Sustainable Operations and Computers 5 (2024) 51–59

Contents lists available at ScienceDirect

Sustainable Operations and Computers

journal homepage: http://www.keaipublishing.com/en/journals/sustainable-operations-and-computers/

Eco-label strategy selection for green product development in supply chain

Gaoxiang Lou [a], Ying Zhang [a], Haicheng Ma [b,c,d,*], Xuechen Tu [a], Yi-Ming Wei [b,c,d]

[a] School of Business, East China University of Science and Technology, Shanghai, China
[b] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing, China
[c] School of Management and Economics, Beijing Institute of Technology, Beijing, China
[d] Beijing Key Lab of Energy Economics and Environmental Management, Beijing, China

ARTICLE INFO

Keywords:
Green supply chain
Self-labeling
Certification label
Consumer green awareness
Consumer trust

ABSTRACT

In a supply chain where a supplier and a manufacturer engage in green innovation activities, we apply the Stackelberg game to investigate the influence of consumer trust and consumer green awareness on supply chain performance when employing self-labeling and certification label strategies. Our research delves into the optimal eco-label strategy through comparative analysis, resulting in the following key points: (1) Under the certification label strategy, the manufacturer and supply chain profits may decrease in consumer green awareness. (2) The manufacturer tends to choose self-labeling strategy, but the supplier has higher profits under certification label strategy. (3) The social welfare under the certification label is greater than that of self-labeling when the cost of certification and consumer trust are low. Further, we extend the certification label from single level to multi-level, and found that when the cost coefficient of manufacturer's green investment is high, a high-level certification may be disadvantageous for the manufacturer. In addition, when consumer trust and cost coefficient of manufacturer's green investment are both low, the manufacturer is more likely to preferentially choose multi-level certification label over self-labeling.

Introduction

With growing green awareness, more and more consumers are opting for green products at higher prices [1]. Contrary to quality of product, greenness of product may be difficult to observe, which making it incredibly difficult for companies to communicate the greenness of their products to consumers. As an approach of certifying green performance, eco-label might reduce information asymmetry and encourage green purchasing, and it has become an effective way for companies notifying consumers about the environmental-friendly nature of their products.

Statistics show that more than 25 industries and 199 nations worldwide have established more than 460 different types of eco-labels, including *Nordic Eco-labelling, Energy Star,*and *China's Environmental Protection Product*. These eco-labels are granted by third-party certification organizations and are generally trusted by consumers, that can be seen as certification label. However, certification label has a set certification standard and can only show consumers the product's greenness as it relates to that standard. It is challenging to effectively explain the actual product's greenness and other green attributes. Because of this, the manufacturer who has access to more detailed information about their products have created additional "green symbols" and self-declared the amount of greenness of their products on their packaging. Walmart, for instance, brands their products as "natural" to denote that they are organic or biodegradable. However, consumers frequently view such self-labeling with some skepticism. Therefore, it is important to consider how the distinctive traits of self-labeling and certification label relate to the development of eco-friendly products and the strategic choice of the two forms of eco-labels.

In addition to the single-level eco-label stated above, there are multi-level labels available in the market. For instance, China's *Carbon Label* rating is divided into three levels (one, two, and three stars) based on carbon footprint, *Cradle-to-Cradle* (C2C) is set to five levels (primary, bronze, silver, gold and platinum). The multi-level certification label strategy makes the selection of label strategy for companies become more complex. As a result, we will also pay attention to how certification levels effect companies profits under multi-level certification label strategy.

Our main research questions are: (1) What are the optimal decisions in the supply chain and how do consumer trust and consumer green awareness influence supply chain price decision and the product's greenness? (2) How do different eco-label strategies impact the profitability of members in the supply chain, and how do the manufacturer strategically determine their selection among eco-label strategies? (3) What impact does the choice of different eco-label strategies have on social welfare?

* Corresponding author.
E-mail address: hcm@mail.ecust.edu.cn (H. Ma).

https://doi.org/10.1016/j.susoc.2023.12.003
Received 9 June 2023; Received in revised form 20 October 2023; Accepted 12 December 2023
Available online 17 January 2024

This paper has the following contributions: (1) We investigate the supplier's and manufacturer's cooperative green innovation activities in different eco-label strategies. At the same time, the influence of consumer trust and consumer green awareness on supply chain decision-making is considered. (2) We expand the single-level eco-label to a multi-level eco-label in the study of green supply chain to examine the effects of certification levels on supply chain members' profits and social welfare. This study can serve as a theoretical foundation for supply chain price decision and eco-label strategies selection. It can also provide management advice to certification bodies about multi-level labeling certification.

The rest of this paper is organized as follows. We first begin with a review of the related literature in Section 2 and then describe the main model in Section 3. In Section 4, we extend the certification label from single level to multi-level. Finally, we conclude our results in Section 5. All the proof is presented in the appendix.

Literature review

We sort out the literature on green supply chain, consumer green awareness and consumer trust, and eco-label. In the green supply chain, scholars have widely discussed the greenness decision of products [2–5]. For instance, Ghosh and Shah [6] study the impact of cost sharing pacts on key supply chain decisions in a supply chain consisting of a manufacturer and a retailer where the manufacturer performs green manufacturing. Hong and Guo [7] investigate in a secondary green supply chain consisting of a manufacturer and a retailer coordination efficiency of wholesale price contract, cost-sharing contract and two-part pricing contract. Du et al. [8] consider both suppliers' and manufacturers' equity concern behaviors to study sustainable supply chain green technology innovation decisions. Hong et al. [9] think about consumer reference behavior to study the issue of green product design in a two-level supply chain and find that consumer reference behavior significantly affects product design and pricing.

Consumer green consciousness has been widely concerned [10–14]. For instance, Li et al. [15] study the impact of two widely-adopted contracting formats on supply chain decision making in a decentralized green product supply chain, considering consumer green awareness. Chen and Akmalul'Ulya [16] examine the impact of consumer green awareness and government regulations on manufacturer's green investments. Zhang et al. [17] consider the effects of retailers' fair concern behavior and consumer green awareness on the greenness of product and price. Ge et al. [18] study consumer green awareness and manufacturer equity concerns in a green two-channel supply chain. Hong et al. [19] find that the price of green product decreases as consumer green preference increases. Han et al. [20] find that consumer green sensitivity is not necessarily beneficial for companies to improve the greenness of their product. Heydari et al. [21] also consider consumer green awareness to study green supply chain channel coordination and pricing issues.

However, only a few scholars have considered consumer trust in manufacturers' products in their studies. Murali et al. [14] consider consumer trust into the model to compare the effects of self-labeling and certification label on green product development of two competing firms. Zhang et al. [22] consider consumer green awareness and consumer trust together, study the optimal eco-label strategy in centralized and decentralized supply chains. Different from the above researches, we introduce multi-level certification label into the selection of label strategies.

Some researchers investigate eco-label as a marketing strategy and discover a favorable correlation between eco-label and consumers' propensity to buy environmentally friendly products [23,24]. Some researchers concentrate on the competitive of eco-label certification organizations, the creation of labeling standards, and the choice of companies' label strategies. For example, Heye and Martin [25] study a model of competition among non-profit organizations providing label certification services. Fischer and Lyon [26] propose a model of eco-label competition between non-profit organizations and industry associations. Fan et al. [27] explore equilibrium strategies for eco-label standards with different objectives. Roe and Sheldon [28] compare voluntary and mandatory labeling and find that firms prefer voluntary labeling, while consumers prefer mandatory labeling.

In addition, other scholars research the problem of multilevel eco-label design, such as Nadar and Erturk [29] who construct a two-stage game of greenness investment and quantity competition in a two-oligopolistic market and find that two-level eco-labels outperform single-level labels in some cases. Li and Veld [30] study the implications of eco-label hierarchy and competition and find that label certification organizations sponsored by environmentalists may prefer multi-level label. The preceding literature examines various aspects of eco-label primarily from the perspective of a single firm.

A few scholars combine eco-label with green supply chain. For instance, Guo et al. [31] consider consumer green awareness and a platform to provide eco-label for qualified manufacturers to study how eco-label affects green supply chain operations. Gao et al. [32] explored eco-label strategies for a two-channel supply chain for two cost types of green products. Further, Gao et al. [33] combine eco-label, government subsidies, and supply chain contracts to study the economic and environmental impacts of eco-label policies in supply chain. Hou et al. [34] consider three types of labels, self-labeling, industry labeling and government labeling, and study how government regulations affect the ecolabel strategy selection of supply chain members in the competitive supply chain.

To summarize, the majority of current research on eco-label strategies focuses on individual enterprises, with only a few scholars focusing on supply chain comprised of manufacturers and retailers. However, in supply chains such as automotive and food, the level of product greenness is defined by green investment activity undertaken collaboratively by the supplier and manufacturer. In addition, the existing literature on supply chain eco-label schemes rarely analyzes the impact of multi-level eco-label on supply chain decisions. In order to investigate the effects of two eco-label strategies, self-labeling and certification label, on supply chain green product development and the eco-label strategy selection problem, we build a supply chain game model that takes both the supplier's and manufacturer's green efforts into account. We also expand certification label from single-level to multi-level to explore the effects of label certification levels on supply chain performance.

Model

The supplier and manufacturer work together to produce green products in a supply chain. Self-labeling (S strategy) and certification label (C strategy) are two different eco-label strategies the manufacturer could select to inform consumers about the product's greenness.

Self-labeling strategy differs from certification label strategy in two ways. Firstly, the model setting is different. According to the study by Murali et al. [14], we assume that k represents consumer green awareness and $u(0 \le u \le 1)$ represents consumer trust with self-labeling product. The product's greenness is $g = g_s + g_m$, where g_s is the supplier's green supplying effort and g_m is the manufacturer's green manufacturing effort. Therefore, the market demand of self-labeling strategy is $D^S = 1 - p + ku(g_s + g_m)$. In the certification label strategy, we assume that the manufacturer can meet the certification standard of G. In addition, the greenness of the product is not less than the certification standard, which can be expressed as $g_s + g_m \ge G$. At this moment, the consumer trust $u = 1$ and consumers consciousness of the product's greenness is G. Therefore, the market demand for the certification label strategy is $D^C = 1 - p + kG$.

Secondly, the decision order is different. In the self-labeling strategy, the supplier first decides the green supplying effort and wholesale price, then the manufacturer decides the green manufacturing effort, sale price and selects self-labeling to self-declare the greenness of the product. In

Table 1
Definition of parameters.

Parameters	Meaning
w	Wholesale price of the supplier
p	Sale price of the manufacturer
g_s	Supplier's green supplying effort
g_m	Manufacturer's green manufacturing effort
g	Product's greenness
G	Certification standard
a	Cost coefficient of supplier's green investment
b	Cost coefficient of manufacturer's green investment
k	Consumer green awareness
u	Consumer trust
T	Certification cost

the certification label strategy, the certification organization first decides the certification standard, then the supplier decides the green supplying effort and wholesale price, and finally the manufacturer decides the green manufacturing effort and sale price.

Same as Ghosh and Shah [6], we assume that the margin production cost of the supplier and manufacturer is 0, which does not affect the final results. Then we utilize an expanding convex function to depict the cost of green innovation for the supplier and manufacturer. The supplier's green supplying investment cost is $ag_s^2/2$ and the manufacturer's green manufacturing investment cost is $bg_m^2/2$, in which a denotes the cost coefficient of supplier's green investment and b denotes the cost coefficient of manufacturer's green investment.

According to Murali et al. [14], we assume that T is the cost of certification, and it is an external variable and a one-time fixed fee. The parameters throughout the paper are summarized in Table 1.

Self-labeling (S strategy)

We use superscript S to represent the self-labeling strategy. The supplier determines the optimal w and g_s first, and then the manufacturer determines the optimal p and g_m. The problems of supplier and manufacturer are as follows:

$$\max_{w,g_s} \pi_s^S = w\left(1 - p + ku\left(g_s + g_m\right)\right) - ag_s^2/2 \tag{1}$$

$$\max_{p,g_m} \pi_m^S = (p - w)\left(1 - p + ku\left(g_s + g_m\right)\right) - bg_m^2/2 \tag{2}$$

Supply chain profit under S strategy can be expressed as:

$$\pi_{sc}^S = p\left(1 - p + ku\left(g_s + g_m\right)\right) - ag_s^2/2 - bg_m^2/2 \tag{3}$$

Social welfare is expressed by the combination of supply chain profit π_{sc}^S, consumer surplus CS^S and environmental improvement performance EI^S. The social welfare formula is:

$$SW^S = \pi_{sc}^S + CS^S + EI^S \tag{4}$$

Under S strategy, we use the reserve price $v^S = 1 + ku(g_s + g_m)$ to represent the price that causes the demand to be 0. With reference to Hong and Guo [7], the consumer surplus is as follows:

$$CS^S = \int_p^{v^S} \left(1 - x + ku\left(g_s + g_m\right)\right)dx = \left(1 - p + ku\left(g_s + g_m\right)\right)^2/2 \tag{5}$$

With reference to Zhang et al. [7], environmental benefit EI is expressed as the product's greenness and the market demand:

$$EI^S = \left(g_s + g_m\right)D^S \tag{6}$$

Proposition 1. *Under S strategy, when* $a > bk^2u^2/(4b - 2k^2u^2)$ *and* $b > k^2u^2/2$, *the optimal decisions of supplier and manufacturer are* $w^{S*} = a(2b - k^2u^2)/S_0$, $p^{S*} = a(3b - k^2u^2)/S_0$, $g_s^{S*} = bku/S_0$ *and* $g_m^{S*} = aku/S_0$. *Thus obtained* $g^{S*} = (a + b)ku/S_0$, $D^{S*} = ab/S_0$, $\pi_s^{S*} = ab/2S_0$, $\pi_m^{S*} = a^2b(2b - k^2u^2)/2S_0^2$, $\pi_{sc}^{S*} = ab(6ab - 3ak^2u^2 - bk^2u^2)/2S_0^2$ *and* $SW^{S*} = ab(7ab + aku(2 - 3ku) + bku(2 - ku))/2S_0^2$, *which* $S_0 = 4ab - 2ak^2u^2 - bk^2u^2$.

Property 1. *(1)* w^{S*}, p^{S*}, g^{S*}, D^{S*}, π_s^{S*}, π_m^{S*}, π_{sc}^{S*} *and* SW^{S*} *increase in* u; *(2)* w^{S*}, p^{S*}, g^{S*}, D^{S*}, π_s^{S*}, π_m^{S*}, π_{sc}^{S*} *and* SW^{S*} *increase in* k.

Property 1 demonstrates that under the self-labeling strategy, product prices, product's greenness, market demand, supply chain member profits, and societal welfare all increase as consumer trust or consumer green awareness increases. This shows that promoting consumer trust or consumer green awareness might encourage the supplier and manufacturer to create greener products, boost supply chain revenues, and benefit the society.

Certification label (C strategy)

We use superscript C to represent the certification label strategy. According to the research of Gao et al. [32], certification organizations decide the product certification standard by maximizing social welfare. The decision-making order of the supply chain under the certification label strategy is as follows: firstly, the certification organization decides the optimal eco-label certification standard, then the supplier decides the optimal w and g_s, and finally the manufacturer decides the optimal p and g_m. The problems of supplier and manufacturer are as follows:

$$\max_{w,g_s} \pi_s^C = w\left(1 - p + kG\right) - ag_s^2/2 \tag{7}$$

$$\max_{p,g_m} \pi_m^C = (p - w)\left(1 - p + kG\right) - bg_m^2/2 - T \tag{8}$$

Under C strategy, we use the reserve price $v^C = 1 + kG$ to represent the price that causes the demand to be 0. With reference to Hong and Guo [7], the consumer surplus is as follows:

$$CS^C = \int_p^{v^C} \left(1 - x + kG\right)dx = \left(1 - p + kG\right)^2/2 \tag{9}$$

SW^C represents social welfare under C strategy.

$$\max_G SW^C = \pi_{sc}^C + CS^C + EI^C \tag{10}$$

Proposition 2 *under C strategy, when* $b > k(8 + 7k)/16$, *the optimal decisions of the supplier, manufacturer, and certification organization are* $w^{C*} = 2(4b - k)/C_0$, $p^{C*} = 3(4b - k)/C_0$, $g_s^{C*} = 0$, $g_m^{C*} = (4 + 7k)/C_0$ *and* $G^{C*} = (4 + 7k)/C_0$. *Thus obtained* $g^{C*} = (4 + 7k)/C_0$, $D^{C*} = (4b - k)/16b - k(8 + 7k)$, $\pi_s^{C*} = 2(4b - k)^2/C_0^2$, $\pi_m^{C*} = (32b^2 + 2k^2 - b(16 + 72k + 49k^2))/2C_0^2 - T$, $\pi_{sc}^{C*} = (96b^2 + 6k^2 - b(16 + 104k + 49k^2))/2C_0^2 - T$ *and* $SW^{C*} = (1 + 7b)/(2C_0) - T$, *in which* $C_0 = 16b - k(8 + 7k)$.

Property 2. w^{C*}, p^{C*}, g^{C*}, G^{C*}, D^{C*}, π_s^{C*} *and* SW^{C*} *increase in* k. *But* π_m^{C*} *and* π_{sc}^{C*} *decrease in* k.

Property 2 shows that the optimal certification standard increases with the rise in consumer green awareness. Consumers are more willing to buy high-green products with the enhancement of consumers green awareness. Consequently, certification organizations will raise the eco-label certification standards because of high demand for green products by consumers. In addition, with consumer green awareness increases, there is an increase in market demand, wholesale price, sale price and greenness of product, but a decrease in manufacturer profit and supply chain profit. This is because the certification organizations may raise the green certification standards of products as consumer demand for green products increases, and under the certification label strategy, the supplier has free-rider behavior, which in turn prompts a significant increase in green investment by the manufacturer. Although the sale price and demand will also increase as consumer green awareness increases, which boosts the overall revenue of the manufacturer in turn, the manufacturer's profit declines as consumer green awareness increases, since the growing revenue cannot offset the increase in green investment costs. Additionally, the profit of the whole supply chain is reduced since the profit gain of supplier is smaller than the profit decline of manufacturer.

Comparative analysis

This section analyzes the manufacturer's eco-label selection strategy by comparing the equilibrium results in the two strategies of self-labeling and certification label.

Proposition 3. *(1)* $g_s^{S*} > g_s^{C*}$, $g_m^{S*} < g_m^{C*}$, $g^{S*} < g^{C*}$*; (2)* $w^{S*} < w^{C*}$, $p^{S*} < p^{C*}$, $D^{S*} < D^{C*}$.

Proposition 3 (1) demonstrates that C strategy increases the manufacturer's green manufacturing effort and product's greenness over S strategy, but decreases the supplier's green supplying effort. Under C strategy, there is a green threshold at the sales end, so the manufacturer is under more pressure to innovate green activities, while the supplier can choose free-rider behavior.

According to Proposition 3 (2), C strategy leads to higher wholesale price, sale price, and market demand. In order to pass the certification of products, the manufacturer must invest more in green manufacturing and enhance product's greenness. Therefore, for protecting their own interests, the manufacturer will then raise the sale price of certified products, while the supplier will also increase wholesale prices. In addition, because the product's greenness with certification label is higher than those under the self-labeling, even if the price of product with certification label rises, demand will not reduce. This encourages consumers' willingness to purchase, which then increasing the market demand under C strategy.

Proposition 4. *(1)* $\pi_s^{S*} < \pi_s^{C*}$, $\pi_m^{S*} > \pi_m^{C*}$*; (2)* $\pi_{sc}^{S*} > \pi_{sc}^{C*}$.

Proposition 4 demonstrates that the supplier and manufacturer have different preferences when choosing eco-label strategy. The wholesale price and market demand under C strategy are higher than those under S strategy, so the supplier's profit under C strategy is higher than S strategy. The supplier hopes the manufacturer to select certification organizations for eco-label certification rather than select S strategy.

In opposite, the manufacturer may be more lucrative under S strategy, which is largely due to the fact that the certification standard under C strategy is much higher than the greenness of the product under S strategy, and the manufacturer have to pay significant green manufacturing cost in order to pass the certification. As a result, the manufacturer profit is less under C strategy. However, for the whole supply chain, S strategy is better than C strategy.

Proposition 5. $\left|\frac{\partial \pi_s^{S*}}{\partial k}\right| < \left|\frac{\partial \pi_s^{C*}}{\partial k}\right|$, $\left|\frac{\partial \pi_m^{S*}}{\partial k}\right| < \left|\frac{\partial \pi_m^{C*}}{\partial k}\right|$.

Proposition 5 demonstrates that, under C strategy, the profits of supply chain members exhibit greater sensitivity to consumer green awareness when compared to S strategy. This phenomenon can be primarily attributed to two key factors. Firstly, consumers do not completely trust the product's greenness under the S strategy, which to some extent diminishes its positive role in fostering green awareness. Secondly, under C strategy, both pricing and market demand are higher than those under S strategy, hence the changes in consumer green awareness have a more pronounced impact under C strategy. Consequently, enhancing the green awareness of consumers proves to be more beneficial for augmenting the profits of supply chain members within C strategy.

Numerical simulations

To further analyze the model, this section uses numerical simulations to explore the impact of consumer green awareness on the profits of supply chain members and social welfare under two eco-label strategies.

Figs. 1 and 2 show how consumer green awareness effects the profits of the supplier and the manufacturer, where the parameters assignment is $a = 1.1$, $b = 1$ and $T = 0$. In addition, we select u = 0.8 and u = 0.4 for robustness check. As seen in Fig. 1, changes in consumer green awareness have little effect on the profits of supply chain members under S strategy. However, under C strategy, increasing consumer green awareness can significantly increase the supplier's profit, which is mostly because consumers trust products with certification label and are rather dubious of the product's greenness with self-labeling strategy.

Fig. 2 shows that under C strategy, the manufacturer's profit declines as consumers green awareness increases. Due to the increase in consumer green awareness, which results in higher certification standards and higher green investment costs, consequently leads to a decline in manufacturer profits. Moreover, the manufacturer is more likely to adopt S strategy since it offers a bigger profit gap than certification label.

Fig. 3 depicts the change trend of social welfare with certification cost and consumer trust under S and C strategies, where the parameters are assigned as $a = 1.1$ and $b = 1$. In addition, we have selected k = 0.8 and k = 0.4 for robustness check. From Propositions 1 and 2, it can be seen that, for any given T, SW^{C*} is a constant for all u and SW^{S*} increases in u; for any given u, SW^{C*} decreases in T, and SW^{S*} is a constant for all T. This seems to indicate that the quantitative relationship between social welfare under the two strategies is uncertain. Fig. 3 validates this idea. When k is high, the social welfare under C strategy is better than that under S strategy only when consumer trust and certification costs are both low. When k is small, if the certification cost or consumer trust is high, the social welfare under S strategy will be better than that under C strategy.

Multi-level certification label (M strategy)

In addition to the single-level certification label mentioned in Section 3, there are some multi-level certification labels in reality as described in Section 1. A few scholars have conducted research on multi-level certification labels. For instance, Nadar and Erturk [29] conducted a comparative analysis of single-level and two-level labels, discovering that two-level labels demonstrate superiority in terms of environmental protection in certain cases. Similarly, Li and Veld [30] noted that the preference for multi-level certification labels by environmental certification organizations can depend on the specific certification organization's characteristics. However, these previous studies did not take the impact of certification levels on supply chain performance into account.

Therefore, in this section, we extend our analysis from single-level eco-label to multi-level eco-labels. We aim to investigate how varying certification levels influence the profits of supply chain members and social welfare.

Under the multi-level certification label strategy, certification levels are divided into $G_1, G_2 ... G_n (n \geq 2, n \in Z)$, and $G_1 < G_2 < ... < G_n$. After balancing the green costs and revenues, the manufacturer chooses a certain level for certification, assuming that the level is $G_i, i \in \{1, 2, ..., n\}$. In addition, the greenness of the product is not less than the certification standard, which can be expressed as $g_s + g_m \geq G_i$.

The supply chain decision sequence is that the supplier decides the optimal w and g_s, then the manufacturer decides the optimal p and g_m. With superscript M representing the multi-level certification label model, the problems of the supplier and manufacturer are as follows:

$$\max_{w, g_s} \pi_s^M = w\left(1 - p + kG_i\right) - a g_s^2/2 \tag{11}$$

$$\max_{p, g_m} \pi_m^M = (p - w)\left(1 - p + kG_i\right) - \mathrm{b} g_m^2/2 - T \tag{12}$$

Proposition 6. *Under M strategy, the optimal decisions of supplier and manufacturer are* $w^{M*} = \frac{1}{2}(1 + kG_i)$, $p^{M*} = \frac{3}{4}(1 + kG_i)$, $g_s^{M*} = 0$ *and* $g_m^{M*} = G_i$*. Thus obtained* $D^{M*} = \frac{1}{4}(1 + kG_i)$, $\pi_s^{M*} = \frac{1}{8}(1 + kG_i)^2$, $\pi_m^{M*} = \frac{1}{16}(-8bG_i^2 + (1 + kG_i)^2) - T$, $\pi_{sc}^{M*} = \frac{1}{16}(-8bG_i^2 + 3(1 + kG_i)^2) - T$ *and* $SW^{M*} = \frac{1}{32}(7 + 2G_i(4 + 7k) + G_i^2(-16b + k(8 + 7k))) - T$.

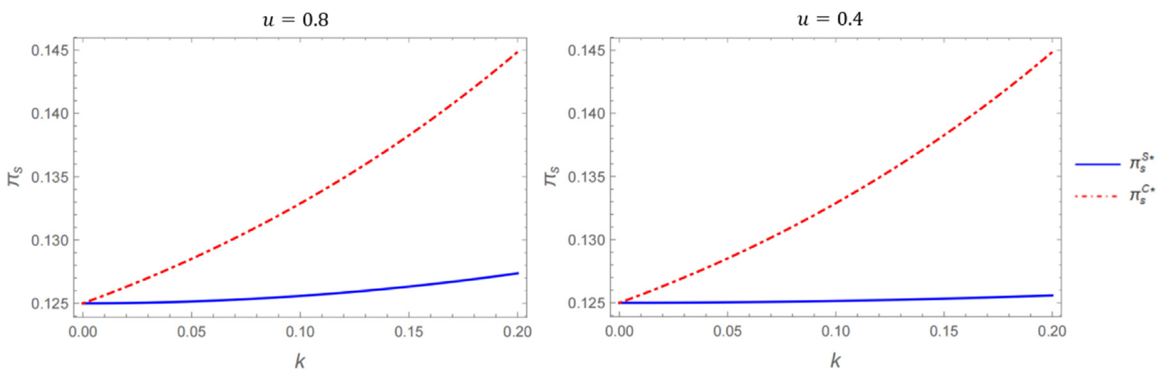

Fig. 1. Supplier's profit changes with consumer green awareness.

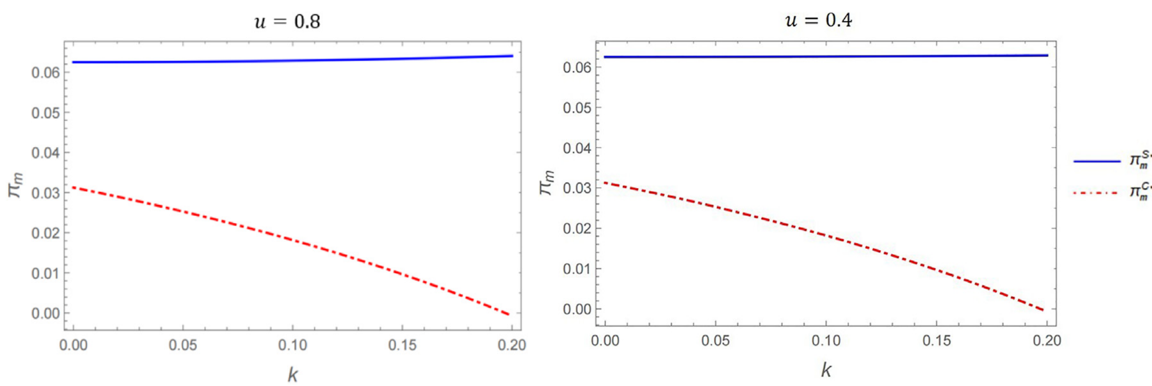

Fig. 2. Manufacturer's profit changes with consumer green awareness.

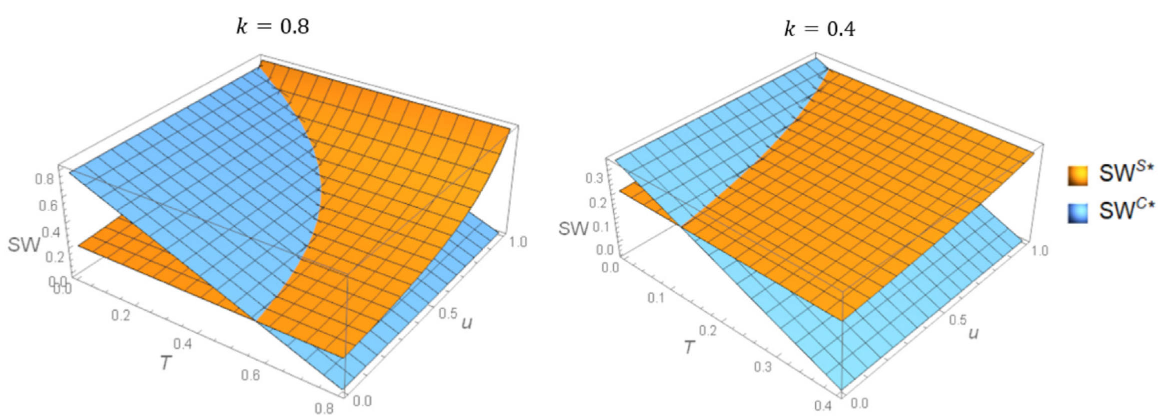

Fig. 3. Social welfare changes with consumer trust and certification cost.

Property 3. *π_s^{M*} increases in G_i. When $b > k^2/8$ and $G_i > \frac{k}{8b-k^2}$, π_m^{M*} decreases in G_i, else π_m^{M*} increases in G_i. When $b > 3k^2/8$ and $G_i > \frac{3k}{8b-3k^2}$, π_{sc}^{M*} decreases in G_i, else π_{sc}^{M*} increases in G_i. When $b > k(8+7k)/16$ and $G_i > \frac{4+7k}{16b-k(8+7k)}$, SW^{M*} decreases in G_i, else SW^{M*} increases in G_i.*

Property 3 demonstrates that the supplier profit increases with the level of certification standard increases, whereas manufacturer profit, supply chain profit, and societal welfare are correlated with cost coefficient of manufacturer's green investment. When the cost coefficient of manufacturer's green investment is relatively high, there exists an optimal certification level that enables the manufacturer to maximize its profit, as well as for supply chain profits and social welfare. Taking manufacturer profit as an example, when its coefficient for green investment costs is high, the manufacturer increases its investment in green activities. Although a higher certification level can always obtain a greater income, there is an optimal certification level exists when manufacturer take a trade-off between its investment in green activities and greater income. Therefore, for the manufacturer, if its cost coefficient of green investment is very high, a higher certification level is not necessarily better.

Next, we will use numerical simulations to intuitively compare the differences in supply chain member profits and social welfare between: (1) multi-level certification label strategy and self-labeling strategy; (2) multi-level certification label strategy and certification label strategy.

We select three certification standards $G_1 = 0.2$, $G_2 = 0.5$ and $G_3 = 0.8$. Other parameters are set as $a = 1.1$ and $T = 0$. In the comparison of M strategy and S strategy, the "$g_s + g_m$" selected by the supplier and manufacturer in S strategy is used as the benchmark 1, and two conditions $u = 0.8$ and $u = 0.4$ are selected for robustness check when $k = 0.8$. In the comparison of M strategy and C strategy, the certification standard "G^C" that maximizes social welfare in C strategy is taken as the

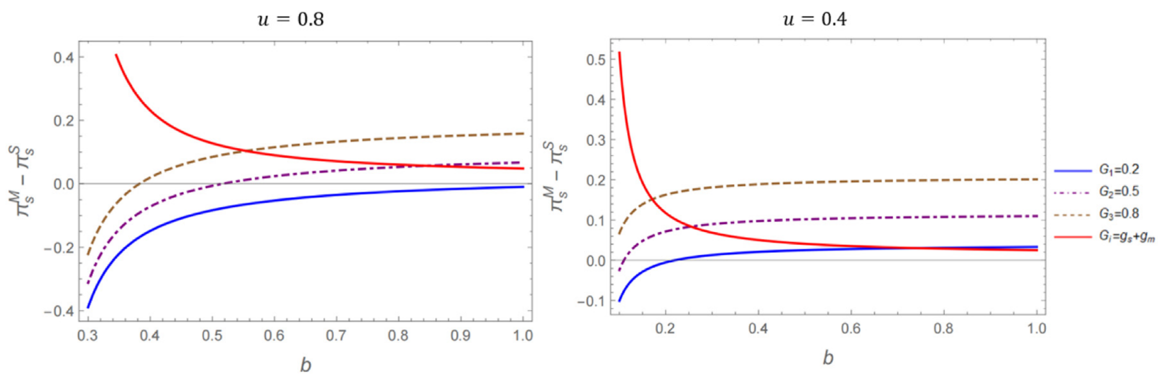

Fig. 4. Change of supplier profit gap with cost coefficient of manufacturer's green investment under M and S strategies.

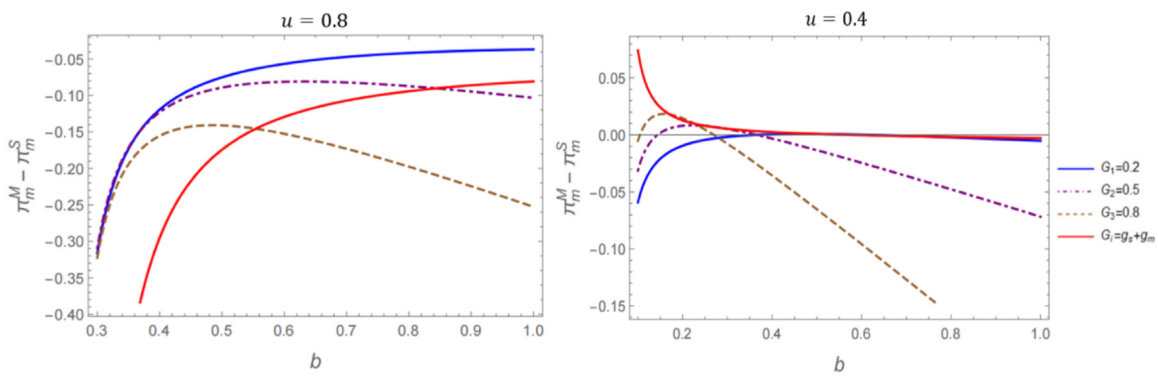

Fig. 5. Change of manufacturer profit gap with cost coefficient of manufacturer's green investment under M and S strategies.

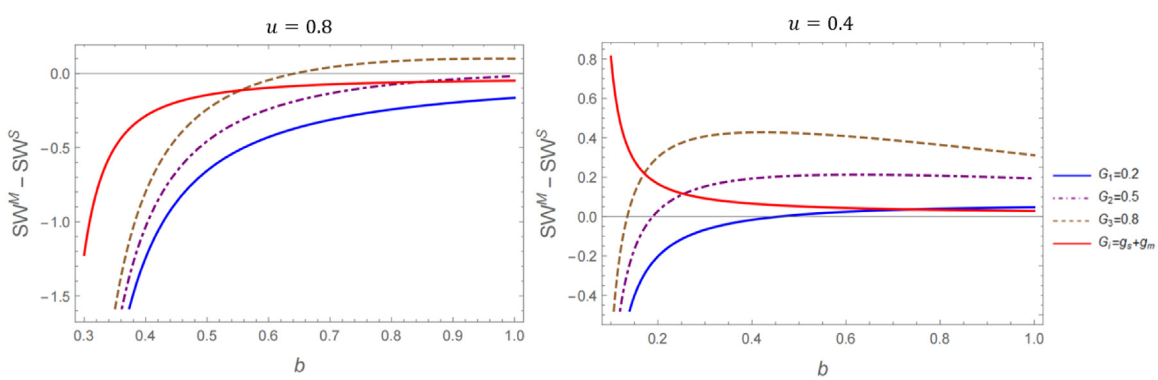

Fig. 6. Change of social welfare gap with cost coefficient of manufacturer's green investment under M and S strategies.

benchmark 2, and two conditions $k = 0.8$ and $k = 0.4$ are selected for robustness check.

(1) Comparison between M and S strategies

In the case of "$g_s + g_m$" as the benchmark 1, Figs. 4–6 illustrate the trends in profits of supply chain members gap and social welfare gap in M strategy and S strategy. Among them, the supplier's profit gap refers to the supplier's profit under M strategy minus the supplier's profit under S strategy. The manufacturer's profit gap and the social welfare gap can be obtained similarly.

In the case of benchmark 1, for supplier, regardless of whether consumer trust is high or low, the supplier's profits under M strategy consistently exceed those under S strategy. However, S strategy results in higher manufacturer profits and social welfare when consumer trust is high. Conversely, when consumer trust is low, M strategy yields better manufacturer profits and social welfare. Furthermore, the profit gap among supply chain members and the social welfare gap between two eco-label strategies steadily decrease with the increase of the manufacturer's green investment cost coefficient.

Regarding the three specified certification levels, when manufacturer's green investment cost coefficient is low, supplier's profit is higher under S strategy compared to M strategy. Conversely, when manufacturer's green investment cost coefficient is high, supplier's profit is better under M strategy. For manufacturer, it is only when both consumer trust and the cost coefficient of manufacturer's green investment are low that manufacturer's profit under M strategy may surpass the profit under S strategy. In such a scenario, manufacturer may choose M strategy, which deviates from Proposition 4. In terms of social welfare, when manufacturer's green investment cost coefficient is low, social welfare is higher under S strategy than under M strategy. Conversely, when manufacturer's green investment cost coefficient is high, social welfare may be better under M strategy.

Comparing three predetermined certification standard curves allows us to gain insights into how certification level effects supply chain per-

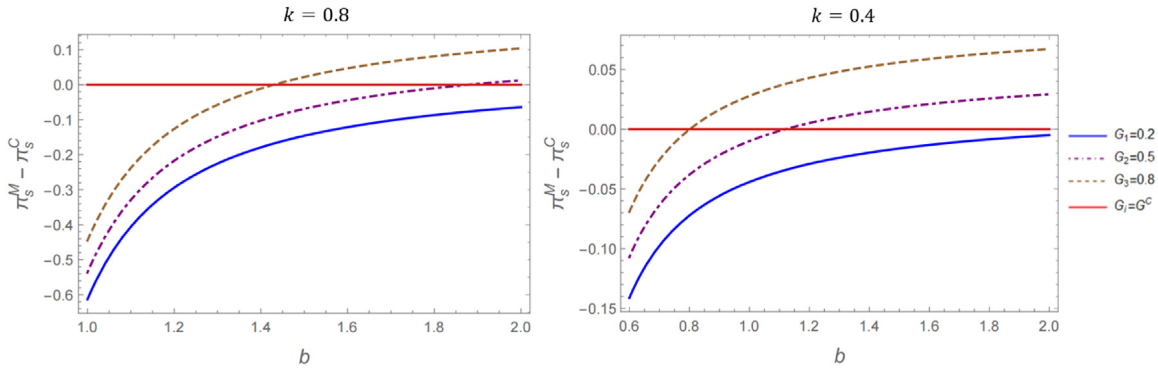

Fig. 7. Change of supplier profit gap with cost coefficient of manufacturer's green investment under M and C strategies.

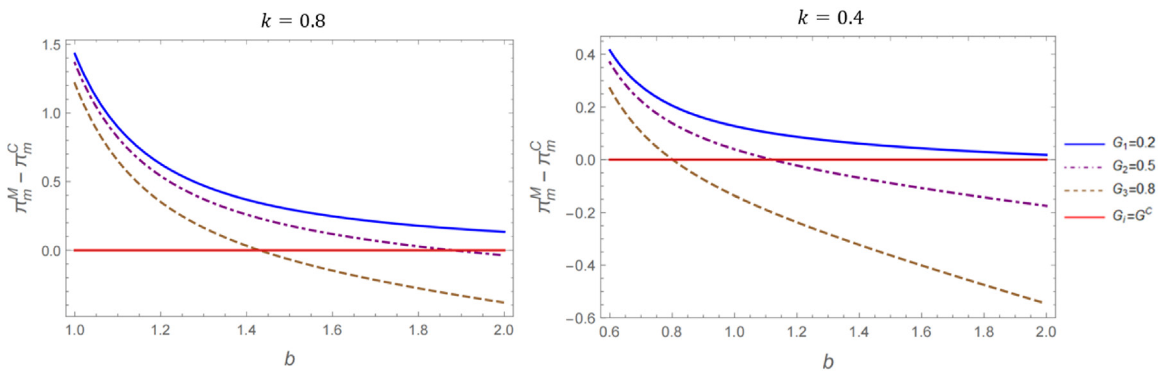

Fig. 8. Change of manufacturer profit gap with cost coefficient of manufacturer's green investment under M and C strategies.

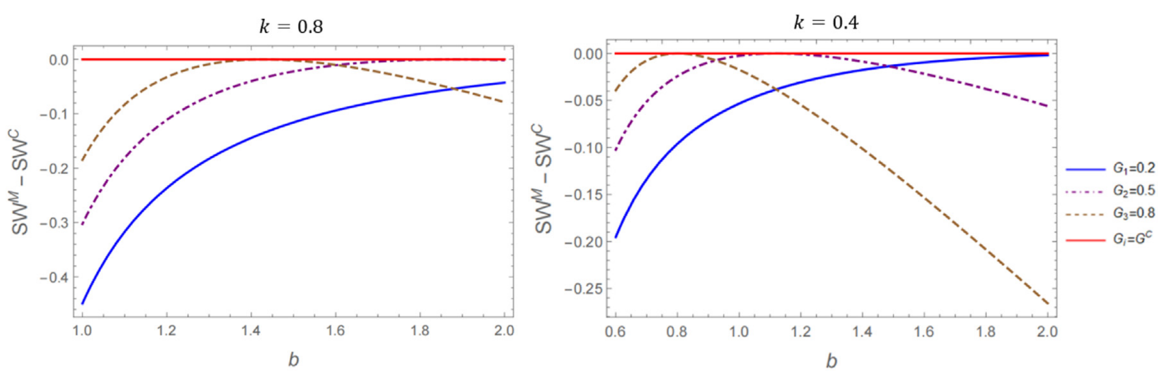

Fig. 9. Change of social welfare gap with cost coefficient of manufacturer's green investment under M and C strategies.

formance. If a curve lies above the horizontal axis and far away from it, both supply chain member profits and overall social welfare are higher under M strategy. Conversely, when a curve lies below the horizontal axis and distanced from it, supply chain member profits and social welfare are lower under M strategy. In Fig. 4, we can conclude that a higher certification level always increases supplier's profit. However, when the manufacturer's green investment cost coefficient is relatively high, the profits of manufacturer might decline at a high certification level. This happens because a high manufacturer's green investment cost coefficient implies increased costs associated with green manufacturing. Although higher certification levels can increase the market demand and revenue, such increasing in revenue may not effectively offset the rising green costs. Therefore, manufacturer profit may decrease with higher certification levels. For social welfare, when the cost coefficient of the manufacturer's green investment falls within a specific range, the curve representing high certification standards is positioned above the curve with low certification standards. This phenomenon suggests that a high certification level is more favorable for enhancing overall social welfare.

(2) Comparison between M and C strategies

In the case of "G^C" as benchmark 2, Figs. 7–9 describes the change of manufacturer profit gap and social welfare gap of M strategy and C strategy with the cost coefficient of manufacturer's green investment in benchmark 2 and three given certification standards ($G_1 = 0.2$, $G_2 = 0.5$ and $G_3 = 0.8$).

In the benchmark 2, the profits of supply chain members under M strategy are the same as those under C strategy, and social welfare is also identical under two strategies. Under the given three certification levels, when the cost coefficient of manufacturer's green investment is low, the supplier prefers C strategy, while when the cost coefficient of manufacturer's green investment is high, the supplier prefers M strategy with a high certification level. The manufacturer holds an opposite label preference than the supplier. When the cost coefficient of manufacturer's green investment is low, the manufacturer prefers M strategy with a low certification level, and when the cost coefficient of manufacturer's green investment is high, the manufacturer tends to choose C strategy. With different certification standards, the social welfare under C strategy is always higher than which under M strategy.

Conclusion

We construct a supply chain model, facilitating collaborative green innovation activities between a supplier and a manufacturer. Taking consumer trust and consumer green awareness into account, we analyze the impact of two eco-labeling strategies, which are self-labeling and certification label, on the development of green products within the supply chain and the choice of eco-labeling strategy. In addition, we extend a single-level label to a multi-level label, investigating the influence of label certification levels on the profits of supply chain participants and social welfare. The principal findings are summarized as follows:

(1) Increasing consumer green awareness may not always benefit the manufacturer and supply chain. In certification label strategy, as consumer green awareness increases, the manufacturer's profit falls. This is mostly because the manufacturer must invest more in green innovation in order to achieve certification standard, which hurts their profitability.
(2) There are contradictions between the supplier and manufacturer in the selection preference of eco-label strategies. By comparing the certification label strategy and self-labeling strategy, we found that the profit of supplier under the certification label strategy is higher than that of self-labeling strategy, thus the supplier prefers the certification label strategy. However, for the manufacturer, the profit under the certification label strategy is always smaller than the self-labeling strategy, thus the manufacturer is more inclined to choose the self-labeling strategy. In addition, when considering multi-level labeling strategies, we found that when the cost coefficient of manufacturer's green investment is low, the supplier instead prefers self-labeling strategy, and when both consumer trust and the cost coefficient of manufacturer's green investment are low, the manufacturer may instead prefer multi-level certification label strategy. Besides, a higher certification level is not better for the manufacturer when the cost coefficient of manufacturer's green investment is high.
(3) For the perspective of social welfare, when both certification cost and consumer trust are relatively low, social welfare under the certification label strategy outperforms the self-labeling strategy. Under the multi-level certification label strategy, when the cost coefficient of manufacturer's green investment is low, social welfare increases with higher certification levels. However, when the cost coefficient of manufacturer's green investment is significant, a higher certification level leads to a decrease in social welfare.

This paper investigates the production of green products and the choice of labeling strategies in the supply chain which considering three eco-label strategies. Future research can focus on the following directions: (1) Considering various contractual cooperation models to address the various labeling strategy preferences of supply chain participants. (2) Introducing different eco-label sponsors, such as industry organizations, environmental organizations, and non-profit organizations, who will set various certification standards according to their own goals.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Gaoxiang Lou: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – original draft. **Ying Zhang:** Software, Data curation, Writing – original draft, Investigation. **Haicheng Ma:** Writing – original draft, Formal analysis, Methodology, Conceptualization. **Xuechen Tu:** Validation, Visualization, Writing – review & editing. **Yi-Ming Wei:** Writing – review & editing, Validation.

Acknowledgments

The authors gratefully acknowledge the editor and two reviewers for their valuable comments and the financial support provided by the National Natural Science Foundation of China (No. 71972070) and the Fundamental Research Funds for the Central Universities.

Appendix A

Proof of Proposition 1: Using the inverse solution method, the manufacturer decides the optimal $p$and $g_{\rm m}$ through profit maximization. The Hessian matrix of manufacturer's profit with respect to p and $g_{\rm m}$ is $\mathrm{H_m} = [\begin{matrix} -2 & ku \\ ku & -b \end{matrix}]$. When $b > \frac{1}{2}k^2u^2$, $\pi_{\rm m}^{\rm S}(p, g_{\rm m})$ is a concave function with respect to p and $g_{\rm m}$. There is an optimal p and $g_{\rm m}$ that maximizes $\pi_{\rm m}^{\rm S}(p, g_{\rm m})$. Through the first-order equation $\partial\pi_{\rm m}^{\rm S}/\partial p = 0$ and $\partial\pi_{\rm m}^{\rm S}/\partial g_{\rm m} = 0$, the manufacturer's optimal reaction function can be obtained as $p = \frac{b + bkug_{\rm s} + bw - k^2u^2w}{2b - k^2u^2}$, $g_{\rm m} = \frac{ku(1 + kug_{\rm s} - w)}{2b - k^2u^2}$. The above optimal reaction function is substituted into the supplier objective function, and its Hessian matrix with respect to w and $g_{\rm s}$ is $\mathrm{H_s} = \begin{bmatrix} \frac{2b}{-2b + k^2u^2} & \frac{bku}{2b - k^2u^2} \\ \frac{bku}{2b - k^2u^2} & -a \end{bmatrix}$. When $a > \frac{bk^2u^2}{4b - 2k^2u^2}$, H_s is negative definite. Through the first-order equation $\partial\pi_{\rm s}^{\rm S}/\partial w = 0$ and $\partial\pi_{\rm s}^{\rm S}/\partial g_{\rm s} = 0$, the supplier optimal response function can be obtained as $w^{\rm S*} = \frac{a(2b - k^2u^2)}{4ab - 2ak^2u^2 - bk^2u^2}$, $g_{\rm s}^{\rm S*} = \frac{bku}{4ab - 2ak^2u^2 - bk^2u^2}$. The optimal retail price and green manufacturing effort can be obtained by substituting the supplier's optimal decision into the manufacturer's optimal response function. Finally, the optimal decisions of the supplier and manufacturer are brought into the objective function and social welfare of channel members to obtain Proposition 1.

Proof of Propositions 2 and 6: The proof for propositions 2 and 6 are very similar. Let's take proposition 2 as an example. Similar to the proof of Proposition 1, inverse method is adopted to solve it. The manufacturer decides the optimal p and $g_{\rm m}$, which is easy to get the negative definite of the Hessian matrix about p and $g_{\rm m}$. Then set $\partial\pi_{\rm m}^{C}/\partial p = 0$ and $\partial\pi_{\rm m}^{C}/\partial g_{\rm m} = 0$ respectively to get p and $g_{\rm m}$. Similarly, we can get the optimal w and $g_{\rm s}$ that maximize the supplier's profit. Let $\partial^2 SW^{\rm C}/\partial G^2 = -b + \frac{1}{16}k(8 + 7k)$, and when $b > \frac{1}{16}k(8 + 7k)$, $SW^{\rm C}$ is a concave function of G. Let $\partial SW^{\rm C}/\partial G = \frac{1}{16}(4 - 16bG + k(7 + G(8 + 7k))) = 0$, and we can get $G^{\rm C*} = (4 + 7k)/(16b - k(8 + 7k))$. We can easily get Proposition 2 by inserting $G^{\rm C*}$ into the supplier and manufacturer profit formula.

Proof of Properties 1 and 2: The proof for properties 1 and 2 are very similar, let's look at the property 2 proof. Take $\frac{\partial w^{\rm C*}}{\partial k}$ and $\frac{\partial \pi_{\rm m}^{\rm C*}}{\partial k}$ as an example, and the rest of the proofs are similar. First, $\frac{\partial w^{\rm C*}}{\partial k} = \frac{2(-7k^2 + 8b(2 + 7k))}{(-16b + k(8 + 7k))^2}$, and due to $b > k(8 + 7k)/16$, so $(-7k^2 + 8b(2 + 7k)) > \frac{1}{3}k(64 + 7k(37 + 28k)) > 0$, then we can get $\frac{\partial w^{\rm C*}}{\partial k} > 0$. Second, $\frac{\partial \pi_{\rm m}^{\rm C*}}{\partial k} = \frac{14k^3 - 16b^2(20 + 21k) - b(128 + 480k + 756k^2 + 343k^3)}{(16b - k(8 + 7k))^3}$, and due to $b > \frac{k(8 + 7k)}{16} = \frac{k}{2} + \frac{7k^2}{16} > \frac{k}{2}$, so $14k^3 - 16b^2(20 + 21k) < 14k^3 - 16(\frac{k}{2})^2(20 + 21k) = -80k^2 - 70k^3 < 0$, then we can easily get $\frac{\partial \pi_{\rm m}^{\rm C*}}{\partial k} < 0$.

Proof of Proposition 3: Take the relationship between g^{S*} and g^{C*} as an example, and the other proofs are similar. Due to $\partial(g^{S*}-g^{C*})/\partial u = \frac{(a+b)k(4ab+ak^2u^2+2bk^2u^2)}{(-4ab+ak^2u^2+2bk^2u^2)^2} > 0$, $g^{S*}-g^{C*}$ is therefore a continuously increasing function of u, and $0<u<1$, $\lim_{u\to 0}(g^{S*}-g^{C*}) = \frac{4+7k}{-16b+k(8+7k)} < 0$, $\lim_{u\to 1}(g^{S*}-g^{C*}) = \frac{(a+b)k}{4ab-ak^2-2bk^2} + \frac{4+7k}{-16b+k(8+7k)} < 0$, $g^{S*} < g^{C*}$ is thus obtained.

Proof of Proposition 4: We take the relationship between π_m^{S*} and π_m^{C*} as an example, and the other proofs are similar. $\partial(\pi_m^{S*}-\pi_m^{C*})/\partial u = \frac{a^2bk^2u(4b(a+b)-(2a+b)k^2u^2)}{(4ab-(2a+b)k^2u^2)^3} > 0$, and $\pi_m^{S*}-\pi_m^{C*}$ is a continuously increasing function of u . Due to $0<u<1$, $\lim_{u\to 0}(\pi_m^{S*}-\pi_m^{C*}) = \frac{1}{16} + \frac{-32b^2-2k^2+b(16+72k+49k^2)}{2(-16b+k(8+7k))^2} + T$. We set $f(k) = \frac{1}{16} + \frac{-32b^2-2k^2+b(16+72k+49k^2)}{2(-16b+k(8+7k))^2}$, and it is easily to get $\partial f(k)/\partial k = \frac{64b(2+5b)+48b(10+7b)k+756bk^2+7(-2+49b)k^3}{(16b-k(8+7k))^3} > 0$, $\lim_{k\to 0} f(k) = \frac{1}{32b} > 0$, so $\lim_{u\to 0}(\pi_m^{S*}-\pi_m^{C*}) = f(k) > 0$, then we can easily find $\pi_m^{S*}-\pi_m^{C*} > 0$.

Proof of Proposition 5: It's easily to get $\frac{\partial \pi_s^{S*}}{\partial k} = \frac{3k}{(4-3k^2)^2}$, $\frac{\partial \pi_s^{C*}}{\partial k} = \frac{4(4-k)(16+7(8-k)k)}{(16-k(8+7k))^3}$, so $|\frac{\partial \pi_s^{S*}}{\partial k}| - |\frac{\partial \pi_s^{C*}}{\partial k}| = -\frac{4096+1024k+6912k^2-12608k^3-4224k^4+3792k^5+504k^6+1281k^7}{(4-3k^2)^2(16-k(8+7k))^3} < 0$. Then we can easily get $|\frac{\partial \pi_s^{S*}}{\partial k}| < |\frac{\partial \pi_s^{C*}}{\partial k}|$. $|\frac{\partial \pi_m^{S*}}{\partial k}| < |\frac{\partial \pi_m^{C*}}{\partial k}|$can be obtained similarly.

Proof of Property 3: Let's take $\frac{\partial \pi_s^{M*}}{\partial G_i}$ and $\frac{\partial \pi_m^{M*}}{\partial G_i}$ as an example, and the rest of the proofs are similar. It's easy to get $\frac{\partial \pi_s^{M*}}{\partial G_i} = \frac{1}{4}k(1+kG_i) > 0$. Because $\frac{\partial^2 \pi_m^{M*}}{\partial G_i^2} = \frac{1}{8}(-8b+k^2)$, when $b < \frac{k^2}{8}$, $\frac{\partial^2 \pi_m^{M*}}{\partial G_i^2} = \frac{1}{8}(-8b+k^2) > 0$ and $\frac{\partial \pi_m^{M*}}{\partial G_i} = \frac{1}{8}(-8bG_i+k+G_ik^2) > 0$, and we can easily get $\frac{\partial \pi_m^{M*}}{\partial G_i} > 0$. But when $b > \frac{k^2}{8}$, $\frac{\partial^2 \pi_m^{M*}}{\partial G_i^2} = \frac{1}{8}(-8b+k^2) < 0$, and when $G_i < \frac{k}{8b-k^2}$, $\frac{\partial \pi_m^{M*}}{\partial G_i} = \frac{1}{8}(-8bG_i+k+G_ik^2) > 0$, and when $G_i > \frac{k}{8b-k^2}$, $\frac{\partial \pi_m^{M*}}{\partial G_i} = \frac{1}{8}(-8bG_i+k+G_ik^2) < 0$.

References

[1] M. Xu, B. Lin, Leveraging carbon label to achieve low-carbon economy: evidence from a survey in Chinese first-tier cities, J. Environ. Manag. 286 (2021), doi:10.1016/j.jenvman.2021.112201.
[2] Y.M. Zhang, B. Hezarkhani, Competition in dual-channel supply chains: the manufacturers' channel selection, Eur. J. Oper. Res. 291 (2021) 244–262, doi:10.1016/j.ejor.2020.09.031.
[3] W. Zhu, Y. He, Green product design in supply chains under competition, Eur. J. Oper. Res. 258 (2017) 165–180, doi:10.1016/j.ejor.2016.08.053.
[4] Y. Zheng, T. Shu, S. Wang, S. Chen, K.K. Lai, L. Gan, Analysis of product return rate and price competition in two supply chains, Oper. Res. 18 (2018) 469–496, doi:10.1007/s12351-016-0273-6.
[5] A. Boskabadi, M. Mirmozaffari, R. Yazdani, A. Farahani, Design of a distribution network in a multi-product, multi-period green supply chain system under demand uncertainty, Sustain. Oper. Comput. 3 (2022) 226–237, doi:10.1016/j.susoc.2022.01.005.
[6] D. Ghosh, J. Shah, Supply chain analysis under green sensitive consumer demand and cost sharing contract, Int. J. Prod. Econ. 164 (2015) 319–329, doi:10.1016/j.ijpe.2014.11.005.
[7] Z. Hong, X. Guo, Green product supply chain contracts considering environmental responsibilities, Omega Int. J. Manag. Sci. 83 (2019) 155–166, doi:10.1016/j.omega.2018.02.010.
[8] B. Du, Q. Liu, G. Li, Coordinating leader-follower supply chain with sustainable green technology innovation on their fairness concerns, Int. J. Environ. Res. Public Health 14 (2017), doi:10.3390/ijerph14111357.
[9] Z. Hong, H. Wang, Y. Gong, Green product design considering functional-product reference, Int. J. Prod. Econ. 210 (2019) 155–168, doi:10.1016/j.ijpe.2019.01.008.
[10] E. Rustico, S. Dimitrov, Environmental taxation: the impact of carbon tax policy commitment on technology choice and social welfare, Int. J. Prod. Econ. 243 (2022), doi:10.1016/j.ijpe.2021.108328.
[11] H. Yang, W. Chen, Retailer-driven carbon emission abatement with consumer green awareness and carbon tax: revenue-sharing versus Cost-sharing, Omega Int. J. Manag. Sci. 78 (2018) 179–191, doi:10.1016/j.omega.2017.06.012.
[12] H. Yang, J. Luo, H. Wang, The role of revenue sharing and first-mover advantage in emission abatement with carbon tax and consumer green awareness, Int. J. Prod. Econ. 193 (2017) 691–702, doi:10.1016/j.ijpe.2017.08.032.
[13] L. Zhang, J. Wang, J. You, Consumer green awareness and channel coordination with two substitutable products, Eur. J. Oper. Res. 241 (2015) 63–73, doi:10.1016/j.ejor.2014.07.043.
[14] K. Murali, M.K. Lim, N.C. Petruzzi, The effects of eco-labels and environmental regulation on green product development, Manuf. Serv. Oper. Manag. 21 (2019) 519–535, doi:10.1287/msom.2017.0703.
[15] G. Li, H. Wu, S.P. Sethi, X. Zhang, Contracting green product supply chains considering marketing efforts in the circular economy era, Int. J. Prod. Econ. 234 (2021), doi:10.1016/j.ijpe.2021.108041.
[16] C.K. Chen, M. Akmalul'Ulya, Analyses of the reward-penalty mechanism in green closed-loop supply chains with product remanufacturing, Int. J. Prod. Econ. 210 (2019) 211–223, doi:10.1016/j.ijpe.2019.01.006.
[17] L. Zhang, H. Zhou, Y. Liu, R. Lu, Optimal environmental quality and price with consumer green awareness and retailer's fairness concerns in supply chain, J. Clean. Prod. 213 (2019) 1063–1079, doi:10.1016/j.jclepro.2018.12.187.
[18] G. Ge, D. Wang, M.B. Epede, Pricing policies of green dual-channel supply chain with fairness concerns and altruistic preferences based on consumers' environmental awareness and channel preference, Int. J. Environ. Res. Public Health 19 (2022), doi:10.3390/ijerph192013564.
[19] Z. Hong, M. Li, X. Han, X. He, Innovative green product diffusion through word of mouth, Transp. Res. Part E Logist. Transp. Rev. 134 (2020), doi:10.1016/tre.2019.101833.
[20] X. Han, M. Khouja, X. Liu, A dynamic model considering consumer green awareness and environmental subsidy, Int. J. Prod. Econ. 260 (2023), doi:10.1016/j.ijpe.2023.108840.
[21] J. Heydari, K. Govindan, Z. Basiri, Balancing price and green quality in presence of consumer green awareness: a green supply chain coordination approach, Int. J. Prod. Res. 59 (2021) 1957–1975, doi:10.1080/00207543.2020.1771457.
[22] H. Zhang, Q. Li, J. Jiang, Effect and formulation of ecolabel policy: a perspective of green supply chain decision and coordination, Environ. Sci. Pollut. Res. (2023), doi:10.1007/s11356-023-28125-4.
[23] Y.N. Cho, C. Berry, Understanding the effects of retailer- and manufacturer-provided sustainability labels on product evaluations and purchase-related outcomes, J. Bus. Res. 100 (2019) 73–85, doi:10.1016/j.jbusres.2019.03.019.
[24] M. Oh, J. Shin, P.J. Park, S. Kim, Does eco-innovation drive sales and technology investment? Focusing on eco-label in Korea, Bus. Strategy Environ. 29 (2020) 3174–3186, doi:10.1002/bse.2565.
[25] A. Heyes, S. Martin, Social labeling by competing NGOs: a model with multiple issues and entry, Manag. Sci. 63 (2017) 1800–1813, doi:10.1287/mnsc.2015.2419.
[26] C. Fischer, T.P. Lyon, A theory of multitier eco-label competition, J. Assoc. Environ. Resour. Econ. 6 (2019) 461–501, doi:10.1086/702985.
[27] T. Fan, Y. Song, H. Cao, H. Xia, Optimal eco-label strategy with imperfectly informed consumers, Ind. Manag. Data Syst. 119 (2019) 1166–1188, doi:10.1108/imds-06-2018-0256.
[28] B. Roe, I. Sheldon, Credence good labeling: the efficiency and distributional implications of several policy approaches, Am. J. Agric. Econ. 89 (2007) 1020–1033, doi:10.1111/j.1467-8276.2007.01024.x.
[29] E. Nadar, M.S. Erturk, Eco-design of eco-labels with coarse grades, Omega Int. J. Manag. Sci. 99 (2021), doi:10.1016/j.omega.2020.102209.
[30] Y. Li, K. van 't Veld, Green, greener, greenest: eco-label gradation and competition, J. Environ. Econ. Manag. 72 (2015) 164–176, doi:10.1016/j.jeem.2015.05.003.
[31] X. Guo, L. Cheng, J. Liu, Green supply chain contracts with eco-labels issued by the sales platform: profitability and environmental implications, Int. J. Prod. Res. 58 (2020) 1485–1504, doi:10.1080/00207543.2019.1658911.
[32] J. Gao, Z. Xiao, H. Wei, G. Zhou, Dual-channel green supply chain management with eco-label policy: a perspective of two types of green products, Comput. Ind. Eng. 146 (2020), doi:10.1016/j.cie.2020.106613.
[33] J. Gao, Z. Xiao, H. Wei, Competition and coordination in a dual-channel green supply chain with an eco-label policy, Comput. Ind. Eng. 153 (2021), doi:10.1016/j.cie.2020.107057.
[34] Y. Hou, P. Guo, D. Kannan, K. Govindan, Optimal eco-label choice strategy for environmentally responsible corporations considering government regulations, J. Clean. Prod. 418 (2023), doi:10.1016/j.jclepro.2023.138013.