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FINANCING GREEN INNOVATION: A SIMULATION APPROACH FOR MANUFACTURING ENTERPRISES

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Abstract
Companies face complex decisions when considering investing in green technology innovation versus traditional products. Key factors include financial constraints, risk of failure, and retailer demand uncertainty and risk aversion for new green products. This study constructs three financing models to analyse green tech manufacturer financing strategies and how the likelihood of success and risk tolerance impacts stakeholder behaviours and profits. Results demonstrate interdependencies between financing model chosen, investment willingness, order volumes, and participant earnings based on the success probability and risk appetite towards unproven green innovations. The models provide nuanced insights into investor and retailer uncertainties surrounding green technology, highlighting how perceived chances of success alongside risk preferences influence funding availability, production scales, and profit outcomes. By quantifying these relationships, the study aims to guide manufacturer decisions and promote suitable financing structures to support wider adoption of sustainability-focused technological innovations.
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Key Words: Financing Strategy, Manufacturing Enterprises, Green Technology Innovation, Risk Aversion

1. INTRODUCTION

In recent years, with the increasingly deteriorating climate and environmental issues, the implementation of green technological innovation and development strategies has become an important issue that countries worldwide must consider. Many countries and international organizations have issued relevant policy documents to encourage related businesses to implement green transformations and upgrades [1]. For example, in March 2021, China released the "14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035", which emphasizes promoting green development, accelerating the transformation of development modes towards greener approaches, and promoting harmonious coexistence between humans and nature. In August 2022, the United States passed the "Inflation Reduction Act", under which the U.S. will invest approximately $370 billion over the next 10 years in the fields of climate and clean energy. In October 2023, France passed the "Green Industry Act" to support the green technology industry and accelerate reindustrialization. In March 2023, the European Union published the "Net Zero Industry Act" and introduced the "Green Pact Industry Plan" to enhance Europe's competitiveness in net zero industries and accelerate the climate neutrality transition. These initiatives aim to improve the investment environment for green technology production, and encourage green investment and financing.

Against this background, an increasing number of manufacturing companies have responded to the call to carry out green technological innovation and transformation to enhance their market competitiveness [2]. However, implementing green technological innovation often requires large investment, especially for some small- and medium-sized manufacturing companies, which may abandon green technological innovation due to financial pressure,

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resulting in a loss of market competitiveness for their products. Companies can solve funding constraints through internal financing from upstream and downstream supply chain companies and external financing from third-party financial institutions outside the supply chain [3].

In addition to funding constraints, companies may face the risks of green technological innovation failure and demand uncertainty. This causes many companies to exhibit risk-averse behaviour when faced with uncertainty risks [4-6], which has a significant impact on the decisions of all companies in the supply chain. Existing research on green technological innovation has primarily focused on the factors that influence green technological innovation, pricing strategies, and decisions regarding product greenness. For example, Wang et al. [7] constructed an evolutionary game model between upstream and downstream enterprises to explore the interaction between credit sales and green technological innovation. Wang et al. [8] used a dynamic evolutionary game model to investigate the impact of factors such as willingness to cooperate, sharing level, income distribution, and punishment mechanisms on the selection of green technology innovation cooperation strategies in the construction industry through numerical simulation. Zhang et al. [9] studied dynamic pricing strategies and green investment in a two-stage dual-channel supply chain. Yu et al. [10] developed a two-level supply chain green technological innovation model of the relationship between automobile manufacturers and battery companies and found that collaborative research and marketing led to higher efficiency in green technological innovation. Ghosh and Shah [11] examined the impact of cost-sharing contracts on the decision making of green technology innovators and the influence of green technology investment costs on pricing and profitability. However, these studies assumed successful green technological innovation. Green technological innovation often faces high technological barriers and financial requirements, and companies are often influenced by various factors during this process. This leads to significant uncertainty about whether and when green technological innovation will succeed [12].

To address the financial difficulties that businesses face during green technological innovation, researchers have primarily assessed the effectiveness of external and internal financing in solving financial constraints. Regarding external financing, Kouvelis and Zhao [13] studied the impact of retailer bankruptcy risk under bank credit financing on supply chain decisions. Hu et al. [14] further studied the optimal external financing and investment portfolio ordering strategy for retailers with funding constraints in supply chains with option contracts. Chen et al. [15] considered pricing and ordering issues in a two-level supply chain, in which a retailer with funding constraints obtains external financing through repurchase guarantees. There is a wealth of research on internal financing. Chod et al. [16] studied how competition between suppliers affects their willingness to provide internal financing. Jiang and Hao [17] found that prepayment financing strategies can effectively solve funding constraints faced by supply chain companies. Many researchers have also focused on comparative analysis of internal and external financing models. For example, Tang et al. [18] explored the choice between prepayment financing and bank loan financing for suppliers with funding constraints. Wu et al. [19] compared the effectiveness of bank and trade credit financing, whereas Qin et al. [20] compared prepayment and bank loan financing.

The aforementioned literature assumed that decision-makers in businesses are risk-neutral and that green technological innovation will always be successful, while ignoring the presence of risk-aversion preferences and the possibility of failures in green technological innovation in real life. According to relevant research, decision-makers' risk-aversion preferences in businesses have a significant impact on pricing, ordering, investment in green technological innovation, and participants' profits [21-23]. Therefore, this study introduced risk-aversion preferences into the manufacturing supply chain and considered the possibility of failure in green technological innovation by manufacturing companies. In summary, this study addresses the financing strategy problem for manufacturing companies under scenarios of no financing, external financing, and internal financing, considering risk-aversion preferences and the possibility of failure in green technology innovation. A comparative analysis of the three financing models is also conducted.

2. MODEL DESCRIPTION AND ASSUMPTIONS

2.1 Model description

As Fig. 1 shows, we consider two competitive manufacturing supply chains, each consisting of a manufacturing company (referred to as the Manufacturer) and a retailer. Manufacturer 1 only produces traditional products and has sufficient funding. In contrast, Manufacturer 2 has the option to produce either traditional products or green technological innovation products. While Manufacturer 2 has sufficient funds to produce traditional products, it faces financial constraints when producing innovative green technological products. In this case, Manufacturer 2 can seek external financing from a third-party financial institution or internal financing from a retailer to address the funding issue. This study investigates the financing strategy selection problem for Manufacturer 2 in this context. To address this, the study considers the following three scenarios:
(1) Scenario A: Both manufacturers in the two supply chains produce traditional products. In this case, Manufacturers 1 and 2 have sufficient funds to produce traditional products.
(2) Scenario B: Manufacturer 1 produces traditional products, whereas Manufacturer 2 seeks external financing to produce innovative green technological products. In this scenario, Manufacturer 2 has decision-making power regarding the green technological innovation level.
(3) Scenario C: Manufacturer 1 produces traditional products, and Manufacturer 2 chooses internal financing through Retailer 2 to produce innovative green technological products. In this scenario, Retailer 2 has decision-making power over the level of green technological innovation.

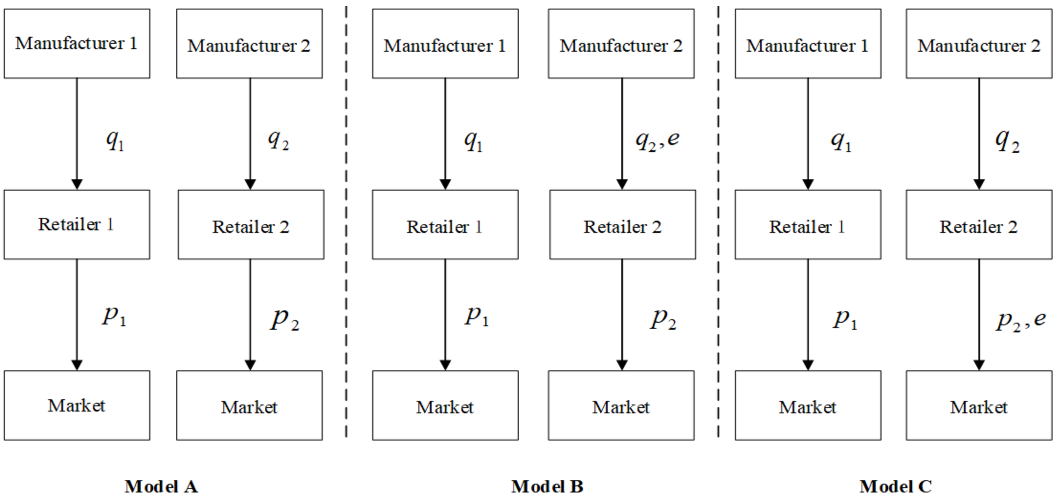


Figure 1: Supply chain structure diagram.

2.2 Model assumptions

The model building in this paper is based on the following assumptions:

Assumption 1: A Nash game is played between two supply chains with the manufacturer acting as the leader in the Stackelberg game.

Assumption 2: The probability of success for Manufacturer 2's green technological innovation is denoted as β. Additionally, due to the inherent uncertainty and risk associated with introducing green technological innovative products into the market, it is assumed that Retailer 2 has a risk-aversion preference when facing uncertainty risk. The utility function for

Retailer 2 under risk aversion is denoted as $U_{R2}^{j} = E[\pi_{R2}^{j}] - \lambda\sqrt{Var(\pi_{R2}^{j})}$ [3], where $\lambda(\lambda > 0)$ represents the degree of risk aversion.

Assumption 3: Drawing on [5, 24], the inverse demand function for the two supply chains is denoted as:

$$\begin{cases} p_1 = \alpha A - q_1 - bq_2 - \theta_1 e \\ p_2 = (1-\alpha)A - q_2 - bq_1 + \theta_2 e + \xi \end{cases} \tag{1}$$

where ξ reflects the randomness of market demand; the mean value of ξ is zero and its variance is δ^2 [25]. The cost of green technological innovation is $C(e) = ke^2$.

Assumption 4: There exists the combination of realistic assumptions $p_i > w_i > c$ ($i \in \{1, 2\}$) [3], $0 < \theta_1 < \theta_2 < 1$ and $0 \le \beta \le 1$.

The symbols involved in this article and their meanings are summarized in Table I.

Table I: Symbols and their meanings.

Symbols	Meaning	Symbols	Meaning
A	Market demand scale	p_i	Retail price of retailer *i*
q_i	Order quantity of Retailer *i*	c	Unit cost of producing traditional products
w_i	Wholesale price of Manufacturer *i*	k	Cost coefficient of green technological innovation
ξ	Stochastic variable of green technological innovative products	δ	Standard deviation of ξ
α	Market share of traditional products in the first supply chain	b	Coefficient of product substitutability
θ_1	Sensitivity coefficient of traditional product consumers towards green products	θ_2	Sensitivity coefficient of green product consumers towards green products
r	Financing interest rate	e	Level of investment in green technology innovation
λ	Degree of risk aversion	β	Probability of success in green technology innovation
π_{Ri}^{j}	The profit of Retailer *i* in scenario *j*	π_{Mi}^{j}	Profit of Manufacturer *i* during time period *j*
U_{R2}^{j}	Utility function of Retailer 2 in scenario *j*	$j = B$	External financing
$j = A$	Manufacturer 2 produces traditional products	$j = C$	Internal financing

3. MODEL CONSTRUCTION

3.1 No financing mode (Mode A)

In Mode A, Manufacturers 1 and 2 have sufficient funds to produce traditional products. The decision sequence in the supply chain is as follows: manufacturers first determine the wholesale price, and then retailers decide their order quantities based on the wholesale price. In this case, the profit functions of the manufacturers and retailers in both supply chains are as follows:

$$\begin{cases} \pi_{M1}^{A} = (w_1 - c)q_1 \\ \pi_{M2}^{A} = (w_2 - c)q_2 \\ \pi_{R1}^{A} = (p_1 - w_1)q_1 = (A - q_1 - bq_2 - w_1)q_1 \\ \pi_{R2}^{A} = (p_2 - w_2)q_2 = (A - q_2 - bq_1 - w_2)q_2 \end{cases} \tag{2}$$

In this case, the Nash equilibrium solution of the supply chain is:

$$\begin{cases} w_1^{A*} = w_2^{A*} = \dfrac{A(2-b)+2c}{4-b} \\ q_1^{A*} = q_2^{A*} = \dfrac{2(A-c)}{(4-b)(2+b)} \\ \pi_{M1}^{A*} = \pi_{M2}^{A*} = \dfrac{2(2-b)(A-c)^2}{(4-b)^2(2+b)} \\ \pi_{R1}^{A*} = \pi_{R2}^{A*} = \dfrac{4(A-c)^2}{(4-b)^2(2+b)^2} \end{cases} \tag{3}$$

3.2 External financing mode (Mode B)

In Mode B, Manufacturer 1 produces traditional products, whereas Manufacturer 2 produces green technology innovation products and engages in external financing. The decision sequence in the supply chain is as follows: Manufacturers i first determine the wholesale price w_i and the level of investment in green technology innovation e, and then Retailers i determine their order quantities q_i. The profit functions of Manufacturer i and Retailer i and the utility function of Retailer 2 are as follows:

$$\begin{cases} \pi_{M1}^{B} = (w_1 - c)q_1 \\ \pi_{M2}^{B} = \beta[(w_2 - c)q_2 - (1+r)ke^2] - (1-\beta)(1+r)ke^2 \\ \pi_{R1}^{B} = (p_1 - w_1)q_1 = (\alpha A - q_1 - bq_2 - \theta_1 e - w_1)q_1 \\ \pi_{R2}^{B} = E\{\beta(p_2 - w_2)q_2 = \beta[(1-\alpha)A - q_2 - bq_1 + \theta_2 e + \xi - w_2]q_2\} \\ U_{R2}^{B} = E[\pi_{R2}^{B}] - \lambda\sqrt{Var(\pi_{R2}^{B})} = \beta[(1-\alpha)A - q_2 - bq_1 + \theta_2 e - w_2]q_2 - \lambda\beta q_2 \end{cases} \tag{4}$$

Similar to Section 3.1, it is easy to determine the optimal decision and profit for decision-makers.

$$\begin{cases} q_1^{B*} = \dfrac{Ab - 2A\alpha - Ab\alpha - b\lambda\sigma + 2w_1^{B*} - bw_2^{B*} + 2c\theta_1 + be^{B*}\theta_2}{b^2-4} \\ q_2^{B*} = \dfrac{2A - 2A\alpha - Ab\alpha - 2\lambda\sigma + bw_1^{B*} - 2w_2^{B*} + bw_2^{B*}\theta_1 + 2e^{B*}\theta_2}{4-b^2} \\ \pi_{M1}^{B*} = (w_1^{B*} - c)q_1^{B*} \\ \pi_{M2}^{B*} = \beta[(w_2^{B*} - c)q_2^{B*} - (1+r)k(e^{B*})^2] - (1-\beta)(1+r)k(e^{B*})^2 \\ \pi_{R1}^{B*} = (\alpha A - q_1^{B*} - bq_2^{B*} - \theta_1 e^{B*} - w_1^{B*})q_1^{B*} \\ \pi_{R2}^{B*} = \beta[(1-\alpha)A - q_2^{B*} - bq_1^{B*} + \theta_2 e^{B*} - w_2^{B*}]q_2^{B*} \end{cases} \tag{5}$$

where w_1^{B*}, w_2^{B*}, and e^{B*} satisfy:

$$\begin{cases} \dfrac{Ab - 2c - 2A\alpha - Ab\alpha - b\lambda\sigma + 4w_1 - bw_2 + 2e\theta_1 + be\theta_2}{b^2-4} = 0 \\ \dfrac{\beta(-2A - 2c + 2A\alpha + Ab\alpha + 2\lambda\sigma - bw_1 + 4w_2 - be\theta_1 - 2e\theta_2)}{b^2-4} = 0 \\ \dfrac{\beta(c - w_2)(b\theta_1 + 2\theta_2)}{b^2-4} - 2ek(1+r) = 0 \end{cases} \tag{6}$$

3.3 Internal financing model (Mode C)

In Mode C, Manufacturer 1 produces traditional products, whereas Manufacturer 2 produces green technological innovation products and engages in internal financing. The decision sequence in the supply chain is as follows: Manufacturers i first determine their wholesale prices w_i, and then Retailers 1 and 2 decide their order quantities q_i and the level of investment in green technology innovation e. The profit functions of Manufacturer i and Retailer i and the utility function of Retailer 2 are as follows:

$$\begin{cases} \pi_{M1}^{C} = (w_1 - c)q_1 \\ \pi_{M2}^{C} = \beta[(w_2 - c)q_2 - (1+r)ke^2] - (1-\beta)(1+r)ke^2 \\ \pi_{R1}^{C} = (p_1 - w_1)q_1 = (\alpha A - q_1 - bq_2 - \theta_1 e - w_1)q_1 \\ \pi_{R2}^{C} = E\{\beta[(p_2 - w_2)q_2 + rke^2] - (1-\beta)(1+r)ke^2\} \\ U_{R2}^{C} = E[\pi_{R2}^{C}] - \lambda\sqrt{Var(\pi_{R2}^{C})} = \beta\{[(1-\alpha)A - q_2 - bq_1 + \theta_2 e - w_2]q_2 + rke^2\} \\ \qquad -(1-\beta)(1+r)ke^2 - \lambda\beta q_2\delta \end{cases} \tag{7}$$

Similar to Section 3.1, we obtain the following Nash equilibrium solution for the supply chain:

$$\begin{cases} q_1^{C*} = \frac{1}{2}(A\alpha - w_1^{C*} - e\theta_1 - bq_2^{C*}) \\ q_2^{C*} = \frac{2k[1-\beta-r(2\beta-1)](2A - 2A\alpha - Ab\alpha - 2\lambda\sigma + bw_1^{C*} - 2w_2^{C*})}{2(4-b^2)k(1+r-\beta-2r\beta) - b\beta\theta_1\theta_2 - 2\beta\theta_2^2} \\ e^{C*} = \frac{\beta(2A - 2A\alpha - Ab\alpha - 2\lambda\sigma + bw_1^{C*} - 2w_2^{C*})\theta_2}{2(4-b^2)k(1+r-\beta-2r\beta) - b\beta\theta_1\theta_2 - 2\beta\theta_2^2} \\ \pi_{M1}^{C*} = (w_1^{C*} - c)q_1^{C*} \\ \pi_{M2}^{C*} = \beta[(w_2^{C*} - c)q_2^{C*} - (1+r)k(e^{C*})^2] - (1-\beta)(1+r)k(e^{C*})^2 \\ \pi_{R1}^{C*} = (\alpha A - q_1^{C*} - bq_2^{C*} - \theta_1 e^{C*} - w_1^{C*})q_1^{C*} \\ \pi_{R2}^{C*} = \beta\{[(1-\alpha)A - q_2^{C*} - bq_1^{C*} + \theta_2 e^{C*} - w_2^{C*}]q_2^{C*} + rk(e^{C*})^2\} \\ \qquad -(1-\beta)(1+r)k(e^{C*})^2 \end{cases} \tag{8}$$

where $w_1^{C*}$and w_2^{C*} satisfy $\frac{\partial \pi_{M1}^{C}(w_1^{C*})}{\partial w_1^{C*}} = 0$ and $\frac{\partial \pi_{M2}^{C}(w_2^{C*})}{\partial w_2^{C*}} = 0$.

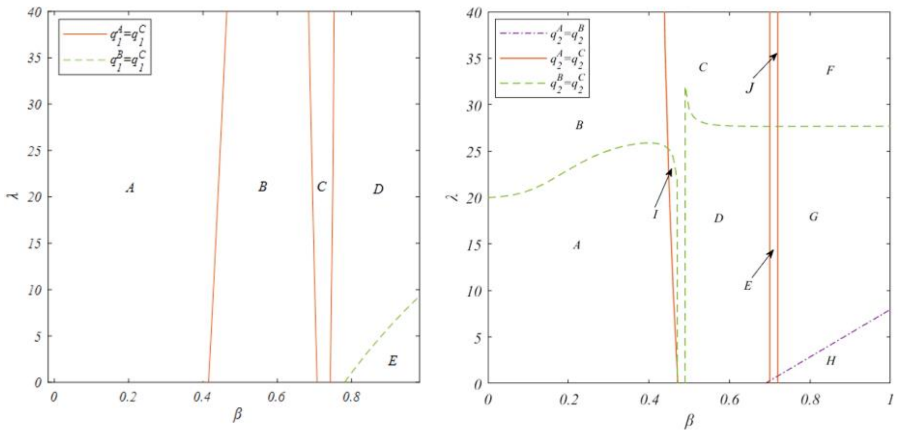
4. SIMULATION ANALYSIS

To obtain more valuable conclusions, this section employs numerical simulation methods to study the impact of the probability of success of green technological innovation β and the degree of risk aversion λ on the optimal decisions and profits of the participants. Without loss of generality, we assume that $A = 100$, $b = 0.3$, $c = 2$, $\alpha = 0.4$, $k = 0.1$, $\sigma = 2$.

4.1 Comparative analysis

As shown in Fig. 2 a, in region A, the order quantity of traditional products is highest under mode A and lowest under mode C; that is, $q_1^{A*} > q_1^{B*} > q_1^{C*}$. In regions B, C, D, and E, the order quantity of traditional products is highest under mode A and lowest under mode B; that is, $q_1^{A*} > q_1^{C*} > q_1^{B*}$. Therefore, for traditional product manufacturers, mode A is the most advantageous.

As shown in Fig. 2 b, in regions A, B, D, E, G, and I, the order quantity of green technological innovation products is highest in mode A and lowest in mode C; that is, $q_2^{A*} > q_2^{B*} > q_2^{C*}$. In regions C, F, and J, the order quantity of green technological innovation products is highest in mode A and lowest in mode B; that is, $q_2^{A*} > q_2^{C*} > q_2^{B*}$. In region H, the order quantity of green technological innovation products is highest in mode B and lowest in mode C; that is, $q_2^{B*} > q_2^{A*} > q_2^{C*}$.

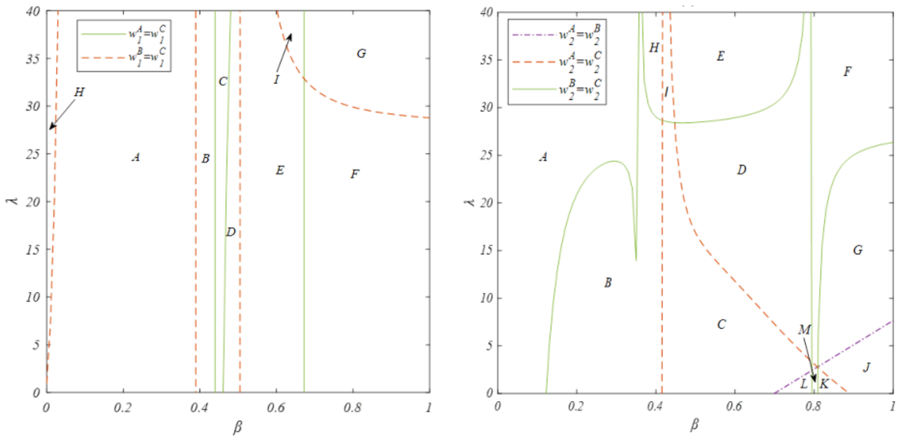


a) b)

Figure 2: Impact of λ and β on the order quantity of traditional products and green technology innovation products.

As shown in Fig. 3 a, in regions A, B, G, H, and I, the wholesale prices of traditional products are highest under mode A and lowest under mode C; that is, $w_1^{A*} > w_1^{B*} > w_1^{C*}$. In regions C, D, E, and F, the wholesale prices of traditional products are highest under mode A and lowest under mode B; that is, $w_1^{A*} > w_1^{C*} > w_1^{B*}$.

As shown in Fig. 3 b, in regions A, B, D, and F, the wholesale prices of green technology innovation products are highest under mode A and lowest under mode B; that is, $w_2^{A*} > w_2^{C*} > w_2^{B*}$. In regions E, G, H, and I, the wholesale prices of green technology innovation products are highest under mode A and lowest under mode C; that is, $w_2^{A*} > w_2^{B*} > w_2^{C*}$. In region C, the wholesale prices of green technology innovation products are highest under mode C and lowest under mode B; that is, $w_2^{C*} > w_2^{A*} > w_2^{B*}$. In region L, the wholesale prices of green technology innovation products are highest under mode C and lowest under mode A; that is, $w_2^{C*} > w_2^{B*} > w_2^{A*}$. In region J, the wholesale prices of green technology innovation products are highest under mode B and lowest under mode C; that is, $w_2^{B*} > w_2^{A*} > w_2^{C*}$. In regions K and M, the wholesale prices of green technology innovation products are highest under mode B and lowest under mode A; that is, $w_2^{B*} > w_2^{C*} > w_2^{A*}$.



a) b)

Figure 3: Impact of λ and β on wholesale prices.

As shown in Fig. 4, the entire plane is divided into two regions: A and B. In region A, the level of green technological innovation input under mode C is higher than that under mode B; that is, $e^{C*} > e^{B*}$. In region B, the level of green technological innovation input under mode C is also higher than that under mode B; that is, $e^{B*} > e^{C*}$.

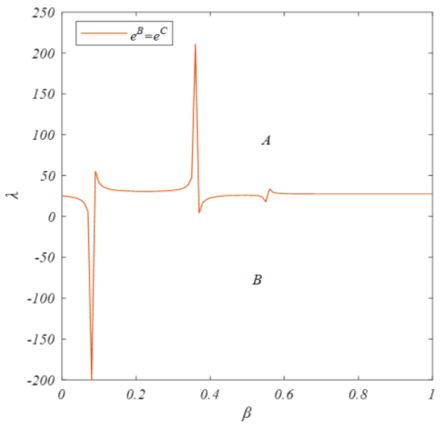
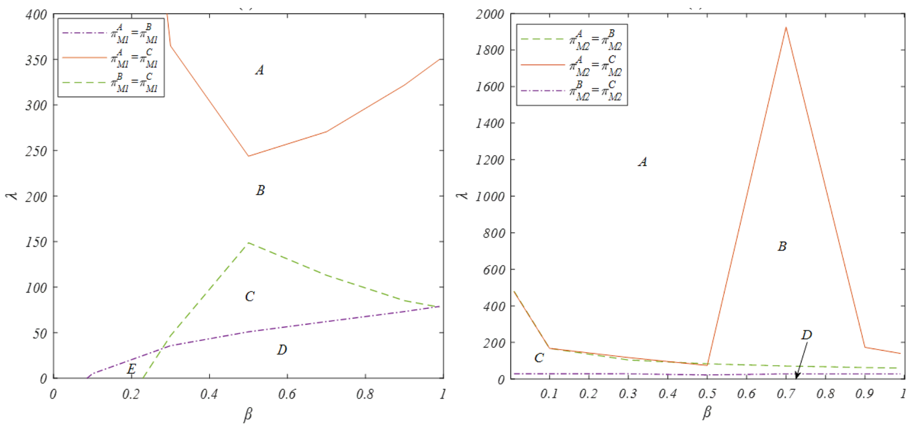


Figure 4: Impact of λ and β on the level of green technology innovation input.

As shown in Fig. 5 a, in regions A and B, the profit of traditional product Manufacturer 1 is highest in mode B and lowest in mode A; that is, $\pi_{M1}^{B*} > \pi_{M1}^{C*} > \pi_{M1}^{A*}$. In region C, the profit of traditional product Manufacturer 1 is highest in mode B and lowest in mode C; that is, $\pi_{M1}^{B*} > \pi_{M1}^{A*} > \pi_{M1}^{C*}$. In region D, the profit of traditional product Manufacturer 1 is highest in mode A and lowest in mode B; that is, $\pi_{M1}^{A*} > \pi_{M1}^{C*} > \pi_{M1}^{B*}$. In region E, the profit of traditional product Manufacturer 1 is highest in mode A and lowest in mode C; that is, $\pi_{M1}^{A*} > \pi_{M1}^{B*} > \pi_{M1}^{C*}$.

As shown in Fig. 5 b, in region A, the profit of green product Manufacturer 2 is highest in mode B and lowest in mode A; that is, $\pi_{M2}^{B*} > \pi_{M2}^{C*} > \pi_{M2}^{A*}$. In region B, the profit of green product Manufacturer 2 is highest in mode B and lowest in mode C; that is, $\pi_{M2}^{B*} > \pi_{M2}^{A*} > \pi_{M2}^{C*}$. In region C, the profit of green product Manufacturer 2 is highest in mode A and lowest in mode B; that is, $\pi_{M2}^{A*} > \pi_{M2}^{C*} > \pi_{M2}^{B*}$. In region D, the profit of green product Manufacturer 2 is highest in mode A and lowest in mode C; that is, $\pi_{M2}^{A*} > \pi_{M2}^{B*} > \pi_{M2}^{C*}$.



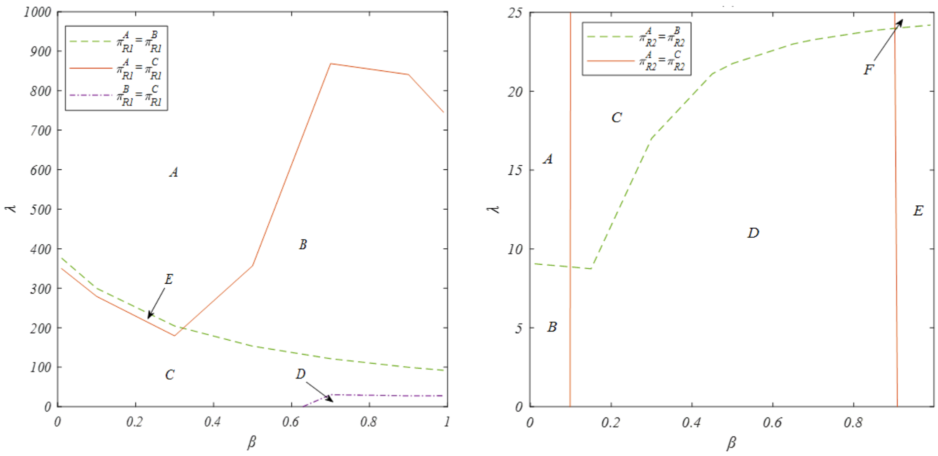
a) b)

Figure 5: Impact of λ and β on manufacturer's profit.

As shown in Fig. 6 a, in regions A and E, the profit of traditional product Retailer 1 is highest in mode C and lowest in mode A; that is, $\pi_{R1}^{C*} > \pi_{R1}^{B*} > \pi_{R1}^{A*}$. In region B, the profit of traditional product Retailer 1 is highest in mode B and lowest in mode C; that is, $\pi_{R1}^{B*} > \pi_{R1}^{A*} > \pi_{R1}^{C*}$. In region C, the profit of traditional product Retailer 1 is highest in mode A and lowest in mode C; that is, $\pi_{R1}^{A*} > \pi_{R1}^{B*} > \pi_{R1}^{C*}$. In region D, the profit of traditional product Retailer 1 is highest in mode A and lowest in mode B; that is, $\pi_{R1}^{A*} > \pi_{R1}^{C*} > \pi_{R1}^{B*}$.

As shown in Fig. 6 b, in regions A and B, the profit of green product Retailer 2 is highest in mode A and lowest in mode C; that is, $\pi_{R2}^{A*} > \pi_{R2}^{B*} > \pi_{R2}^{C*}$. In regions C and D, the profit of green product Retailer 2 is highest in mode B and lowest in mode C; that is, $\pi_{R2}^{B*} > \pi_{R2}^{A*} > \pi_{R2}^{C*}$.

In regions E and F, the profit of green product Retailer 2 is highest in mode C and lowest in mode A; that is, $\pi_{R2}^{C*} > \pi_{R2}^{B*} > \pi_{R2}^{A*}$.



a) b)

Figure 6: Impact of λ and β on retailer's profit.

4.2 Sensitivity analysis

Table II shows the impact of the probability of success of green technological innovation β and the degree of risk aversion λ on the optimal decisions and profits of the participants.

From Table II, we can observe the following in Mode B: (1) An increase in the probability of success in green technology innovation $\boldsymbol{\beta}$ will lead to an increase in green technology innovation $\boldsymbol{e^{B*}}$, wholesale price $\boldsymbol{w_2^{B*}}$, and order quantity $\boldsymbol{q_2^{B*}}$. However, these will decrease with an increase in the degree of risk aversion $\boldsymbol{\lambda}$. (2) An increase in the probability of success in green technology innovation $\boldsymbol{\beta}$ will result in a decrease in the wholesale price $\boldsymbol{w_1^{B*}}$ and order quantity $\boldsymbol{q_1^{B*}}$. However, these will increase with an increase in the degree of risk aversion $\boldsymbol{\lambda}$. (3) The profits of Manufacturer 1 and Retailer 1 will decrease with an increase in the probability of success in green technology innovation $\boldsymbol{\beta}$. However, these profits increase with an increase in the degree of risk aversion $\boldsymbol{\lambda}$. (4) The profits of Manufacturer 2 and Retailer 2 will increase with an increase in the probability of success in green technology innovation $\boldsymbol{\beta}$. However, these profits will decrease with an increase in the degree of risk aversion $\boldsymbol{\lambda}$.

In Mode C: (1) As the probability of success in green technology innovation β increases, the level of investment in green technology innovation e^{C*} and the wholesale price w_2^{C*} will initially increase and then decrease, while the order quantity q_2^{C*} will decrease. At the same time, the wholesale price w_1^{C*} will increase, but the order quantity q_1^{C*} will initially decrease and then increase. (2) With an increase in the probability of success in green technology innovation β, the profits of traditional product Retailer 1 and green product Retailer 2 will initially decrease and then increase, while the profit of traditional product manufacturer 1 will increase and the profit of green product manufacturer 2 will decrease. (3) With an increase in the degree of risk aversion λ, the order quantity q_2^{C*}, wholesale price w_2^{C*}, and profit of green product Manufacturer 2 will decrease. When the probability of success in green technology innovation β is low, the order quantity q_1^{C*}, wholesale price w_1^{C*}, profits of traditional product Manufacturer 1 and Retailer 1 will increase with an increase in the degree of risk aversion λ, but the level of investment in green technology innovation e^{C*} will decrease. On the other hand, when the probability of success in green technology innovation β is high, the situation is reversed.

Table II: Impact of $\boldsymbol{\lambda}$ and $\boldsymbol{\beta}$ on decision-making and profits.

$\boldsymbol{\beta}$	$\boldsymbol{\lambda}$	q_1^{B*}	q_2^{B*}	w_1^{B*}	w_2^{B*}	e^{B*}	π_{M1}^{B*}	π_{M2}^{B*}	π_{R1}^{B*}	π_{R2}^{B*}
0.3	0.5	7.49	15.28	16.65	31.87	9.45	109.77	122.60	56.15	74.61
	1	7.53	15.00	16.73	31.32	9.28	110.92	118.11	56.73	76.46
	1.5	7.57	14.71	16.80	30.76	9.10	112.07	113.71	57.32	78.19
0.6	0.5	6.16	17.17	14.04	35.56	21.25	74.11	273.52	37.91	187.15
	1	6.22	16.85	14.16	34.94	20.85	75.66	263.50	38.70	190.59
	1.5	6.28	16.53	14.29	34.32	20.46	77.22	253.68	39.50	193.78
0.9	0.5	4.44	19.59	10.69	40.30	36.37	38.60	463.78	19.75	363.11
	1	4.54	19.23	10.87	39.60	35.70	40.28	446.80	20.60	367.44
	1.5	4.63	18.87	11.06	38.89	35.02	41.99	430.13	21.48	371.36
$\boldsymbol{\beta}$	$\boldsymbol{\lambda}$	q_1^{C*}	q_2^{C*}	w_1^{C*}	w_2^{C*}	e^{C*}	π_{M1}^{C*}	π_{M2}^{C*}	π_{R1}^{C*}	π_{R2}^{C*}
0.3	0.5	7.25	14.71	15.45	35.85	14.09	97.53	117.67	52.54	47.95
	1	7.29	14.44	15.54	35.23	13.83	98.83	113.35	53.24	50.78
	1.5	7.34	14.17	15.63	34.60	13.57	100.14	109.12	53.95	53.47
0.6	0.5	6.53	3.08	18.10	62.75	19.77	105.20	49.56	42.70	-105.55
	1	6.57	3.02	18.19	61.64	19.41	106.38	47.76	43.18	-91.45
	1.5	6.61	2.96	18.28	60.52	19.04	107.56	45.99	43.65	-77.82
0.9	0.5	10.30	1.75	23.85	44.97	-12.41	224.96	42.91	106.03	331.10
	1	10.28	1.71	23.81	44.18	-12.18	224.09	41.34	105.62	336.58
	1.5	10.26	1.68	23.76	43.38	-11.96	223.23	39.80	105.21	341.61

5. CONCLUSION

This study analyses two competing manufacturing supply chains – one producing traditional products and one capable of also manufacturing green technology innovation products. However, high production costs financially constrain green tech product manufacturers. They can seek external financing from third-party institutions (e.g. banks) or internal financing from retailers. This research explores no financing, internal financing, and external financing models within a Stackelberg game framework led by the manufacturer. Specifically, it examines the financing strategies of the green tech Manufacturer 2 and the impacts of successful innovation probability and Retailer 2's risk aversion towards unproven products on participant decision-making and profits. Key findings are:

(1) Retailer 1 (Manufacturer 1) in the traditional product chain has the highest order quantity (wholesale price) under no financing, while order quantities under the other two financing models depend on the green innovation success probability and Retailer 2's risk tolerance. Meanwhile, Retailer 2 (Manufacturer 2) has different order quantity rankings among financing models contingent on its risk appetite and success probability, resulting in three or six distinct rankings. Additionally, the green innovation investment level relies on the success probability and Retailer 2's risk profile, yielding two ranking scenarios between internal and external financing.

(2) The profits of traditional Manufacturer 1 and Retailer 1 vary by financing model as determined by the likelihood of a successful green technology launch and risk preferences of Retailer 2, with four identifiable profit ranking combinations.

(3) Manufacturer 2's optimal decisions around producing either traditional or green innovations and financing approach are impacted by success probability and Retailer 2's risk

disposition. This yields four distinguishable Manufacturer 2 profit-ranking arrangements across financing models. Furthermore, Retailer 2 sees three possible profit ranking permutations under the three financing options depending on innovation success odds and its risk orientation.

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