Research on Corporate Data Sharing Policies with the Government and Incentive Mechanisms Based on Evolutionary Game Theory

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Abstract. Enterprise-to-government data sharing is a crucial link in enhancing national governance capability, yet the incentive effects of existing policy tools often fall significantly short of expected targets. This study introduces a dual-policy framework combining reputation-based incentives and fiscal subsidies to construct an evolutionary game model of enterprise-to-government data sharing, exploring the nonlinear dynamic characteristics of corporate sharing behavior. The research finds that when data sharing leads to substantial resource and competitiveness losses for enterprises, the effectiveness of reputation mechanisms exhibits an inverted U-shaped threshold dependency, creating a "high-standard trap." Furthermore, the "subsidy paradox" reveals the limitations of universal subsidy schemes: while low subsidies encourage "efficiency-oriented" sharing, high subsidies trigger "data hoarding" behavior due to enterprises' concerns over competitiveness erosion. The research findings provide an important theoretical basis for the government to design an adaptive reputation mechanism for data sharing and precision-targeted fiscal incentives.

Keywords: Enterprise-to-Government Data Sharing, Evolutionary Game, Reputation Mechanism, Fiscal Subsidy.

1 Introduction

As the digital economy deepens, data has become a key factor of production. Enterprise-to-government data sharing—a form of collaboration in which enterprises or other private sector entities provide their data or data products to the public sector based on the public interest[1]—has gradually drawn increasing attention in recent years. In December 2022, the Central Committee of the Communist Party of China and The State Council issued the "Opinions on Building a Data Foundation System to Better Play the Role of Data Elements", which classified data into government data, enterprise data and personal data, and proposed "supporting data processors to circulate data in accordance with laws and regulations through open, shared, exchanged and traded means both on and off the premises". As the holders of massive high-value data, enterprises' sharing of data with the government plays a crucial role in enhancing government governance capacity, optimizing public services and unlocking the value of data elements[2-4].

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Domestic and international scholars have engaged in extensive discussions on the practical models and institutional frameworks of enterprise-to-government data sharing. At the level of institutional and policy design, developed countries have formed a relatively systematic experience. By analyzing data practices from American enterprises to the government, Song et al. constructed a data-sharing environment, embedded legal and regulatory systems, defined guiding principles and quality control supervision, and formed diverse cooperation types such as paid, mandatory, voluntary, collaborative, and agreement-based, indicating that the key to incentivezing enterprise participation lies in flexible and adaptable cooperation methods[1]. In terms of domestic research, taking "Red Shield Cloud Bridge" as a case, Sun et al. constructed a four-dimensional analysis framework of "social demand - market environment - government-enterprise relationship - government support", and used the fuzzy set qualitative comparative analysis method to reveal five configuration paths that drive enterprises to voluntarily share data. The research found that the market environment and government support are core conditions, and there is a substitution effect between broad social demand and good government-enterprise relations under certain conditions. This conclusion provides a new perspective for understanding the complex causal relationship driven by multi-agent synergy[5].

Enterprise-to-government data sharing is, in essence, a strategic interaction process between the two major actors—government and enterprises—under bounded rationality. Evolutionary games are widely used to analyze the problem because they can well depict the characteristics that the subjects eventually reach a stable state through learning and strategy adjustment. Li constructs an evolutionary game model of government data openness and enterprise utilization to deeply analyze the impact of technical costs, risk costs, reputation benefits and regulatory measures on the system's evolutionary path. The research shows that reducing the cost of government data opening, enhancing the data innovation application capabilities of enterprises, introducing reputation mechanisms and reasonable cost-benefit allocation mechanisms can effectively promote the evolution of the system towards (high-quality, positive) ideal stable state[6]. Corresponding to this, Chen focuses on how the government incentives data sharing among enterprises, subdividing government strategies into "direct incentives" and "indirect regulation", and revealing the close relationship between the strategic choices of both sides and relative net payments[7]. Her research suggests that the government's choice of a direct incentive strategy, which reduces the technical and legal risks of corporate sharing, helps increase corporate willingness to share. The above studies have laid a solid theoretical foundation for understanding the strategic interactions in enterprise-to-government data sharing, generally confirming the profound influence of factors such as cost-benefit considerations, risk control, and reputation mechanisms on enterprise-to-government data sharing. Moreover, the evolutionary game analysis method has become the mainstream paradigm for examining the interactive strategies of government-enterprise data sharing.

Although existing research on enterprise-to-government data sharing has made significant progress, there remains room for further exploration in areas such as the design of nonlinear reputation-based reward and punishment mechanisms, the heterogeneous effects of subsidy incentives, and the interactions among multiple mechanisms [8-10]. In response, this study constructs an evolutionary game model of enterprise-to-government data sharing that integrates the dual policy instruments of reputation-based rewards and punishments and fiscal subsidies, aiming to identify the critical conditions of reputation-based reward and punishment mechanisms that trigger changes in enterprises' data sharing strategies, as well as enterprises' data sharing tendencies under fiscal subsidies of heterogeneous intensities. The core objective of this study is to systematically address the following questions: Do reputation mechanisms and fiscal subsidies of varying intensities always positively promote enterprises' data sharing? If not, under what conditions do they produce reverse inhibitory effects? By answering these questions, this study seeks to provide more explanatory theoretical support for optimizing the current policy framework for government-enterprise data sharing.

The research's innovation lies in breaking the traditional game model's linear assumptions about policy tools, revealing the complex nonlinear dynamics of corporate behavior under the dual policy tools, and deepening the understanding of the micro mechanism of corporate data sharing with the government. At the practical level, the research results provide a scientific decision-making basis for the government to design adaptive reputation reward and punishment mechanisms for enterprise sharing behavior and formulate differentiated fiscal incentive measures precisely associated with data value, which is of great practical significance for solving the current predicament of enterprise data sharing with the government and fully releasing the value of data elements.

2 Construction of Evolutionary Game Models

Evolutionary game theory, in contrast to traditional game methods, refers to the process in which players in an ecosystem composed of finite rational agents repeatedly revise their strategy choices through continuous learning. Given that it is difficult for governments and enterprises to reach a state of complete rationality in the process of data sharing in reality, and under the influence of internal and external factors, both sides will constantly adjust their strategy choices until equilibrium is reached. Therefore, the study uses the evolutionary game method to characterize the data sharing process between the government and enterprises, construct an ecosystem composed of multiple governments and multiple enterprises, and randomly select governments and enterprises to play games around data sharing under the requirements of policies related to the digital economy and the development of social digital transformation. During this process, the government can choose to cooperate actively or passively. Enterprises can choose to share actively or passively, and a dual mechanism of reputation rewards and punishments and financial subsidies is introduced, allowing both sides to continuously adjust and improve their strategies through repeated games under the constraint of the principle of maximizing expected returns until evolution stabilizes. To elaborate on the game process between the government and the enterprise, the study makes the following assumptions about the game process, and the basic symbols are illustrated in Table 1.

Table 1. Basic symbol description.

Name	Meaning
q	Unit data quality, $0 < q \leq 1$
t_i	The amount of data a company provides when adopting a strategy, $i = p$、$n, 0 < t_n < t_p$
V_i	The value of data sharing when enterprises adopt strategies, $i = p$、$n, 0 < V_n < V_p$
A	The government provides enterprises with subsidies in terms of technology, talent, resources, etc, $A > 0$
θ	Loss of enterprise resources and competitiveness per unit of data value, $\theta > 0$
s	The ability of government data value to generate economic benefits, $s > 0$
γ	Government revenue co-distribution coefficient, $0 < \gamma < 1$
k	The social reputation transformation coefficient for the government's assessment of corporate data sharing, $k > 0$
β	Average level of digital transformation in society, $\beta > 0$
e	Under the average level of digital transformation in a unit society, the requirements for data sharing, $e > 0$

2.1 Game Theory Hypothesis

1)Government strategy behavior hypothesis: x Although the government is the designer of the data sharing policy and mechanism, in the actual sharing process, problems such as uneven quality of government data, difficulty in ensuring data security, and incomplete sharing channels are prominent, which restrict the government's enthusiasm for opening non-classified data to enterprises. Therefore, assume that the government has two strategies, "active cooperation" and "passive cooperation", with probabilities of x and $1 - x$ respectively, satisfied $x \in [0,1]$.On the one hand, under the "active cooperation" strategy, it indicates that the government has a friendly and open attitude towards enterprises, is willing to actively carry out data value transformation with the support of enterprises, and incentive-driven enterprise sharing behavior through subsidies for technology, talent, resources, etc. to enterprises. At the same time, to optimize and iterate the process of data sharing between the government and enterprises, the government establishes channels for the transmission of corporate social reputation, evaluates the data sharing behavior of enterprises after cooperation, and discloses the evaluation results to the public. On the other hand, under the "passive cooperation" strategy, it indicates that the government considers data sharing risky, holds an indifferent and evasive attitude towards enterprises during the sharing process, lacks the enthusiasm to carry out data value transformation, and does not subsidize or evaluate enterprises' data sharing behavior.

2)Enterprise strategy behavior assumption: Under the general trend of social data sharing, in the process of pursuing the maximization of their own interests, enterprises have two strategies, "active sharing" and "passive sharing", with probabilities of y and

$1-y$, satisfaction $y \in [0,1]$. The study hypothesizes that the "sharing" behavior refers to enterprises proactively sharing data with unit quality of q to the government on the basis of data desensitization. The amount of shared data varies under different strategy choices, which in turn leads to differences in data value. Based on this, the value of data shared by enterprises under the active sharing strategy is $V_p = qt_p$; Under the negative sharing strategy, the value of data shared by the enterprise is $V_n = qt_n$. Among them, q represents the unit data quality, which takes a real value between 0 and 1, where 1 indicates perfect quality and 0 indicates complete ineffectiveness. According to GB/T 44811-2024 "Internet of things — Data quality evaluation methods", the focus of data quality evaluation lies in data accuracy, consistency, completeness, standardization, timeliness, and accessibility. t_i denotes the amount of data provided by the enterprise when adopting a strategy, defined as the number of characters of text data, with $t_p > t_n$.

2.2 Game Cost Hypothesis

1)Government game cost assumption: When the government chooses to cooperate actively, it will smooth the data sharing channels, actively share high-quality data resources with enterprises, explore as many opportunities as possible for the transformation of data value, achieve revenue appreciation, and encourage enterprises to share data by providing subsidies . At this point, the government offers subsidies A to enterprises in terms of technology, talent, resources, etc., as well as potential risk costs R for data sharing. When the government opts for passive cooperation, it does not provide subsidies to enterprises and lacks the incentive to share high-value data resources, so there are no subsidy costs and potential risk costs. At the same time, given that the government is a bounded rational entity in an information asymmetry environment, it may miss a large number of opportunities for data value transformation by adopting a passive cooperation strategy, and there is an opportunity cost c_i $(i = p, n)$, $c_p > c_n$.

2)Enterprise game cost assumption: Enterprises face the potential risk of losing their unique advantages due to sharing high-value data, and thus there is a loss $\theta V_i (i = p, n)$ of resources and competitiveness regardless of which strategy is chosen. Here, θ is the loss of resources and competitiveness per unit of data value.

2.3 Game-Theoretic Payoff Hypothesis

1)Government game benefit assumption: The purpose of data sharing between government and enterprises is to convert data value into economic benefits, but there are differences in the distribution of economic benefits under the influence of the inherent attributes of both parties in the game. $\gamma s V_i$The study takes into account that the government has the responsibility and obligation to promote the progress of the entire society. In the process of government-enterprise data sharing, the economic benefits generated from the transformation of data value will be actively shared with enterprises, while enterprises have a relatively low sense of responsibility in promoting social progress and have significant "economic man" attributes. Therefore, they will not actively share the economic benefits brought by the transformation of data value with the government in the absence of external causes. In this regard, when the government chooses to cooperate actively, assume that the government has economic benefits $\gamma sV_i(i = p, n)$ from the transformation of data value. Specifically, s represents the government's capacity to generate economic benefits through data value conversion, that is, the incremental economic benefits that can be directly or indirectly created through the government's data operation capabilities per unit of effectively shared data from enterprises. The government uses historical data to establish a statistical relationship between the "government-led data sharing volume" and "relevant economic benefit indicators." sV_i represents the economic gains generated by the government through data value conversion. γ is the "share of benefits from data sharing" defined by the government for itself, while$1 - \gamma$ represents the economic share granted to enterprises by the government in monetary form (or other measurable benefits), which influences the intensity of the economic incentives provided by the government for enterprises' data sharing behavior.

2)Enterprise game benefit assumption: Based on the above government game benefit assumption, when the government actively cooperates, enterprises, regardless of which strategy they adopt, will obtain the economic benefits $(1 - \gamma)sV_i(i = p, n)$ generated by data value transformation, subsidies A provided by the government in terms of technology, talent, resources, etc. Conversely, when the government adopts a passive cooperation strategy, enterprises will not gain any economic benefits regardless of the strategy they adopt.

2.4 Social Reputation Hypothesis

The study hypothesizes that when the government opts for active cooperation, in order to further optimize the data sharing process with enterprises, starting from the result-oriented approach of data sharing to enhance total factor productivity of enterprises, the actual data sharing situation of enterprises is compared with the data sharing requirements at the average level of digital transformation of society, Reputation incentives or reputation penalties $k(\frac{V_i}{\beta e} - 1)$ $(i = p, n)$ are imposed on enterprises based on the relative value of the difference between the two and the data sharing requirements at the average level of digital transformation in society. Specifically, k is the social reputation transformation coefficient set by the government based on the enterprise's data sharing situation, used to measure the extent to which an enterprise's deviation from the industry average leads to changes in its reputation evaluation by society (or the government). This parameter is defined by the government and realized through means such as news disclosure and qualification access. β represents the average level of social digital transformation, $\beta > 0$, reflecting a comprehensive index of the overall digital development maturity of enterprises within a given social unit (country, region, or industry). This indicator is established with reference to the "Digital Economy and Society Index (DESI)" in the European Union's "2030 Digital Compass" plan, focusing on four aspects: digital education and talent development, data infrastructure, enterprise digitalization, and public service digitalization. e represents the data sharing value requirement under a unit level of average social digital transformation β. Given that data resources are a core element for enhancing the digital transformation level of social units at all levels, e is the benchmark value of data that each enterprise is required to share or generate on average per unit of average digital transformation level, as mandated by regulation, industry chain collaboration, and market conventions. Conversely, when the government chooses passive cooperation, it lacks the motivation to share data with enterprises, and in this case, enterprises will not be subject to the social reputation evaluation assessed by the government.

In summary, this study constructs a payoff matrix that considers the dual policy instruments of reputation-based rewards and punishments and fiscal subsidies, as shown in Table 2. Chapter 3 solves for the equilibrium points of the game matrix and conducts stability analysis, while Chapter 4 focuses on examining how the above variables cross-influence enterprises' strategic choices, thereby revealing the nonlinear effects of incentive policies.

Table 2. Revenue payment matrix of enterprise-to-government data sharing game model.

		Enterprises Positive Sharing	Negative sharing
Government	Actively co-operate	$\gamma sV_p - R - A, (1-\gamma)sV_p + A + k(\frac{V_p}{\beta e} - 1) - \theta V_p$	$\gamma sV_n - R - A, (1-\gamma)sV_n + A + k(\frac{V_n}{\beta e} - 1) - \theta V_n$
	Negative co-operation	$-c_p, -\theta V_p$	$-c_n, -\theta V_n$

3 Solving the Game Matrix and Stability Analysis

3.1 Game Matrix Solution

For the government, the expected utility for choosing active cooperation is $f_1 = y(\gamma sV_p - R - A) + (1-y)(\gamma sV_n - R - A)$, and the expected utility for choosing passive cooperation is $f_2 = y(-c_p) + (1-y)(-c_n)$. At this point, the average expected utility for each government department in the group is $\overline{f}_{12} = xf_1 + (1-x)f_2$.Based on the replication dynamic equation, the rate of change of each government department's choice of active cooperation is $\frac{dx}{dt} = x(f_1 - \overline{f}_{12}) = x(1-x)(f_1 - f_2) = x(1-x)\{\gamma sV_n - R - A + c_n + y[\gamma s(V_p - V_n) + (c_p - c_n)]\}$. The above equation indicates that if the utility of the government's choice of active cooperation exceeds the average expected utility, then the probability of its active cooperation increases; otherwise, it decreases.

For enterprises, the expected utility of choosing positive sharing is $f_3 = x[(1-\gamma)sV_p + A + k(\frac{V_p}{\beta e} - 1) - \theta V_p] + (1-x)(-\theta V_p)$, and the expected utility of choosing negative sharing is $f_4 = x[(1-\gamma)sV_n + A + k(\frac{V_n}{\beta e} - 1) - \theta V_n] + (1-x)(-\theta V_n)$. At this point, the average expected utility for each enterprise in the group is $\overline{f}_{34} = yf_3 + (1-y)f_4$. Based on the replication dynamic equation, the rate of change of each enterprise's choice of positive sharing is $\frac{dy}{dt} = x(f_3 - \overline{f}_{34}) = y(1-y)(f_3 - f_4) = y(1-y)\{\theta(V_n - V_p) + x(V_p - V_n)[(1-\gamma)s + \frac{k}{\beta e}]\}$. The above equation indicates that if the utility of an enterprise's choice of positive sharing exceeds the average expected utility, then the probability of its positive sharing increases; otherwise, it decreases.

Based on the above analysis, the replication dynamic equation of the government-enterprise data sharing game model is obtained, as shown in Equation (1).

$$\begin{cases} \frac{dx}{dt} = x(f_1 - \overline{f}_{12}) = x(1-x)(f_1 - f_2) = x(1-x)\{\gamma sV_n - R - A + c_n + y[\gamma s(V_p - V_n) + (c_p - c_n)]\} \\ \frac{dy}{dt} = x(f_3 - \overline{f}_{34}) = y(1-y)(f_3 - f_4) = y(1-y)(V_p - V_n)\{-\theta + x[(1-\gamma)s + \frac{k}{\beta e}]\} \end{cases} \quad (1)$$

3.2 Equilibrium Point Solution

According to evolutionary game theory, the equilibrium point of the system can be obtained by solving the replication dynamic equation, which provides a basis for the stability analysis in the following text.

Lemma 1: The equilibrium point of the replication dynamic equation (1) is $(0,0)$, $(1,0)$, $(0,1)$, $(1,1)$ and when the parameter conditions $0 < \theta < (1-\gamma)s + \frac{k}{\beta e}$ and $\gamma sV_n + c_n - A < R < \gamma sV_p + c_p - A$ are satisfied, (x^*, y^*) is also the equilibrium point of equation (1), where $x^* = \frac{\theta}{(1-\gamma)s + \frac{k}{\beta e}}$, $y^* = \frac{R + A - \gamma sV_n - c_n}{\gamma s(V_p - V_n) + (c_p - c_n)}$.

Proof: To explore the equilibrium points of the replicated dynamic system, let, respectively, clearly there exists $(0,0)$, $(1,0)$, $(0,1)$, $(1,1)$, which is the equilibrium point of the system. Furthermore, when the parameter conditions $0 < \theta < (1-\gamma)s + \frac{k}{\beta e}$ and $\gamma sV_n + c_n - A < R < \gamma sV_p + c_p - A$ are satisfied, let $x^* = \frac{\theta}{(1-\gamma)s + \frac{k}{\beta e}}$, $y^* = \frac{R + A - \gamma sV_n - c_n}{\gamma s(V_p - V_n) + (c_p - c_n)}$, substituting (x^*, y^*) into the replication dynamic equation (1), $\frac{dx}{dt} = 0$, $\frac{dy}{dt} = 0$ at this point. So it is also the equilibrium point of equation (1). That's all.

3.3 Equilibrium Stability Analysis

The following text explores the stability of the equilibrium point of the replicated dynamic equation using the local stability analysis of the Jacobian matrix. The partial derivatives of the replicated dynamic equation of the rate of change of government and enterprise choice are successively taken with respect to x and y to obtain the Jacobian matrix $\boldsymbol{J}$, as shown in Equation (2):

$$\boldsymbol{J} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \quad (2)$$

Among them $J_{11} = (1-2x)\{\gamma s V_n - R - A + c_n + y[\gamma s(V_p - V_n) + (c_p - c_n)]\}$, $J_{12} = x(1-x)[\gamma s(V_p - V_n) + (c_p - c_n)]$, $J_{21} = y(1-y)(V_p - V_n)[(1-\gamma)s + \frac{k}{\beta e}]$, $J_{22} = (1-2y)(V_p - V_n)\{-\theta + x[(1-\gamma)s + \frac{k}{\beta e}]\}$.

At this point, the determinant of the matrix $\boldsymbol{J}$ is as shown in Equation (3) :

$$det\boldsymbol{J} = (1-2x)\{\gamma s V_n - R - A + c_n + y[\gamma s(V_p - V_n) + (c_p - c_n)]\}(1-2y)(V_p - V_n)\{-\theta + x[(1-\gamma)s + \frac{k}{\beta e}]\} - x(1-x)[\gamma s(V_p - V_n) + (c_p - c_n)]y(1-y)(V_p - V_n)[(1-\gamma)s + \frac{k}{\beta e}] \tag{3}$$

The trace of the matrix $\boldsymbol{J}$ is as shown in Equation (4) :

$$tr\boldsymbol{J} = (1-2x)\{\gamma s V_n - R - A + c_n + y[\gamma s(V_p - V_n) + (c_p - c_n)]\} + (1-2y)(V_p - V_n)\{-\theta + x[(1-\gamma)s + \frac{k}{\beta e}]\} \tag{4}$$

According to lemma 1, substitute the equilibrium point (0,0), (1,0), (0,1), (1,1), (x^*, y^*) and after sorting, the expressions of the matrix determinant and trace are shown in Table 3.

Table 3. Replicator dynamic equation (1): expressions of matrix determinants and traces for each equilibrium point.

Equilibrium points	The expressions of matrix determinants and traces
(0,0)	$det\boldsymbol{J} = (\gamma s V_n - R - A + c_n)(V_p - V_n)(-\theta)$, $tr\boldsymbol{J} = (\gamma s V_n - R - A + c_n) + (V_p - V_n)(-\theta)$.
(1,0)	$det\boldsymbol{J} = (-1)(\gamma s V_n - R - A + c_n)(V_p - V_n)[-\theta + (1-\gamma)s + \frac{k}{\beta e}]$, $tr\boldsymbol{J} = (-1)(\gamma s V_n - R - A + c_n) + (V_p - V_n)[-\theta + (1-\gamma)s + \frac{k}{\beta e}]$.
(0,1)	$det\boldsymbol{J} = (\gamma s V_p + c_p - R - A)(-1)(V_p - V_n)(-\theta)$, $tr\boldsymbol{J} = (\gamma s V_p + c_p - R - A) + (-1)(V_p - V_n)(-\theta)$
(1,1)	$det\boldsymbol{J} = (-1)(\gamma s V_p + c_p - R - A)(-1)(V_p - V_n)[-\theta + (1-\gamma)s + \frac{k}{\beta e}]$, $tr\boldsymbol{J} = (-1)(\gamma s V_p + c_p - R - A) + (-1)(V_p - V_n)[-\theta + (1-\gamma)s + \frac{k}{\beta e}]$.
(x^*, y^*)	$det\boldsymbol{J} = -x^*(1-x^*)[\gamma s(V_p - V_n) + (c_p - c_n)]y^*(1-y^*)(V_p - V_n)[(1-\gamma)s + \frac{k}{\beta e}]$, $tr\boldsymbol{J} = 0$.

According to evolutionary game theory, when the equilibrium point satisfies $det\boldsymbol{J} > 0$ and $tr\boldsymbol{J} < 0$, that point is an evolutionary stable point. From the analysis in Table 3, it can be seen that since $tr\boldsymbol{J}_{(x^*,y^*)} = 0$, (x^*, y^*) is not stable. As an internal equilibrium point of the system, x^* and y^* respectively represent the average proportion of government departments choosing the active cooperation strategy and the average proportion of enterprises choosing the active sharing strategy. Under the unstable state of the system, the behaviors of the government and enterprises interact with each other, and both sides' strategies fluctuate around (x^*, y^*). Therefore, the following text focuses on analyzing the prerequisite conditions when (0,0), (1,0), (0,1) and (1,1) are stable points, as well as the changing trends of key parameters in (x^*, y^*) when the system does not have a stable strategy.

4 Research Findings and Discussion: The Effects of Dual Policy Instruments

4.1 Analysis of the Impact of Reputation-Based Reward and Punishment Mechanisms on Enterprises' Stable Strategies

To focus on the impact of reputation mechanisms on enterprise decision-making, this study fixes the government's strategy as actively cooperate and examines the dynamic influence of the average level of social digital transformation β. The model solution results indicate that the effectiveness of reputation incentives has a strict boundary, which fundamentally depends on the relative magnitude of the enterprise's competitiveness loss θ and the data sharing revenue share $(1-\gamma)s$. When $\theta > (1-\gamma)s$, that is, when the competitiveness loss caused by enterprise data sharing is substantial, there exists a threshold $\beta^* = \frac{k}{e[\theta-(1-\gamma)s]}$ of the average level of social digital transformation.

Incentive effective zone: When $0 < \beta < \beta^*$, the overall level of social digitalization is relatively low, and enterprises only need to share a small amount of data to obtain positive reputation incentives. In this case, enterprises will invariably choose the actively sharing strategy.

The "High-Standard Trap" zone: When $\beta > \beta^*$, the level of social digitalization raises the reputation threshold. Enterprises must pay a high competitiveness cost to meet the standard, at which point the reputation mechanism becomes ineffective and enterprises will invariably choose the passively sharing strategy.

This finding corroborates and deepens the "High-Standard Trap" conjecture proposed in the introduction. It is essentially an inverted U-shaped threshold effect: higher reputation standards are not always better; excessively high reputation thresholds that exceed the industry's capacity to bear will instead suppress enterprises' willingness to share. See Proposition 1 for details.

Proposition 1: In the case where the government always opts for active cooperation, based on the differences in the value of enterprise resource and competitiveness loss θ per unit data value, as the average level of digital transformation in society β rises, the evolution of enterprise stability strategies varies:

(i) When the premise $0 < \theta < (1-\gamma)s$ is met, regardless of the value, enterprises always choose to actively share;

(ii) When the premise $\theta > (1-\gamma)s$ is met, there is a threshold $\beta^* = \frac{k}{e[\theta-(1-\gamma)s]}$ for the average level of digital transformation in society: when $0 < \beta < \beta^*$, the enterprise must choose an active sharing strategy; When $\beta > \beta^*$, the enterprise must choose a passive sharing strategy.

Prove: Based on Table 3, analyze the stability conditions of the equilibrium points (0, 0), (1, 0), (0, 1), and (1, 1).

Case 1: Stability Analysis of the Equilibrium Point $(0,0)$: According to the evolutionary game theory, when $(0,0)$ is a stable point, to ensure $det\boldsymbol{J}_{(0,0)} > 0$ and $tr\boldsymbol{J}_{(0,0)} < 0$, the conditions in Equations (5) and (6) need to be satisfied:

$$\gamma s V_n - R - A + c_n < 0 \tag{5}$$

$$(\gamma s V_n - R - A + c_n) + (V_p - V_n)(-\theta) < 0 \tag{6}$$

Since Equation (6) holds invariably when Equation (5) holds, when γ is relatively small, satisfying that the government's potential risk cost of data sharing $R > \gamma s V_n - A + c_n$, $(0,0)$ is a stable point, that is, the government cooperates passively and enterprises share passively.

Case 2: Stability Analysis of the Equilibrium Point (1, 0) According to evolutionary game theory, when (1, 0) is a stable equilibrium point, the conditions in Equations (7) and (8) must be satisfied to ensure $det\boldsymbol{J}_{(1,0)} > 0$and $tr\boldsymbol{J}_{(1,0)} < 0$:

$$\gamma s V_n - R - A + c_n > 0 \tag{7}$$

$$-\theta + (1-\gamma)s + \frac{k}{\beta e} < 0 \tag{8}$$

From Equation (7), it can be seen that at this time, the potential risk cost of government data sharing $R < \gamma s V_n - A + c_n$. Additionally, in Equation (8), under the influence of different values of θ, which represents the loss of enterprise resources and competitiveness per unit data value, the range of values for the average social digital transformation level β varies, leading to different stable strategies, namely:

Case 2(a): Under the premise that $0 < \theta < (1-\gamma)s$, a relatively small γ will result in the benefit that enterprises obtain per unit of shared data $(1-\gamma)s$ exceeding the resource and competitiveness loss per unit of data value θ. Enterprises will always tend to share more data actively to obtain higher benefits, which means there exists no value of β that satisfies the conditions for $(1,0)$ to be a stable point.

Case 2(b): Under the premise that $\theta > (1-\gamma)s$, when $\beta > \frac{k}{e[\theta-(1-\gamma)s]}$, a relatively large γ causes the benefit that enterprises obtain per unit of shared data $(1-\gamma)s$ to be less than the resource and competitiveness loss per unit of data value θ. Moreover, the decrease in the social reputation transformation coefficient k used by the government to evaluate enterprises' data sharing and the increase in the data sharing requirement e lead to a decline in the threshold β^* of the average level of social digital transformation, making it impossible for enterprises to compensate for their economic losses through the reputation mechanism. As a result, enterprises tend to share passively to reduce losses, and $(1,0)$ becomes a stable point, that is, the government cooperates actively while enterprises share passively.

Case 3: Stability analysis of the equilibrium point (0, 1): According to evolutionary game theory, when (0, 1) is a stable point, to ensure $det\boldsymbol{J}_{(0,1)} > 0$, it is necessary to satisfy $\gamma sV_p + c_p - R - A > 0$. However, in this case, $tr\boldsymbol{J}_{(0,1)} > 0$, thus (0, 1) is unstable.

Case 4: Stability analysis of the equilibrium point (1, 1): According to evolutionary game theory, when (1, 1) is a stable point, to ensure $det\boldsymbol{J}_{(1,1)} > 0$ and $tr\boldsymbol{J}_{(1,1)} < 0$, the conditions in Equations (9) and (10) must be met.

$$\gamma sV_p + c_p - R - A > 0 \tag{9}$$

$$-\theta + (1-\gamma)s + \frac{k}{\beta e} > 0 \tag{10}$$

From Equation (9), it can be known that at this time, the potential risk cost of government data sharing $R < \gamma sV_p + c_p - A$. Additionally, in Equation (10), under the influence of different values of θ, which represents the loss of enterprise resources and competitiveness per unit data value, the range of values for the average social digital transformation level β varies, leading to different stable strategies. Specifically, there are the following scenarios:

Case 4(a): Under the premise that $0 < \theta < (1-\gamma)s$, when $\frac{k}{e[\theta-(1-\gamma)s]} < 0$, regardless of the value of β ($\beta > 0$), a relatively small γ will cause the benefit that enterprises obtain per unit of shared data $(1-\gamma)s$ to exceed the resource and competitiveness loss per unit of data value θ. Enterprises will always tend to share more data actively to obtain higher benefits, and $(1, 1)$ will invariably be a stable point, that is, the government cooperates actively and enterprises share actively.

Case 4(b): Under the premise that $\theta > (1-\gamma)s$, when $0 < \beta < \frac{k}{e[\theta-(1-\gamma)s]}$, a relatively large γ causes the benefit that enterprises obtain per unit of shared data $(1-\gamma)s$ to be less than the resource and competitiveness loss per unit of data value θ. However, the increase in the social reputation transformation coefficient k used by the government to evaluate enterprises' data sharing and the decrease in the data sharing requirement e lead to an increase in the threshold β^* of the average level of social digital transformation, enabling enterprises to compensate for their economic losses through the reputation mechanism. Consequently, enterprises tend to share actively to obtain benefits, and (1, 1) becomes a stable point, that is, the government cooperates actively and enterprises share actively.

To sum up, the following three conclusions are drawn:

(1) When $0 < R < \gamma sV_n - A + c_n$, the government always opts for an active cooperation strategy. Under this circumstance, the enterprise's strategy choice varies depending on the different values of θ, the loss of enterprise resources and competitiveness per unit of data value. On one hand, when$0 < \theta < (1-\gamma)s$, the system's stable point is (1, 1), and the enterprise will definitely actively share. On the other hand, when in $\theta > (1-\gamma)s$, there exists a threshold of the average digital transformation level of the society, $\beta^* = \frac{k}{e[\theta-(1-\gamma)s]}$, such that when$0 < \beta < \beta^*$, the system's stable point is (1, 1), and the enterprise will definitely actively share; when $\beta > \beta^*$, the system's stable point is (1, 0), and the enterprise will definitely passively share.

(2) When $\gamma sV_n - A + c_n < R < \gamma sV_p + c_p - A$, it is divided into two cases based on the different values of $-\theta + (1-\gamma)s + \frac{k}{\beta e}$.

a) Under the conditions mentioned above, if $-\theta + (1-\gamma)s + \frac{k}{\beta e} > 0$, there exist two stable points (0, 0) and (1, 1), and the final stable state of the system is related to the initial probabilities of the government choosing active cooperation x_0 and the enterprise choosing active sharing y_0. At this time, there are critical points $x^* = \frac{\theta}{(1-\gamma)s+\frac{k}{\beta e}} \in (0,1)$ and $y^* = \frac{R+A-\gamma sV_n-c_n}{\gamma s(V_p-V_n)+(c_p-c_n)} \in (0,1)$:

i) When $x_0 > x^*$ and $y_0 > y^*$, $\frac{dx}{dt} \geq 0$ and $\frac{dy}{dt} \geq 0$ always hold, x and y increase with time t, and the final stable state of the system is (1, 1).

ii) When $x_0 < x^*$ and $y_0 < y^*$, $\frac{dx}{dt} \leq 0$ and $\frac{dy}{dt} \leq 0$ always hold, x and y decrease with time t, and the final stable state of the system is (0, 0).

iii) When $x_0 > x^*$ and $y_0 < y^*$, in the early stage of the evolutionary game, $\frac{dx}{dt} \leq 0$ and $\frac{dy}{dt} \geq 0$, x and y decrease and increase respectively with time t, and approach their critical points x^* and y^*. If at time t^*, $x_{t^*} = x^*$ and $y_{t^*} < y^*$, the final stable state of the system is (0, 0). If at time t^*, $x_{t^*} > x^*$ and $y_{t^*} = y^*$, the final stable state of the system is (1, 1).

iv) When $x_0 < x^*$ and $y_0 > y^*$, in the early stage of the evolutionary game, $\frac{dx}{dt} \geq 0$ and $\frac{dy}{dt} \leq 0$, x and y increase and decrease respectively with time t, and approach their critical points x^* and y^*. If at time t^*, $x_{t^*} < x^*$ and $y_{t^*} = y^*$, the final stable state of the system is (0, 0). If at time t^*, $x_{t^*} = x^*$ and $y_{t^*} > y^*$, the final stable state of the system is (1, 1).

b) Under the aforementioned conditions, if $-\theta + (1-\gamma)s + \frac{k}{\beta e} < 0$, the system's stable point is (0, 0), and the government always opts for passive cooperation while enterprises always choose passive sharing.

(3) When $R > \gamma sV_p + c_p - A$, the system's stable point is (0, 0), and the government always opts for passive cooperation while enterprises always choose passive sharing.

The above analysis indicates that the effectiveness of reputation-based reward and punishment mechanisms is not constant. When the resource and competitiveness losses incurred by enterprise data sharing are substantial, the incentive effect exhibits an inverted U-shaped relationship with the average level of social digital transformation. This finding raises a deeper question: since the reputation mechanism is subject to a "High-Standard Trap," can the government compensate for this incentive gap by increasing fiscal subsidies? In other words, can higher subsidies always "pull" enterprises out of the locked-in state of passive sharing?

Intuitively, higher fiscal subsidies imply stronger economic incentives and should seemingly promote enterprise data sharing in a positive manner. However, the game payoff matrix presented earlier shows that fiscal subsidies and reputation mechanisms do not operate independently—both are embedded in the cost-benefit function of enterprises, and their interactive effects may undergo qualitative changes as data quality varies. In particular, when the subsidy intensity reaches a certain critical level, the core trade-off faced by enterprises shifts from "obtaining subsidies versus avoiding reputation penalties" to "obtaining fixed subsidies versus avoiding competitiveness losses," a shift that may lead to a reversal of the incentive effect.

Based on this, Section 4.2 below will focus on the fiscal subsidy mechanism, systematically analyzing the impact of changes in data quality on enterprises' equilibrium strategies under different subsidy intensities, in order to test whether the above "subsidy paradox" holds, and to provide a theoretical basis for the subsequent design of differentiated incentive policies.

4.2 Analysis of the Impact of Fiscal Subsidy Mechanisms on Corporate Equilibrium Strategies

This section aims to explore how the subsidies A provided by the government, covering aspects such as technology, talent, and resources, influence enterprises' strategy choices under different levels of data quality q. The core finding of the model analysis is that subsidies do not always positively incentivize high-quality data sharing; their effects exhibit significant "context dependency."

To intuitively reveal the internal mechanism of this "subsidy paradox," it is necessary to first provide an economic interpretation of the relationships among the variables.

In the low-subsidy range, as data quality q increases, the equilibrium probability y^* of enterprises choosing active sharing also increases. This means that when the subsidy alone is insufficient to constitute an independent economic incentive, enterprises instead turn to pursuing "efficiency-oriented" benefits from data sharing—placing greater emphasis on obtaining the government's reputation recognition and maintaining cooperative relationships through high-quality sharing. In this context, the risk-aversion psychology regarding reputation penalties is amplified, and enterprises tend to proactively improve their sharing quality to avoid being labeled as "low-quality sharers."

However, in the high-subsidy range, y^* decreases as q increases. The underlying reason for this counter intuitive result is that when the government provides substantial fixed subsidies, enterprises already possess a considerable "guaranteed benefit." At this point, further improving data quality not only entails higher resource input and competitiveness loss but may also lead to the loss of long-term business opportunities caused by the spillover of core data assets. This "high-quality, high-loss" marginal trade-off fosters a "reluctance to share" mentality among enterprises—they would rather maintain low-quality sharing to secure stable subsidies than exchange high-quality sharing for diminishing marginal additional returns. In other words, high subsidies inadvertently raise enterprises' "risk perception threshold" for data sharing, thereby suppressing their willingness to circulate high-quality data.

Proposition 2 provides a formal proof for the above analysis through mathematical derivation.

Proposition 2: Depending on the differences in the subsidy A provided by the government to enterprises in terms of technology, talent, resources, etc., as the unit data quality q increases, the evolution of enterprise strategies varies, that is,

(i) When $0 < A < \frac{c_p t_n - c_n t_p}{t_n - t_p} - R$, as the unit data quality q increases, y^* increases;

(ii) When $A > \frac{c_p t_n - c_n t_p}{t_n - t_p} - R$, as the unit data quality q increases, y^* decreases.

Proof: To further explore the impact of unit data quality q on the enterprise's strategy choice, substitute $V_i = qt_i(i = p, n)$ into the equilibrium point y^* of the enterprise's strategy choice, and obtain $y^* = \frac{R+A-\gamma sqt_n - c_n}{\gamma sq(t_p - t_n)+(c_p - c_n)}$. Next, take the partial derivative of y^* with respect to q, and obtain Equation (11):

$$\frac{\partial y^*}{\partial q} = \frac{\gamma s[(R+A)(t_n - t_p) + c_n t_p - c_p t_n]}{[\gamma sq(t_p - t_n)+(c_p - c_n)]^2} \tag{11}$$

When $\frac{\partial y^*}{\partial q} > 0$ as shown in Equation (11), y^* increases as the unit data quality q rises. At this point, $\frac{\partial y^*}{\partial q} = \frac{\gamma s[(R+A)(t_n - t_p) + c_n t_p - c_p t_n]}{[\gamma sq(t_p - t_n)+(c_p - c_n)]^2} > 0$ is satisfied, that is,$\gamma s\left[(R + A)(t_n - t_p) + c_n t_p - c_p t_n\right] > 0$ and $A < \frac{c_p t_n - c_n t_p}{t_n - t_p} - R$.

When $\frac{\partial y^*}{\partial q} < 0$ as shown in Equation (11), y^* decreases as the unit data quality q rises. At this point, $\frac{\partial y^*}{\partial q} = \frac{\gamma s[(R+A)(t_n - t_p) + c_n t_p - c_p t_n]}{[\gamma sq(t_p - t_n)+(c_p - c_n)]^2} < 0$ is satisfied, that is, $\gamma s\left[(R + A)(t_n - t_p) + c_n t_p - c_p t_n\right] < 0$ and $A > \frac{c_p t_n - c_n t_p}{t_n - t_p} - R$.

The above mathematical derivation indicates that the incentive effectiveness of fiscal subsidies is not solely determined by their absolute scale, but rather depends on the dynamic balance between the subsidy intensity and the marginal net benefit induced by data quality. This also provides a direct model basis for the subsequent proposal of "precise and structured" fiscal incentive improvement pathways.

5 Revelation

Based on the analysis conclusions of the above evolutionary game model, the study reveals the complexity and intrinsic motivation of the strategy choice of enterprises to share data with the government under the interaction of reputation mechanism and fiscal subsidies. The above findings have the following two core policy implications for constructing and optimizing the governance system of data circulation between government and enterprises:

5.1 Establishing an Adaptive Reputation Mechanism for Data Sharing

Study the construction of a reputation reward and punishment mechanism to provide a dynamic and relative reference benchmark for corporate data sharing behavior through the social comparison effect, in order to effectively observe the effective range of the reputation reward and punishment mechanism. Proposition 1 shows that when enterprises perceive high competitiveness loss, the effectiveness of the reputation reward and punishment mechanism is not constant, and its efficacy significantly depends on the parameter "average digital transformation level of society", and there is a nonlinear inverted U-shaped relationship between the willingness of enterprises to share and the average sharing level of society. Given the linear correlation between the average digital transformation level of society and the reputation reward and punishment threshold, the above conclusion implies that if the government sets the reputation reward and punishment threshold as a rigid standard beyond the capacity of most entities to bear, it may lead to the alienation of the governance mechanism, that is, enterprises do not improve the quality of sharing under incentives, but calculate cost minimization under constraints, There is a tendency to adopt opportunistic strategies such as symbolic sharing or marginal data substitution, which eventually leads to a deviation between policy goals and micro incentives, falling into the "high standard trap". In this regard, the study suggests that the design of the reputation mechanism for government-enterprise data sharing should shift from "rigid threshold management" to "adaptive threshold governance", designing a dynamically evolving reputation mechanism based on factors such as industrial ecology, technical conditions, and data endowment, and gradually guiding the enterprise data sharing stability strategy to evolve benign from "low-level equilibrium" to "gradual improvement".

5.2 Achieving Precise Alignment Between Data Value and Fiscal Incentives

To reveal the effectiveness of the financial support for digital transformation that is currently widely applied in various regions, the study sets and analyzes the impact of the parameter "subsidies provided by the government to enterprises in terms of technology, talent, resources, etc." on data sharing between the government and enterprises. Proposition 2 indicates that financial subsidies have a "context-dependent" effect on corporate data sharing strategy tendencies, that is, their incentive effects change with the variation of data quality. Under low subsidy conditions, the improvement in data quality significantly amplifies the risk-averse mentality of corporate reputation penalties, turning to "efficiency-oriented" data sharing that is not aimed at obtaining financial subsidies; Under high-subsidy conditions, the potential loss of competitiveness and business opportunities resulting from high-quality data, which exceeds the gains from constant financial subsidies, will instead lead to a "reluctance to sell" behavior of core assets by enterprises. The "subsidy paradox" highlights the limitations of indiscriminate, inclusive subsidy tools. For this reason, the study suggests that fiscal incentives for enterprise data sharing should take a precise and structured development path, construct a differentiated subsidy function linked to the data classification and grading system, and explore a compound incentive contract of "fixed subsidy + long-term value sharing". By dynamically aligning external incentives for data sharing, the intrinsic economic value of data and the opportunity cost of enterprises, effectively leverage the willingness to circulate data at different levels and with different sensitivities, and improve the allocation efficiency of policy resources.

6 Conclusions and Outlook

By constructing an evolutionary game model that integrates reputation-based rewards and punishments with fiscal subsidies, this study systematically examines enterprises' strategic choices in sharing data with the government. The main theoretical and practical contributions are as follows:

First, at the theoretical level, the study reveals the "nonlinear incentive" effects of policy instruments. Unlike traditional research that assumes a linear relationship with incentive intensity, this paper finds that the incentive effect of the reputation mechanism exhibits an inverted U-shaped threshold dependency, while the effect of fiscal subsidies reverses as data quality changes. This provides a new micro-level explanatory framework for understanding why "policy incentives deviate from expectations" in government-enterprise data sharing.

Second, at the policy pathway level, the study provides a scientific basis for differentiated incentive design. In response to the "High-Standard Trap" of the reputation mechanism, the government should abandon rigid standard management and shift toward "adaptive threshold" governance that dynamically aligns with the level of industrial digitalization. In response to the "contextual paradox" of fiscal subsidies, policy design should transition from "universal" investment to "precise" matching, exploring composite incentive contracts linked to hierarchical data value.

The model in this study assumes homogeneous enterprises and has not yet fully depicted the complex games of heterogeneous enterprises under information asymmetry. Future research can introduce heterogeneity factors such as enterprise size and industry attributes, and explore the synergistic effects of government open data and policy incentives, so as to further refine the theoretical framework for governing government-enterprise data circulation.

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References

1. Song, W., Huang, H., Gao Y.: Enterprise data sharing with government: American practices and implications for China. Chinese public administration 1(1), 100–111 (2024) DOI:10.19735/j.issn.1006-0863.2024.01.09.
2. Desouza, K., Jacob, B.: Big data in the public sector: lessons for practitioners and scholars. Administration & society 49, 1043-1064 (2017) DOI:10.1177/0095399714555751.
3. Alemanno, A.: Big data for good: unlocking privately-held data to the benefit of the many. European journal of risk regulation 9(2), 183–191 (2018) DOI:10.1017/err.2018.34.
4. Klevink, B., Janssen, M., van der Voort, H.,: Regulatory compliance and over-compliant information sharing-changes in the B2G landscape. In: Parycek, P., et al. (eds.) ELECTRONIC GOVERNMENT 2018, LNCS, vol. 11020, pp. 1–13. Springer, Cham (2018) DOI:10.1007/978-3-319-98690-6_21.
5. Sun, X., Wang, S., Xiao, Y.: Research on the influence pathways of voluntary corporate data sharing with government: a fuzzy set qualitative comparative analysis approach. Journal of information science 42(1), 115–121 (2024) DOI:10.13833/j.issn.1007-7634.2024.01.014.
6. Xu, X., Li, Y., Pang, Q.: Evolutionary game analysis of government open data sharing in the digital economy. Journal of intelligence 39(12), 119–125 (2020) . DOI:10.3969/j.issn.1002-1965.2020.12.018.
7. Chen, L., Li, X.: Government strategies and corporate choices in data sharing under the digital economy: an evolutionary game analysis. Credit reference 41(10), 51–60 (2023) DOI:10.3969/j.issn.1674-747X.2023.10.006.
8. Fan, K.: A differential game study on data resource integration between local governments and enterprises under central government subsidies. Chongqing University of Posts and Telecommunications, Chongqing (2022) DOI:10.27675/d.cnki.gcydx.2022.000385.
9. Bates, J.: The strategic importance of information policy for the contemporary neoliberal state: the case of open government data in the United Kingdom. Government information quarterly 31(3), 388–395 (2014) DOI:10.1016/j.giq.2014.02.009.
10. Attard, J., Orlandi, F., Auer, S.: Value creation on open government data. In: 49th Hawaii International Conference on System Sciences, pp. 2605–2614. IEEE, Koloa, HI, USA (2016) DOI:10.1109/HICSS.2016.326.