Research Article
Modeling of Multitask Principal-Agent Based on Accounts Receivable

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1. Introduction

In recent years, with the global economic recession and bank credit tightening, the development of more and more enterprises is restricted by capital constraints and cash flow. Facing the financing dilemma caused by this, enterprises and financial institutions begin to focus on seeking solutions for supply chain capital flow management [1, 2]. As an emerging solution that can coordinate capital flow, product flow and information flow in supply chain, supply chain finance (SCF) is attracting the attention of more and more researchers and market practitioners [3]. Supply chain finance is a method by which partners in the supply chain jointly create value by planning, directing and controlling the flow of financial resources, it aims to optimize the flow of funds between organizations through solutions provided by financial institutions, improve cash flow management from a supply chain perspective, the goal is to keep capital flow consistent with product flow and information flow within the supply chain [4, 5].

The current popular supply chain financial products can be divided into two types [6, 7]: One is the financing provided by financial institutions to supply chain members, the other is the financing between the upstream and downstream enterprises of the supply chain. Among the two modes, the former is finance-oriented and is regarded as a financial solution driven by buyers [8, 9]. More et al. [10] conceptually divide it into three types: pre-shipment financing, in-transit financing and post-shipment financing. The latter is supply chain oriented and extends the framework of working capital to finance fixed assets including inventory, for example, through a pay per production solution [11, 12].

The successful operation of supply chain finance business is based on the effective cooperation among supply chain members. However, due to information asymmetry, adverse selection and moral hazard will occur among supply chain members, which will affect the overall performance of the supply chain [13]. For this reason, Holmstrom et al. [14] proposed principal-Agent model to solve the problem of information asymmetry between parties in the process of supply chain financial transactions. Later, the multi-task Principal-Agent model was developed by Holmstrom et al. [15], which has been widely applied in many fields.

Principal-Agent Theory (PAT) aims to solve the conflict of interest between principal and agent in the case of information asymmetry [16]. In the transaction process, When the principal hands over the decision-making power to the agent with different interests, the principal-agent relationship occurs [17]. In the principal-agent relationship, the
agent works for the principal and the two parties belong to the partnership [18]. When the agent mischaracterizes its capabilities, objective conflict and information asymmetry will stimulate the occurrence of opportunistic behavior, and can lead to moral hazard, agent lack of effort, and adverse selection [19]. When the agent deviates from the principal’s interests, agency costs will exist. Principals can reduce agency costs by motivating and supervising the agent’s behavior. The focus of the theory is to design the optimal contract that the principal uses to motivate the agent. After years of development, especially the introduction of contract theory based on the principle of labor economics, the theory is increasingly used to study incentive models between principal and agent in different fields, such as electricity markets [20], public companies [21], financial institutions [22] and supply chains [23].

However, the application of principal-agent theory in supply chain finance is quite scarce, which may depend on the fact that principal-agent theory has traditionally been used in pairs, whereas in a supply chain there are multiple agents serving a principal [6]. When there are multiple principals, the principal-agent relationship will become more complex because the goals and interests of multiple principals are not consistent. In addition, the identity construction of principal and agent is complex, and sometimes, an entity can be both principal and agent. Therefore, some scholars have explored the principal-agent relationship in supply chain finance from a new perspective. Pfahl et al. [24] compared the two ways of internal and external capital flow in the supply chain, and used the principal-agent theory to conduct mathematical modeling, and mentioned supervision and long-term commitment as effective ways to reduce agency costs. This problem has been extended further, Jiang et al. [25] introduced commercial banks into the traditional principal-agent model and designed the optimal incentive contract for banks. Wandelh et al. [26] took the procurement and finance departments in the supply chain as the principal and the supplier as the agent, and analyzed the relationship between the buyer and the supplier from the principal-agent perspective, and further explored the factors affecting their performance. Recently, Yin et al. [27] introduced principal-agent theory and incentive theory into supply chain finance under the condition of incomplete information, and on this basis analyzed various influencing factors at different stages of enterprise life cycle. Wang et al. [28] studied the incentive mechanism of the cooperative relationship between principals and agents in the supply chain by building a multi-task principal-agent model. According to the above research, although the current principal-agent model applied to supply chain finance has broken through the limitations of the traditional principal-agent theory. However, there is neither a decisive model nor an in-depth study on the multiple principal-agent relationship.

In order to overcome the defects of traditional principal-agent theory, this paper constructs a more practical multitask principal-agent model. Basing on the mode of accounts receivable of supply chain finance, with the supplier as agent and the manufacturer as the client, and bringing the bank financing factor into the principal-agent relationship, and introducing Holmstrom-Milgrom multitask principal-agent model to establish the principal-agent model of supply chain finance. Firstly, we analyze the principal-agent relationship between supplier and manufacturer of supply chain finance. Then, the incentive contract is built with symmetric information. Next, the incentive mechanism is discussed under asymmetrical information. Finally, how to achieve manufacturer’s own interests as well as enable the supplier to maximize the possibility of repayment through incentive is analyzed.

2. Principal-Agent Relationship between Supplier and Manufacturer of Supply Chain Finance

Principal-agent relationship in economics refers to any kind of transaction involving asymmetric information. The party with information superiority is called the agent, and the other is known as the client. In this study, as the provider of materials, the supplier who has all the information associated with the business (such as product quality, and so on) is the agent. And the manufacturer is the client because it is difficult to get all private information of supplier. In the accounts receivable financing mode, the bank, as a third party, lends money to the supplier through a certain program. The service process is illustrated in Figure 1. In this mode, the bank does not assess the individual SME only, but pays more attention on the trading risk of entire supply chain. Undoubtedly, the credit of supply chain is much stronger than the individual SME’s. Therefore, compared with the traditional model, the risk of bank becomes lower to some extent.

However, according to Figure 1, the bank still has some risks in the receivables financing mode. That is, through the design of incentive mechanism for the supplier, if the final net income of manufacturer is less than the material accounts payable, it would have no motivation to repay the loans. As a result, the bank would have difficulties collecting the loans and interest group from the supplier.

The number ①–⑦ in Figure 1 means steps of accounts receivable financing:
(i) Establish the supply contract;
(ii) Approach the bank for a loan against the contract;
(iii) The bank issues loans;
(iv) Deliver goods;
(v) Provide the accounts receivable document to the bank;
(vi) Pay for the accounts receivable;
(vii) The bank deducts principal and interest of the loans and pays the balance.

3. The Establishment of Multitask Principal-Agent Model of Supply Chain Finance

Hypothesis 1. Assuming that there is a certain background of cooperation between the core enterprise manufacturer G with good reputation and the SME supplier g in the supply chain. Now, the manufacturer has a project D and builds a contract of materials supply with the supplier. The needed money for the supplier to prepare for the materials is I, and the supplier’s own money is B. Therefore, the external financing need is \( L = I - B \). And the supplier decides to finance the loan from the bank. Due to the high credit background and strong capital position of enterprise G, the bank will provide the receivables financing service to the enterprise g through effective assessment. And the financing interest rate is \( r \).

Hypothesis 2. There are two tasks the supplier should complete: providing materials to the manufacturer and improving the quality of corresponding services such as delivery. Assuming that \( e = (e_1, e_2) \) is on behalf of the effort vector of supplier. Where \( e_1 \) represents the indicator of effort level in supply, such as improving the shipments. And the indicator of effort level on related services as distribution equipment and supply channels are denoted by \( e_2 \). The effort level of supplier cannot be directly observed by the manufacturer, but the results of its effort can be observed:

\[
x = f(e) + \xi.
\]

Supposing that \( f(e) : R^2 \rightarrow R^2 \) is a concave function. Where \( R \) is the real number, and the superscript represents the amount of information that can be observed. \( \xi \) is the random vector subjected to the normal distribution. And its mean and variance are 0 and \( \sigma^2 \) respectively. For simplicity, assuming \( f(e_i) \), so there are \( x_1 = e_1 + \xi_1 \) and \( x_2 = e_2 + \xi_2 \).

Hypothesis 3. \( B(e_1, e_2) \) represents the manufacturer’s earnings and it depends on the completion of the two tasks. Besides, it obeys Douglas function. That is \( B(e_1, e_2) = Ae_1^\theta_1 e_2^\theta_2 \). Where, \( A \) is output coefficient, and \( \theta_1, \theta_2 \) are the impacts(or contributing ratio) the material supply and service level on the revenue of manufacturer.

Hypothesis 4. \( C(e_1, e_2) \) is the cost function of vendor’s efforts. And it is convex function increased strictly, that is \( \partial C/\partial e_i > 0, \partial^2 C/\partial e_i^2 > 0, i = 1, 2 \). In order to analyze the results conveniently, assuming \( C(e_1, e_2) = b_1e_1^2 + b_2e_2^2/2(b_1, b_2 > 0) \).

Hypothesis 5. The manufacturer is risk neutral. The supplier is risk aversion, and its utility function has the character of constant absolute risk aversion, i.e., \( u(y) = -e^{-\rho y} \). Where, \( \rho \) is the degree of absolute risk aversion, and \( y \) is the real money income. So, the certainty equivalent income of supplier meets (If \( \mu(x) = Eu(y) \) (where \( y \) is random income), \( x \) is called the deterministic equivalent of \( y \), because the expected utility the consumer gets from random revenue \( y \) is equal to the utility from deterministic income \( x \)):

\[
Eu(y) = u(CE).
\]

If the random variable \( y \) follows a normal distribution, the mean and standard deviation are \( h \) and \( \sigma_y \), then,

\[
Eu(y) = \int_{-\infty}^{\infty} -e^{-\rho y} \frac{1}{\sqrt{2\pi}\sigma_y^2} e^{-(y-h)^2/2\sigma_y^2} dy = -e^{\rho(h-\rho\sigma_y^2/2)} \cdot \setminus (3)\] .

According to the equation \( -e^{-\rho(CE)} = -e^{-\rho(h-\rho\sigma_y^2/2)} \), we can get the certainty equivalent income \( CE = h - \rho\sigma_y^2/2 \).

Hypothesis 6. the revenue function of supplier is \( s(x) \), and the linear incentive contract is adopted: \( s(x) = \alpha + \beta_1 x_1 + \beta_2 x_2 \). Where \( \alpha \) is the fixed payment of manufacturer, and \( \beta_1, \beta_2 \) are the incentive shares of supplier.

The symbols and meanings of the parameters used throughout this research are provided in Table 1.

For the supplier of supply chain finance, not only does it pay the costs but also should repay the principal and interest. Therefore, the income of supplier is

\[
\pi_g = s(x) - C(e_1, e_2) - (r + 1)
\]

\[
L = \alpha + \beta_1 x_1 + \beta_2 x_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L,
\]

AND, \( E\pi_g = \alpha + \beta_1 e_1 + \beta_2 e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L \),

\[
\text{Var}\pi_g = \beta_1^2 \sigma_1^2 + \beta_2^2 \sigma_2^2.
\]

Then, the deterministic equivalent income of supplier is

\[
\hat{\pi}_g = \alpha + \beta_1 e_1 + \beta_2 e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L
\]

\[
-\frac{1}{2} \rho \beta_1^2 \sigma_1^2 - \frac{1}{2} \rho \beta_2^2 \sigma_2^2.
\]

The real income of manufacturer is

\[
\pi_z = Ae_1^\theta_1 e_2^\theta_2 - s(x) = Ae_1^\theta_1 e_2^\theta_2 - \alpha - \beta_1 x_1 - \beta_2 x_2.
\]

So, its expected income is
Table 1: Parameter symbols and meanings.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Meanings</th>
</tr>
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<tbody>
<tr>
<td>G</td>
<td>The core enterprise manufacturer</td>
</tr>
<tr>
<td>g</td>
<td>The SME supplier</td>
</tr>
<tr>
<td>D</td>
<td>A material’s supply project</td>
</tr>
<tr>
<td>I</td>
<td>The needed money for the supplier to prepare for the materials</td>
</tr>
<tr>
<td>B</td>
<td>The supplier’s own money</td>
</tr>
<tr>
<td>L</td>
<td>The external financing need</td>
</tr>
<tr>
<td>r</td>
<td>The financing interest rate</td>
</tr>
<tr>
<td>e₁</td>
<td>The supplier’s effort level in supply</td>
</tr>
<tr>
<td>e₂</td>
<td>The supplier’s effort level in service</td>
</tr>
<tr>
<td>x</td>
<td>The results of supplier effort</td>
</tr>
<tr>
<td>ξ</td>
<td>The random vector subjected to the normal distribution</td>
</tr>
<tr>
<td>𝜎₁²</td>
<td>The variance of the random vector</td>
</tr>
<tr>
<td>θ₁</td>
<td>The output coefficient</td>
</tr>
<tr>
<td>θ₂</td>
<td>The contributing coefficient the material supply on the manufacturer</td>
</tr>
<tr>
<td>ρ</td>
<td>The risk aversion coefficient</td>
</tr>
<tr>
<td>y</td>
<td>The real money income</td>
</tr>
<tr>
<td>h</td>
<td>The mean of the real money income</td>
</tr>
<tr>
<td>𝜎₂</td>
<td>The standard deviation of the real money income</td>
</tr>
<tr>
<td>α</td>
<td>The fixed payment of manufacturer</td>
</tr>
<tr>
<td>β</td>
<td>The supplier incentive coefficient</td>
</tr>
</tbody>
</table>

\[
Eπ_{z} = Ae_1^θ_1e_2^θ_2 - \alpha - \beta_1e_1 - \beta_2e_2. \tag{7}
\]

As the leader in the Stackelberg game as well as the designer of contract, the manufacturer has the advantage of advance decision. However, it will be subject to the individual rationality and incentive compatibility of supplier in asymmetric information. Therefore, we can establish the following incentive program model,

\[
\text{Max} Eπ_{z} = Ae_1^θ_1e_2^θ_2 - \alpha - \beta_1e_1 - \beta_2e_2, \tag{8}
\]

\[
\text{(IC)s.t.} \ e_1, e_2 \in \arg \max \alpha + \beta_1e_1 + \beta_2e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L - \frac{1}{2}\rho\beta_1^2\sigma_1^2 - \frac{1}{2}\rho\beta_2^2\sigma_2^2, \tag{9}
\]

\[
\text{(IR)}\alpha + \beta_1e_1 + \beta_2e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L - \frac{1}{2}\rho\beta_1^2\sigma_1^2 - \frac{1}{2}\rho\beta_2^2\sigma_2^2 \geq \pi_0. \tag{10}
\]

where \(\pi_0\) represents the retained revenue (or the opportunity cost) of supplier without participating in the service of supply chain finance.

4. Model Solution

4.1. The Incentive under Symmetry Information. Under the circumstance of information symmetry, the effort level of supplier can be observed directly by the manufacturer. Hence, the manufacturer can implement rewards and punishments to the supplier by observing its efforts. At this time, the individual rationality (10) functions, and the incentive compatibility (9) is not. So, the model changes into,

\[
\text{Max} Eπ_{z} = Ae_1^θ_1e_2^θ_2 - \alpha - \beta_1e_1 - \beta_2e_2, \tag{11}
\]

\[
\text{(IR)}\alpha + \beta_1e_1 + \beta_2e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L - \frac{1}{2}\rho\beta_1^2\sigma_1^2 - \frac{1}{2}\rho\beta_2^2\sigma_2^2 \geq \pi_0. \tag{12}
\]

In optimal circumstance, the equation of (12) is valid (because the manufacturers do not have to pay more to the supplier). So, there is

\[
\text{Max} Eπ_{z} = Ae_1^θ_1e_2^θ_2 - \alpha - \beta_1e_1 - \beta_2e_2, \tag{13}
\]

\[
\text{(IR)}\alpha + \beta_1e_1 + \beta_2e_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L - \frac{1}{2}\rho\beta_1^2\sigma_1^2 - \frac{1}{2}\rho\beta_2^2\sigma_2^2 \geq \pi_0. \tag{14}
\]

Putting \(\alpha\) into (13), we will get,

\[
\text{Max} Eπ_{z} = Ae_1^θ_1e_2^θ_2 - \frac{b_1e_1^2 + b_2e_2^2}{2} - (r + 1)L - \frac{1}{2}\rho\beta_1^2\sigma_1^2 - \frac{1}{2}\rho\beta_2^2\sigma_2^2 \geq \pi_0. \tag{15}
\]

Then, taking the derivative of this with respect to \(e_1, e_2, \beta_1, \beta_2\),

\[
e_{1s} = \left(\frac{b_1}{A\theta_1} \left(\frac{b_1\theta_2}{b_2\theta_1}\right)^{\theta_1/2} + \theta_2 - 2\theta_1\theta_2\right), \tag{16}
\]

\[
e_{2s} = \left(\frac{b_1}{A\theta_2} \left(\frac{b_1\theta_1}{b_2\theta_2}\right)^{\theta_2/2} + \theta_1 - 2\theta_1\theta_2\right), \tag{17}
\]

\[
\beta_{1s} = \beta_{2s} = 0.
\]

Putting these results into (14),

\[
\alpha_s = \frac{b_2}{2} \left(\frac{b_1}{A\theta_1} \left(\frac{b_1\theta_2}{b_2\theta_1}\right)^{\theta_1/2} + \theta_2 - 2\theta_1\theta_2\right) \tag{18}
\]

\[
+ \frac{b_1}{2} \left(\frac{b_1}{A\theta_2} \left(\frac{b_1\theta_1}{b_2\theta_2}\right)^{\theta_2/2} + \theta_1 - 2\theta_1\theta_2\right) + (r + 1)L + \pi_0.
\]

And the income of manufacturer is,

\[
Eπ_{zs} = \frac{b_1}{2} (2\theta_1 - \theta_2) \left(\frac{b_1}{A\theta_1} \left(\frac{b_1\theta_2}{b_2\theta_1}\right)^{\theta_1/2} - \theta_2 - 2\theta_1\theta_2\right) - (r + 1)L - \pi_0.
\]
Conclusion 1. In the case of information symmetry, through the design of linear incentive mechanisms, the manufacturer can maximize its own interests. Meanwhile, the supplier also achieves Pareto optimum effort level with meeting the individual rationality. At the same time, it has the ability to repay bank loans and maximizes its self-interest.

4.2. The Incentive under Asymmetric Information. The manufacturer cannot directly observe the effort level of the supplier with asymmetric information. Therefore, the incentive compatibility of supplier works.

Taking the derivative of (9), we have

\[ e_1 = \beta_1 / b_1, \quad e_2 = \beta_2 / b_2. \]

So,

\[ \text{MaxE} \pi_z = A \alpha e_1 e_2 - \alpha - \beta_1 e_1 - \beta_2 e_2, \]

(1IC) s.t. \[ e_1 = \frac{\beta_1}{b_1}, \quad e_2 = \frac{\beta_2}{b_2} \]

(1R) \[ \alpha + \beta_1 e_1 + \beta_2 e_2 - \frac{b_1 e_1^2 + b_2 e_2^2}{2} - (r + 1)L - \frac{1}{2} \rho \beta_1^2 \sigma_1^2 - \frac{1}{2} \rho \beta_2^2 \sigma_2^2 \geq \pi_0. \]

Similarly, under the optimal circumstance, the equation of (20) is valid. Therefore,

\[ \text{MaxE} \pi_z = A \alpha e_1 e_2 - \alpha - \beta_1 e_1 - \beta_2 e_2, \]

(1IC) s.t. \[ e_1 = \frac{\beta_1}{b_1}, \quad e_2 = \frac{\beta_2}{b_2} \]

(1R) \[ \alpha + \beta_1 e_1 + \beta_2 e_2 - \frac{b_1 e_1^2 + b_2 e_2^2}{2} - (r + 1)L - \frac{1}{2} \rho \beta_1^2 \sigma_1^2 - \frac{1}{2} \rho \beta_2^2 \sigma_2^2 = \pi_0. \]

Factoring out \( \alpha \) from (23) and putting it into (21) with (22), we can get the revenue of manufacturer.

\[ \text{E} \pi_z = A \left( \frac{\beta_1}{b_1} \right)^{\theta_1} \left( \frac{\beta_2}{b_2} \right)^{\theta_2} - \frac{\beta_1^2}{2b_1} - \frac{\beta_2^2}{2b_2} - (r + 1)L \]

\[ - \frac{1}{2} \rho \beta_1^2 \sigma_1^2 - \frac{1}{2} \rho \beta_2^2 \sigma_2^2 - \pi_0. \]

Taking the derivative of this with respect to \( \beta_1, \beta_2 \), and letting \( \partial \text{E} \pi_z / \partial \beta_1 = 0, \partial \text{E} \pi_z / \partial \beta_2 = 0 \), there are,

\[
\beta_{1c} = \left\{ \frac{b_1^{\theta_1-1} b_2^{\theta_2} (1 + b_1 \rho \sigma_1^2)}{A \theta_1} - \frac{b_2 \theta_2 (1 + b_1 \rho \sigma_1^2)}{b_1 \theta_1 (1 + b_2 \rho \sigma_2^2)} \right\}^{\frac{1}{\theta_1 + \theta_2 - 2}} \\
\beta_{2c} = \left\{ \frac{b_1^{\theta_1-1} b_2^{\theta_2} (1 + b_1 \rho \sigma_1^2)}{A \theta_1} - \frac{b_2 \theta_2 (1 + b_1 \rho \sigma_1^2)}{b_1 \theta_1 (1 + b_2 \rho \sigma_2^2)} \right\}^{\frac{1}{\theta_1 + \theta_2 - 2}} \\

\]
Conclusion 2. Due to

\[
\beta_{1c} = \left\{ \frac{b_1^{(\rho - 1)} \beta_{2c} (1 + b_1 \rho \sigma_1^2)}{A \theta_1} b_1 \theta_2 (1 + b_1 \rho \sigma_1^2) \right\}^{1/2} \theta_1 - \theta_2 - 2 .
\]

(29)

\[
\beta_{2c} = \left\{ \frac{b_1^{(\rho - 1)} \beta_{2c} (1 + b_1 \rho \sigma_1^2)}{A \theta_1} b_1 \theta_2 (1 + b_1 \rho \sigma_1^2) \right\}^{1/2} \theta_1 - \theta_2 - 2 .
\]

(30)

Conclusion 3. Assuming \( \beta_{1c}/\beta_{2c} = [b_1 \theta_1 (1 + b_1 \rho \sigma_1^2)]/b_1 \theta_2 (1 + b_1 \rho \sigma_1^2)]^{1/2} \gamma \), it means the relative excitation intensity the supply level for service level. So we can get,

(1) \( \partial \gamma/\partial \theta_1 = 1/2 \left[ b_1 (1 + b_1 \rho \sigma_1^2)/b_1 \theta_2 (1 + b_1 \rho \sigma_1^2) \right]^{1/2} > 0 \). Therefore, there is a positive correlation between \( \gamma \) and contributing ratio. In other words, in certain conditions, the manufacturer should give greater incentive to the task with more contribution.

(2) \( \partial \gamma/\partial \sigma_1 = b_1 \theta_1 (1 + b_1 \rho \sigma_1^2)/b_1 \theta_2 (1 + b_1 \rho \sigma_1^2) ]^{1/2} < 0 \) and \( \partial \gamma/\partial \sigma_2 = b_1 \theta_1 (1 + b_1 \rho \sigma_1^2)/b_1 \theta_2 (1 + b_1 \rho \sigma_1^2) ]^{1/2} < 0 \). That is, \( \gamma \) will decrease when the uncertainty of supply level of supplier increases and has a positive correlation with service level. So the task with lower uncertainty will get more incentives given by the manufacturer than the one with higher uncertainty.

Conclusion 4. From (28), we have,

(1) \( \partial E \pi_1/\partial b_1 = -\left\{ 1 + 2b_1 \rho \sigma_1^2 / 2 \left[ b_1 b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) \right] \right\} / A \theta_1^{1/2} (b_1 b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) < 0 \partial E \pi_2/\partial b_2 = -\left\{ 1 + 2b_1 \rho \sigma_1^2 / 2 \left[ b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) \right] \right\} / A \theta_1^{1/2} (b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) < 0 \).

This indicates that the income of manufacturer has a negative correlation with the supplier’s cost coefficient.

(2) \( \partial E \pi_1/\partial b_1 = -\left\{ 2b_1 b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) \right\} / A \theta_1^{1/2} (b_1 b_2 (1 + b_1 \rho \sigma_1^2)/(\theta_1 - \theta_2 - 2) < 0 \), that is, the income of manufacturer is inversely proportional to the degree of risk aversion of supplier.

In the receivables financing mode, supplier’s repayment comes from the income of supply project. However, the profits of project depend on the manufacturer’s income and the disbursement rate of accounts receivable. Generally, we assume that the core enterprise does not have intentional default. Thus, the supply chain finance business could run smoothly only if the expected net income of manufacturer is higher than its accounts payable. And supposing that the unit price of supplier’s product is \( \omega \), and under the optimal effort level of \( e_{1c}, e_{2c} \), the quantity delivered are \( q_1 \) and \( q_2 \), respectively.

In information symmetry condition, there is

\[ E \pi_1 = Ae_1^{\beta_1} e_2^{\beta_2} + \alpha \beta_1 e_1 - \beta_2 e_2 \geq \omega q_1, \]

That is \( Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \geq \omega q_1 + \alpha \).\)

Therefore, in the case of information symmetry, if \( Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \geq \omega q_1 + \alpha \), the supplier will select the optimal effort level \( e_{1c}, e_{2c} \) with the linear criterion. At this point, the manufacturer and supplier all maximize their income. Moreover, the supplier can obtain income from the project to repay bank loans and interest. Nevertheless, if \( Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \leq \omega q_1 + \alpha \), the manufacturer is bound to make the supplier’s selection is higher than the effort level \( e_{1c}, e_{2c} \), until inequality (32) comes true. However, at this time, the supplier cannot achieve the optimal effort level, and the cost of efforts will increase, so it cannot get maximum profits. Consequently, the supplier will give up the linear incentive mechanism.

In the circumstances of asymmetry information, the requirement for the normal operation of supply chain finance is

\[ E \pi_1 = Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \geq \omega q_2, \]

That \( Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \geq \omega q_2 + \alpha \).

So, under information asymmetry, if \( Ae_1^{\beta_1} e_2^{\beta_2} - \beta_1 e_1 - \beta_2 e_2 \geq \omega q_2 + \alpha \), the supplier will select the optimal effort level \( e_{1c}, e_{2c} \) with the linear incentive. The manufacturer gets maximum profits, so does the supplier. On the other
hand, if \( Ae_1^\theta_1 \varepsilon_1^\beta_1 - \beta_1 \varepsilon_1^\alpha - \beta_2 \varepsilon_2^\alpha \leq \omega q_2 + \alpha \), because the information is asymmetric, in order to maximize the benefits of manufacturer, the supplier will select optimal level effort \( \varepsilon_1^c, \varepsilon_2^c \). However, the manufacturer does not have enough money to pay for the accounts receivable. So the manufacturer will change the original incentive mechanism.

**Conclusion 5.** Under the different information condition, the incentive mechanism designed by the manufacturer should make the optimal effort level of supplier reach to manufacturer’s required effort for paying accounts receivable. Otherwise, the supplier will abandon the incentive mechanism or the manufacturer will change the original incentive mechanism.

### 5. Numerical Analysis

Through the above research, this section uses MATLAB software to carry out numerical simulation analysis on the above proposed mathematical model. By analyzing the changes in the supply-level contribution coefficient, service-level contribution coefficient, output coefficient, risk aversion coefficient, and other parameters, the effect of each parameter change on the optimal supplier incentives and supplier effort level is studied. According to the existing literature [29, 30], assign the initial value of each parameter and make the initial parameters: \( \theta_1 = 0.7, \theta_2 = 0.8, b_1 = 1.5, b_2 = 2.5, \sigma_1 = 1, \sigma_2 = 1, A = 0.5, \rho = 0.5 \).

#### 5.1. Analysis of the Impact of Supply-Level Contribution Coefficient on Supplier Incentive Coefficient and Supplier Effort Level

Figures 2 and 3, respectively, show the influence of supply-level contribution coefficient on supplier effort and supplier incentive coefficient. As can be seen from Figure 2, with the increasing of the supply-level contribution coefficient, the supplier’s service effort level under information asymmetry and the supplier’s supply effort level under information symmetry are decreasing, and the supplier’s supply effort level under information asymmetry and the supplier’s service effort level under information symmetry are increasing. As can be seen from Figure 3, with the increasing of the supply-level contribution coefficient, the supplier’s service incentive coefficient under information asymmetry is decreasing, and the supplier’s supply incentive coefficient under information asymmetry is increasing. Therefore, the relationship among the supply-level contribution coefficient, the incentive coefficient, and effort level depends on whether the information is symmetric.

#### 5.2. Analysis of the Impact of Service Level Contribution Coefficient on Incentive Coefficient and Supplier Effort Level

Figures 4 and 5, respectively, show the influence of service-level contribution coefficient on supplier effort and supplier incentive coefficient. As can be seen from Figure 4, with the increasing of the service-level contribution coefficient, regardless of whether the information is symmetric or not, the supplier’s supply effort level and service effort level are decreasing, moreover, the effort level under symmetric information is higher than that under asymmetric information. As can be seen from Figure 5, with the increasing of the supply level contribution coefficient, the supplier’s supply incentive coefficient and service incentive coefficient under information asymmetry are decreasing. Therefore, the service-level contribution coefficient is negatively related to the incentive coefficient and the effort level.
5.3. Analysis of the Impact of Output Coefficient on Incentive Coefficient and Supplier Effort Level. Figures 6 and 7, respectively, show the influence of output coefficient on supplier effort and supplier incentive coefficient. As can be seen from Figure 6, with the increasing of the output coefficient, regardless of whether the information is symmetric or not, the supplier’s supply effort level and service effort level are increasing, moreover, the effort level under symmetric information is higher than that under asymmetric information. As can be seen from Figure 7, with the increasing of the output coefficient, the supplier’s supply incentive coefficient and service incentive coefficient under information asymmetry are increasing. Therefore, the output coefficient is positively related to the incentive coefficient and the effort level.

5.4. Analysis of the Impact of Risk Aversion Coefficient on Incentive Coefficient. Figures 8 shows the influence of risk aversion coefficient on supplier incentive coefficient. As can be seen from Figure 8, with the increasing of the risk aversion coefficient, the supplier incentive coefficient is decreasing. In the asymmetric information case, the incentive coefficient is negatively related to the coefficient of risk aversion. So, when designing incentive contracts, we should focus on risk aversion.
Conclusions and Enlightenment

With the core enterprise as the starting point, supply chain finance, based on trading relationships and collateral of supply chain, refers to comprehensive financial services of finance, settlement, insurance, and other related business the bank provided to its clients. The successful operation of the supply chain finance business is built on good cooperation between supply chain partners. From the study of this article, the following conclusions can be drawn:

1. In the case of information symmetry, through the design of linear incentive mechanism, the manufacturer can maximize its own interests. Meanwhile, the supplier also achieves pareto optimum effort level with meeting the individual rationality. At the same time, it has the ability to repay bank loans and maximizes its self-interest.

2. Through the design of incentive contract, the manufacturer is enabled the supplier to achieve optimal effort level with taking certain risks. And the incentive intensity has a negative correlation with the degree of risk aversion. So the manufacturer should take it into account when designing the incentive contract.

3. When the information is asymmetric, the income of manufacturer has a negative correlation with the supplier’s cost coefficient and the degree of risk aversion.

4. Under asymmetric information, the task with lower uncertainty will get more incentives given by the manufacturer than the one with higher uncertainty.

5. Under the different information condition, the incentive mechanism designed by the manufacturer should make the optimal effort level of supplier reach to manufacturer’s required effort for paying accounts receivable. Otherwise, the supplier will abandon the incentive mechanism or the manufacturer will change the original incentive mechanism.

In this paper, the principal-agent model of supply chain finance considers only one side has asymmetric information. But in the actual supply chain, the supplier and manufacturer may all have asymmetric information. So, the design of optimal incentive mechanism which asymmetric information exists in both sides will be one of future research directions.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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