Pricing and coordination in green supply chains: The impact of overconfident retailers under reference price effect

Abstract: Given consumers' growing preference for sustainable products and the impact of reference prices, supply chain firms often exhibit notable overconfidence when determining optimal pricing and product greenness. Investigating how this overconfidence, influenced by reference price, shapes green supply chain operations can provide effective strategies for fostering collaboration. A Stackelberg game framework is used to develop models for centralized decisions, decentralized decisions and revenue-sharing contract. Additionally, we derive optimal pricing strategies across different models and improves the supply chain coordination by using a revenue-sharing contract mechanism. The results indicate that retailers' overconfidence, when shaped by reference pricing perceptions, adversely affects green product adoption. As overconfidence intensifies, wholesale and retail prices, product greenness, and manufacturer profits decline, whereas retailer profits initially rise before ultimately falling. Implementing revenue-sharing agreements improves overall supply chain profitability, mitigates overconfidence, and facilitates coordination. These findings offer strategic guidance for green supply chain firms, particularly in contexts where overconfidence and reference price considerations are pivotal.

Keywords: Supply chain management; Reference price effect; Overconfidence; Pricing; Coordination

1 Introduction

The challenges of resource depletion, energy shortages, and recurring haze caused by economic growth have become more severe, making green development a shared global priority (Demirbaş & Deniz, 2024; Zhou et al., 2020). Green innovation provides enterprises with an effective means to reduce environmental harm (Awan et al., 2021). To address these concerns, governments across the world have enacted various laws, regulations, and policies to incentivize businesses to incorporate environmental considerations into their management strategies (Begum et al., 2022; Habib, 2023). As a result, companies are increasingly adopting eco-friendly production techniques and pursuing long-term sustainability initiatives (Hou et al., 2024).

In green manufacturing, some companies utilize precise market analysis to gauge consumer interest in eco-friendly products and effectively attract buyers. However, others overestimate market potential due to unwarranted confidence in green product demand, resulting in overproduction, profit declines, and even financial collapse (Zhou et al., 2022). For example, the China Association of Automobile Manufacturers reported that by late 2020, China's production capacity for new energy vehicles skyrocketed to 26.69 million units, while actual sales amounted to just 1.367 million units, revealing a substantial misjudgment of market demand (Zou et al., 2024). Likewise, LDK Solar, formerly the world's leading polysilicon wafer producer, faced bankruptcy and corporate restructuring after its founder's excessive optimism about the green market led to severe overcapacity and cumulative losses exceeding 20 billion yuan (Liu et al., 2019). These instances demonstrate that overconfidence not only weakens individual enterprises but also destabilizes the broader green product sector (Gong et al., 2024).

Consumer behavior is a crucial determinant when assessing demand for green products, with the reference price effect heavily influencing corporate strategies (Zhang et al., 2023). This effect arises from consumers' reliance on past pricing experiences, which strongly shape their purchasing decisions (Cao & Duan, 2020). With the growing prevalence of e-commerce platforms, price transparency has improved, further intensifying how reference pricing impacts demand for sustainable products (Feng & Li, 2023). As a result, predicting green market demand becomes increasingly challenging. Additionally, for firms exhibiting overconfidence, errors in demand forecasting can result in substantial financial setbacks.

However, the influence of consumer reference pricing on overconfidence has been largely overlooked in most studies. To address this problem, this research examines pricing strategies within green supply chains, incorporating both overconfidence and reference price. In line with this objective, we define the key research questions explored in this paper:

(1) What are the equilibrium conditions for the green supply chain when retailers display overconfidence influenced by reference pricing?

(2) Compared to an integrated decision-making model, how does retailer overconfidence, shaped by

reference price perception, affect pricing, product greenness, and profitability?

(3) What measures can be adopted to regulate retailer overconfidence within a reference pricing framework?

To analyze these research issuses, a green supply chain framework was created. Within this setting, the manufacturer oversees green product production, determines wholesale pricing, and establishes the greenness level. The retailer acquires products from the manufacturer, determines selling prices. Applying a backward method, the optimal solutions across various model scenarios could be obtained. Additionally, to assess how retailer overconfidence interacts with reference price perceptions, we develop both integrated and decentralized models. A comparative examination of these models examines how retailer overconfidence influences pricing strategies, product greenness, and member profits. Lastly, a revenue-sharing mechanism is introduced to counteract the adverse effects of retailer overconfidence within a reference price effect environment. Through numerical simulations, we validate the contract's effectiveness in enhancing overall performance.

The organization of this study is outlined as follows: The second part explores the theoretical foundation, while the third part presents an in-depth review of related literature. The fourth section details the research approach and modeling framework. The fifth section showcases numerical findings. The sixth section delves into theoretical contributions, managerial insights, and study limitations. Finally, the seventh section presents the conclusions.

2 Theoretical backgrounds

This research builds upon the Stackelberg game framework, originally introduced by Heinrich Freiherr von Stackelberg in 1934 (Yue & You, 2014). As a form of sequential decision-making model (Khanlarzade & Farughi, 2024). It characterizes interactions where a dominant player acts first, followed by subordinate players who adjust their strategies accordingly (Mahato et al., 2024). The Stackelberg approach is widely used as a solution to represent the link between supply chain members (Choudhury et al., 2023; Khalafi et al., 2024).

Recent studies employ Stackelberg game theory to tackle challenges in pricing (Januardi et al., 2024; Sadrabadi et al., 2024; Zhao et al., 2024) and coordination (Assarzadegan et al., 2023; Zou et al., 2020) within supply chain operations. In the realm of pricing, Zhang et al. (2022) examines effect of live-streaming service spillover on pricing strategies in dual-channel e-commerce. Huang et al. (2023) investigates the pricing decisions of logistics firms operating under carbon cap-and-trade regulations within a Stackelberg framework. Gharegozlu et al. (2024) applies this game-theoretic approach to analyze location-based pricing strategies in two-tier distribution networks. Regarding coordination, Jiang et al. (2023) explores how varying hierarchical structures influence supply chain collaboration in prefabricated construction. Asghari et al. (2022) studies cooperative mechanisms in green closed-loop supply chains through Stackelberg modeling, while Vazifeh et al. (2023) proposes its application for optimizing biomass supply chain coordination.

3 Literature review

3.1 Green supply chain decision-making

As global governments increasingly focus on ecological issues, sustainable supply chain management continues to be emphasised (Awan et al., 2023; Habib, 2022; Yao & Shao, 2025). The primary goal is to mitigate negative impact of the environment (Khan et al., 2024; Okay et al., 2024). The works of green supply chain have been explored, focusing on both single-channel decisions (Awan, 2019; Habib & Mourad, 2024; Shetty et al., 2024) and dual-channel decision-making (Mondal & Giri, 2022; Nersesian et al., 2023; Pal et al., 2023).

Regarding single-channel, Bai et al. (2023) investigated financial incentives in single-channel green supply chains. Their study revealed that, under stringent carbon emission regulations, green credit subsidies were ineffective. Zaefarian et al. (2023) explored government intervention on demand disruptions within single-channel green supply chains. Their findings indicated that government support boosts demand for green products, encourages manufacturers to enhance product greenness, and increases profits. In the dual-channel, most scholars focus on the competition and cooperation among members across different channels (Habib et al., 2024; Mandal & Pal, 2023; Yan et al., 2024). Hsieh and Lathifah (2024) examined the spillover effects in dual-channel sustainable supply networks. It was determined that such effects benefit the members of coordinated supply chains. Das et al. (2024) addressed pricing and coordination challenges within a sustainable supply network, a two-part tariff agreement was suggested to enhance coordination.

The above literature has explored green supply chains and provided valuable insights. A common feature across these studies is the assumption that participants in the supply network are entirely rational.. However, in real-world green supply chain operations, members often exhibit behavioral biases that deviate from rational optimal decisions, potentially impacting overall performance. Therefore, incorporating behavioral factors into green supply chain analysis is particularly meaningful.

3.2 Green supply chain with behavior

Regarding behavioral considerations in green supply chains, studies have investigated factors such as risk aversion (Wu et al., 2024; Xia et al., 2023) and fairness concerns (Chen et al., 2024; Song et al., 2024; Sun & Zhong, 2023), which are not addressed here. Additionally, the literature has explored decision-making in supply chains influenced by overconfidence (Lu et al., 2023; Xiang et al., 2024; Xu et al., 2022).

Overconfidence, as defined by Moore and Healy, has become a widely accepted concept. They identified three distinct types of overconfidence. The first is overestimation, the second is overplacement, and the third is overprecision. Overestimation refers to the tendency to overrate the outcomes of one's actions, overplacement is the belief of being superior to others, and overprecision involves having an unjustified level of confidence in predicting uncertain outcomes (Moore & Healy, 2008).

Building on the definition of overconfidence, recent research has increasingly explored its effects on green supply chains. Wang and Liu (2023) introduced overconfidence in a competitive channel, finding that overconfident behavior by retailers tends to increase product retail prices and boost the profits of their competitors. Zou et al. (2024) analyzed the financing approaches of overconfident manufacturers in green supply chains, discovering that overconfidence has a detrimental effect on green investments, regardless of whether the financing model is based on bank loans or equity. Sun et al. (2023) analyzed overconfidence on decisions regarding emission reductions in supply chains, finding that both manufacturer and retailer overconfidence lead to diminished profits for retailers.

Previous studies have examined overconfidence behavior from various perspectives, yet few have explored its interaction with consumer behavior in the context of supply chains. Consumer behavior adds complexity to green demand information, making it more challenging for supply chain members to predict market demand accurately, thereby increasing the overconfidence behavior. Thus, this research explores how overconfidence behavior influences sustainable supply networks within the framework of the reference price effect. This analysis aims to help supply chain members better understand market demand and provide reference for pricing strategies.

3.3 Reference price effect

Our study is also connected to the consumer reference price effect. Recent works have explored this effect (Dang et al., 2024; Jiang et al., 2024). Feng and Li (2023) developed three green supply chain decision models, incorporating manufacturer, retailer, and overall fairness concerns under the reference price effect. They discovered that fairness concerns and reference price effect coefficients significantly affect product pricing and greenness levels.Under the consumer reference price effect Huang et al. (2024) examined subsidy strategies, concluding that R&D subsidies to manufacturers are advisable. Ma et al. (2020) analyzed the trade-in strategy for recycled products considering dual reference price effects, with findings indicating that lower unit costs benefit manufacturers under such effects.

While pricing strategies on the consumer reference price effect has been widely explored, this study considers overconfidence and reference price effects in the coordination problem under green supply chains. Specifically, our focus is on the design of coordination contracts to manage overconfidence behavior effectively. By implementing such contracts, both member profits and product greenness can be improved.

3.4 Differences and contributions

Existing literature has explored several aspects related to this study. Table 1 provides an analysis of this study in relation to other works. As indicated in Table 1, this study makes notable contributions in three key areas:

First, although overconfidence behavior has become an important topic within sustainable supply networks, its impact under consumer reference pricing influences are still underexplored. Our research fills this gap by investigating overconfidence behavior within green supply chains under the influence of consumer reference price effects, thereby advancing integration in green supply chain management and behavioral operations research. Second, traditional studies in supply chain management often concentrate on member profits without considering environmental impacts. With increasing regulatory demands and heightened consumer awareness of environmental issues, promoting green investments and improving product greenness are now crucial corporate responsibilities. This study aims to enhance supply chain member profits and optimizes green investment strategies. Finally, whereas earlier studies on the reference price effect have mainly concentrated on pricing tactics, there has been limited exploration of coordination mechanisms. We introduce a revenue-sharing contract designed to manage overconfidence behavior among retailers under reference price effects. By supporting decision-making, this mechanism promotes stronger collaboration between manufacturers and retailers, leading to enhanced overall green supply chain performance.

Table 1 Related works on the study of overconfidence and reference price effect.

Related paper	Green technology	Reference price	Over confidence	Price strategy	Coordination
Sang and Zhang (2020)	√	√		√	√
Shi et al. (2022)		√		√	
Yu and Sun (2022)	√		√	√	
Zhou (2022)	√		√	√	
Zhou et al. (2022)	√		√	√	√
Dai et al. (2023)	√	√		√	√
Lin and Wu (2023)	√	√		√	√
Li and Shan (2023)	√			√	
Bai et al. (2023)	√			√	
Ganguly et al. (2023)	√		√	√	
Hou et al. (2023)	√			√	√
Wang and Liu (2023)			√	√	
Feng and Li (2023)	√	√		√	
Dang et al. (2024)		√		√	
Huang et al. (2024)	√	√		√	

Saha et al. (2024)	√			√	√
Huang and Lu (2024)	√			√	√
Chen et al. (2024)	√			√	
Gong et al. (2024)	√		√	√	
Xiang et al. (2024)			√	√	
This paper	√	√	√	√	√

4 Methodology

This study employs the Stackelberg game method, which is widely used in non-cooperative games (Ziaei et al., 2024). The game between the manufacturer and the retailer regarding pricing decisions is displayed in Figure 1.

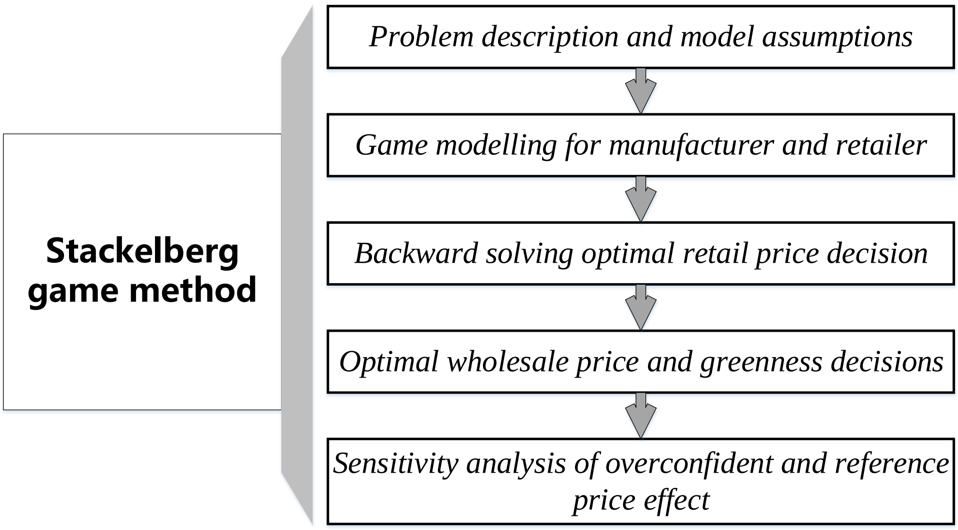

Fig 1. Research methodology.

As illustrated in Figure 1, this research models a strategic interaction where the manufacturer assumes the leadership role, while the retailer follows. The manufacturer determines both the wholesale pricing and product greenness levels, whereas the retailer sets the final selling price. Additionally, Table 2 presents a comparative analysis of previous studies employing the Stackelberg framework, evolutionary dynamics, and Nash equilibrium models, reinforcing the appropriateness of this approach.

Table 2 Comparison of different game models.

Study	Application	Methodology
Gharegozlu et al. (2024)	Location-pricing problem	Stackelberg game
Huang et al. (2023)	Pricing strategies of risk-averse logistics firms	Stackelberg game
Sadrabadi et al. (2024)	Optimal pricing approach within a closed-loop supply network	Stackelberg game
Ning and Xiong (2024)	Dynamic evolution process of the digital transformation	Evolutionary game
Xu et al. (2024)	Influence of equity considerations on resource allocation choices	Evolutionary game

Li et al. (2023)	Evolutionary game dynamics among platform enterprises, governmental bodies,	Evolutionary game
Chu et al. (2024)	Dynamic bargaining model for allocating carbon emissions reduction using DEA	Nash equilibrium game
Wang et al. (2024)	Improved capsule networks for malicious code classification	Nash equilibrium game
Gopalan et al. (2024)	Cognitive radio spectrum allocation	Nash equilibrium game

In a decentralized decision framework, both the manufacturer and retailer independently strive to optimize their own profits, leading to a competitive, non-cooperative setting. This lack of coordination often yields lower overall profitability than a centralized approach. Within this study, the manufacturer takes on the leadership role, while the retailer responds accordingly. Furthermore, this study uses centralized decision-making as a benchmark and introduces a revenue-sharing contract to optimize the green supply chain system, aiming to enhance overall efficiency and coordination.

This research involves a two-stage green supply chain. Comparable to Pal et al. (2023), the producer develops environmentally friendly products. When designing these sustainable offerings, taking automotive greenization as an example, traditional technologies require additional equipment, materials, and parts, increasing the cost per vehicle. These products are considered cost-intensive green products. In contrast, electric vehicles rely on R&D for green propulsion, and these green products are R&D-intensive (Zhu & He, 2017). This study focuses on R&D-intensive green products.

4.1 Model assumptions

To examine how retailer overconfidence and the reference price effect influence supply chain member profitability, the study establishes the following assumptions.

Assumption 1. According to Ghosh and Shah (2015), consumer demand is affected by product greenness, with higher greenness levels driving an increase in market demand. Market demand influenced by greenness is $\alpha - \beta p + k\theta$ (Dey et al., 2019; Raj et al., 2018; Shen, 2024). Additionally, reference price effect impacts product demand (Dang et al., 2024). When the reference price is higher than the retail price, consumer demand rises; conversely, if the reference price falls below the retail price, demand declines (Zhang et al., 2023). This effect is $\lambda(p-r)$ (Zhang & Chiang, 2020). Therefore, the demand of our research is $q = \alpha - \beta p + k\theta - \lambda(p-r)$.

Assumption 2. The greenness of products is closely associated with manufacturers' R&D investments (Gupta et al., 2023). The cost $c(\theta)$ is represented as a quadratic function based on the level of product greenness θ, i.e., $c(\theta) = \eta\theta^2 / 2$ (Cai & Jiang, 2023). This assumption adequately illustrates the diminishing marginal returns of green innovation investments (Ma et al., 2019).

Assumption 3. Green demand is influenced by overconfidence behavior (Wei et al., 2023). Overconfident retailers believe that market demand q is more sensitive to product greenness than it actually is, i.e., $(1+\delta)k\theta$ (Zhang et al., 2023), where $\delta(0 \le \delta \le 1)$ represents the degree of overconfidence in retailers. A greater value of δ indicates a higher degree of retailer overconfidence. Specifically, $\delta = 0$ indicates that retailers do not exhibit overconfidence, while $\delta = 1$ represents complete overconfidence in retailers.

Assumption 4. Information is perfectly shared between suppliers and sellers. Both engage in a Stackelberg competition, striving to optimize their earnings. The supplier holds a dominant position in the supply chain, and the retailer acts as a follower (Barman et al., 2023; Maihami & Ghalehkhondabi, 2022).

The symbols and variables for this research are presented in Table 3.

Table 3 Symbols and variables.

Notations Descriptions			
c	Unit product cost	β	Retail price to demand sensitivity
w	Wholesale price, decision variable	δ	Level of retailer overconfidence
p	Retail price, decision variable	k	Product greenness to demand sensitivity
θ	Product greenness, decision variable	λ	Reference price to demand sensitivity
q	Market demand	η	Product greenness to cost sensitivity
$c(\theta)$	Green input costs of manufacturers	π_{r}	Retailer profit
r	Consumers' unit reference prices for green products	π_{m}	Manufacturer profit
α	Market scale	π_{sc}	Total profit

In the two-stage supply chain, the manufacturer determines the wholesale price and product greenness, while the retailer determines the retail price, similar to Tirkolaee et al. (2020). The game sequence for centralized and decentralized decision-making is shown in Fig 2.

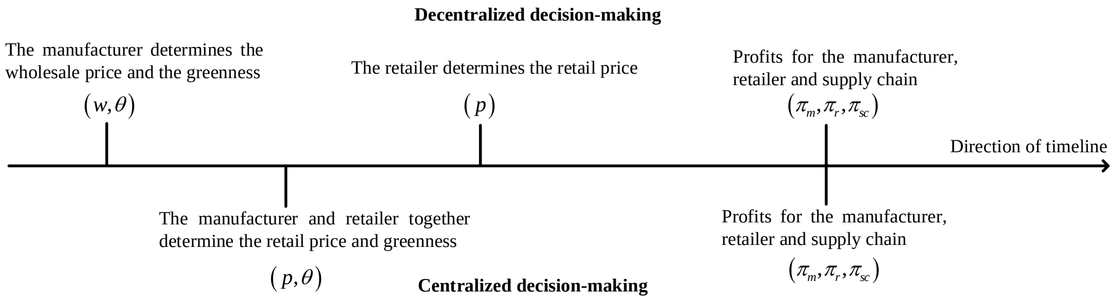

Fig 2. Timeline of the game sequence for decentralized (top), and centralized (bottom) decision-making.

For the analysis, table 4 lists the correspondence between models and symbols.

Table 4 Model symbols.

Symbol	Description	Symbol	Description
m	Manufacturer	C	Centralized
r	Retailer	D	Decentralized
sc	Supply Chain	RS	Revenue-sharing contract

4.2 Centralized decision-making

Under centralized decision-making, the manufacturer and the retailer exhibit no overconfidence behavior and work together to maximize profits. The manufacturer and retailer jointly decide on the product's greenness θ and retailer price p. Keep in mind that wholesale price w is not independently determined when the manufacturer and retailer are analyzed as a unified entity. Under these circumstances, Equation (1) defines the overall earnings of the supply chain.

$$\pi_{sc} = (p-c)(\alpha - \beta p + k\theta - \lambda(p-r)) - \frac{1}{2}\eta\theta^2 \tag{1}$$

Proposition 1 In a centralized framework, if $k^2 < 2\lambda\eta + 2\beta\eta$, the overall revenue generated by the supply network reaches its optimal solution. The optimal decisions are shown in Equations (2) and (3).

$$p^C = \frac{\eta(\alpha + r\lambda - c\lambda - c\beta)}{2\lambda\eta + 2\beta\eta - k^2} + c \tag{2}$$

$$\theta^C = \frac{k(\alpha + r\lambda - c\lambda - c\beta)}{2\lambda\eta + 2\beta\eta - k^2} \tag{3}$$

Further substituting p^C and θ^C back into Equation (5), the optimal total profit π_{sc}^C is expressed as shown in Equation (4).

$$\pi_{sc}^C = \frac{\eta(c\lambda + c\beta - \alpha - r\lambda)^2}{2(2\lambda\eta + 2\beta\eta - k^2)} \tag{4}$$

4.3 Decentralized decision-making

In a decentralized framework, the producer does not exhibit overestimation tendencies, while the seller overestimates the environmental attributes of the product. The extent of this overconfidence is represented by δ. Equations (5) and (6) illustrate the earnings of both the seller and the producer. η θ

$$\pi_r = (p-w)(\alpha - \beta p + (1+\delta)k\theta - \lambda(p-r)) \tag{5}$$

$$\pi_m = (w-c)(\alpha - \beta p + k\theta - \lambda(p-r)) - \frac{1}{2}\eta\theta^2 \tag{6}$$

Proposition 2 In a decentralized setting, the supply network reaches an optimal outcome. The optimal decisions are given by Equations (7), (8), and (9).

$$w^D = \frac{2\eta(\alpha + r\lambda - c\lambda - c\beta)}{L} + c \tag{7}$$

$$\theta^D = \frac{k(1-\delta)(\alpha + r\lambda - c\lambda - c\beta)}{L} \tag{8}$$

$$p^D = \frac{(\alpha + r\lambda - c\lambda - c\beta)(3\lambda\eta + 3\beta\eta + k^2\delta - k^2\delta^2)}{(\lambda+\beta)L} + c \tag{9}$$

where, $L = 4\lambda\eta + 4\beta\eta - k^2\delta^2 + 2k^2\delta - k^2$.

Further substituting w^D, θ^D, and p^D back into Equations (5) and (6), the optimal profits for the supply chain members are expressed as shown in Equations (10), (11), and (12).

$$\pi_r^D = \frac{\left(\alpha + r\lambda - c\lambda - c\beta\right)^2 \left(\lambda\eta + \beta\eta + k^2\delta - k^2\delta^2\right)^2}{\left(\lambda + \beta\right)L^2} \tag{10}$$

$$\pi_m^D = \frac{\eta\left(\alpha + r\lambda - c\lambda - c\beta\right)^2}{2L} \tag{11}$$

$$\pi_{sc}^D = \frac{\left(\alpha + r\lambda - c\lambda - c\beta\right)^2 A}{\left(2\lambda + 2\beta\right)L^2} \tag{12}$$

where, $A = 2k^4\delta^4 - 4k^4\delta^3 + 2k^4\delta^2 + \left(\lambda\eta + \beta\eta\right)\left(6k^2\delta - 5k^2\delta^2 - k^2\right) + 6\eta^2\left(\lambda + \beta\right)^2$.

Proposition 3 Under centralized model, π_{sc}^C is bigger than π_{sc}^D under decentralized model.

Proof: Equation (13) is obtained by subtracting the π_{sc}^C from π_{sc}^D.

$$\pi_{sc}^C - \pi_{sc}^D = \frac{\left(\alpha + r\lambda - c\lambda - c\beta\right)^2 \left(B + F + G\right)}{\left(2\lambda + 2\beta\right)\left(2\lambda\eta + 2\beta\eta - k^2\right)L} \tag{13}$$

where, $B = 2k^2\delta^2\left(1 - 2\delta\right) + k^4\delta^3\left(\lambda\eta + \beta\eta\right)\left(4 - 3\delta\right) + k^4\delta\left(\lambda\eta + \beta\eta\right)\left(2 - 3\delta\right)$,

$F = 2k^6\delta^4 + 2k^2\delta^2\beta^2\eta^2 + 4k^2\beta^2\delta\eta^2 + 4k^2\lambda\beta\delta^2\eta^2 + 8k^2\lambda\beta\delta\eta^2 + 2k^2\lambda^2\delta^2\eta^2$,

$G = 4k^2\lambda^2\delta\eta^2 + 4\beta^3\eta^3 + 12\lambda\beta^2\eta^3 + 12\lambda^2\beta\eta^3 + 4\lambda^3\eta^3$。

According to assumption $0 \le \delta \le 1$, we get $B + F + G > 0$. Further combining with assumption $k^2 < 2\lambda\eta + 2\beta\eta$, we get $\pi_{sc}^C - \pi_{sc}^D > 0$. Proposition 3 is proved.

Property 1 Under decentralized decision-making, the wholesale price w^D, product greenness θ^D, and retail price p^D negatively correlate with the retailer's overconfidence level δ.

Proof: To determine how w^D, θ^D, and p^D change with the retailer's overconfidence level δ, we take the partial derivatives of Equations (7), (8), and (9) concerning the retailer's overconfidence. Thus, we have:

$$\frac{\partial w}{\partial \delta} = \frac{4k^2\eta\left(\delta - 1\right)\left(\alpha + r\lambda - c\lambda - c\beta\right)}{L^2} < 0$$

$$\frac{\partial \theta}{\partial \delta} = -\frac{k\left(\alpha + r\lambda - c\lambda - c\beta\right)\left(4\lambda\eta + 4\beta\eta + k^2\left(1 - \delta\right)^2\right)}{L^2} < 0$$

$$\frac{\partial p}{\partial \delta} = -\frac{k^2(\alpha + r\lambda - c\lambda - c\beta)\left(k^2(1-\delta)^2 + 2\eta(\lambda+\beta)(1+\delta)\right)}{(\lambda+\beta)L^2} < 0$$

Property 1 is proven.

4.4 Revenue-sharing contract

Under the revenue-sharing contract, the retailer allocates a specific proportion g of earnings to the manufacturer. The retailer's per-unit earnings from environmentally friendly products are denoted as $(1-g)p - w$, while the manufacturer's per-unit earnings from these products are labeled as $w - c + gp$. Equations (14) and (15) illustrate the earnings of both parties within this revenue-sharing framework.

$$\pi_r = \left((1-g)p - w\right)\left(\alpha - \beta p + (1+\delta)k\theta - \lambda(p-r)\right) \tag{14}$$

$$\pi_m = (w - c + gp)\left(\alpha - \beta p + k\theta - \lambda(p-r)\right) - \frac{1}{2}\eta\theta^2 \tag{15}$$

Proposition 4 Within the revenue-sharing framework, the supply network attains an optimal outcome. The optimal decisions are shown in Equations (16), (17), and (18).

$$w^{RS} = \frac{(\lambda+\beta)\left(ck^2g^2\delta - ck^2g\delta + ck^2g\right) - 2c\eta(\lambda+\beta)^2 + (\alpha + r\lambda)M_1}{(\lambda+\beta)M} + c \tag{16}$$

$$\theta^{RS} = \frac{k(g\delta - \delta + 1)(\alpha + r\lambda - c\lambda - c\beta)}{M} \tag{17}$$

$$p^{RS} = \frac{(\alpha + r\lambda - c\lambda - c\beta)\left(\delta^2k^2(2g - g^2 - 1) + \delta k^2(1-g) + +(\lambda+\beta)\eta(3-2g)\right)}{(\lambda+\beta)M} + c \tag{18}$$

where, $M = -k^2g^2\delta^2 + 2gk^2\delta^2 - 2gk^2\delta - 2g\lambda\eta - 2g\beta\eta - k^2\delta^2 + 2k^2\delta - k^2 + 4\lambda\eta + 4\beta\eta$,

$M_1 = k^2g^3\delta^2 - k^2g^2\delta^2 + k^2g^2\delta + gk^2\delta^2 - gk^2\delta + \left(2g^2\eta - 4g\eta + 2\eta\right)(\lambda+\beta)$ 。

Furthermore, substituting w^{RS}, θ^{RS}, p^{RS} back into Equations (14) and (15), the optimal profits are shown in Equations (19), (20), and (21).

$$\pi_r^{RS} = \frac{(1-g)(\alpha + r\lambda - c\lambda - c\beta)^2\left(gk^2\delta^2 - k^2\delta^2 + k^2\delta + \lambda\eta + \beta\eta\right)^2}{(\lambda+\beta)M^2} \tag{19}$$

$$\pi_m^{RS} = \frac{\eta(\alpha + r\lambda - c\lambda - c\beta)^2}{M} \tag{20}$$

$$\pi_{sc}^{RS} = \frac{(\alpha + r\lambda - c\lambda - c\beta)^2\left((\lambda+\beta)k^2\eta M_2 + k^4M_3 + (\lambda+\beta)^2\eta^2(4g-6)\right)}{(2\lambda + 2\beta)M} \tag{21}$$

where, $M_2 = 5g^2\delta^2 - 10g\delta^2 + 6g\delta + 5\delta^2 - 6\delta + 1$,

$$M_3 = 2g^3\delta^4 - 6g^2\delta^4 + 4g^2\delta^3 + 6g\delta^4 - 8g\delta^3 + 2g\delta^2 - 2\delta^4 + 4\delta^3 - 2\delta^2$$ 。

Proposition 5 The profits satisfy: $\pi_m^{RS} > \pi_m^D$, $\pi_r^{RS} > \pi_r^D$, $\pi_{sc}^{RS} > \pi_{sc}^D$.

Proof: Equations (22), (23), and (24) are derived by analyzing the optimal choices within the revenue-sharing framework in relation to those in a decentralized decision-making structure.

$$\frac{\pi_m^{RS}}{\pi_m^D} - 1 = \frac{g\left(gk^2\delta^2 - 2k^2\delta^2 + 2k^2\delta + 2\lambda\eta + 2\beta\eta\right)}{M} > 0 \tag{22}$$

$$\frac{\pi_r^{RS}}{\pi_r^D} - 1 = \frac{gM_4}{\left(-k^2\delta^2 + k^2\delta + \lambda\eta + \beta\eta\right)^2 M^2} > 0 \tag{23}$$

$$\pi_{sc}^{RS} - \pi_{sc}^D = \left(\pi_m^{RS} + \pi_r^{RS}\right) - \left(\pi_m^D + \pi_r^D\right) > 0 \tag{24}$$

where M_4 is a complex polynomial. In simplifying M_4, the positive terms are much bigger than the negative ones. Proposition 5 is proven.

Property 2 w^{RS}, θ^{RS}, and p^{RS} negatively correlate with δ.

Proof: To ascertain how w^{RS}, θ^{RS}, and p^{RS} change with δ, we take the partial derivatives of Equations (19), (20), and (21) concerning the retailer's overconfidence δ. Then there are:

$$\frac{\partial w}{\partial \delta} = -\frac{k^2(1-\mathrm{g})(\alpha + r\lambda - c\lambda - c\beta)\begin{pmatrix} k^2\delta\left(-g^3\delta + 2g^2\delta - 2g^2\right) - gk^2(\delta-1)^2 \\ +(\lambda+\beta)\eta(4g\delta - 4g - 4\delta + 4) \end{pmatrix}}{(\lambda+\beta)M^2} < 0$$

$$\frac{\partial \theta}{\partial \delta} = -\frac{k(1-g)(\alpha + r\lambda - c\lambda - c\beta)\left(4\eta(\lambda+\beta)(2-g) - M\right)}{M^2} < 0$$

$$\frac{\partial p}{\partial \delta} = -\frac{k^2(1-g)(\alpha + r\lambda - c\lambda - c\beta)\left((\lambda+\beta)\eta(6 + 2\delta - 4g - 2g\delta) - M\right)}{(\lambda+\beta)M^2} < 0$$

Property 2 is thus proven.

Property 3 The green supply chain pricing decisions satisfies: $w^D > w^{RS}$, $\theta^{RS} > \theta^D$, $p^{RS} > p^D$.

Proof: Subtracting the wholesale price w^D from w^{RS}, we get:

$$w^D - w^{RS} = \frac{(1-g)M_5}{(\lambda+\beta)M} + \frac{-ck^2\delta^2 + 2ck^2\delta - ck^2 + 2c\lambda\eta + 2c\beta\eta + 2\eta(\alpha + r\lambda)}{L} > 0 .$$

Where, M_5 is the same to M_4. Therefore, $w^D > w^{RS}$. Furthermore, subtracting θ^{RS} from θ^D, we get:

$$\theta^{RS} - \theta^D = \frac{gk(\alpha + r\lambda - c\lambda - c\beta)\left(-gk^2\delta^3 + gk^2\delta^2 + k^2\delta^3 - 2k^2\delta^2 + k^2\delta + 2\eta(\lambda+\beta)(1+\delta)\right)}{LM} > 0 .$$

Thus, $\theta^{RS} > \theta^{D}$. Subtracting p^{RS} from p^{D}, we get:

$$p^{RS} - p^{D} = \frac{g\left(\alpha + r\lambda - c\lambda - c\beta\right)\begin{pmatrix} k^{4}\left(-g\delta^{3} + g\delta^{2} + \delta^{3} - 2\delta^{2} + \delta\right) \\ +\left(\left(\lambda+\beta\right)k^{2}\eta\left(-g\delta^{2} + 2\delta^{2} + 2\right)\right) - 2\eta^{2}\left(\lambda+\beta\right)^{2} \end{pmatrix}}{\left(\lambda+\beta\right)LM} > 0 .$$

Therefore, $p^{RS} > p^{D}$. Property 3 is proven.

5 Results

To further confirm the key findings of this study, we examine how reference price influences and the retailer's overconfidence level affect pricing results. We assign values to the parameters and variables concerning Feng and Li (2023) and Sang and Zhang (2020) to make the variables and parameters reasonable. Parameter settings: $\alpha = 1000$, $\beta = 2$, $c = 6$, $r = 15$, $k = 2$, $\eta = 1$, $\lambda = 0.5$ and $\delta = 0.5$.

5.1 Scenario 1: Results under cost-sharing ratios

Fig 3 shows the range of values g under the revenue-sharing contract.

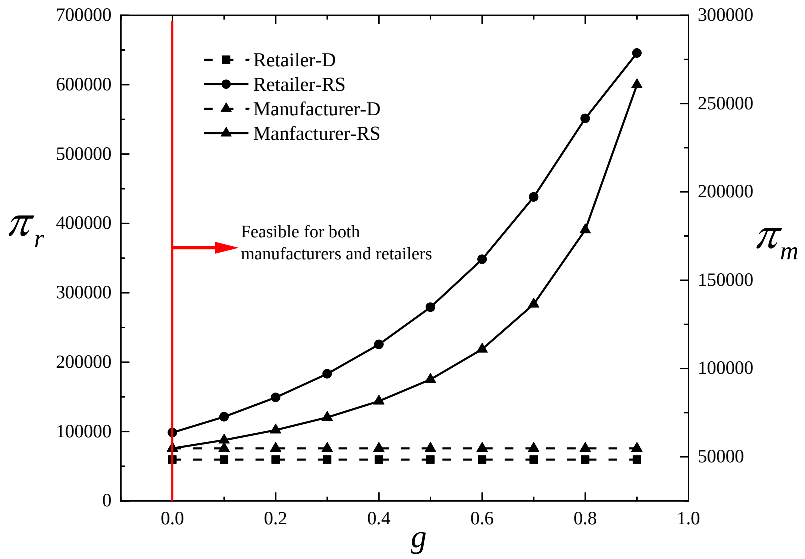

Fig 3. Feasible intervals for the contract parameter g.

As illustrated in Fig. 3, Retailer-D and Manufacturer-D denote the earnings of retailers and manufacturers within a decentralized framework. Similarly, Retailer-RS and Manufacturer-RS signify their respective earnings under a revenue-sharing agreement. The range of contract parameters g is [0, 1]. The viewpoints of both the producer and the seller establish the upper and lower bounds for this parameter. Consequently, we assign $g = 0.5$ within its feasible range to compute other variables.

5.2 Scenario 2: Impact of overconfidence level on pricing, greenness and profits

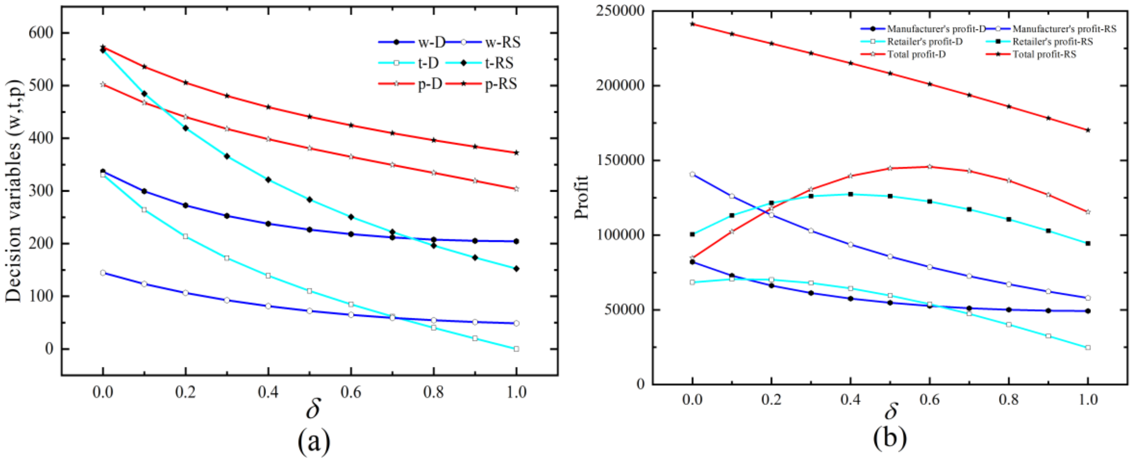

Fig 4. Sensitivity of overconfidence level δ .

Figure 4 illustrates that overconfidence affects decision-makers not only product pricing and greenness but also impacts the profits. In a decentralized decision-making model, overconfidence negatively influences the member decisions, resulting in lower wholesale and retail prices and reducing the greenness. Overconfidence leads decision-makers to overestimate market demand, causing them to make irrational decisions regarding the pricing and production investment in green products. However, under a revenue-sharing contract, while overconfidence still affects pricing and greenness, the contractual mechanism enables manufacturers and retailers to share profits, thereby partially mitigating the negative impact of overconfidence.

5.3 Scenario 3: Impact of λ *and* δ *on supply chain decisions*

Overconfidence behavior influences green supply chain decisions, while consumer reference price effects also play an essential role. Hence, we examine the extent of overconfidence and the influence of reference prices to develop a deeper insight into the study's core issue and explore the proposed model in greater detail.

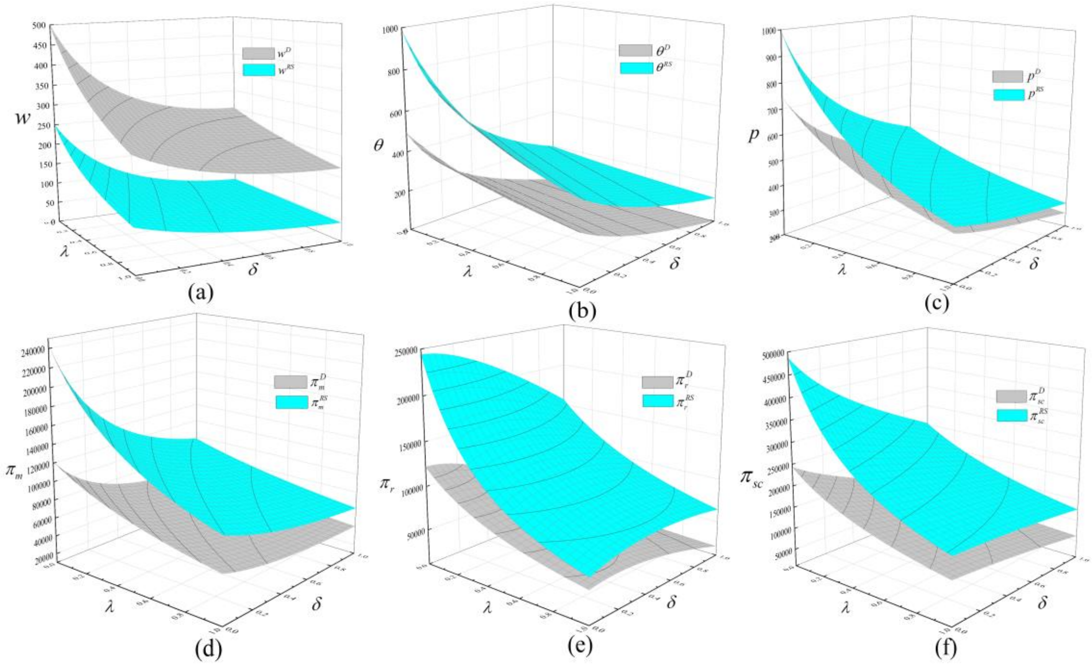

Fig 5. λ and δ impact on decision-making variables.

Figure 5 illustrates how the profit-sharing agreement plays a vital role in reducing the adverse effects of overconfidence influenced by reference pricing. By fostering a stronger connection between producers and sellers, this arrangement promotes greater collaboration and alignment of interests. Within this framework, the wholesale cost is comparatively lower. Manufacturers are willing to reduce prices in exchange for increased retailer sales, while retailers benefit from the lower wholesale price. Due to the revenue-sharing mechanism, both parties' profits are improved. The profit-sharing agreement efficiently directs overconfident participants in the distribution network under the influence of reference pricing.

6 Discussion

6.1 Discussion of findings

This research investigates the pricing and coordination problem in a green supply chain, considering the reference price effect and retailer overconfidence. The results of the study are discussed below: (1) Overconfidence significantly impacts greenness and supply chain profitability. The results show that overconfidence generally reduces product greenness, aligning with the results of Wang et al. (2022). Additionally, overconfidence reduces both member profit and the overall profit, consistent with Wei et al. (2023) and Xiao et al. (2021). However, a key distinction is that low levels of overconfidence can increase the retailer's profit, whereas higher levels lead to a decline, differing from Zou et al. (2024). Future research could explore strategies to mitigate overconfidence. (2) The influence of reference pricing intensifies the adverse effects of overconfidence on pricing strategies. Gong et al. (2024) found that overconfidence reduces profits. However, their analysis did not entirely consider the impact of reference price influences. In comparison, this study reveals that as both reference price effects and overconfidence levels rise, supply chain profits decline significantly, further exacerbating the adverse effects of overconfidence. Future research could further investigate the interactive effects between consumer behavior and overconfidence, which would provide deeper insights into their impact on supply chain pricing decisions. (3) Revenue-sharing contracts reduce wholesale prices while enhancing product greenness and profits. This finding supports prior theoretical studies (Saha et al., 2024), emphasizing the benefits of profit-sharing agreements in coordinating sustainable supply networks. Future research could explore additional contract types that promote collaboration between manufacturers and retailers, as well as foster technological innovation and business practices. (4) The proportion of revenue distribution is a key factor in determining contract efficiency. The findings indicate that raising this ratio is vital for enhancing cooperation between manufacturers and retailers while boosting the performance of sustainable supply networks. Previous theories (Cao & Zhang, 2024; Das et al., 2023) explored revenue-sharing contracts but neglected the effect of sharing ratios, which is further complemented in this paper. Future research could investigate how to adjust the revenue-sharing ratio based on market conditions, as well as dynamic profit-sharing models for different stages of market development, in order to better coordinate manufacturers and retailers and promote the long-term sustainability of green supply chains.

6.2 Theoretical implications

This research provides multiple theoretical insights. We incorporate overconfidence behavior and reference price effects into green supply chains, making it more applicable to complex supply chain scenarios. As consumer behavior increasingly impacts green supply chains, our study will contribute to a more in-depth analysis of decision-making issues in green supply chain management. We integrate relevant theories from game theory, optimization theory, and behavioral economics. Integrating overconfidence and reference price effect sensitivity coefficients into the demand function would be more beneficial in predicting the impact of green consumer behavior on demand. This study enhances supply chain alignment by demonstrating how revenue-sharing agreements enable manufacturers and retailers to foster stronger cooperation. This collaborative approach enhances product greenness and promotes mutual profitability.

6.3 Managerial implications

This research explores the impact of overconfidence on decision-making, considering the effects of reference pricing. The findings yield several practical implications for managing green supply chains:

Overconfidence behavior negatively affects supply chain decisions, which requires increased attention from supply chain members. An excessive degree of overconfidence negatively impacts the sustainability of the supply network and reduces the gains of manufacturers, retailers, and the system as a whole.

Producers and sellers should acknowledge the significant influence of reference pricing on sustainable supply chain decisions. When the impact of reference pricing strengthens, both environmental sustainability and financial returns decline. To counteract this effect, businesses can boost consumer preference for eco-friendly products through strategic advertising and promotional efforts. Government campaigns promoting environmentally friendly products can further incentivize consumers to consume green.

As leaders in the green supply chain, manufacturers should actively enhance cooperation with retailers. The revenue-sharing contract proposed in this research has been shown to improve supply chain profits. Increased collaboration enables manufacturers to receive support from retailers, Encouraging them to manufacture more environmentally friendly products, thus promoting the sustainability objectives of the eco-conscious supply network.

7 Conclusion

With the worsening of environmental pollution, more companies have been actively promoting green production. However, due to uncertainty in consumer demand, firms often exhibit overconfidence in green demand. While manufacturers can attract consumers influenced by the reference price effect by enhancing product greenness, this can also increase production costs. Therefore, manufacturers must balance investments in green products with consumer behavior considerations. To explore this issue, This research constructs a two-level sustainable supply network model to analyze how overconfidence and reference pricing influence pricing strategies and coordination mechanisms within eco-friendly supply systems. This study yields several conclusions, as outlined below:

When considering the reference price effect, retailer overconfidence results in a reduction in the environmental friendliness of the product. Under a revenue-sharing contract, the wholesale price decreases, and product greenness increases. A revenue-sharing contract can efficiently align the supply network when the seller exhibits overconfidence. Therefore, within an eco-friendly supply system, producers and sellers can implement such a contract to enhance profits for both parties and improve product greenness, achieving a mutually beneficial outcome.

Future studies can expand in the following areas. To begin with, this research assumes a deterministic demand function, whereas real-world market environments are often uncertain (Chen et al., 2023). Future studies could explore how stochastic demand conditions affect pricing decisions and overconfidence behavior. Second, this research exclusively examines retailers' overconfidence, while existing research has also examined manufacturers' overconfidence (Gong et al., 2024; Zhou et al., 2012). Since both manufacturers and retailers may exhibit behavioral biases, future research could incorporate overconfidence behavior for both participants in the supply network. Finally, this research utilizes a Stackelberg game model driven by the manufacturer., yet in practice, retailers may also play a dominant role in decision-making (Pokorny & Fiala, 2024). Investigating overconfidence within a retailer-led sustainable supply chain offers a compelling direction.

Data availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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