Research Article

The Design of Incentive Mechanism for Policy-Oriented Guarantee Institutions' Digital Transformation in China

Youqing Lv [1,2] **Guojian Ma,** [1] **Linlin Lv,** [3] **and Juan Ding** [1]

[1]*School of Management, Jiangsu University, Zhenjiang 212013, China*
[2]*School of Economics and Management, Chuzhou University, Chuzhou 239000, China*
[3]*School of Computer and Information, Anqing Normal University, Anqing 246133, China*

Correspondence should be addressed to Guojian Ma; profma406@163.com

Currently, China is actively promoting the reform process of the digital economy, and the digital transformation of the credit financing guarantee sector is gradually emerging. As the core driving force for the progress of digital transformation, the optimal design of the incentive mechanism is undoubtedly essential. Based on the principal-agent relationship between local governments and policy-oriented guarantee institutions, this study constructs a basic incentive model (model I) and an incentive model introducing a regulatory signal (model II), empirically analyzes the digital transformation effort of guarantee institutions under the influence of different factors and discusses how local governments should design the optimal incentive mechanism. The results show that the digital transformation effort level of guarantee institutions in model II is higher than that in model I, while the incentive intensity of local governments in model II is lower than that in model I. Within the range of guarantee compensation rate less than a specific threshold, the risk perception degree has negative effects on the effort level and incentive intensity of DT. In addition, the regulatory intensity has a constant negative effect on the incentive intensity of the DT, while it has a negative effect on the effort level of the DT only if the guarantee capacity is below a specific threshold. The research results can provide practical guidance for local governments to effectively promote digital transformation activities and improve the competitiveness of credit financing guarantee.

1. Introduction

The existing literature has confirmed that policy-oriented financing guarantee is an effective scheme to improve loan availability of small and medium-sized enterprises (SMEs) [1, 2]. Likewise, since the issuance of the "Opinions on Promoting the Accelerated Development of Financing Guarantee Industry" in 2015, policy-oriented financing guarantee has gradually become an important tool for Chinese governments to alleviate the financing dilemma of SMEs [3]. However, the magnification of China's guarantee business is only 2-3 times, which is far lower than the 30–50 times of developed countries [4, 5]. Admittedly, the operational efficiency of China's policy-oriented financing guarantee institutions is generally low.

Fortunately, due to the remarkable development of new technologies, e.g., big data, cloud computing, and artificial intelligence [6, 7], enterprises in almost all industries have conducted a number of initiatives to explore these technologies and to transform how they create an appropriate value [8, 9]. Moreover, disruptions of lockdowns, restrictions on movement, and restructuring of businesses caused by the COVID-19 pandemic [10] have speeded up the pace of digital transformation (DT) [11]. In fact, some institutions in China's policy-oriented guarantee industry have begun to make useful attempts to the DT strategy and realized the improvement of guarantee business efficiency. For instance, in the DT attempt to deal with the pandemic, Xinzheng Investment and Guarantee Group developed and designed a special loan guarantee platform, which won the award of "2020 Digital Service Model" (available on Xinzheng Group's website: https://www.hljdb.com.cn/html/2021/jtxw_0311/165.html (accessed on 25 December 2021)).

Although an increasing number of guarantee institutions have undergone or are undergoing DT, the adoption of the DT strategy also involves challenges [12, 13], which make the failure rate for DT reach 80% [14]. According to a recent report, the DT of guarantee institutions in China is still at an early stage, with limited success in business expansion, risk identification, and postguarantee management [15]. One major challenge is that DT involves an investment of enormous amounts of money, without any guarantee of return [16]. Accordingly, we pose the following research question: How to design an effective incentive mechanism to ensure the advancement of policy-oriented guarantee institution's DT strategy?

Given the above, this study analyzes the relationship between local governments and policy-oriented guarantee institutions, constructs two incentive models of DT, that is, the basic incentive model and the incentive model introducing a regulatory signal, and then compares the differences between the two incentive models. Moreover, this study puts forward decision-making propositions for the DT of China's policy-oriented financing guarantee institutions, as well as simulating the effective incentive paths.

This study claims several contributions. First, this study takes the DT of financing guarantee institutions as the research object and explores the design of incentive mechanism from the microlevel. It further enriches the research scope of the DT theory, especially making up for the deficiency of DT incentive mechanism. Second, considering the special principal-agent relationship between local governments and policy-oriented guarantee institutions in China, this study incorporates supervision signals into the design of basic optimal reward contracts, which has important theoretical and practical significance for regulating local governments' participation in the strategic reform of guarantee institutions and improving guarantee institutions' digitalization level. Finally, this study designs practical parameters (e.g., risk perception degree, guarantee capacity, and guarantee compensation rate) to make the research results more consistent with the reality.

The rest of this study is structured as follows: Section 2 summarizes the relevant literature. Section 3 constructs and compares the two incentive models of policy-oriented guarantee institution's DT. Section 4 simulates and discusses the incentive paths. Section 5 gives the main conclusions and suggestions.

2. Literature Review

According to the research purposes of this study, the related literature can be divided into three categories: digital transformation, digital transformation in financing guarantee sector, and incentive mechanism in digital transformation.

2.1. Research on Digital Transformation. DT requires not only the use of various new digital technologies, but also the reconstruction of the enterprise's strategy, organizational structure, business model, or culture to adapt to the everchanging digital market environment [17]. Scholars have carried out in-depth research on the successful factors, implementation paths, and transformational practices of DT. First, most scholars mainly focus on manufacturing enterprises and explore the impact of organizational factors (e.g., digital strategy and supportive organizational culture) [18, 19], technological factors (e.g., infrastructure and digital capability) [17, 20], and environmental factors (e.g., market competition and policies) [21, 22] on the success of DT through exploratory cases, questionnaires, and other methods. Second, based on the successful factors, scholars further demonstrate the potential implementation paths of DT. For instance, Jin et al. [23] and Fang et al. [24] try to reveal the optimal implementation strategies (e.g., product embedded in the platform and in-house development) of DT from a data ownership or value-driven perspective [23, 24], while Malik et al. [25] present 52 application paths of DT in different fields from a method perspective of artificial intelligence and deep learning [25]. Third, DT practices in the sectors of maritime transport [26], retail banking [27], heavy metal [28], health service [29] or architecture, engineering, and construction (AEC) [30] are also a main discussion point in academia circle, and transformational challenges and values are summarized.

2.2. Research on Digital Transformation in Financing Guarantee Sector. Few studies have explored the DT issue in the financing guarantee sector, but the application of digital technology in the credit financing sector has been extensively studied from the technical perspective. Former research results suggest that digital technology is an effective tool to mitigate credit information friction [31], control credit financing risk [32], and reduce economic costs [33]. Therefore, the business model of Big Tech Lending is proposed [34]. In particular, the value of this business model has been proven in several countries, such as WeBank in China, Paytm in India, Amazon Lending in the US, Mercado Libre in Argentina, and Kakao Bank in South Korea [35]. With the mature application of digital technology, scholars discuss DT issues in the banking or financial sector from the perspective of management. Butler [36] proposes the DT's future direction of the financial industry (e.g., optimizing investment portfolios, performing accurate credit, and risk scoring) based on the application reality of artificial intelligence [36], while Filotto et al. [27] and Diener et al. [37] analyze the obstacles (e.g., strategic management and structural guarantee mechanism) to the DT of the banking industry in Italy and Germany [27, 37]. Recently, scholars have tried to explore the application of digital technology in financing guarantee business. For instance, Xu et al. [38] and Tan et al. [39] suggest that guarantee institutions integrate big data, blockchain, and other financial technology tools to carry out risk warning and credit rating for SMEs [38, 39].

2.3. Research on Incentive Mechanisms in Digital Transformation. Due to various challenges, issues, barriers, and problems in the DT process [10], incentive mechanisms have been proposed and validated with different concerns in

former studies. In terms of macropolicy design, Khanna [40] considers that policy incentives are likely to be required to induce the adoption of digital technologies [40]. The same research idea can be drawn from the study of Yang et al. [21] and Chen et al. [41], which shows that the incentive policy has a more significant role in promoting DT, and the government can strengthen the incentive effect through various paths, such as building a digital platform or digital collaboration ecosystem. In terms of microincentive implementation, Aben et al. [42] apply information processing theory to four cases of public-private relationships in the Dutch infrastructure sector, and find that precise contract clauses should be an effective guarantee for implementing DT incentive schemes [42]. Furthermore, Liu et al. [43] propose an improved hybrid incentive contract with a reward and punishment mechanism to better incentivize enterprises to participate in DT [43]. In fact, most scholars have studied the incentives for the diffusion of digital technologies in different industries, e.g., the application of blockchain in the pharmaceutical supply chain and community digital inclusion [44, 45] from the perspective of technology adoption.

Reviewing the existing literature, we can find that the research on DT is mainly concentrated in the past 3 years, and the findings are not uniform. Digital transformation has gradually become a hot issue, especially the proliferation of digital technology and its corresponding business model reform in the financial industry. However, research on the DT of policy-oriented financing guarantee institution is relatively limited, and few scholars have explored its incentive mechanism. As such, this study intends to explore the design of the optimal incentive mechanism for policy-oriented financing guarantee institution's DT.

3. Incentive Model Construction and Comparison

3.1. Problem Description and Assumptions. China's policy-oriented financing guarantee institutions funded by local governments provide quasi-public financing guarantee services to SMEs [3], thus forming the principal-agent relationship between local governments and guarantee institutions. As the entrusting party, local governments actively guide guarantee institutions to implement the DT strategy, so as to improve the support for SMEs' financing. However, as the agent, guarantee institutions have to focus on the maintenance and appreciation assessment of the state-owned capital [4]. This orientation will inevitably strengthen their self-protection awareness and only consider the minimization of costs and risks, which will lead to the "speculation" behavior of DT. Therefore, local governments need to design reasonable and effective incentive mechanisms to encourage guarantee institutions to implement DT strategy with maximum effort.

Based on the above principal-agent relationship and problem description, the following reasonable assumptions are given.

Assumption 1. Financial institutions improve the adaptability of digital loan technology to SMEs through DT, and the scale of loans will also increase accordingly [46]. This study measures the business volume of the guarantee institution based on a linear function, that is, $K = (t\theta + \varepsilon)$. Among them, θ is the DT effort of the guarantee institution and t is the level of financing guarantee capability (related to the capital scale of the guarantee institution and business processing system). Meanwhile, ε is an external random variable (such as changes in guarantee demand caused by social emergencies), and there is a state distribution of $\varepsilon \sim N(0, \sigma_\varepsilon^2)$.

Assumption 2. Under the principle of market-oriented operation [3], the income of guarantee institutions' DT mainly comes from guarantee fees, that is $R_{d1} = gK$, where g is the guarantee rate. Local governments give corresponding monetary incentives according to DT effectiveness. This study adopts the linear method of Holmstrom and Milgrom [47] to design the incentive reward, that is $R_{d2} = (\alpha + \beta eK)$. Among them, α is the fixed reward, e is the compensatory loss rate of the guarantee business, and β is the incentive intensity coefficient, which represents the compensatory loss given by local governments. Correspondingly, the cost of guarantee institutions' DT is $C_d = 1/2a\theta^2 + eK + H$, where a is the effort cost coefficient and H is the fixed cost of business processing system construction and personnel salaries.

Assumption 3. Due to the positive externality of credit guarantee to government economy [48], the benefits of local governments are mainly manifested in the value of local economics and government reputation, that is $R_{g1} = \gamma K$ and $R_{g2} = \eta K$. Among them, γ is the economic value coefficient, which represents the economic benefits created by the guarantee business of the DT strategy, and η is the reputation value coefficient, which represents the corresponding reputation benefit.

Assumption 4. Similar to the research assumption of Yan et al. [49], this study assumes that guarantee institutions are risk-averse, while local governments are risk-neutral. Therefore, the utility function of guarantee institutions should be expressed as $\mu = -e^{-\rho\omega}$, where ρ is the degree of risk aversion and ω is the actual monetary income of guarantee institutions.

3.2. Construction of the Basic Incentive Model (Model I). According to the above assumptions, the return functions π_g and π_d of the local government and policy-oriented guarantee institution are as follows:

$$\pi_g = R_{g1} + R_{g2} - R_{d2} = (\gamma + \eta - \beta e)(t\theta + \varepsilon) - \alpha, \quad (1)$$

$$\pi_d = R_{d1} + R_{d2} - C_d = (g + \beta e - e)(t\theta + \varepsilon) + \alpha - \frac{1}{2}a\theta^2 - H. \quad (2)$$

Certainly, the corresponding expected utility functions $E(\pi_g)$ and $E(\pi_d)$ of the local government and policy-oriented guarantee institution are as follows:

$$E\left(\pi_g\right) = (\gamma + \eta - \beta e)t\theta - \alpha, \tag{3}$$

$$E\left(\pi_d\right) = (g + \beta e - e)t\theta + \alpha - \frac{1}{2}a\theta^2 - H. \tag{4}$$

From formulas (2) and (4), the variance of policy-oriented guarantee institution's total return can be obtained as follows:

$$\begin{aligned}\text{Var}\left(\pi_d\right) &= E[\pi d - E(\pi_d)]^2 \\ &= (g + \beta e - e)^2 \sigma\varepsilon^2.\end{aligned} \tag{5}$$

Combined with the absolute risk aversion degree of Arrow–Pratt, it can be seen that the risk cost of policy-oriented guarantee institution's DT is as follows:

$$C_r = \frac{1}{2}\rho \text{Var}\left(\pi_d\right) = \frac{1}{2}\rho(g + \beta e - e)^2 \sigma\varepsilon^2. \tag{6}$$

Due to the characteristics of risk aversion, the certainty equivalent return of policy-oriented guarantee institution obtained from formulas (4) and (6) is as follows:

$$\pi_{d1} = (g + \beta e - e)t\theta + \alpha - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho(g + \beta e - e)^2 \sigma\varepsilon^2. \tag{7}$$

Under the incentive mechanism, when the principal pursues the maximization of the expected utility, there are two constraints of the agent. The first constraint is the participation constraint (IR), that is, the agent's expected utility of a certain action cannot be less than the maximum expected utility of inaction. And the second constraint is the incentive compatibility constraint (IC), that is, the agent always takes the action to maximize its expected utility. Therefore, the basic incentive model (model I) of policy-oriented guarantee institution's DT is as follows:

$$\begin{cases} \max E\left(\pi_g\right) = \max[(\gamma + \eta - \beta e)t\theta - \alpha], \\[2mm] s.t.\,(IR)\,(g + \beta e - e)t\theta + \alpha - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho(g + \beta e - e)^2 \sigma\varepsilon^2 \geq u_0, \\[2mm] (IC)\theta^* \in \arg\max\left[(g + \beta e - e)t\theta + \alpha - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho(g + \beta e - e)^2 \sigma\varepsilon^2\right], \\[2mm] \forall \theta^* \in A. \end{cases} \tag{8}$$

Among them, u_0 is the minimum reserved utility when the guarantee institution does not further carry out DT; A is the set of all actions that can be adopted by the guarantee institution.

According to the condition of excitation compatibility constraint (IC) in formula (8), we perform a first-order operation on θ and make its first-order derivative equal to zero. Finally, θ can be solved:

$$\theta = \frac{(g + \beta e - e)t}{a}. \tag{9}$$

Substitute formula (9) to the objective function $E(\pi_g)$ in formula (8), then

$$\max E\left(\pi_g\right) = \max\left[\frac{(\gamma + \eta - \beta e)(g + \beta e - e)t^2}{a} - \alpha\right]. \tag{10}$$

In the case of optimal solution, the equal sign of participation constraint (IR) in formula (8) is valid. Meanwhile, referring to the idea of Woon et al. [50], we introduce a Lagrange function multiplier λ to solve the nonlinear optimization problem and construct Lagrange function L, as shown in the following formula .

$$L = \left\{\frac{(\gamma + \eta - \beta e)(g + \beta e - e)t^2}{a} - \alpha + \lambda\left[(g + \beta e - e)t\theta + \alpha - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho(g + \beta e - e)^2 \sigma_\varepsilon^2 - u_0\right]\right\}. \tag{11}$$

Eventually, let $(\partial L/\partial \alpha) = 0$ and $(\partial L/\partial \beta) = 0$, the solution can be obtained as follows:

$$\beta^* = \frac{t^2(\gamma + \eta) - a\rho\sigma_\varepsilon^2(g - e)}{et^2 + ae\rho\sigma_\varepsilon^2}. \tag{12}$$

Substitute formula (12) to formula (9), then

$$\theta^* = \frac{(g + \beta e - e)t}{a} = \frac{t^3(\gamma + \eta + g - e)}{a(t^2 + a\rho\sigma_\varepsilon^2)}. \tag{13}$$

3.3. Construction of the Incentive Model Introducing a Regulatory Signal (Model II). In model I, the incentive intensity coefficient is related to the scale of the guarantee business,

which is difficult to directly observe the effort level of policy-oriented guarantee institution's DT. However, some actions of a guarantee institution can reflect its effort level, such as the efficiency of business operation, the cycle of project review, and the level of informatization. Accordingly, the local government can adopt a targeted regulatory mechanism to estimate the effort level of policy-oriented guarantee institution's DT. On the basis of model I, we give the following supplementary assumption.

Assumption 5. Drawing on the research of Li et al. [51], we assume that the regulatory signal is only related to the effort level θ of policy-oriented guarantee institution, so the regulatory signal is $\phi = (\theta + v)$. Thereinto, v is an external random variable, which represents the influence of external factors on the regulatory accuracy, and the condition of $v \sim N(0, \sigma v^2)$ is met. Meanwhile, we introduce the regulation intensity coefficient δ. Then, there is $R_{d2} = (\alpha + \beta eK) + \delta\phi$, that is, the incentive remuneration of

policy-oriented guarantee institution is also affected by the regulatory signal.

Based on the above supplementary assumption, the expected utility function $E(\pi_g)$ of the local government and the certainty equivalent return π_{d1} of policy-oriented guarantee institution are, respectively, transformed into the following:

$$E(\pi_g) = (\gamma + \eta - \beta e)t\theta - \alpha - \delta\phi, \tag{14}$$

$$\pi_{d1} = (g + \beta e - e)t\theta + \alpha + \delta\phi - \frac{1}{2}a\theta^2 - H \\ - \frac{1}{2}\rho\left[(g + \beta e - e)^2\sigma\varepsilon^2 + \delta^2\sigma v^2\right]. \tag{15}$$

Combining formulas (14) and (15), the incentive model introducing a regulatory signal (model II) can be constructed as follows:

$$\begin{cases} \max E(\pi_g) = \max[(\gamma + \eta - \beta e)t\theta - \alpha - \delta\phi], \\ \\ s.t. (IR)(g + \beta e - e)t\theta + \alpha + \delta\phi - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho\left[(g + \beta e - e)^2\sigma\varepsilon^2 + \delta^2\sigma v^2\right] \geq u_1, \\ \\ (IC)\theta^{**} \in \arg\max\left\{(g + \beta e - e)t\theta + \alpha + \delta\phi - \frac{1}{2}a\theta^2 - H - \frac{1}{2}\rho\left[(g + \beta e - e)^2\sigma\varepsilon^2 + \delta^2\sigma v^2\right]\right\}, \\ \\ \forall\theta^{**} \in A. \end{cases} \tag{16}$$

Among them, u_0 is the minimum reserved utility when the guarantee institution does not further carry out DT after the introduction of a regulatory signal.

Similarly, the solution of formula (16) can be obtained as follows:

$$\beta^{**} = \frac{t^2(\gamma + \eta) - a\rho\sigma\varepsilon^2(g - e) - 2\delta t}{\left(et^2 + ae\rho\sigma_\varepsilon^2\right)}, \tag{17}$$

$$\theta^{**} = \frac{(g + \beta e - e)t + \delta}{a} \\ = \frac{t^3(\gamma + \eta + g - e) + \delta\left(a\rho\sigma\varepsilon^2 - t^2\right)}{a\left(t^2 + a\rho\sigma\varepsilon^2\right)}. \tag{18}$$

3.4. Model Analysis and Comparison. According to the solution results of formulas (12), (13), (17), and (18), the following propositions can be obtained.

Proposition 1. *The effort level of policy-oriented guarantee institutions' DT in model II is higher than that in model I, while the incentive intensity of local governments in model II is lower than that in model I.*

Proof. According to the results of formulas (13) and (18), the existence of $(\theta^{**} - \theta^*) = \delta/a \geq 0$ is always established, that is, $\theta^{**} \geq \theta^*$. Meanwhile, judging from the results of formulas (12) and (17), there is also a constant relationship of $(\beta^{**} - \beta^*) = -2\delta t/e(t^2 + a\rho\sigma\varepsilon^2) \leq 0$, that is, $\beta^{**} \leq \beta^*$. Clearly, under the regulatory mechanism, policy-oriented guarantee institutions will increase their effort in DT, while local governments can reduce incentive intensity.

Proposition 1 indicates that model II is significantly more conducive to the advancement of policy-oriented guarantee institutions' DT. Therefore, the following contents focus on the analysis of key influencing factors of the effort level, incentive intensity, and expected utility in model II. □

Proposition 2. *Given the effort level in model II, several influencing mechanisms are represented as follows:*

(i) *If $t < \sqrt{a\rho\sigma_\varepsilon^2}$, the greater the regulatory intensity of local governments is, the higher the effort level of policy-oriented guarantee institutions' DT will be*

(ii) *If $e < r + \eta + g - 2\delta/t$, the higher the risk perception degree of policy-oriented guarantee institutions is, the lower the effort level of DT will be*

Proof. According to the effort level in model II, taking first-order derivative of θ^{**} with respect to δ and $\rho\sigma_\varepsilon^2$, we get $\partial\theta^{**}/\partial\delta = (a\rho\sigma\varepsilon^2 - t^2)/a(t^2 + a\rho\sigma_\varepsilon^2)$ and $\partial\theta^{**}/\partial(\rho\sigma_\varepsilon^2) = a^2t^2[2\delta - t(r + \eta + g - e)]/a^2(t^2 + a\rho\sigma_\varepsilon^2)^2$. When $t\langle\sqrt{a\rho\sigma_\varepsilon^2}$, $\partial\theta^{**}/\partial\delta\rangle0$ is always established, that is, the regulatory intensity of local governments has a significant positive impact on the effort level of policy-oriented guarantee institutions' DT. In addition, drawing on the research of Zhong et al. [52], $\rho\sigma_\varepsilon^2$ represents the risk perception degree of policy-oriented guarantee institutions to DT strategy. When $e\langle r + \eta + g - 2\delta/t$, $\partial\theta^{**}/\partial(\rho\sigma_\varepsilon^2)\langle0$ is always established, that is, the risk perception degree of policy-oriented guarantee institutions has a significant negative impact on the effort level of policy-oriented guarantee institutions' DT. □

Proposition 3. *Given the incentive intensity in model II, several influencing mechanisms are represented as follows:*

  (i) *The greater the regulatory intensity of local governments is, the lower the incentive intensity will be*

  (ii) *If $e\langle r + \eta + g - 2\delta/t$, the higher the risk perception degree of policy-oriented guarantee institutions is, the lower the incentive intensity of local governments will be*

Proof. According to the incentive intensity in model II, taking the first-order derivative of β^{**} with respect to δ and $\rho\sigma_\varepsilon^2$, we get $\partial\beta^{**}/\partial\delta = -2t/et^2 + ae\rho\sigma_\varepsilon^2$ and $\partial\beta^{**}/\partial(\rho\sigma_\varepsilon^2) = ate[2\delta - t(r + \eta + g - e)]/(et^2 + ae\rho\sigma_\varepsilon^2)^2$. Consequently, there is a constant relationship of $\partial\beta^{**}/\partial\delta\langle0$, that is, the regulatory intensity of local governments has a significant negative impact on the incentive intensity. For another, $\partial\beta^{**}/\partial(\rho\sigma_\varepsilon^2)\langle0$ will establish only when the condition of $e\langle r + \eta + g - 2\delta/t$ is satisfied, that is, the risk perception degree of policy-oriented guarantee institutions has a significant negative impact on the incentive intensity of local governments. □

4. Simulations and Results

4.1. Simulation Scenario Analysis. The financing guarantee system in the Hubei province was explored and established in 2018, which is representative in the practice of policy-oriented financing guarantee for SMEs in China [5]. Under the promotion of the provincial reguarantee company, the cooperative guarantee institutions accelerate the process of DT and connect with the national government financing guarantee industry digital platform of the State Fund. According to the actual operation of the "4321" guarantee business in this province and the parameter assignment in the studies of Li et al. [51] and Zhong et al. [52], the parameter values that satisfy different constraints are shown in Table 1. Although there is a certain difference between the assignment and the actual situation, the simulation results can still reflect the variation trend of the DT effort level and incentive intensity when the parameters change.

4.2. Comparative Simulation of Model I and Model II. To verify the differences of local governments' incentive intensity and guarantee institutions' DT effort degree under different incentive mechanisms, this study takes DT effort cost coefficient (a) as a random variable and assigns parameters according to array I. The simulation results are shown in Figure 1. Surely, Figure 1(a) shows that no matter how the DT effort cost coefficient changes, the DT effort level in model II is always greater than that in model I, while Figure 1(b) shows that the DT incentive intensity in model I is greater than that in model II under the same change constraint. This simulation result is consistent with Proposition 1, which also verifies the positive effect of the regulatory signal in the study of Li et al. [51]. Specifically, on the basis of the basic incentive model, the introduction of regulatory signal can improve the effort level of guarantee institutions and reduce the incentive cost of local governments. To a certain extent, the improved incentive mechanism alleviates the information asymmetry between guarantee institutions and local governments and weakens the "speculative" or "inaction" behaviors of guarantee institutions in the DT process. Therefore, the incentive mechanism of introducing the regulatory signal is more reasonable.

4.3. Impact of Risk Perception Degree and Regulatory Intensity on the Effort Level of DT. In view of the incentive effect of model II, the main purpose of this section is to simulate the impact trajectories of risk perception degree and regulatory intensity on the effort level of DT. According to the calculation, array II can satisfy the conditions of $t\langle\sqrt{a\rho\sigma_\varepsilon^2}$ and $e\rangle r + \eta + g - 2\delta/t$, and its simulation result is shown in Figure 2(a). With the increase of risk perception degree and regulatory intensity coefficient, the DT effort level of guarantee institutions generally shows an increasing trend, and the growth trend gradually becomes steeper. Conversely, array III and array IV only satisfy the conditions of $e\langle r + \eta + g - 2\delta/t$ and $t\rangle\sqrt{a\rho\sigma_\varepsilon^2}$, respectively, and their simulation result (Figure 2(b)) shows that the DT effort level exhibits an opposite trend under the same effects of risk perception degree and regulatory intensity. It can be seen that there are critical values for the effects of risk perception degree and regulatory intensity on the DT effort level. In other words, when the guarantee capability level is low or the guarantee compensation rate is high, risk perception degree or regulatory intensity has a more significant incentive effect on the DT of guarantee institutions. The main reason is that DT has important economic value in business efficiency improvement and credit risk control, which is also consistent with the research conclusions of Sutherland [32], Tan et al. [39], and Zhang et al. [46].

4.4. Impact of Risk Perception Degree and Regulatory Intensity on Incentive Intensity of DT. Similar to Proposition 2, Proposition 3 also suggests that the effect of risk perception degree on DT incentive intensity is constrained by other factors. Array V can satisfy the condition of $e\langle r + \eta + g - 2\delta/t$, and its simulation result is shown in

TABLE 1: Parameter assignments under different constraints.

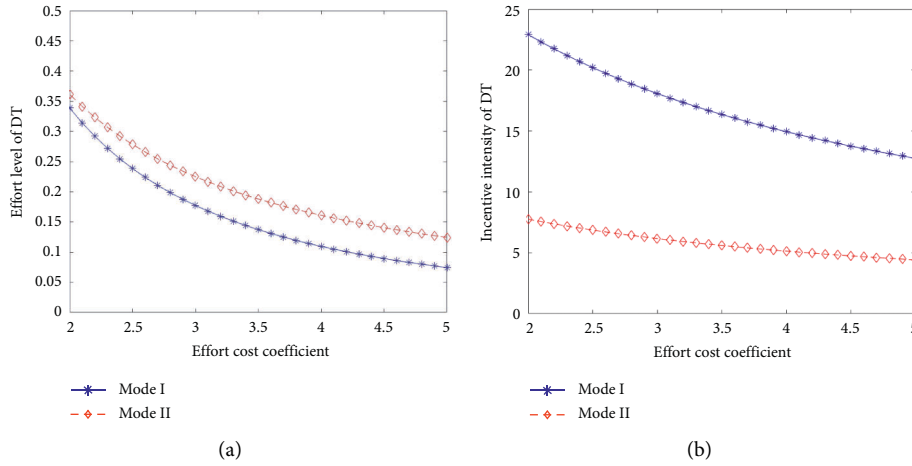| Parameters	t	a	g	e	$\rho\sigma_\varepsilon^2$	δ	$(\gamma + \eta)$
Array I	1	[2, 5]	0.02	0.03	0.6	0.5	1.5
Array II	1	3	0.02	0.03	[0.4, 0.8]	[0.3, 0.7]	0.5
Array III	1	3	0.02	0.03	[0.4, 0.8]	0.3	1.5
Array IV	1	2	0.02	0.03	0.4	[0.3, 0.7]	1.5
Array V	3	2	0.02	0.03	[0.4, 0.8]	[0.3, 0.7]	0.5
Array VI	3	2	0.02	0.03	[0.4, 0.8]	0.3	0.2

(a)

(b)

FIGURE 1: Comparative results of model I and model II. (a) The effort level of DT. (b) Incentive intensity of DT.
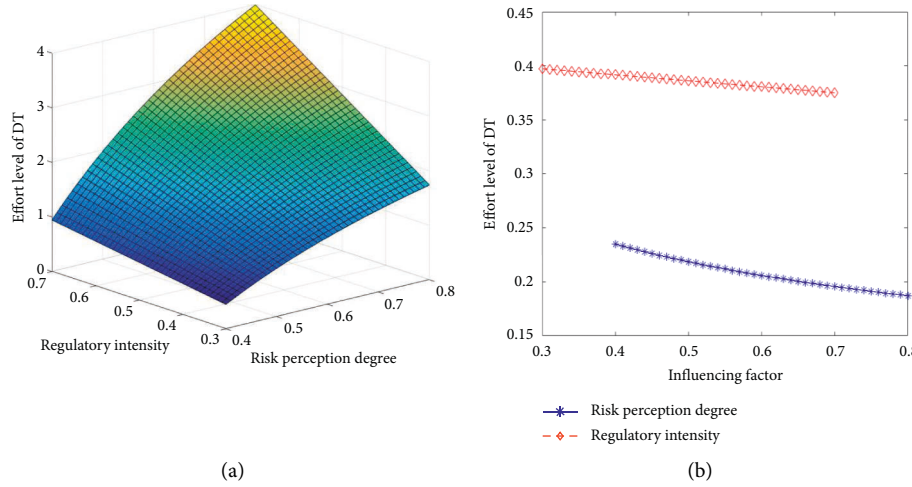

(a)

(b)

FIGURE 2: Effect results of risk perception degree and regulatory intensity on the effort level of DT. (a) The scenario result of array II. (b) Scenario results of array III and array IV.

Figure 3(a). With the increase of risk perception degree or the decrease of regulatory intensity coefficient, the DT incentive intensity of guarantee institutions decreases continuously, and the growth trend is generally stable. Furthermore, Array VI satisfies the condition of $e \rangle r + \eta + g - 2\delta/t$, then Figure 3(b) shows that DT incentive intensity and risk perception degree have an opposite relationship to that in the case of array V. However, there is a constant negative correlation between DT incentive intensity and regulatory intensity. Consequently, there is a critical

value for the effect of risk perception degree on DT incentive intensity, while there is no critical value for the effect of regulatory intensity on DT incentive intensity. Different from the research of Yang et al. [21], Khanna [40], and Chen et al. [41], which focus on the necessity and significance of the government's promulgation of DT incentive policies, the above simulation results further reveal the internal mechanism of maximizing the effect of these incentive policies. Specifically, on the one hand, it is difficult for the regulatory intensity and the incentive intensity to produce the
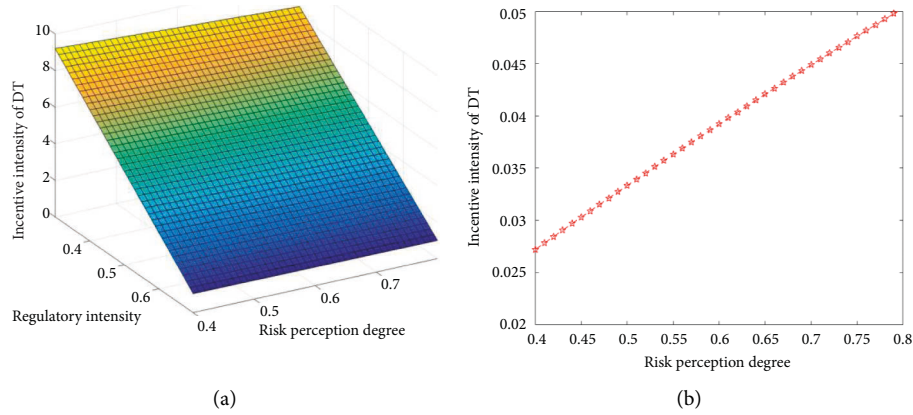
(a)

(b)

FIGURE 3: Effect results of risk perception degree and regulatory intensity on incentive intensity of DT. (a) The scenario result of array V. (b) The scenario result of array VI.

superposition effect of DT. On the other hand, for the guarantee institutions with more sensitive risk perception, the improvement of incentive intensity is conducive to the advancement of DT process when the guarantee compensation rate is high or out of control.

5. Conclusions

As we discussed above, the former research on DT incentive mechanism mainly emphasizes the consideration of implementers' incentive factors and lacks the analysis of incentive parties' supervision factors. Based on the principal-agent relationship between local governments and policy-oriented guarantee institutions in China, this study compares the differences between the basic incentive mechanism and the incentive mechanism introducing a regulatory signal, and explores the effects of regulatory intensity and risk perception on the effort level and incentive intensity of DT through mathematical modeling and simulation analysis. The main research conclusions and related suggestions are as follows:

(1) Compared with the basic incentive mechanism, the incentive mechanism introducing a regulatory signal can play a good role in monitoring the principal-agent relationship between local governments and guarantee institutions, prompting guarantee institutions to improve the DT effort level and weakening the possible unwillingness or formalized speculative. Certainly, although the incentive intensity of local governments will decrease, it will not be as low as zero, which will help to design more reasonable incentive contracts. The DT process of Chinese guarantee institutions is still in the exploratory stage, and the relevant incentive policies are imperfect. Therefore, it is urgent for local governments to supervise and regulate the DT of guarantee institutions, such as establishing an evaluation system of DT or improving the data governance system.

(2) Within the range of the guarantee compensation rate less than a specific threshold, the risk perception

degree has negative effects on the effort level and incentive intensity of the DT. This means that the higher the risk perception degree of guarantee institutions is, the lower the effort level of guarantee institutions and the incentive intensity of local governments will be. From the perspective of incentive utility, when the guarantee compensation rate is low, the incentive effect of relevant policies on the DT of guarantee institutions is limited. Therefore, local governments should appropriately reduce the incentive intensity coefficient. On the contrary, in the case of a high guarantee compensation rate, local governments should increase the incentive investment to maximize the DT's willingness of guarantee institutions.

(3) Regulatory intensity has a constant negative effect on the incentive intensity of the DT, while it has a negative effect on the effort level of the DT only if the guarantee capacity is below a specific threshold. In other words, the greater the regulatory intensity of local governments is, the lower the effort level of guarantee institutions within a specific range or the incentive intensity of local governments will be. Accordingly, for guarantee institutions with weak guarantee capabilities, it is suggested that local governments should appropriately increase the supervision intensity to urge guarantee institutions to speed up the implementation of the DT. Meanwhile, local governments need to make up for the loss of incentive utility caused by the reduction of economic compensation, such as promulgating due diligence exemption policies of the DT.

However, considering that the impact of the DT incentive mechanism on the guarantee system is dynamic and long-term, that is, the incentives of local governments will not immediately be fully reflected in the DT effort of guarantee institutions in the same cycle. Therefore, exploring the effect of incentive mechanism on the growth of DT's long-term benefit level and using dynamic models to analyze the guarantee system are the research directions in the future.

Data Availability

All data used to support the findings of this study are available from the corresponding author on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed to the study conception and material preparation. The writing and review of the manuscript were performed by Guojian Ma and Youqing Lv. The models were constructed by Linlin Lv and Juan Ding. All authors read and approved the final manuscript.

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