enterprises, scholars have proposed many solutions in terms of innovation ability, enterprise control and development environment. In terms of innovation ability, Liang et al. believed that the innovation breakthrough and transformation and development of private enterprises can be promoted through strengthening basic research, focusing on key industries, and digital technology empowerment [4]. Through empirical research, Xu tested that the optimization of the business environment has a positive orientation to the digital transformation of enterprises, pointing out that the government should promote the digital transformation of private enterprises from entrepreneurs as a breakthrough [5]. Zhu et al. proposed to promote the innovative development of the private economy through active government guidance and other measures [6]; Cheng used a double-difference method to prove that government data openness can significantly improve the performance of private enterprises and reduce the institutional transaction costs of enterprises [7]. In terms of corporate control, Wang encouraged private enterprises to optimize their equity structure and effectively improve their management in strategy, business, and functions [8]; Chen highlighted the importance of internal auditing in assessing risk management, information disclosure, and social responsibility [9]; and Cui proved that ESG investment can improve the return on assets, environmental protection investment, and research and development (R&D) innovation ability of private enterprises, and alleviate financing constraints [10]; Jing found that financial and tax support can promote the high-quality development of private enterprises; Hao used behavioral economics and evolutionary game theory to construct an audit and enterprise game model for simulation analysis to determine the factors affecting the strategy and put forward optimization suggestions for audit supervision strategy [11]. In terms of the development environment, Wang believed that the implementation of measures to further create a fair competitive market environment, optimize the business environment and service mechanism can reverse the disadvantageous position of private enterprises, and transform the system dividend into enterprise dividend [8]; Shao and others proposed that government departments should actively advocate private enterprises to carry out "reverse mixing", while private enterprises should At the same time, private enterprises should utilize state-owned capital to participate in the high-quality development of private enterprises by improving environmental protection subsidies, strengthening the disclosure of social responsibility information and governance dimensions [12].

### *2.2 Blockchain Technology*

The age of digital intelligence deeply integrates digitalization and intelligence, forming unprecedented new quality productivity and promoting the change of the domestic industrial system, in which blockchain technology as a key product of the age of digital intelligence, the research of Samuel et al. puts forward the characteristics of blockchain technology, that is, through its distributed architecture and encrypted means, it ensures the fixity and consistency of the transaction records, and realizes the tamper-proofness and transparency of the data [13]. Kakavand et al. argued that in the current competitive economic landscape of globalization, the financial services industry is facing severe challenges and must innovate to reduce transaction costs [14]. As a result, the industry has achieved a leading

position in the field of business innovation with blockchain technology. Peters and Panayi proposed blockchain technology as an innovative solution in the areas of clearing and settlement of financial assets, payment systems, smart contracts, and risk management of financial market operations [15].

With the continuous breakthroughs and innovations in blockchain technology, blockchain technology has been upgraded and strengthened in the areas of government accounting regulation, data management and privacy protection, auditing model, and avoidance of financial fraud. In strengthening government regulation, blockchain technology can optimize the government accounting system, but faces challenges such as cost control, ecological construction and data security. Scholars such as Zhang believed that it is necessary to strengthen the top-level design, the integration of technical and professional capabilities and external regulation to cope with it, while blockchain has the characteristics of decentralization, tampering and confidentiality, so that blockchain technology can be applied to government regulation, which can help to reduce the risk of supply chain information leakage and loss of revenue, and enhance the willingness of enterprises to collaborate and innovate [16]. In terms of enhancing the auditing model, Xing found that under the technological innovation regulatory model, enterprises still tend to choose collaborative innovation. The application of blockchain technology in the field of accounting and auditing can help reduce accounting malpractice and financial fraud, and promote the development of enterprises to a higher quality [17]. Tan used the "blockchain+ audit" model, and its decentralized characteristics help create a new audit regulatory system, solve the problem of information silos and real-time regulation, and provide a theoretical basis for audit regulatory innovation [18]. In terms of avoiding financial fraud, Sun believed that accounting firms fail to perform their duties in auditing, resulting in audit opinions without reasonable assurance and misrepresentation of the company's condition. In the short term, this behavior may make private enterprises seem to develop well; however, in the long term, with the revelation of the media and the public as well as the government's strengthening of supervision, the financial fraud of private enterprises will be made public [19].

Blockchain technology can practically solve the problems of irrational high- and low-end product structure, mismatch between R&D investment and output, business environment to be improved, and financial fraud highlighted by private enterprises, and can provide a solid foundation for promoting the process of Chinese-style modernization. The existing research literature mainly focuses on the regulatory issues of blockchain and state-owned enterprises and listed enterprises, while there are fewer related studies on private enterprises. Therefore, this paper takes blockchain technology as the basis of the influence of social audit regulatory subjects on the strategic choice of enterprises, constructs a tripartite game model of private enterprises, the government, and accounting firms, analyzes the game strategies and influencing factors of each subject, and finally draws relevant conclusions to provide corresponding substantive suggestions for the high-quality development of private enterprises, as well as to give practical significance to the comprehensive deepening of reform in China.

This study has the following contributions: (1) It takes private enterprises as one of the new research objects. (2) It utilizes stability and sensitivity analysis to explore the influence of each key variable on the strategy choice of each subject. (3) It gives policy suggestions and countermeasures for the high-quality development of private enterprises under the three-party game situation.

## 3. Methodology

### *3.1 Model Construction*

Based on the theory of limited rationality and information asymmetry, this paper makes the following assumptions for constructing the tripartite evolutionary game model of private enterprises, government and accounting firms:

Assumption 1: The assumption of participating subjects. Social auditing in the main existence of three participating subjects, respectively, private enterprises, accounting firms, the government, the subject of the pursuit of maximizing the benefits of its strategy selection over time evolution gradually converge to the optimal.

Hypothesis 2: the assumption of the probability of strategy selection of participating subjects. It is assumed that the probability that a private enterprise chooses the compliance strategy is $x$ and the probability that it chooses the non-compliance strategy is $1-x\ (0 \le x \le 1)$ . Assume that the probability of accounting firms choosing strict auditing strategy is $y$ and the probability of choosing lenient auditing strategy is$1-y\ (0 \le y \le 1)$ . Suppose the probability that the government chooses a regulatory strategy is $z$ and the probability that it chooses a non-regulatory strategy is $1-z\ (0 \le z \le 1)$ .

Hypothesis 3: Hypotheses related to private enterprises. The compliance benefit of the private firm's high quality development goal is $R_1$ , when the government that regulates gives incentives to the firm in order to incentivize high quality development $K_1$ . However, in order to maximize their profits, private enterprises, through financial

fraud, attempt to pay the cost of collusion to the accounting firm $C_1$ , low-quality development goals that is, the benefits of non-compliance $R_2(R_2 > R_1)$ , at this time the government to regulate the identification of low-quality development goals of non-compliance need to bear the penalties for non-compliance $P_1$ , and bear the reputational damage$L_1$ .

Assumption 4: Assumptions related to accounting firms. Accounting firms strict audit when the cost $C_2$ , used to search for corresponding evidence, including the cost of time, labor costs, sunk costs, etc., strict audit revenue earned $M$ . Costs at the time of lenient audits by accounting firms $C_3$ ( $C_2 > C_3$) , at this time $C_2 > (C_1 + C_3)$ . Which is not recognized by the government regulator lax audit when the revenue gained $R_3$ . If the government effectively regulates the goal of high-quality development of enterprises, accounting firms to report the behavior of private enterprises under the violation of the operation will be rewarded by the government $V$ ( $V < K_3$) , accounting firms to choose lax auditing will not be able to obtain the corresponding compensation and rewards, the government found that lax auditing scenarios, accounting firms did not abide by the due diligence of the fines carried out by the accounting firms $P_2$ , accounting firms are identified to bear the reputational damage$L_2$ .

Hypothesis 5: Government-related hypothesis. There is a cost to the government to regulate $C_4$ , effective regulation of firms brings social benefits $W$ , and identification of firms that violate the law is rewarded with an additional incentive from higher authorities $K_2$ ( $K_2 > C_4$) . If the government abandons its regulatory strategy and colludes with the enterprise, the cost of not supervising is zero, and it is difficult to identify whether the enterprise is compliant or not. Therefore, the private enterprise chooses to violate the operation and implement rent-seeking behavior to the accounting firm, which brings losses to the accounting firm and gives implicit compensation $K_3$ .

To summarize the above assumptions, private enterprises may choose to operate in violation of the rules in order to comply with the trend of the digital age and pursue high-quality target development and fail to avoid the risks, or they may choose to operate in compliance according to their own situation to comply with the laws and regulations of the market; accounting firms may choose to conduct strict audits for fear of damage to their reputation, or they may choose to conduct loose audits in order to obtain huge profits; government regulators may choose to regulate for the sake of effective operation of the social order, or they may choose to regulate for the sake of quick success. Government regulators may choose to regulate for the effective operation of social order, or they may choose not to regulate for the sake of quick success and quick profit. Therefore, private enterprises, accounting firms, and government regulators have two strategies to construct a three-party game matrix, as shown in Table 1.

According to Table 1, the expected return functions of private enterprises choosing the strategies of "compliance" and "non-compliance" in the game are $E_x$ and $E_{1-x}$ , respectively, while the average expected return function is $\overline{E}_1$ , and each expected return function is as follows:

$$E_x = yz(R_1 + K_1) + y(1-z)R_1 + (1-y)z(R_1 + K_1) + (1-y)(1-z)R_1 \quad (1)$$

$$E_{1-x} = yz(R_2 - C_1 - P_1 - L_1) + y(1-z)(R_2 - C_1 - K_3) + (1-y)z(R_2 - C_1 - P_1 - L_1) + (1-y)(1-z)(R_2 - C_1 - K_3) \quad (2)$$

$$\overline{E}_1 = xE_x + (1-x)E_{1-x} \quad (3)$$

According to the Malthusian dynamic equation, the replication dynamic equation for innovative firms is $F(x)$ : the following

$$F(x) = \frac{dx}{dt} = x\left(E_x - \overline{E}_1\right) = x(1-x)[z(K_1 - K_3 + L_1 + P_1) + C_1 + K_3 + R_1 - R_2] \quad (4)$$

Table 1. Benefits matrix of the gaming system

| Private enterprise | Government Regulator | | |
|---|---|---|---|
| | Accounting firm | Regulate (z) | No regulation (1-z) |
| Compliance (x) | Strictly audited (y) | $R_1$+$K_1$<br>$M$-$C_2$ | $R_1$<br>$M$-$C_2$ |
| | Lax auditing (1-y) | $W$-$C_4$+$K_3$-$K_1$<br>$R_1$+$K_1$ | 0<br>$R_1$ |

| | | | |
|---|---|---|---|
| Non-compliant operation (1-x) | Strictly audited (y) | $-C_3-P_2$ | $-C_3+R_3$ |
| | | $W-C_4+K_2+P_2$ | 0 |
| | | $R_2-C_1-P_1-L_1$ | $R_2-C_1-K_3$ |
| | | $M-C_2+V$ | $M-C_2+K_3$ |
| | Lax auditing (1-y) | $-C_4+K_2+P_1-V$ | 0 |
| | | $R_2-C_1-P_1-L_1$ | $R_2-C_1-K_3$ |
| | | $-C_3-P_2-L_2$ | $R_3-C_3+K_3$ |
| | | $-C_4+K_2+P_1+P_2$ | 0 |

The expected payoffs of the accounting firms choosing the "strict audit" and "lenient audit" strategies in the game are $\mathrm{E_y}$ and $\mathrm{E_{1-y}}$, respectively, while the average expected payoff is $\overline{\mathrm{E}}_2$, and each expected payoff is specified as follows:

$$\mathrm{E_y} = \mathrm{xz}(\mathrm{M}-\mathrm{C_2}) + \mathrm{x}(1-\mathrm{z})(\mathrm{M}-\mathrm{C_2}) + (1-\mathrm{x})\mathrm{z}(\mathrm{M}+\mathrm{V}-\mathrm{C_2}) + (1-\mathrm{x})(1-\mathrm{z})(\mathrm{M}+\mathrm{K_3}-\mathrm{C_2}) \quad (5)$$

$$\mathrm{E_{1-y}} = \mathrm{xz}(-\mathrm{C_3}-\mathrm{P_2}) + \mathrm{x}(1-\mathrm{z})(\mathrm{R_3}-\mathrm{C_3}) + (1-\mathrm{x})\mathrm{z}(\mathrm{C_3}-\mathrm{P_2}-\mathrm{L_2}) + (1-\mathrm{x})(1-\mathrm{z})(\mathrm{R_3}+\mathrm{K_3}-\mathrm{C_3}) \quad (6)$$

$$\overline{\mathrm{E}}_2 = \mathrm{yE_y} + (1-\mathrm{y})\mathrm{E_{1-y}} \quad (7)$$

According to the Malthusian dynamic equation, the replication dynamic equation for innovative firms is $\mathrm{F(y)}$ : the following

$$\mathrm{F(y)} = \frac{\mathrm{dy}}{\mathrm{dt}} = \mathrm{y}\left(\mathrm{E_y}-\overline{\mathrm{E}}_2\right) = \mathrm{y}(1-\mathrm{y})[\mathrm{z}(\mathrm{L_2}+\mathrm{P_2}+\mathrm{R_3}+\mathrm{V}) - \mathrm{xz}(\mathrm{L_2}+\mathrm{V}) + \mathrm{C_3} + \mathrm{M} - \mathrm{C_2} - \mathrm{R_3}] \quad (8)$$

The expected payoffs of the government regulator choosing the "supervise" and "do not supervise" strategies in the game are $\mathrm{E_z}$ and $\mathrm{E_{1-z}}$, respectively, while the average expected payoff is $\overline{\mathrm{E}}_3$, and each expected payoff is specified as follows:

$$\mathrm{E_z} = \mathrm{xy}(\mathrm{W}+\mathrm{K_2}-\mathrm{C_4}-\mathrm{K_1}) + \mathrm{x}(1-\mathrm{y})(\mathrm{W}+\mathrm{K_4}+\mathrm{P_2}-\mathrm{C_4}) + (1-\mathrm{x})\mathrm{y}(\mathrm{K_2}+\mathrm{P_1}-\mathrm{C_4}-\mathrm{V}) + (1-\mathrm{x})(1-\mathrm{y})(\mathrm{K_2}+\mathrm{P_1}+\mathrm{P_2}-\mathrm{C_4}) \quad (9)$$

$$\mathrm{E_{1-z}} = 0 \quad (10)$$

$$\overline{\mathrm{E}}_3 = \mathrm{yE_y} + (1-\mathrm{y})\mathrm{E_{1-y}} \quad (11)$$

According to the Malthusian dynamic equation, the replication dynamic equation for innovative firms is $\mathrm{F(z)}$ :

$$\mathrm{F(z)} = \frac{\mathrm{dz}}{\mathrm{dt}} = \mathrm{z}\left(\mathrm{E_z}-\overline{\mathrm{E}}_3\right) = \mathrm{z}(1-\mathrm{z})[\mathrm{x}(\mathrm{W}-\mathrm{P_1}) - \mathrm{y}(\mathrm{P_2}+\mathrm{V}) + \mathrm{xy}(\mathrm{V}-\mathrm{K_1}) - \mathrm{C_4} + \mathrm{K_2} + \mathrm{P_1} + \mathrm{P_2}] \quad (12)$$

Therefore, the joint equations (4), (8) and (12) can construct the three-dimensional dynamic system of private enterprises, accounting firms and government regulators:

$$\begin{cases} \mathrm{F(x)} = \mathrm{x}(1-\mathrm{x})[\mathrm{z}(\mathrm{K_1}-\mathrm{K_3}+\mathrm{L_1}+\mathrm{P_1}) + \mathrm{C_1} + \mathrm{K_3} + \mathrm{R_1} - \mathrm{R_2}] \\ \mathrm{F(y)} = \mathrm{y}(1-\mathrm{y})[\mathrm{z}(\mathrm{L_2}+\mathrm{P_2}+\mathrm{R_3}+\mathrm{V}) - \mathrm{xz}(\mathrm{L_2}+\mathrm{V}) + \mathrm{C_3} \\ \quad +\mathrm{M} - \mathrm{C_2} - \mathrm{R_3}] \\ \mathrm{F(z)} = \mathrm{z}(1-\mathrm{z})[\mathrm{x}(\mathrm{W}-\mathrm{P_1}) - \mathrm{y}(\mathrm{P_2}+\mathrm{V}) + \mathrm{xy}(\mathrm{V}-\mathrm{K_1}) - \mathrm{C_4} + \mathrm{K_2} + \mathrm{P_1} + \mathrm{P_2}] \end{cases} \quad (13)$$

*3.2 Stability Analysis*

According to the replicated dynamic equations, the equilibrium point of the game dynamic system can be found. According to the existing research results, the stability of the equilibrium point $E_1(0,0,0)$, $E_2(0,1,0)$, $E_3(0,1,1)$, $E_4(0,0,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$ is mainly considered. In addition, referring to Lyapunov's conclusion [20], it is known that the equilibrium point is an evolutionarily stable strategy (ESS) of the game system when all the eigenvalues are negative. The Jacobi matrix is obtained according to equation (13) as follows:

$$J=\begin{pmatrix}\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z}\\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z}\\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z}\end{pmatrix}=\begin{pmatrix}J_{11} & J_{12} & J_{13}\\ J_{21} & J_{22} & J_{23}\\ J_{31} & J_{32} & J_{33}\end{pmatrix} \tag{14}$$

$$\begin{cases}J_{11}=(1-2x)[z(K_1-K_3+L_1+P_1)+C_1+K_3+R_1-R_2]\\ J_{12}=0\\ J_{13}=x(1-x)(K_1-K_3+L_1+P_1)\\ J_{21}=y(1-y)[z(-L_2-V)]\\ J_{22}=(1-2y)[z(R_3+P_2+L_2+V)-xz(L_2+V)-C_2+C_3+M-R_3]\\ J_{23}=y(1-y)[x(-L_2-V)+R_3+P_2+L_2+V]\\ J_{31}=z(1-z)[y(V-K_1)+W-P_1]\\ J_{32}=z(1-z)[x(V-K_1)+V-P_2]\\ J_{33}=(1-2z)[x(W-P_1)-y(P_2+V)+xy(V-K_1)-C_2+K_2+P_1+P_2]\end{cases} \tag{15}$$

In the Jacobi matrix, 8 equilibrium points are brought in, resulting in each eigenvalue as shown in Table 2. Combining the model assumptions with the actual situation, all model parameters are non-negative, so the equilibrium solutions, $E_1(0,0,0)$ $E_5(1,0,0)$ are not ESS of the gaming system.

Table 2. Stability Analysis of Pure Strategy Equilibrium Points.

| Equilibrium point | $\lambda_1$ | $\lambda_2$ | $\lambda_3$ | Stability |
|---|---|---|---|---|
| $E_1(0,0,0)$ | $C_1+K_3+R_1-R_2$ | $-C_2+C_3+M-R_3$ | $-C_4+K_2+P_1+P_2$ | Instability |
| $E_2(0,1,0)$ | $C_1+K_3+R_1-R_2$ | $C_2-C_3-M+R_3$ | $-C_4+K_2+P_1-V$ | $\lambda_1,\lambda_2,\lambda_3<0$ |
| $E_3(0,1,1)$ | $C_1+K_1+L_1+P_1+R_1-R_2$ | $C_2-C_3-L_2-M-P_2-V$ | $C_4-K_2-P_1+V$ | $\lambda_1,\lambda_2,\lambda_3<0$ |
| $E_4(0,0,1)$ | $C_1+K_1+L_1+P_1+R_1-R_2$ | $C_3-C_2+L_2+M+P_2+V$ | $C_4-K_2-P_1-P_2$ | $\lambda_1,\lambda_2<0$ |
| $E_5(1,0,0)$ | $-C_1-K_3-R_1+R_2$ | $-C_2+C_3+M-R_3$ | $K_2-C_4+P_2+W$ | Instability |
| $E_6(1,0,1)$ | $R_2-C_1-K_1-L_1-P_1-R_1$ | $-C_2+C_3+L_2+M+P_2$ | $C_4-K_2-P_2-W$ | $\lambda_1,\lambda_2<0$ |
| $E_7(1,1,0)$ | $-C_1-K_3-R_1+R_2$ | $C_2-C_3-M+R_3$ | $W-C_4-K_1+K_2$ | $\lambda_1,\lambda_2,\lambda_3<0$ |
| $E_8(1,1,1)$ | $R_2-C_1-K_1-L_1-P_1-R_1$ | $C_2-C_3-M+P_2$ | $C_4+K_1-K_2-W$ | $\lambda_1,\lambda_2,\lambda_3<0$ |

## 4. Numerical Analysis and Results

The previous section explored the stability conditions of the gaming system, and in this section, the gaming system is simulated using MATLAB R2022a, and six of the scenarios are analyzed in detail, as shown in Figure 1.

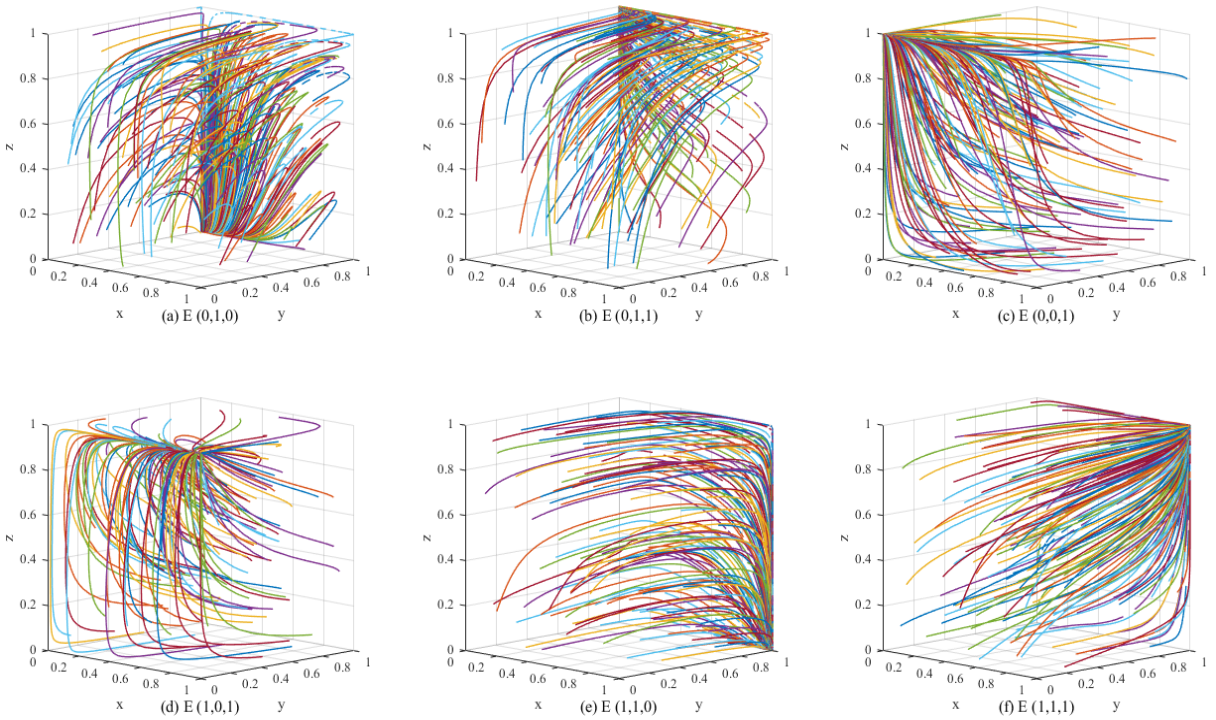


Figure 1. Evolutionary trajectory of the three parties

Scenario 1, $E_2$ (0,1,0):

Assuming $K_1 = 10,\ K_2 = 10,\ K_3 = 32,\ L_1 = 3,\ L_2 = 3,\ P_1 = 15,\ P_2 = 26,\ C_1 = 2,\ C_2 = 6,\ C_3 = 2,\ C_4 = 7,\ R_1 = 6,\ R_2 = 42,\ R_3 = 13,\ V = 30,\ M = 20,\ W = 8$, the evolution trend is shown in Fig. 1(a). In this case, private enterprises choose to operate in violation of the law, accounting firms choose to strictly regulate, and the government chooses not to regulate, and this equilibrium state shows that although accounting firms perform strict auditing duties, due to the lack of government regulation, private enterprises still tend to obtain excess returns by operating in violation of the law, and the benefits of violation are significantly higher than the sum of the benefits of compliance and the costs of violation, forming a regulatory vacuum under the Incentives for non-compliance.

Scenario 2,$E_3$ (0,1,1):

Assuming $K_1 = 10,\ K_2 = 10,\ K_3 = 32,\ L_1 = 3,\ L_2 = 3,\ P_1 = 15,\ P_2 = 26,\ C_1 = 2,\ C_2 = 6,\ C_3 = 2,\ C_4 = 7,\ R_1 = 6,\ R_2 = 42,\ R_3 = 13,\ V = 16,\ M = 20,\ W = 8$, the evolutionary trend is shown in Fig. 1(b). In this scenario, private firms choose to operate in violation of the law, accounting firms choose to strictly regulate, and the government chooses to regulate, and this state reflects the fact that despite the active regulatory measures taken by both the government and the accounting firms, the fact that private firms' gains from operating in violation of the law are significantly higher than the gains from compliance and the penalties for violation of the law are not strong enough to form an effective deterrent causes the firms to still stick to their strategy of violating the law.

Scenario 3, $E_4(0,0,1)$ :

Assuming $K_1 = 10,\ K_2 = 10,\ K_3 = 10,\ L_1 = 3,\ L_2 = 3,\ P_1 = 5,\ P_2 = 6,\ C_1 = 2,\ C_2 = 25,\ C_3 = 2,\ C_4 = 7,\ R_1 = 6,\ R_2 = 30,\ R_3 = 13,\ V = 5,\ M = 5,\ W = 8$, the evolutionary trend is shown in Figure 1(c). In this scenario, private firms choose to operate in violation of the law, accounting firms choose to audit loosely, and the government chooses to regulate. This equilibrium shows that accounting firms choose to audit loosely due to the high cost of strict auditing, and form a collusion with private firms; although the government implements regulation, it fails to curb the violations due to the lack of effectiveness of the regulation.

Scenario 4,$E_6$ (1,0,1):

Assuming $K_1 = 10,\ K_2 = 10,\ K_3 = 10,\ L_1 = 3,\ L_2 = 3,\ P_1 = 5,\ P_2 = 6,\ C_1 = 2,\ C_2 = 25,\ C_3 = 2,\ C_4 = 7,\ R_1 = 6,\ R_2 = 20,\ R_3 = 13,\ V = 5,\ M = 5,\ W = 8$, and the evolutionary trend is shown in Figure 1(d). In this scenario, private enterprises choose to operate in compliance, accounting firms choose to audit loosely, and

the government chooses to will, this state indicates that when the gap between compliance benefits and violation benefits is narrowed and government regulation is effective, private enterprises tend to operate in compliance; however, accounting firms still choose to audit loosely due to audit cost considerations, reflecting the irrationality of audit resource allocation.

Scenario 5, $E_7$ (1,1,0):

Assuming $K_1 = 8,\ K_2 = 6,\ K_3 = 8,\ L_1 = 2,\ L_2 = 6,\ P_1 = 4,\ P_2 = 2,\ C_1 = 2,\ C_2 = 6,\ C_3 = 2,\ C_4 = 5,\ R_1 = 2,\ R_2 = 10,\ R_3 = 3,\ V = 4,\ M = 25,\ W = 3$, the evolutionary trend is shown in Figure 1(e). In this case, private enterprises choose compliance, accounting firms choose lenient auditing, and the government chooses not to regulate. This equilibrium suggests that, in the case of a more perfect market mechanism, even if the government does not directly intervene, private enterprises and accounting firms can spontaneously form a compliance equilibrium, reflecting the role of the market's self-regulatory mechanism.

Scenario 6,$E_8$ (1,1,1):

Assuming $K_1 = 8,\ K_2 = 6,\ K_3 = 8,\ L_1 = 2,\ L_2 = 6,\ P_1 = 4,\ P_2 = 2,\ C_1 = 2,\ C_2 = 6,\ C_3 = 2,\ C_4 = 5,\ R_1 = 2,\ R_2 = 10,\ R_3 = 3,\ V = 4,\ M = 25,\ W = 12$, and the evolutionary trend is shown in Figure 1(f). In this case, private enterprises choose to operate in compliance, accounting firms choose strict auditing, and the government chooses the regulatory strategy, this state represents the most ideal regulatory equilibrium, and the three parties synergize their roles: the government effectively regulates and creates a good market environment, the private enterprises obtain stable income by operating in compliance, and the accounting firms maintain the market order by strict auditing, which forms a blockchain technology-enabled virtuous circle mechanism.

## 5. Conclusions and Recommendations

Based on the evolutionary game theory, this study constructs a tripartite game model of private enterprises, accounting firms and government regulators, and through stability analysis and numerical simulation, reveals the evolutionary law of the social auditing and regulatory system under the empowerment of blockchain technology. This paper reveals the existence of eight pure strategy equilibria and six possible ESSs through stability analysis, where the most strategies are (compliance, strict regulation, and supervision).

Based on the findings of this paper, the paper makes the following recommendations:

For private enterprises, they should establish a sound internal compliance management system, apply blockchain technology to financial information disclosure, and improve operational transparency. Take the initiative to accept third-party audit supervision, obtain government policy support and market trust through compliance operation, and realize long-term sustainable development.

For accounting firms, strengthen the construction of industry self-discipline, establish an audit quality evaluation system, deeply integrate blockchain technology into the audit process, and realize the automated execution of audit procedures through smart contracts. Improve the audit accountability mechanism, and impose severe penalties such as industry bans on collusive behavior.

For the government, establish a hierarchical regulatory mechanism to implement differentiated regulatory intensity based on the compliance records of enterprises, reduce the inspection frequency for compliant enterprises, and strengthen the regulatory efforts for non-compliant enterprises. Improve the construction of the blockchain regulatory platform to realize real-time sharing and cross-validation of audit data, reduce regulatory costs and improve regulatory efficiency.

This paper mainly considers the game relationship of the three parties, and does not involve more stakeholders such as media supervision and public participation. In addition, this paper mainly analyzes the enabling role of blockchain technology from the theoretical level, without quantitatively evaluating its specific implementation effect. Future research can explore other subjects to reflect the complexity of social audit regulation more comprehensively, and empirical research methods can be used to measure the changes in regulatory effectiveness before and after the application of blockchain technology.

### CRediT Authorship Contribution Statement

Yuqiong Li: Writing – review & editing, Funding acquisition, Supervision. Jiale Li: Writing – original draft, Conceptualization, Methodology, Formal analysis.

### Declaration of Competing Interest

There are no conflicts of interest disclosed in the submission of this article, and the article is approved for publication by all authors.

**Data Availability**

The article includes figures and tables illustrating the results of this study.

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