

Research on the Financing Decisions of Manufacturers in a Three-Tier Supply Chain Considering Corporate Social Responsibility

Chenwei Tong

School of Economics and Management, Tongji University, Shanghai 200000

ABSTRACT

This paper constructs a three-tier supply chain consisting of a supplier, a manufacturer, and a retailer. Considering the manufacturer's need for financing to enhance its level of corporate social responsibility, we develop Stackelberg game models under two financing modes: advance payment financing and bank loan financing. We derive the optimal decision variables and profits for each supply chain member. Furthermore, through comparative analysis, we investigate the manufacturer's optimal financing choice. Numerical simulations are conducted to analyze the impacts of the social responsibility factor, social responsibility cost coefficient, initial capital of the manufacturer, and financing interest rate on supply chain decisions and the manufacturer's profitability under the two financing modes.

KEYWORDS

supply chain financing; three-tier supply chain; corporate social responsibility; advance payment; bank loan

1 Research Background

With the growing global attention to environmental, social, and governance (ESG) issues, corporate social responsibility has increasingly become a focal point for the public, governments, investors, and consumers. Consumer attention to the level of corporate social responsibility has been steadily increasing, profoundly influencing both companies and markets.

First, consumer concern about environmental protection has intensified, with growing expectations that companies adopt environmentally friendly practices during their production processes to reduce negative environmental impacts ^[1]. According to Deng Hongbing et al. ^[2], many consumers are more inclined to purchase products from companies that use sustainable raw materials and promote energy conservation and emission reduction. This heightened awareness has prompted companies to actively fulfill their environmental responsibilities in order to meet consumer demands. Second, consumers place high importance on product safety and quality ^[3]. They expect companies to rigorously control production processes to ensure that products meet relevant standards. Research by Zuo Wei et al. ^[4] indicates that the frequent exposure of food safety issues in recent years has led consumers to demand higher quality control standards from food companies. Finally, consumers are more likely to support companies that actively engage in social welfare activities and give back to society. Research by Tang Linjia et al. ^[5] suggests that corporate donations and investments in areas such as education, healthcare, and poverty alleviation help win consumer favor and recognition.

Improving corporate social responsibility levels often brings many positive effects to companies, and actively fulfilling CSR is an inevitable choice for adapting to the sustainable development of the economy and society. First, actively fulfilling CSR helps companies build a good brand image, enhancing the reputation and visibility of the brand. Yang Boru et al. ^[6] argue that consumers often associate a company's CSR performance with its brand image. A company with a strong sense of social responsibility is more likely to leave a positive impression on consumers. Second, according to research by Luo Ziwei et al. ^[7], when a company meets consumers' expectations for social responsibility, consumers are more likely to become loyal customers, consistently purchasing the company's products or services and willing to engage in word-of-mouth promotion. Finally, in a highly competitive market environment, a company's CSR performance can become an important means of differentiation. Zhang Changjiang et al. ^[8] suggest that companies with a strong CSR record are more likely to stand out among consumers, attracting a larger market share. Therefore, companies should actively fulfill their CSR obligations, and achieve high-quality growth.

The process of fulfilling corporate social responsibility presents both opportunities and challenges for businesses. On the one hand, an increasing number of companies are beginning to focus on CSR issues in their operations, taking a series of proactive measures in areas such as environmental protection, employee rights, and technological innovation. As the main contributors to pollution emissions, companies are responsible for addressing the externalities generated during their production and business activities ^[9]. On the other hand, businesses still face numerous challenges in fulfilling CSR, particularly the issue of financial shortages. To meet the growing consumer demands, companies must invest substantial funds to redesign products, improve product quality, or produce safe and eco-friendly products. These investments often lead to insufficient funds for businesses.

To address the issue of financial shortages, businesses can opt for bank loan financing. Banks evaluate various factors,

such as the company's credit status, financial condition, and repayment ability, before granting loans. However, the application conditions for bank loans are often stringent. Small and medium-sized enterprises facing financial shortages may also resort to internal financing within the supply chain to overcome the funding bottleneck ^[10].

Lin Zhibing et al. ^[11] found that an increase in a manufacturer's CSR level can improve the profits of both retailers and the supply chain system. Additionally, when retailers adopt green manufacturing strategies, a reasonable level of CSR can further enhance manufacturer profits. Sun Lipeng et al. ^[12], in the context of manufacturers fulfilling CSR, explored the impact of retailer-led revenue-sharing contracts and bargaining revenue-sharing contracts on optimal decisions, individual member profits, and overall supply chain profits. Wei Zongqiang et al. ^[13] discovered that when e-commerce platforms increase their CSR awareness, the intermediary loan financing model can coordinate relationships between supply chain members, leading to higher overall supply chain profits. Tian Lizhi and Du Wenyi ^[14] constructed a Stackelberg game model between manufacturers and retailers in a CSR context, addressing financial shortages and developing models for unconstrained funds, advance payment, and bank loan-based secondary supply chain financing.

The existing literature mentioned above has not focused on the impact of corporate social responsibility behavior within a three-tier supply chain. Different levels of CSR are likely to affect the allocation and distribution of funds, which in turn influences the decision-making strategies of upstream and downstream companies in the supply chain. Therefore, it is necessary to study the operational decisions of firms under financial constraints in a CSR context.

2 Problem Description

This study considers a three-tier supply chain composed of a single raw material supplier, a single manufacturer, and a single retailer. The supplier provides raw materials to the manufacturer, who processes the materials into final products. These products are then sold to the retailer, who in turn sells them to end consumers. It is assumed that both the supplier and the manufacturer have sufficient production and supply capacities, and that all products manufactured are successfully sold. All supply chain members are assumed to be rational decision-makers.

In this supply chain, the manufacturer faces a capital constraint and has the need to obtain financing. Two financing modes are analyzed in this study: advance payment financing and bank loan financing.

3 Model Formulation

The symbols and notations used in this study are defined as follows:

Table 1 Symbols and Their Definitions

Symbol	Definition
q	Market demand
a	Market capacity
s	Consumer price sensitivity coefficient
p_1	Raw material price
p_2	Product wholesale price
p_3	Product retail price
π_1	Supplier's profit
π_2	Manufacturer's profit
π_3	Retailer's profit
π_s	Total supply chain profit
k	Corporate social responsibility factor
e	Corporate social responsibility level
B	Initial capital of the manufacturer
c_1	Unit raw material production cost
c_2	Unit product production cost
c_e	Corporate social responsibility investment cost
γ_B	Bank loan interest rate
γ_r	Advance payment interest rate
ρ	Social responsibility cost coefficient

Model Assumptions:

(1) Decision-making order of participants: First, the supplier decides the raw material supply price p_1 . Then, the manufacturer decides the product wholesale price p_2 and the level of corporate social responsibility e . Finally, the retailer sets the product retail price p_3 . All firms have symmetric information regarding the market and costs, and they are rational decision-makers seeking to maximize their own profits.

(2) Considering that consumers have different price sensitivities to various products, the market demand is a function of the retail price p_3 and the level of CSR e , which can be expressed as $q = a - sp_3 + ke$, where k is the CSR factor ($k > 0$), representing the manufacturer's proactive investment in CSR to improve its corporate image. It is further assumed that the manufacturer's CSR cost is $c_e = \rho e^2/2$, where ρ is the CSR cost coefficient.

(3) To ensure the comparability of optimal decision results under different decision models and to guarantee that the profit functions under these models are strictly concave and differentiable, the parameters satisfy $p_3 > p_2 > p_1 + c_2$.

(4) For clearer analysis, k^2/ρ is defined as the efficiency of CSR investment.

3.1 Advance Payment Financing Decision Model in a Three-Tier Supply Chain

The advance payment financing model in a three-tier supply chain refers to the manufacturer requesting the retailer to make advance payments in order to maintain normal production activities. In return, the manufacturer offers the retailer an advance payment discount γ_r to incentivize them to reach the agreement. Additionally, the retailer, in order to avoid stockout risks, is motivated to provide advance payment financing to the manufacturer. When $(p_1 + c_2)q + \frac{\rho e^2}{2} > B$, before the manufacturer organizes production, the retailer makes an advance payment $L^{SF} = (p_1 + c_2)q + \frac{\rho e^2}{2} - B$ to the manufacturer (where the superscript "SF" denotes the advance payment financing model in the three-tier supply chain). It can be observed that the supplier's profit function is

$$\pi_1^{SF} = (p_1 - c_1)q \quad (1)$$

The profit function of the manufacturer is

$$\pi_2^{SF} = p_2 q - (p_1 + c_2)q - \frac{\rho e^2}{2} - \gamma_r L^{SF} \quad (2)$$

The profit function of the retailer is

$$\pi_3^{SF} = (p_3 - p_2)q + \gamma_r L^{SF} \quad (3)$$

The total profit function of the supply chain is

$$\pi_s^{SF} = (p_3 - c_1 - c_2)q - \frac{\rho e^2}{2} \quad (4)$$

By using backward induction, the solution can be obtained as follows:

$$e^{SF*} = \frac{ak - sk(c_1 + c_2)}{8s\rho(1 + \gamma_r) - 2k^2} \quad (5)$$

$$p_1^{SF*} = \frac{a + s(c_1 - c_2)}{2s} \quad (6)$$

$$p_2^{SF*} = \frac{2s\rho(1 + \gamma_r)[(3 + 2\gamma_r)a + s(1 + 2\gamma_r)(c_1 + c_2)] - [a + s(c_1 + c_2)](1 + \gamma_r)k^2}{2s[4s\rho(1 + \gamma_r) - k^2]} \quad (7)$$

$$p_3^{SF*} = \frac{2s\rho(1 + \gamma_r)[7a + s(c_1 + c_2)] - [a + s(c_1 + c_2)]2k^2}{4s[4s\rho(1 + \gamma_r) - k^2]} \quad (8)$$

$$\pi_1^{SF*} = \frac{\rho(1 + \gamma_r)[a - s(c_1 + c_2)]^2}{4[4s\rho(1 + \gamma_r) - k^2]} \quad (9)$$

$$\pi_2^{SF*} = \frac{\rho(1 + \gamma_r)[a - s(c_1 + c_2)]^2}{8[4s\rho(1 + \gamma_r) - k^2]} + B\gamma_r \quad (10)$$

$$\pi_3^{SF*} = \frac{\rho[a - s(c_1 + c_2)]^2[2s\rho(1 + \gamma_r)^2 - \gamma_r k^2]}{8[4s\rho(1 + \gamma_r) - k^2]^2} - B\gamma_r \quad (11)$$

Proposition 1 $1 \frac{\partial e^{SF*}}{\partial k} > 0, \frac{\partial p_3^{SF*}}{\partial k} > 0, \frac{\partial \pi_2^{SF*}}{\partial k} > 0, \frac{\partial \pi_3^{SF*}}{\partial k} > 0$

Proposition 1 indicates the manufacturer's level of corporate social responsibility, product retail price, manufacturer's profit, and retailer's profit all increase as the CSR factor rises. A higher CSR factor leads to greater potential market demand, which effectively incentivizes the manufacturer to invest more in CSR activities. At the same time, the additional CSR costs will be partially transferred to consumers by increasing the product retail price. As a result, the product retail price rises, and the profit levels of both the manufacturer and the retailer in the supply chain increase.

Proposition 2 $2 \frac{\partial e^{SF*}}{\partial \rho} < 0, \frac{\partial p_3^{SF*}}{\partial \rho} < 0, \frac{\partial \pi_2^{SF*}}{\partial \rho} < 0, \frac{\partial \pi_3^{SF*}}{\partial \rho} < 0$

Proposition 2 indicates the manufacturer's level of corporate social responsibility, product retail price, manufacturer's profit, and retailer's profit all decrease as the CSR cost coefficient rises. The higher the CSR cost coefficient, the higher the manufacturer's CSR costs for achieving the same level of CSR. To avoid incurring excessive debt, the manufacturer opts to reduce the level of CSR. The decrease in CSR level leads to a reduction in the attractiveness to consumers. In order to attract more consumers, the retailer chooses to lower the product retail price.

Proposition 3 $\frac{\partial e^{SF*}}{\partial \gamma_r} < 0, \frac{\partial p_3^{SF*}}{\partial \gamma_r} < 0$

When $B \in (0, \frac{\rho k^2 [a - s(c_1 + c_2)]^2}{8(-k^2 + 4ps(\gamma_r + 1))})$, $\frac{\partial \pi_2^{SF*}}{\partial \gamma_r} < 0$; when $B \in (\frac{\rho k^2 [a - s(c_1 + c_2)]^2}{8(-k^2 + 4ps(\gamma_r + 1))}, (p_1 + c_2)q + \frac{\rho e^2}{2})$, $\frac{\partial \pi_2^{SF*}}{\partial \gamma_r} > 0$.

When $B \in (0, A_1)$, $\frac{\partial \pi_3^{SF*}}{\partial \gamma_r} > 0$; when $B \in (A_1, (p_1 + c_2)q + \frac{\rho e^2}{2})$, $\frac{\partial \pi_3^{SF*}}{\partial \gamma_r} < 0$.

Proposition 3 indicates the manufacturer's level of corporate social responsibility and product retail price both decrease as the retailer's advance payment interest rate increases. When the manufacturer's initial capital is relatively low, the manufacturer's profit decreases as the retailer's advance payment interest rate rises, while the retailer's profit increases with the higher advance payment interest rate. However, when the initial capital exceeds a certain threshold, the manufacturer's profit increases as the retailer's advance payment interest rate rises, while the retailer's profit decreases. This is because when the manufacturer's initial capital is low, the funding gap is larger, and borrowing incurs higher interest costs.

3.2 Bank Loan Financing Decision Model in a Three-Tier Supply Chain

The bank loan financing model refers to the bank providing a loan to the manufacturer to sustain normal production activities, with an agreed interest rate of γ_B . When $(p_1 + c_2)q + \frac{\rho e^2}{2} > B$, before the manufacturer organizes production, the bank provides a loan $L^{BF} = (p_1 + c_2)q + \frac{\rho e^2}{2} - B$ to the manufacturer (where the superscript "BF" denotes the bank loan financing model in the three-tier supply chain). It can be observed that the supplier's profit function is

$$\pi_1^{BF} = (p_1 - c_1)q \quad (12)$$

The profit function of the manufacturer is

$$\pi_2^{BF} = qp_2 - (p_1 + c_2)q - \frac{\rho e^2}{2} - \gamma_B L^{BF} \quad (13)$$

The profit function of the retailer is

$$\pi_3^{BF} = (p_3 - p_2)q \quad (14)$$

The total profit function of the supply chain is

$$\pi_s^{BF} = (p_3 - c_1 - c_2)q - \frac{\rho e^2}{2} - \gamma_B L^{BF} \quad (15)$$

By using backward induction, the solution can be obtained as follows:

$$e^{BF*} = \frac{ak - sk(1 + \gamma_B)(c_1 + c_2)}{8s\rho(1 + \gamma_B) - 2k^2} \quad (16)$$

$$p_1^{BF*} = \frac{a}{2s(1 + \gamma_B)} + \frac{c_1 - c_2}{2} \quad (17)$$

$$p_2^{BF*} = \frac{2s\rho(1 + \gamma_B)[3a + s(1 + \gamma_B)(c_1 + c_2)] - [a + s(1 + \gamma_B)(c_1 + c_2)]k^2}{2s[4s\rho(1 + \gamma_B) - k^2]} \quad (18)$$

$$p_3^{BF*} = \frac{(1 + \gamma_B)[\rho[3a + s(1 + \gamma_B)(c_1 + c_2)] - k^2(c_1 + c_2)]}{8s\rho(1 + \gamma_B) - 2k^2} + \frac{a}{2s} \quad (19)$$

$$\pi_1^{BF*} = \frac{\rho[a - s(1 + \gamma_B)(c_1 + c_2)]^2}{4[4s\rho(1 + \gamma_B) - k^2]} \quad (20)$$

$$\pi_2^{BF*} = \gamma_B B + \frac{\rho(1 + \gamma_B)[a - s(1 + \gamma_B)(c_1 + c_2)]^2}{8[4s\rho(1 + \gamma_B) - k^2]} \quad (21)$$

$$\pi_3^{BF*} = \frac{s(1 + \gamma_B)^2 \rho^2 [a - s(1 + \gamma_B)(c_1 + c_2)]^2}{4[4s\rho(1 + \gamma_B) - k^2]^2} \quad (22)$$

$$\text{Proposition 4 } \frac{\partial e^{BF*}}{\partial k} > 0, \frac{\partial p_3^{BF*}}{\partial k} > 0, \frac{\partial \pi_2^{BF*}}{\partial k} > 0, \frac{\partial \pi_3^{BF*}}{\partial k} > 0$$

Proposition 4 indicates the manufacturer's level of corporate social responsibility and product retail price both increase as the CSR factor rises. The higher the CSR factor, the greater the potential market demand, which effectively incentivizes the manufacturer to invest more in CSR activities.

$$\text{Proposition 5 } \frac{\partial e^{BF*}}{\partial \rho} < 0, \frac{\partial p_3^{BF*}}{\partial \rho} < 0, \frac{\partial \pi_2^{BF*}}{\partial \rho} < 0, \frac{\partial \pi_3^{BF*}}{\partial \rho} < 0$$

Proposition 5 indicates the manufacturer's level of corporate social responsibility and product retail price both decrease as the CSR cost coefficient rises. The higher the CSR cost coefficient, the higher the CSR costs for achieving the same level of CSR. To avoid incurring excessive debt, the manufacturer opts to reduce the level of CSR, which leads to a decrease in the product's attractiveness to consumers. In order to attract more consumers, the retailer chooses to lower the product retail price.

$$\text{Proposition 6 } \frac{\partial e^{BF*}}{\partial \gamma_B} < 0;$$

$$\text{When } \frac{k^2}{\rho} \in (0, A_2), \frac{\partial p_3^{BF*}}{\partial \gamma_B} > 0; \text{ when } \frac{k^2}{\rho} \in (A_1, 4s(1 + \gamma_B)), \frac{\partial p_3^{BF*}}{\partial \gamma_B} < 0.$$

$$\text{When } B \in (0, A_3), \frac{\partial \pi_2^{BF*}}{\partial \gamma_B} < 0; \text{ when } B \in (A_2, (p_1 + c_2)q + \frac{\rho e^2}{2}), \frac{\partial \pi_2^{BF*}}{\partial \gamma_B} > 0.$$

Proposition 6 indicates the manufacturer's level of corporate social responsibility decreases as the bank loan interest rate increases. When the manufacturer's CSR investment efficiency is relatively low, the product retail price rises with an increase in the bank loan interest rate.

3.3 Model Comparison

This section compares the optimal financing strategies between bank loan financing and advance payment financing in the three-tier supply chain. By analyzing the equilibrium solutions under both financing modes, the relationships among the manufacturer's corporate social responsibility level, product retail price, manufacturer's profit, and retailer's profit are derived respectively.

Proposition 7 When the financing interest rates under the two financing schemes are equal, that is, when $\gamma_B = \gamma_r = \gamma$, it holds that $e^{SF*} > e^{BF*}$ and $\pi_2^{SF*} > \pi_2^{BF*}$.

$$\text{When } \frac{k^2}{\rho} \in (0, s(\gamma + 1)), p_3^{SF*} < p_3^{BF*}; \text{ when } \frac{k^2}{\rho} \in (s(\gamma + 1), 4s(\gamma + 1)), p_3^{SF*} > p_3^{BF*}.$$

$$\text{When } 0 < B < \frac{-2\rho^2 s(a - s(c_1 + c_2)(\gamma + 1))^2 (\gamma + 1)^2 + \rho(a - s(c_1 + c_2))^2 (-\gamma k^2 + 2\rho s(\gamma + 1)^2)}{8\gamma(-k^2 + 4\rho s(\gamma + 1))^2}, \pi_3^{SF*} - \pi_3^{BF*} > 0; \text{ otherwise,}$$

$$\pi_3^{SF*} - \pi_3^{BF*} < 0.$$

Proposition 7 indicates when the interest rates under the two financing schemes are equal, the manufacturer's optimal corporate social responsibility level and profit are always higher under the advance payment financing model than under the bank loan financing model. However, when the manufacturer's CSR investment efficiency is relatively high, the optimal product retail price under the advance payment financing model also exceeds that under the bank loan financing model. Moreover, when the manufacturer's initial capital is at a relatively low level, the retailer's optimal profit is higher under the advance payment financing model; whereas when the initial capital exceeds a certain threshold, the opposite occurs.

4 Numerical Analysis

In this section, numerical analysis is conducted to intuitively explore how, in the context of a three-tier supply chain, the social responsibility factor, the social responsibility cost coefficient, and the retailer's advance payment interest rate/bank loan interest rate affect the manufacturer's optimal production decisions and profit.

Following the parameter settings referenced in relevant literature, the baseline parameters are set as follows: $a = 500, s = 15, k = 2, \rho = 40, B = 200, c_1 = 1, c_2 = 20, \gamma_B = \gamma_r = 4\%$.

4.1 Impact of the Social Responsibility Factor

Figures 1-2 illustrate as the social responsibility factor increases, both the manufacturer's CSR level and profit rise accordingly. This suggests that an increase in the social responsibility factor can effectively stimulate manufacturers to enhance their CSR investment, thereby improving the overall CSR level of the supply chain and ultimately increasing the

manufacturer's profit.

In addition, Figures 1 and 2 reveal that under the advance payment financing model, the supply chain achieves a higher CSR level, and the manufacturer's profit exceeds that under the bank loan financing model.

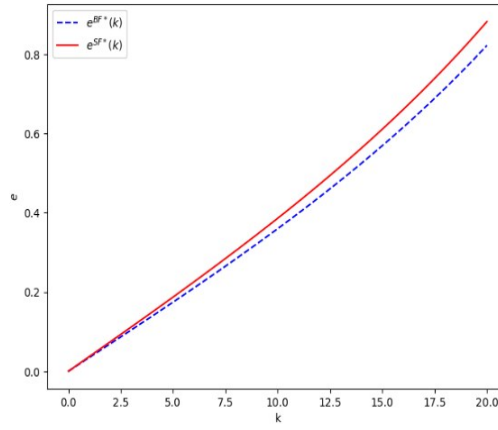


Figure 1 Impact of k on e under different financing modes

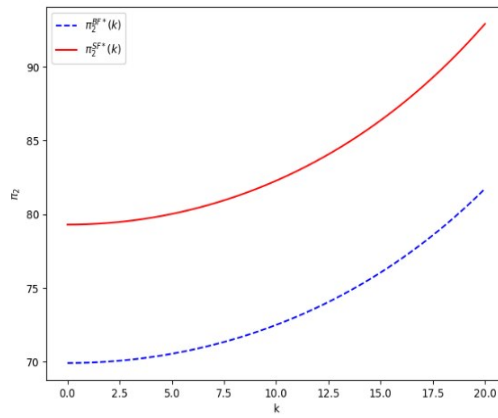


Figure 2 Impact of k on π_2 under different financing modes

4.2 Impact of the Social Responsibility Cost Coefficient

Figures 3 and 4 illustrate under both financing modes, as the social responsibility cost coefficient increases, the manufacturer's CSR level and profit both decrease accordingly.

This indicates that an increase in the social responsibility cost coefficient significantly discourages manufacturers from investing in CSR efforts, thereby reducing the overall CSR level of the supply chain and diminishing the profits of supply chain members.

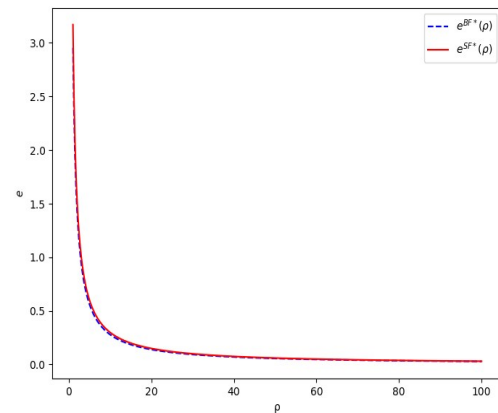
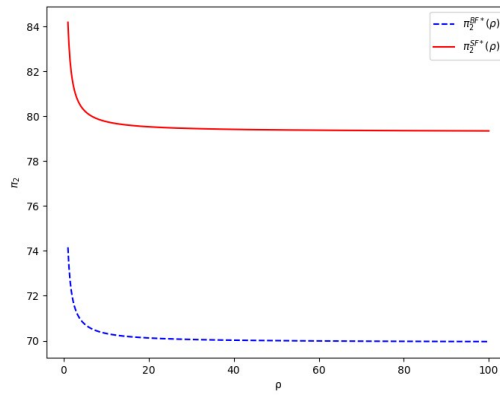
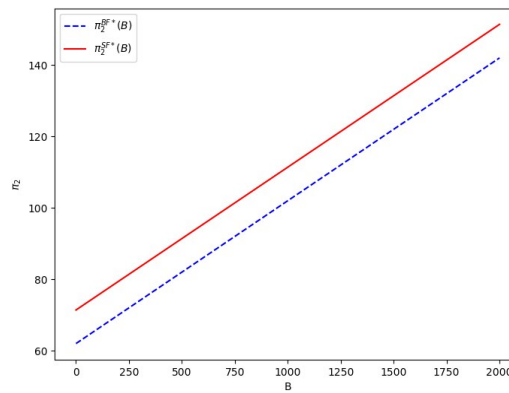
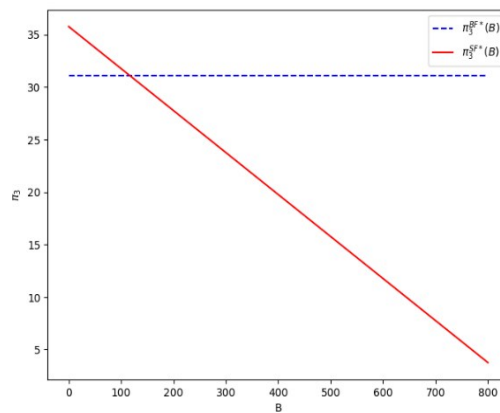


Figure 3 Impact of ρ on e under different financing modes

Figure 4 Impact of ρ on π_2 under different financing modes

4.3 Impact of Manufacturer's Initial Capital

Figures 5 and 6 depict under both financing modes, the manufacturer's profit increases with the growth of its initial capital. However, the retailer's profit is independent of the manufacturer's initial capital in the bank loan financing strategy, while it is negatively correlated with the manufacturer's initial capital under the advance payment financing strategy.

Figure 5 Impact of B on π_2 under different financing modesFigure 6 Impact of B on π_3 under different financing modes

4.4 Impact of Advance Payment Interest Rate and Bank Loan Interest Rate

Figures 7 and 8 illustrate the effects of changes in bank loan interest rates and advance payment interest rates on CSR level and manufacturer profit. Under both financing modes, as the interest rates increase, the CSR level decreases.

As shown in Figure 8, the manufacturer's profit increases with the advance payment interest rate. This is because, when interest costs rise, the manufacturer raises the product wholesale price to maintain its profit levels. As the bank loan interest rate increases, the manufacturer's profit first decreases and then increases. This is because, beyond a certain threshold, no matter how much the manufacturer invests in CSR, they will incur losses. That is, the positive benefits

brought by increasing CSR cannot offset the high interest expenses. As the CSR level rises, the manufacturer's profit decreases. Therefore, at this point, the manufacturer will actively reduce the CSR level to minimize losses, and as a result, the profit begins to increase again.

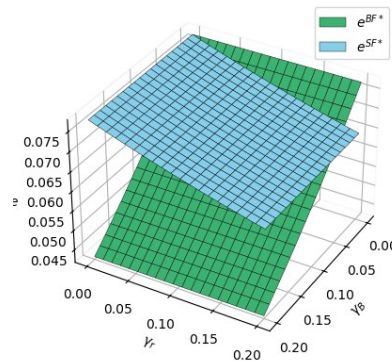


Figure 7 Impact of γ on e

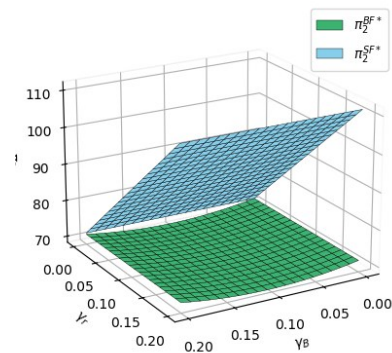


Figure 8 Impact of γ on π_2

5 Conclusion

This paper investigates the impact of bank loan financing and advance payment financing on financing decisions in a three-tier supply chain. By constructing a Stackelberg game model, the differences in decision-making among supply chain member enterprises under different financing strategies are analyzed and compared. Based on model construction and solution, the optimal pricing strategies, production scale, and profit levels of manufacturers are revealed. Furthermore, through sensitivity analysis of key parameters, the dynamic adjustment of critical variables (such as interest rates) and their marginal effects on supply chain operational strategies and profit distribution are explored in detail. The following main conclusions are drawn based on theoretical analysis and numerical simulation:

- (1) Under both bank loan financing and advance payment financing modes, the level of social responsibility, manufacturer profit in the three-tier supply chain all increase with the social responsibility factor and decrease with the increase of the social responsibility cost coefficient.
- (2) Under both bank loan financing and advance payment financing modes, the relationship between manufacturer profit and financing rate depends on the manufacturer's initial funds. When the manufacturer's initial funds exceed a certain threshold, the manufacturer's profit increases with the financing rate.
- (3) When the financing rates for bank loan financing and advance payment financing are the same, the manufacturer always prefers to choose advance payment financing. In this case, the manufacturer's profit and social responsibility investment level under the advance payment financing model are higher than those under the bank loan financing model.

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