Evolutionary Game Research of Intelligent Transformation of Water Conservancy Enterprises in the Digital Background

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Abstract. In the context of digitalization, to promote the intelligent transformation of water conservancy enterprises and ensure their high-quality development. Given that evolutionary game theory combines game theory and dynamic evolutionary process analysis, it does not require complete rationality or information from participants, but rather emphasizes a dynamic equilibrium or evolutionary stability strategy, which can be well applied to decision-making research among multiple agents. Therefore, this article applies evolutionary game theory to construct a game model between water conservancy enterprises, governments, and third-party platforms, and uses Matlab software for numerical simulation analysis to explore the most suitable evolutionary path for the transformation and upgrading of water conservancy enterprises. The results indicate that under certain conditions, the game system will evolve and stabilize in a more ideal equilibrium state (1,0,1); The changes in the initial intentions of the three parties in the game have a significant impact on the convergence speed of the evolution of the subject's behavioral strategies; The cost-effectiveness of transformation and the fee coefficient of the plan have reduced the willingness of water conservancy enterprises to transform and the enthusiasm of third-party platform support; The government should establish a reasonable reward and punishment mechanism and provide appropriate policies such as interest rate subsidies and risk compensation for water conservancy enterprises.

Keywords: Digitization; water conservancy enterprises; intelligent transformation; platform empowerment; evolutionary game

1 Introduction

With the advent of the digital economy era, traditional water conservancy enterprises are no longer able to meet the development needs of the times. Therefore, in the context of digitalization, how to promote the intelligent transformation and upgrading of water

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conservancy enterprises and achieve high-quality development of the water conservancy industry is a key issue that needs to be focused on at present. Cracking the problem of intelligent transformation in water conservancy enterprises requires efforts from multiple parties. Third party platforms should be considered as assisting parties for the intelligent transformation of water conservancy enterprises. They should be included in the same framework as water conservancy enterprises and governments, and a three-party evolutionary game model should be constructed. Matlab should be used for simulation analysis.

1.1 Research Background and Significance

With the popularization and application of digital technologies such as big data, cloud computing, and artificial intelligence, modern society is entering the digital age[1]. Digitization is an important force leading a new round of technological revolution and industrial transformation. The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China clearly proposed to accelerate digital development and build a digital China. As the main body responsible for undertaking water conservancy construction tasks, water conservancy enterprises should actively adapt to the requirements of the times, find their positioning and play a role in the construction of a digital China, and contribute to the country's promotion of smart water conservancy construction. In this context, this article aims to connect the intelligent transformation and development of water conservancy enterprises with government policies and third-party platforms, search for the most suitable evolutionary path for the intelligent transformation and development of water conservancy enterprises, and explore the mechanism of platform empowerment and government incentive mechanisms on the intelligent transformation strategy of water conservancy enterprises, providing decision-making reference for multiple parties to assist in the intelligent transformation of water conservancy enterprises.

1.2 Research Status at Home and Abroad

From the level of enterprises themselves, the academic community has discussed many factors that affect smart transformation, including technological innovation, organizational change, operational efficiency and efficiency. Some scholars believe that technological innovation is the core driving force to promote the intelligent transformation of enterprises[2]. Yu et al.[3] emphasizes that for enterprises, continuous updating of organizational capabilities can realize their dynamic response to digital change strategies. Scholars have also analyzed the effects of government support and intervention from different policy perspectives. The research results show that government subsidies can stimulate the innovative behavior of smes[4], and talent policies can provide support for the intelligent transformation of enterprises[5]. Some scholars also pointed out that the government and enterprises alone are not enough to achieve the goal of smart transformation, and most smes have to rely on third-party digital platforms. Yang Wei et al.[6] pointed out that small and medium-sized enterprises are faced with the challenge of "digital divide" due to their own insufficient capabilities and resources, and need the support of third-party digital platforms or technical service providers.

The existing research results indicate that support from third-party digital platforms or technology service providers has a significant promoting effect on the intelligent transformation of small and medium-sized enterprises, providing theoretical basis for this article, but there are still shortcomings. On the one hand, most studies focus only on a single subject when exploring subject factors, without considering multiple subjects comprehensively. On the other hand, most existing research adopts qualitative analysis or case study methods, lacking quantitative analysis work, making it difficult to reveal the interactions and synergies between different entities, and also difficult to evaluate the actual effects of different entities participating in the intelligent transformation of water conservancy enterprises. The government and third-party platforms are two important forces in the intelligent transformation of water conservancy enterprises, and it is of practical significance to include them in a unified framework analysis with water conservancy enterprises.

2 Model Assumptions and Construction

The process of intelligent transformation of water conservancy enterprises is a complex system of multi-agent interactive games, involving multiple stakeholders. According to the roles and relationships of various stakeholders in the game interaction process, the main stakeholders can be divided into three categories: water conservancy enterprises (the main carriers of transformation), governments (led by policies and regulations), and third-party platforms (empowerment, cooperation, and driving). The relationship between the three parties in the game is shown in Figure 1. For the convenience of writing in the following text, water conservancy enterprises and third-party platforms are referred to as "enterprises" or "platforms".

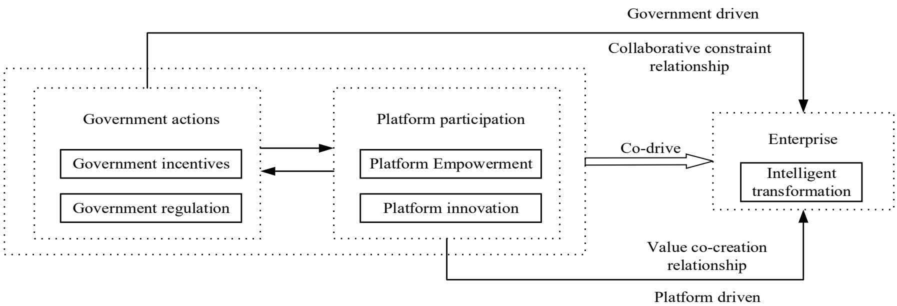


Fig. 1. Diagram of the relationship between three party game subjects

2.1 Model Assumptions

Assumption 1: It is impossible for each game subject to obtain the optimal strategy after only one or two games, and the optimal strategy selection is often the result of long-term learning, imitation, and continuous adjustment[7].

Assumption 2: The ratio of enterprises participating in intelligent transformation and upgrading is x ($0 \leq x \leq 1$), and when x=0 or 1, it represents "not participating" or "participating", respectively. The ratio of the government promoting the intelligent transformation of water conservancy enterprises is y ($0 \leq y \leq 1$), and when y=0 or 1, it represents "negative promotion" or "positive promotion", respectively. The ratio of platforms to develop digital construction plans is z ($0 \leq z \leq 1$), and when z=0 or 1, it represents "passive development" or "active development", respectively.

Assumption 3: The revenue from maintaining traditional operating methods for the enterprise is E_1, and the operating cost is C_1. The incremental benefits of intelligent transformation for enterprises are ΔE_1, and the transformation cost is "C" - "1" ("C" - "1">"C" - "1"), including normal operating costs and the software and hardware costs, human resource costs, technology costs, etc. of enterprise intelligent transformation. At the same time, the investment risk that enterprises need to bear for transformation is f, and participating enterprises will choose to cooperate with the platform. At this time, they need to pay the digital construction plan fee provided by the platform as S. If a company chooses not to participate in the strategy in order to avoid investment risks in transformation, but with the development of digital technology, companies that maintain traditional operating methods will gradually lose competitiveness in the industry, resulting in reputation and economic losses of B ($B<f$).

Assumption 4: When the government chooses to actively promote strategies, the cost spent on policy formulation, promotion, and implementation is C_2. The reward given to enterprises that choose intelligent transformation and platforms that actively develop digital construction plans is W, including financial subsidies, tax incentives, etc. The proportion of rewards given to enterprises is: β. On the contrary, if a company does not participate in intelligent transformation, it will be punished P_1 ($P_1>\beta W$) The fine imposed on platforms that passively formulate digital construction plans is P_2. When the government chooses a negative promotion strategy, it is unable to obtain information on the strategy choices of enterprises and platforms, and the government does not provide rewards or punishments. The participation of enterprises in intelligent transformation strategies has positive external effects on the enterprise itself, industry construction, and social development, bringing social benefits to the government. When enterprises do not participate in intelligent transformation and platforms passively formulate digital construction plans, the government's losses are L, including the loss of credibility and social benefits.

Assumption 5: The basic revenue of the platform is E_3. When a company chooses intelligent transformation and platform cooperation, and the platform actively formulates targeted and personalized digital construction plans based on the company's business scale, the benefits obtained by the platform are $S=\gamma E_1$, where γ the fee coefficient for the digital construction plan actively formulated by the platform. If the platform passively formulates a digital construction plan, the sales price of the plan will be recorded as S=N. The cost and platform intelligence required for the platform to actively develop digital construction plans θ (0＜θ＜1) Positive correlation, intelligence cost coefficient is δ， according to literature, the cost function of platform intelligence is $0.5\delta\theta^2$. The cost required for the platform to passively develop a digital construction plan is C_3.

2.2 Model Construction

Based on the above assumptions and analysis, the income matrix of the game between enterprises, governments, and platforms is shown in Table 1.

Table 1. Game matrix of enterprises, governments and platforms

Government			Platform: Actively formulating digital construction plans z	Platform: Negatively formulating digital construction plans 1-z
Enterprise	Participating x	Actively promoting y	$E_1+\Delta E_1-C'_1-f-\gamma E_1+\beta W$, E_2-W-C_2, $E_3+\gamma E_1-0.5\delta\theta^2+(1-\beta)W$	$E_1+\Delta E_1-C'_1-f-N+\beta W$, $E_2+P_2-\beta W-C_2$, $E_3+N-C_3-P_2$
		Passive promotion 1-y	$E_1+\Delta E_1-C'_1-f-\gamma E_1$, $E_2, E_3+\gamma E_1-0.5\delta\theta^2$	$E_1+\Delta E_1-C'_1-f-N$, E_2, E_3+N-C_3
	Not participating 1-x	Actively promoting y	$E_1-C_1-B-P_1$, $P_1-C_2-(1-\beta)W$, $E_3+(1-\beta)W$	$E_1-C_1-B-P_1$, $P_1+P_2-C_2-L$, E_3-P_2
		Passive promotion 1-y	$E_1-C_1-B, 0, E_3$	$E_1-C_1-B, -L, E_3$

3 Analysis of Evolutionary Game Models

Based on the above evolutionary game payment matrix, calculate the average expected returns of enterprises, governments, and platforms, construct a three party evolutionary game replication dynamic equation, and solve the equilibrium point of system evolution from it.

3.1 Analysis of Strategic Stability of Enterprises

The expected benefits of enterprises participating in intelligent transformation:

$$E_x = -y\beta W - z(\gamma E_1 - N) + E_1 + \Delta E_1 - C'_1 - f - N \tag{1}$$

Expected benefits of enterprises not participating in intelligent transformation:

$$E_{1\text{-}x} = -yP_1 + E_1 - C_1 - B \tag{2}$$

The average expected return of a company's mixed strategy:

$$\overline{E_1} = xE_x + (1 - x)E_{1\text{-}x} \tag{3}$$

Therefore, the replication dynamic equation of corporate behavior strategy:

$G(x) = \frac{dx}{dt} = x(x-1)L(y)$, among them,

$$L(y) = y(\beta W - P_1) + z(\gamma E_1 - N) - \Delta E_1 + C'_1 + f + N - C_1 - B \tag{4}$$

At $y = \frac{\Delta E_1 - C'_1 - f - N + C_1 + B - z(\gamma E_1 - N)}{\beta W - P_1} = y^*$ time, $L(y) = 0$ and $G(x) \equiv 0$, indicating that any value of x can lead the enterprise to a stable state of evolution, meaning that the enterprise's strategic choices do not change over time; At $y < y^*$, $L(y) > 0$ time, it can be inferred that x=0 means that maintaining the status quo is a stable strategy for the enterprise; Similarly, at $y > y^*$ time, $L(y) < 0$ known that x=1, which means the enterprise's intelligent transformation into a stable strategy. The phase diagram of enterprise strategy evolution is shown in Figure 2.

3.2 Analysis of the Stability of Government Strategies

The expected benefits of the government's active promotion of enterprise intelligent transformation strategy:

$$E_y = xE_2 - x\beta W - z(1-\beta)W - C_2 + (1-x)P_1 + (1-z)P_2 - (1-x)(1-z)L \tag{5}$$

The expected benefits of the government's passive promotion of enterprise intelligent transformation strategy:

$$E_{1\text{-}y} = xE_2 - (1-x)(1-z)L \tag{6}$$

The average expected return of the government's mixed strategy is:

$$\overline{E_2} = yE_y + (1-y)E_{1\text{-}y} \tag{7}$$

Therefore, the replication dynamic equation of government behavior strategy:

$G(y) = \frac{dy}{dt} = y(y-1)S(x)$, among them,

$$S(x) = x(P_1 + \beta W) + z(P_2 + (1-\beta)W) + C_2 - P_1 - P_2 \tag{8}$$

At $x=\frac{P_1+P_2-C_2-z\left(P_2+(1-\beta)W\right)}{P_1+\beta W}=x^*$ time, $S(x)=0$ and $G(y)\equiv 0$, indicating that for any y, it is a stable strategy of the government. At $x<x^*$ time, $S(x)<0$ known that y=1 means that the government's "active promotion" is a stable strategy; similarly at $x>x^*$ time, $S(x)>0$, it can be seen that the government's "passive promotion" is a stable strategy. The phase diagram of the government's strategic evolution is shown in Figure 3.

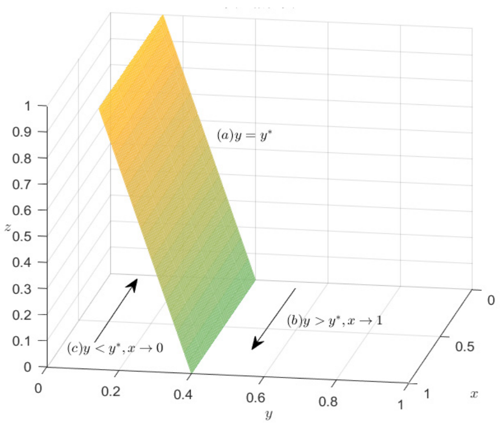


Fig. 2. Phase diagram of enterprise strategy evolution

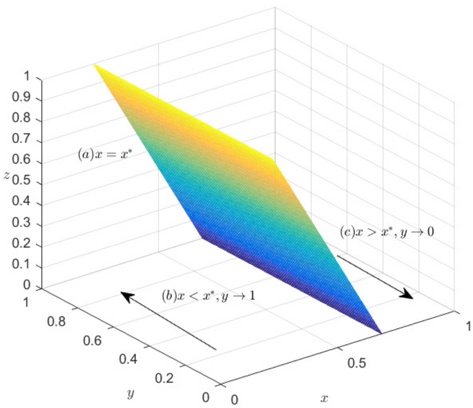


Fig. 3. Phase diagram of government strategy evolution

3.3 Analysis of the Stability of Platform Strategies

The expected benefits of actively developing digital construction plans for platform selection:

$$E_z = x\left(\gamma E_1 - 0.5\delta\theta^2\right) + y\left(1 - \beta\right)W + E_3 \tag{9}$$

The expected benefits of a platform choosing to passively formulate digital construction plans:

$$E_{1-z} = x\left(N - C_3\right) + yP_2 + E_3 \tag{10}$$

The average expected return of the platform's hybrid strategy is:

$$\overline{E_3} = zE_z + \left(1 - z\right)E_{1-z} \tag{11}$$

Therefore, the replication dynamic equation of platform behavior strategy: $G\left(z\right) = \frac{dz}{dt} = z(z-1)H\left(y\right)$, among them,

$$H\left(y\right) = x\left(0.5\delta\theta^2 + N - \gamma E_1 - C_3\right) - y\left(P_2 + \left(1 - \beta\right)W\right) \tag{12}$$

At $y = \frac{x\left(0.5\delta\theta^2 + N - \gamma E_1 - C_3\right)}{P_2 + \left(1 - \beta\right)W} = y^*$ time, $H\left(y\right) = 0$ and $G\left(z\right) \equiv 0$, indicating that any value of z can lead the platform towards an evolutionary stable state; At $y < y^*$ time, $H\left(y\right) > 0$, it can be seen $z = 0$ that the platform's passive development of digital construction plans is a stable strategy; Similarly , at $y > y^*$ time, $H\left(y\right) < 0$ It can be seen $z = 1$ that actively formulating digital construction plans on the platform is a stable strategy. The phase diagram of the platform's strategy evolution is shown in Figure 4.

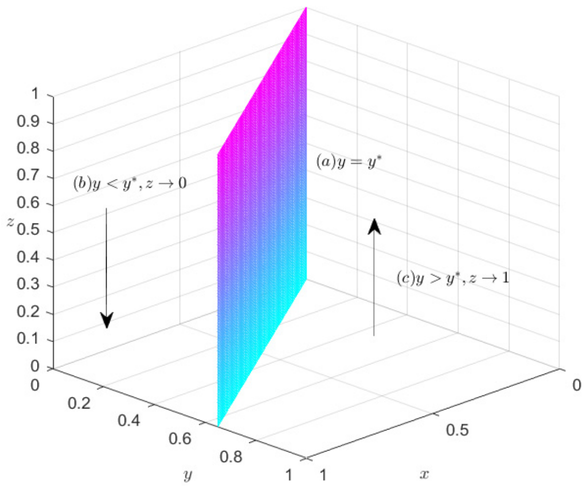


Fig. 4. Phase diagram of platform strategy evolution

3.4 Stability Analysis of System Equilibrium Point

Due to the fact that in asymmetric games, mixed strategy equilibrium is not an evolutionarily stable equilibrium, only pure strategy equilibrium is an evolutionarily stable equilibrium. Therefore, this article only discusses the asymptotic stability of pure strategy equilibrium, that is, there are 8 pure strategy equilibrium points in the evolutionary game model, which are $P_1(0,0,0), P_2(1,0,0), P_3(0,1,0), P_4(0,0,1), P_5(0,1,1), P_6(1,0,1), P_7(1,1,0), P_8(1,1,1)$.

According to the replicated dynamic equation system, the Jacobian matrix of the system is as follows:

$$J=\begin{bmatrix} \frac{\partial G(x)}{\partial x} & \frac{\partial G(x)}{\partial y} & \frac{\partial G(x)}{\partial z} \\ \frac{\partial G(y)}{\partial x} & \frac{\partial G(y)}{\partial y} & \frac{\partial G(y)}{\partial z} \\ \frac{\partial G(z)}{\partial x} & \frac{\partial G(z)}{\partial y} & \frac{\partial G(z)}{\partial z} \end{bmatrix}=\begin{bmatrix} (2x-1)\begin{bmatrix} y(\beta W-P_1)+z(\gamma E_1-N) \\ -\Delta E_1+C'_1+f+N-C_1-B \end{bmatrix} & x(x-1)(\beta W-P_1) & x(x-1)(\gamma E_1-N) \\ y(y-1)(P_1+\beta W) & (2y-1)\begin{bmatrix} x(P_1+\beta W)+z(P_2+(1-\beta)W) \\ +C_2-P_1-P_2 \end{bmatrix} & y(y-1)(P_2+(1-\beta)W) \\ z(z-1)(0.5\delta\theta^2+N-\gamma E_1-C_3) & z(z-1)(-P_2-(1-\beta)W) & (2z-1)\begin{bmatrix} x(0.5\delta\theta^2+N-\gamma E_1-C_3) \\ -y(P_2+(1-\beta)W) \end{bmatrix} \end{bmatrix} \tag{13}$$

By substituting point P_1~P_8 into the Jacobian matrix mentioned above, the corresponding feature matrix can be obtained. Using the first Lyapunov method: if all eigenvalues of the Jacobian matrix have negative real parts, then the equilibrium point is asymptotically stable; If the eigenvalues of a Jacobian matrix have at least one positive real part, then the equilibrium point is an unstable fixed point. The characteristic values corresponding to each equilibrium point and their stability analysis results are shown in Table 2.

Table 2. Stability analysis of equant

Equilibrium point	Eigenvalues of Jacobian matrix		Stability	condition
	$\lambda_1,\lambda_2,\lambda_3$	Real part symbol		
$P_1(0,0,0)$	$\Delta E_1+C_1+B-C'_1-f-N, P_1+P_2-C_2, 0$	(×,+,0)	Unstable fixed point	\
$P_2(1,0,0)$	$C'_1+f+N-\Delta E_1-C_1-B, P_2-\beta W-C_2, \gamma E_1-0.5\delta\theta^2-(N-C_3)$	(×,−,×)	ESS	①
$P_3(0,1,0)$	$P_1+\Delta E_1+C_1+B-\beta W-C'_1-f-N, C_2-P_1-P_2, P_2+(1-\beta)W$	(×,−,+)	Unstable fixed point	\
$P_4(0,0,1)$	$\Delta E_1+C_1+B-\gamma E_1-C'_1-f, P_1-(1-\beta)W-C_2, 0$	(×,×,0)	ESS	②
$P_5(0,1,1)$	$P_1+C_1+B-\beta W-\gamma E_1+\Delta E_1-C_1-f, (1-\beta)W+C_2-P_1, -(P_2+(1-\beta)W)$	(×,×,−)	ESS	③

$P_6(1,0,1)$	$\gamma E_1 + C'_1 + f - \Delta E_1 - C_1 - B, -(W + C_2), N - C_3 - (\gamma E_1 - 0.5\delta\theta^2)$	(×,−,×)	ESS	④
$P_7(1,1,0)$	$\beta W + C'_1 + f + N - P_1 - \Delta E_1 - C_1 - B, \beta W + C_2 - P_2,$ $\gamma E_1 - 0.5\delta\theta^2 - (N - C_3) + P_2 + (1-\beta)W$	(×,+,×)	Unstable fixed point	\
$P_8(1,1,1)$	$\beta W + \gamma E_1 + C'_1 + f - P_1 - \Delta E_1 - C_1 - B, W + C_2,$ $N - C_3 - (\gamma E_1 - 0.5\delta\theta^2) - P_2 - (1-\beta)W$	(×,+,×)	Unstable fixed point	\

Note: x represents inability to determine symbols, + represents $\lambda > 0$, - represents $\lambda < 0$.

According to Table 2, when conditions ①, ②, ③, and ④ are met, there are four evolutionarily stable equilibrium points, which are $P_2(1,0,0)$、$P_4(0,0,1)$、$P_5(0,1,1)$ and $P_6(1,0,1)$, can be divided into 4 scenarios. Scenario I: when condition ①: $C'_1 + f + N - \Delta E_1 - C_1 - B < 0$, $P_2 - \beta W - C_2 < 0$, $\gamma E_1 - 0.5\delta\theta^2 < N - C_3$, when simultaneously satisfied, $P_2(1,0,0)$ is the equilibrium point of system evolution. Scenario II: when condition ②: when both $\Delta E_1 + C_1 + B - \gamma E_1 - C'_1 - f < 0$ and $P_1 - (1-\beta)W - C_2 < 0$ are satisfied, $P_4(0,0,1)$ is the equilibrium point of system evolution. Scenario III: when condition ③: when both $P_1 + C_1 + B - \beta W - \gamma E_1 + \Delta E_1 - C'_1 - f < 0$ and $(1-\beta)W + C_2 - P_1 < 0$ are satisfied, $P_5(0,1,1)$ is the equilibrium point of system evolution. Scenario IV: when condition ④: when both $\gamma E_1 + C'_1 + f - \Delta E_1 - C_1 - B < 0$ and $N - C_3 < \gamma E_1 - 0.5\delta\theta^2$ are satisfied, $P_6(1,0,1)$ is the equilibrium point of system evolution.

4 Simulation Analysis of Evolutionary Game Model

Through the analysis of the evolutionary stability of each equilibrium point mentioned above, four stable evolutionary strategies were determined under the corresponding conditions. In addition, to verify its effectiveness, based on consulting relevant experts in the field and referring to the assignment rules of existing literature, the evolutionary game model was assigned numerical values, and numerical simulations were conducted using Matlab R2016b software. The evolution paths of each stable equilibrium point were visually observed through simulation diagrams, and the impact of parameter changes on the evolutionary stability strategy was analyzed in Scenario IV.

4.1 Analysis of the Evolution Path of Stable Equilibrium Points

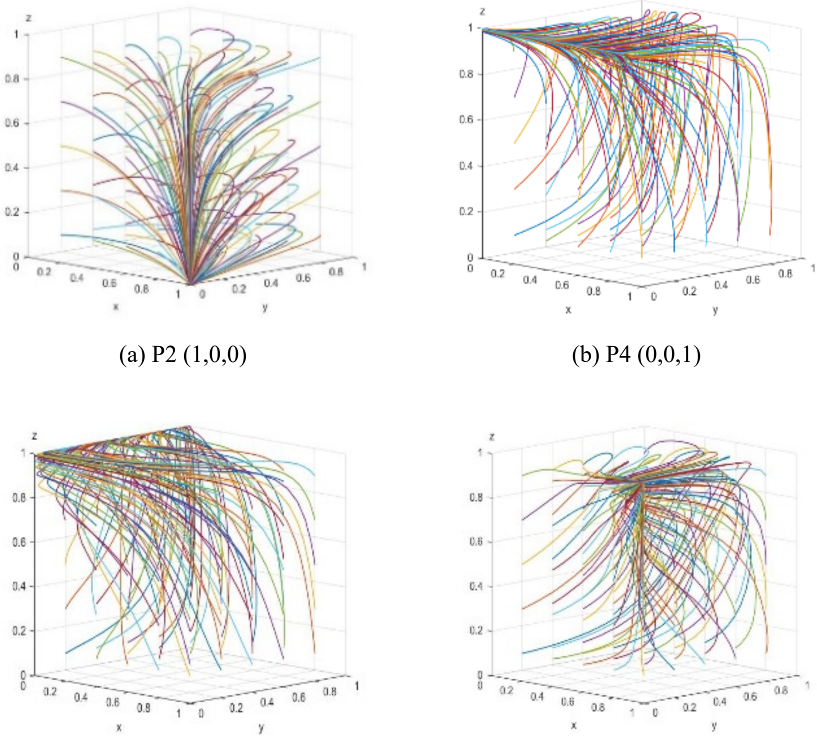
The following will discuss the impact of tripartite random initial strategies on evolutionary stability in four scenarios.

Scenario I: The impact of random initial strategy on evolutionary stability under $P_2(1,0,0)$ state. Based on this point, evolve the constraint conditions for stability parameters ①, set the parameter value to $E_1=10$, $\Delta E_1=20, C_1=C'_1=8, f=4, B=3, C_2=12, \beta=0.6$, $W=20, P_2=15$, $\gamma=0.2, \theta=0.9, \delta=0.2, N=4$, $C_3=2$. Evolve the values 50 times over time from different initial strategy combinations, as shown in Figure 5 (a). The simulation results show that different initial strategy combinations ultimately converge to point $(1,0,0)$, but the direction of convergence during the process is different.

Scenario II: The impact of random initial strategy on evolutionary stability under $P_4(0,0,1)$ state. Based on this point, evolve the constraint conditions for stability parameters ②, set the parameter value to $E_1=10, \Delta E_1=12, C_1=6, C'_1=15$, $f=4, B=3, C_2=16, \beta=0.6, W=20, P_1=20, \gamma=0.6$. Evolve the values 50 times over time from different initial strategy combinations, as shown in Figure 5 (b). The simulation results show that the probability of enterprises and governments choosing "participation" and "active promotion" strategies decreases continuously with the development of evolution, while the probability of platforms choosing "active formulation" strategies increases continuously.

Scenario III: The impact of random initial strategy on evolutionary stability under $P_5(0,1,1)$ state. Based on this point, evolve the constraint conditions for stability parameters ③, set the parameter value to $E_1=30, \Delta E_1=15, C_1=6, C'_1=16$, $f=8, B=3, C_2=10, \beta=\gamma=0.6, W=P_1=20$. Evolve the values 50 times over time from different initial strategy combinations, as shown in Figure 5 (c). The simulation results show that regardless of the initial intentions of the three parties in the game, the final evolutionary outcome is point $(0,1,1)$. At this point, the benefits obtained from the intelligent transformation of water conservancy enterprises are lower than those from their traditional operations, and the sum of costs and rewards paid by the government to actively promote enterprise transformation is lower than the fines imposed on enterprises.

Scenario IV: The impact of random initial strategy on evolutionary stability under $P_6(1,0,1)$ state. Based on this point, evolve the constraint conditions for stability parameters ④, set the parameter value to $E_1=10, \Delta E_1=15, C_1=6, C'_1=10,$, $f=4, B=3, \gamma=0.6, \theta=0.3, \delta=0.2, N=4$, $C_3=2$. Evolve the values 50 times over time from different initial strategy combinations, as shown in Figure 5 (d). The simulation results show that the probability of the government choosing the "actively promoting" strategy is constantly approaching 0, while the probability of enterprises and platforms choosing the "participating" and "actively formulating" strategies is gradually approaching 1.



(a) P2 (1,0,0)

(b) P4 (0,0,1)

(c) P5 (0,1,1)

(d) P6 (1,0,1)

Fig. 5. The evolution process of enterprises, governments and platforms

4.2 Parameter Analysis

Compared to the four evolutionary stability strategies mentioned above, from the perspective of sustainable development of hydropower enterprises, Scenario IV is more suitable. Firstly, digital transformation of enterprises will enhance their reputation and lay a solid foundation for their future development. Secondly, actively developing digital construction plans on the platform can help enterprises accelerate their digital transformation progress. Thirdly, when hydropower companies have a good reputation and hardware and software equipment, and platforms actively cooperate, the government can shift the focus of regulation. Therefore, next we will explore the impact of parameter changes on the evolutionary stability strategy under scenario IV.

4.2.1 The Impact of Tripartite Initial Intentions on Evolutionary Outcomes

To explore the impact of changes in the initial willingness of the three parties in the game on the evolution path and results of the subject's behavior strategy during the intelligent transformation process of water conservancy enterprises, three scenarios were set up: low initial willingness $x, y, z = 0.2$, medium initial willingness $x, y, z = 0.5$, and high initial willingness $x, y, z = 0.7$ to analyze the evolution results, as shown in Figure 6.

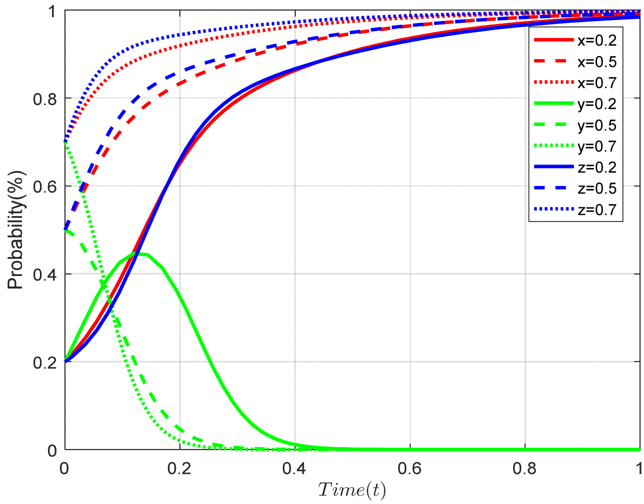


Fig. 6. The influence of the initial willingness of three parties in a game on evolution results

It is not difficult to see from Figure 6 that the change in initial intention has a significant impact on the evolution trajectory of the subject behavior strategy in the process of intelligent transformation of water conservancy enterprises. Overall, the higher the initial willingness ratio, the faster the system evolves towards a stable strategy. At the same time, in the case of a low initial willingness $(y = 0.2)$ ratio, the evolution trajectory of government stability strategies shows a change from "positive promotion" to "negative promotion". In the early stages of intelligent transformation of water conservancy enterprises, the government should provide active guidance to accelerate the evolution of enterprise and platform behavior towards "participation" and "active formulation". Therefore, even if the government chooses a "passive promotion" strategy in the later stage, the strategies of enterprises and platforms still evolve towards "participation" and "active formulation".

4.2.2 The Impact of Transformation Cost-effectiveness on Evolutionary Outcomes

To explore the impact of incremental benefits and transformation costs on the evolution path and results of subject behavior strategies in the process of intelligent transformation of water conservancy enterprises, it is assumed that the initial intention of the game subject is $x, y, z = 0.5$, the incremental benefits of the enterprise are set to ΔE_1 =15, 20 and 25, and the transformation costs are set to $C'_1 = 10,15$ and 20 for analysis. The simulation results are shown in Figures 7 and 8.

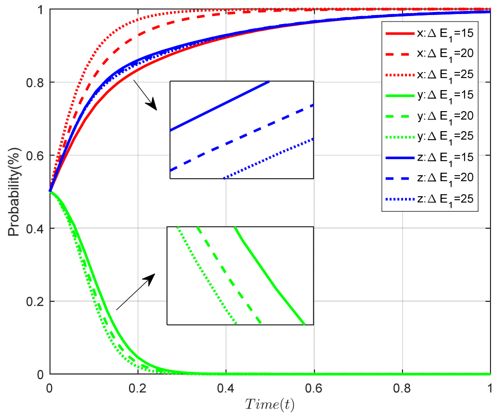


Fig. 7. The impact of incremental benefits on evolution results

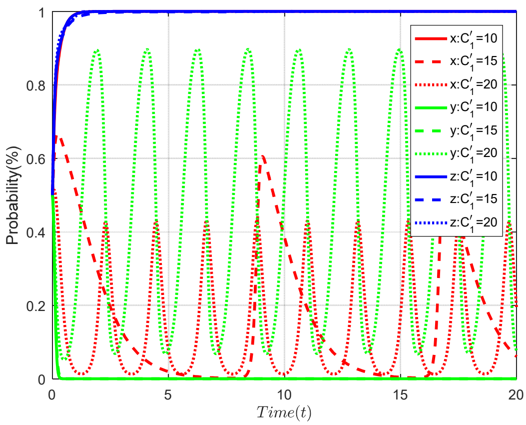


Fig. 8. The impact of transformation costs on evolution results

As shown in Figure 7, with the continuous increase of incremental benefits, the willingness of enterprises to participate in intelligent transformation gradually increases, and the higher ΔE_1, the faster the evolution speed, and the shorter the time for stable evolution. At this point, the probability of the government and platform choosing "actively promoting" and "actively formulating" strategies remains almost unchanged, indicating that the incremental benefits of enterprises have little impact on the government and platform strategy choices. As shown in Figure 8, when the transformation cost C'_1 exceeds a certain threshold, the stability strategies of enterprises and governments will become unstable, and the evolution path will be in a fluctuating state. The system is constantly changing as the number of games increases and time prolongs. Therefore, changes in the cost-effectiveness of transformation not only affect the decision-making of enterprises, but also affect the decision-making patterns of the government.

4.2.3 The Impact of Government Awards and Punishments on Evolutionary Results

To explore the impact of government rewards and punishments on the evolution path and results of subject behavior strategies in the process of intelligent transformation of water conservancy enterprises, the evolution status of each subject's behavior strategy was observed by changing the proportion of enterprise rewards and the amount of government penalties. Assuming the initial intention of the game subject is $x, y, z = 0.5$, the reward ratio is set to β =0.2, 0.4 and 0.6, and the penalty amount is set to P_1 =20, 25, 30, and P_2 =10, 15 and 20 for analysis. The simulation results are shown in Figures 9 and 10.

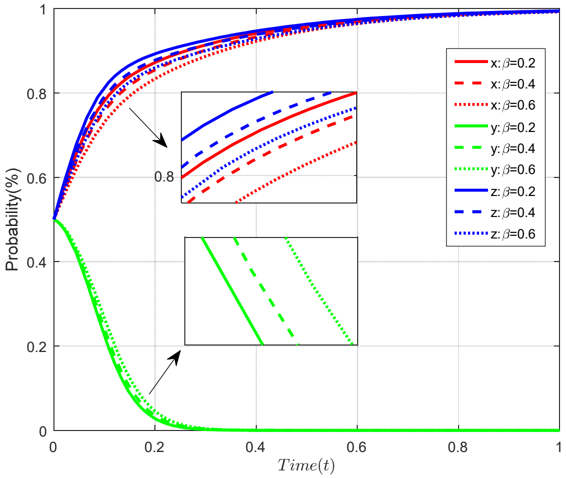


Fig. 9. The impact of the proportion of rewards on the evolution results

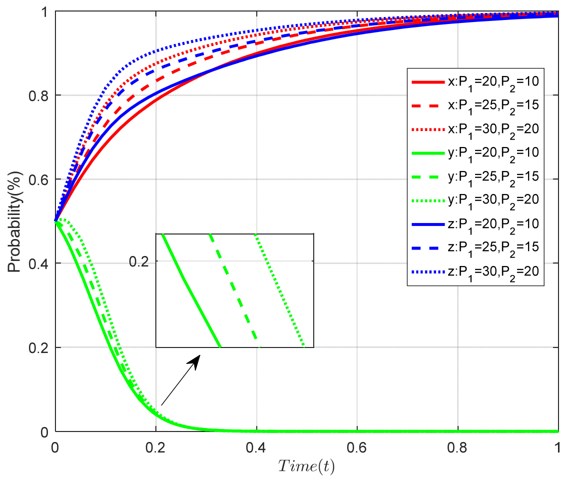


Fig. 10. The impact of punishments on evolution results

The red, green, and blue lines in Figures 9 and 10 represent the dynamic evolution paths of enterprises, governments, and platforms under different levels of reward and punishment. As the enthusiasm of enterprises to participate in transformation increases, the evolution speed of the government from "active promotion" to "passive promotion" will accelerate, confirming that policy subsidies have a positive impact on the intelligent transformation of enterprises. Secondly, when the penalty amount P_1 and P_2 increase, the convergence speed of the enterprise towards a stable strategy significantly accelerates in the short term, then gradually slows down and eventually approaches 1. In the early stages of enterprise transformation, the increase in fines to some extent increased the opportunity cost of not participating in the transformation, and the enterprise made the optimal choice on the basis of quickly weighing cost-effectiveness. However, after the government actively guides for a period of time, most enterprises have already undergone a certain degree of transformation. At this time, the increase in fines cannot effectively promote the rapid evolution of corporate strategies.

4.2.4 The Impact of Platform Intelligence and Scheme Fee Coefficients on Evolutionary Results

To explore the impact of platform intelligence and scheme fee coefficients on the evolution path and results of subject behavior strategies in the process of intelligent transformation of water conservancy enterprises, assuming that the initial intention of the game subject is $x, y, z = 0.5$, the platform intelligence is set to θ =0.1, 0.3 and 0.6, and the scheme fee coefficients are set to γ =0.2, 0.4 and 0.6 for analysis. The simulation results are shown in Figures 11 and 12.

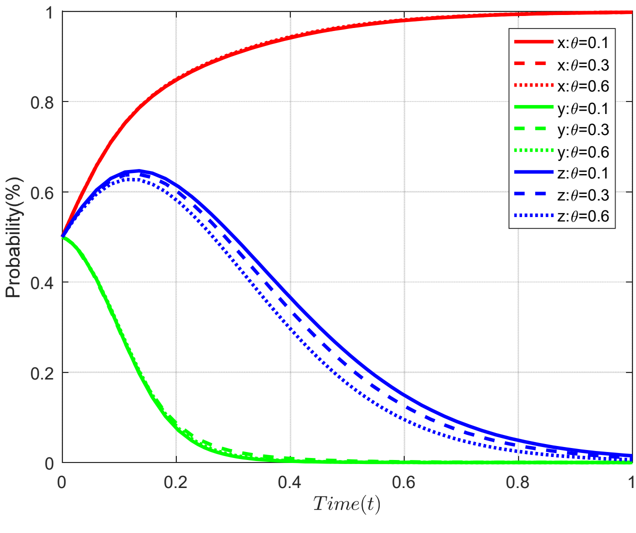


Fig. 11. The impact of platform intelligence on evolution results

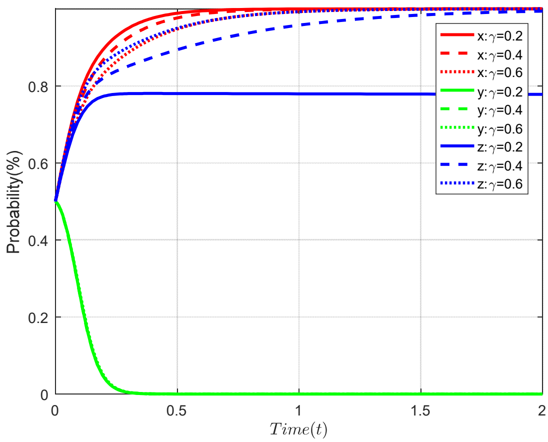


Fig. 12. The impact of scheme fee coefficient on evolution results

As shown in Figure 11, with the improvement of platform intelligence, the probability of actively formulating digital construction plans on the platform first increases and then gradually decreases, and stabilizes at 0. Moreover, as θ increases, the speed of system evolution approaching 0 becomes faster, and the time for stable evolution becomes shorter. Meanwhile, the probability of enterprises and governments choosing "participation" and "active promotion" strategies remains almost unchanged, indicating that θ has little impact on the strategic choices of enterprises and governments. As shown in Figure 12, the fee coefficient of digital construction schemes has a positive impact on the evolution of corporate and platform behavior strategies, but there are differences in the impact effects. Therefore, to a certain extent, the fee coefficient of the plan increases the cost of enterprises participating in smart transformation and reduces their willingness to participate in smart transformation.

5 Conclusion

This article takes water conservancy enterprises as the research object, constructs a tripartite evolutionary game model with water conservancy enterprises, government, and third-party platforms as the main body, analyzes the behavior strategy selection and evolution process of relevant subjects, and further simulates and analyzes the evolution path of each stable equilibrium point and the impact of parameter changes on the evolutionary stability strategy using Matlab software. The conclusion is as follows:

(1) The evolutionary game model has 8 pure strategy equilibrium points, but only 4 evolutionarily stable strategies. From theoretical analysis and numerical simulation results, it can be concluded that the equilibrium point is a more suitable choice for the intelligent transformation of water conservancy enterprises.

(2) The initial willingness of the government to actively promote and the initial willingness of third-party platforms to actively formulate have an impact on the evolution speed of water conservancy enterprises, and the larger the initial willingness, the faster

the evolution speed. In the case of low initial willingness, the evolution trajectory of government stability strategy shows a trend of first evolving towards a "positive promotion" strategy, and then gradually evolving towards a "negative promotion" strategy.

(3) The cost-effectiveness of transformation, government rewards and punishments, platform intelligence, and scheme fee coefficients are the main influencing factors on the intelligent transformation and upgrading of water conservancy enterprises.

The policy implications are as follows: First, pay attention to the initiative of water conservancy enterprises themselves and refine the incentive mechanism to enhance their enthusiasm for transformation. The second is to reduce the third-party platform support concerns need water conservancy enterprises and the government to work together. Third, in the process of transformation, the sense of government participation and the sense of responsibility of third-party platforms should be strengthened, and supporting policies should be improved. In future studies, we can consider including more stakeholders in the evolutionary game model for analysis.

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