RAIRO-Oper. Res. 58 (2024) 4035–4067
https://doi.org/10.1051/ro/2024139

RAIRO Operations Research
www.rairo-ro.org

AGENCY OR RESELLING: OPTIMAL RETURN POLICY IN E-COMMERCE RETAIL SYSTEMS UNDER CAP-AND-TRADE REGULATION

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Abstract. In recent years, the government has issued regulations on environmental protection, carbon emissions, and trading. Enterprises' environmental awareness has increased, and the operational strategies of manufacturers and platforms have also been affected by environmental regulations. This study considers the interactive effects of agency and reselling contracts between manufacturers and platforms and the cap-and-trade regulation on return policy. Our findings reveal that government-imposed caps on total carbon emissions consistently influence optimal pricing and profits under cap-and-trade regulation, regardless of the presence of a return policy. Additionally, the emission intensity of manufacturers plays a pivotal role in determining the return policy. High manufacturer emission intensity leads decision-makers to provide return services only under specific conditions. Moreover, manufacturers opt for agency contracts when faced with low commission rates, and this threshold is intricately linked to carbon emission intensity, the cap, and the return rate. The government's ability to adjust the cap enables control over changes in manufacturers' profits and output, thereby influencing industrial structure and carbon emissions. Manufacturers strategically choose return policies, considering factors such as carbon intensity, return rate, and commission rate. Remarkably, even under cap-and-trade regulations, manufacturers remain inclined to offer returns under optimal conditions.

Mathematics Subject Classification. 90B06, 90B50.

Received April 25, 2023. Accepted July 7, 2024.

1. Introduction

In 2021, the landscape of online retail witnessed remarkable growth, as reported by the National Retail Federation (NRF), with U.S. online sales reaching a staggering \$1.05 trillion, constituting 23% of the nation's retail sales. Simultaneously, China's online retail sales, totaling 13.1 trillion yuan, saw a year-on-year surge of 14.1%, representing 24.5% of total retail sales of consumer goods. The rise of the online channel sales model, particularly in technologically advanced countries like the United States and China, has dismantled temporal and spatial constraints inherent in traditional sales models. This shift fosters an environment where suppliers effortlessly showcase their products, and consumers enjoy the flexibility of making purchases at their convenience. The efficiency advantages of online channels, driven by reduced circulation costs, transaction costs, and management costs, have led suppliers to increasingly embrace this model. While traditional channels grapple with escalating building materials and inventory costs, the costs associated with computers and telecommunication equipment

Keywords. Cap-and-trade regulation, agency contract, reselling contract, return policy.

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to support online stores continue to decline. As a result, consumers, armed with just a cell phone or computer, can seamlessly place orders, access diverse product information, benefit from personalized recommendations, and peruse post-consumer evaluations without the need to visit physical stores.

E-commerce platforms serve as effective communication bridges between suppliers and consumers, fostering a conducive trading environment. Currently, two predominant contracts, agency and reselling, dominate online platforms. In the agency model, exemplified by Alibaba's Tmall.com, manufacturers directly sell to consumers through platforms, remitting a commission fee. Conversely, the reselling model involves manufacturers selling products at wholesale prices to platforms, which then set retail prices for consumers. For instance, JD.com operates a self-supporting procurement and sales model where manufacturers decide wholesale prices, and JD.com manages subsequent sales.

Despite the convenience ushered in by the platform economy, the surge in online consumerism has given rise to a significant challenge – product returns. In a landscape where consumers rely solely on digital representations of products, the inability to physically touch items contributes to a disconnection between expectations and reality. Manufacturers leverage photo-retouching software and professional shooting skills to stimulate consumer interest, but this can lead to a misalignment between the product received and consumer expectations. Additionally, logistical delays diminish the satisfaction and expectations of consumers upon receiving products compared to the impulsivity of payment. The repercussions of these factors manifest in a substantial problem of returns, with a reported loss of over $218 billion in the U.S. in 2021, constituting 20.8% of online retail sales. Consumer decisions are significantly influenced by return policies, with 67% checking return terms before making purchases. A money-back guarantee (MBG) holds particular significance for consumers, reducing the risk of retaining undesirable goods [2]. Suwelack *et al.* [28] considered customers' emotions in an empirical study and found that MBG can evoke positive emotional responses that increase customers' willingness to buy and pay. Flexible return policies can enhance consumers' willingness to buy, thus stimulating higher demand [34].

There is growing concern about the environmental damage caused by returns. According to a 2021 survey from Optoro, more than 27 million tons of carbon dioxide emissions annually in the U.S. are attributed to returns, with five billion pounds ending up in landfills. Although platforms and manufacturers use return strategies to stimulate consumer demand and achieve maximum profit, that profit is damaged because some products are returned due to consumer dissatisfaction rather than any particular fault. The production of products that ultimately are returned, for whatever reason, generates and emits large amounts of carbon dioxide into the air, which harms the environment [9]. According to data from the Global Real-Time Carbon Data Network (GRCDN), for example, global carbon emissions from the industrial sector are 10.3 Gt CO_2 in 2021 and 10.46 Gt CO_2 in 2022. Increasingly, governments are trying to adopt various policies to limit carbon emissions to achieve economic sustainability. One of the most widely used policies is the cap-and-trade regulation. The government will give manufacturers free carbon credits (the cap), and if the manufacturer's carbon emissions exceed the cap allocated by the government, they must buy carbon credits from the carbon trading market. If the manufacturer's carbon emissions are lower than the cap allocated by the government, they can sell the remaining carbon credits in the carbon trading market [36]. The government's concern for the environment inevitably impacts the business strategies of enterprises; therefore, the business strategies of enterprises considering environmental impacts deserve the attention and research of enterprises and scholars [7, 17]. Under cap-and-trade regulation, the enterprise or platform must decide when it should provide return services. Analysis of the current literature on return strategy does not consider the impact of carbon emission policies, existing literature mainly focuses on return strategy studies from the perspectives of return leniency, channel structure, and return shipping costs [16, 26, 38].

Therefore, we consider two research questions. First, what is the impact of the cap-and-trade regulation on manufacturers' or platforms' return decisions? Second, considering the optimal choice of return strategy, should the manufacturer sign an agency or a reselling contract? To address the above issues, we consider the interaction between a manufacturer and platform under cap-and-trade regulation, in our model, the manufacturer signs an agency or reselling contract with the platform under the cap-and-trade regulation. The manufacturer decides whether to provide return services under the agency contracts. The platform decides whether to provide return services under the reselling contracts. We first explore the manufacturer's and the platform's return strategies under these two contracts separately. Then we compare the manufacturer's choices for the two contracts. Our contributions are as follows.

First, we find that reducing the cap can effectively control carbon emissions under both contracts, regardless of whether the manufacturer or platform provides return services. When the emission intensity (manufacturer's carbon emissions per unit of product) is high, the manufacturer's profit first decreases with the reduction of the cap, but it increases with decreasing cap when the cap is below a certain threshold. When the emission intensity is low, the manufacturer's profit first increases with the reduction of the cap, but it decreases with decreasing cap when the cap is below a certain threshold. When the emission intensity is moderate, the monotonicity (positive or negative) of the manufacturer's profits with decreasing cap depends on the carbon price sensitivity factor and also on the demand price factor when the platform offers returns in the reselling contract.

Second, this study argues that under both contracts, (1) manufacturers under the agency model (platforms under the reselling model) can choose an appropriate return strategy under certain conditions when manufacturers' emission intensity is low, and (2) when manufacturers' emission intensity is high, manufacturers in the agency model offer returns only if the commission rate and the return rate are low, otherwise, they will not produce; the platform in the resale model only offers returns in case of low return rates.

Third, we compare manufacturers' optimal decisions and profits under the reselling and agency contracts, with and without providing return services. We conclude that: (1) when the commission rate is low, the production quantity and carbon emissions are larger under agency contract. (2) When the commission rate is low, manufacturers prefer the agency contract. The threshold at which manufacturers are indifferent between agency and reselling is influenced by the cap the government has allocated, the manufacturer's emission intensity, and the return rate if return services are provided.

The results of this paper have some limitations in that we distill realistic factors and only consider the effect of carbon. The remainder of this paper is structured as follows. In the next section, we review the relevant literature. In Section 3, we formulate our research question and develop the corresponding model. Section 4 investigates the optimal return decision under the agency and reselling contracts considering the cap-and-trade regulation. Section 5 considers whether the manufacturer should adopt the agency or reselling model when considering the optimal choice of return strategy. In Section 6, we extend the basic model to consider return and production costs. The paper concludes in Section 7, which presents several potential research directions to build on this work.

2. Related literature

This paper is related to three streams of studies: optimal contract selection, return decisions, and production decisions under cap-and-trade regulation.

2.1. Optimal contract strategy

Scholars usually study optimal business decisions under the marketplace and reselling contract and discuss the optimal choice between these two contracts. For example, Hagiu *et al.* [10] study contract model selection from the competition perspective and found that reselling contract is optimal when there are spillover effects and network effects of marketing activities between products, leading to unfavorable expectations of supplier participation. Unlike Hagiu *et al.* [10], Abhishek *et al.* [1] consider the coexistence of two contractual models and investigate the platforms' choices of three contractual models, *i.e.*, resale *versus* resale (RR), agency *versus* agency (AA), and hybrid (RA), by modeling the interaction between a manufacturer and two competing intermediary platforms. If transactions through the platform negatively affect the demand in the manufacturer's traditional channel, then the platform prefers the marketplace contract; otherwise, it prefers the reselling contract. Furthermore, if the competition between intermediary platforms is intense, the platform preference for either particular contract will be weakened. Tian *et al.* [31] continue to consider the case of platform monopolization, by studying a model with two manufacturers and an intermediary platform, they found that (1) it is optimal for the intermediary platform to choose the pure reselling contract when the order fulfillment cost is high and the similarity of the products offered by the manufacturer is low; (2) when the cost of order fulfillment is low, and the similarity of products offered by manufacturers is high, it is optimal for the intermediary platform to choose a pure marketplace contract; and (3) when the order fulfillment cost and the similarity of the products offered by the manufacturer are moderate, the intermediary platform will choose the hybrid strategy. Liu *et al.* [18] consider the supply chain structure of a manufacturer and a platform and find that the platform prefers the agency model when the potential market size is moderate.

Considering the return strategy, Taleizadeh *et al.* [29] defined four contractual models, cost sharing, profit sharing, revenue sharing, and repurchase, and considered the full refund return policy and warranty, confirming that profit sharing and repurchase contracts maximize the profits of both the manufacturer and the retailer. Alaei *et al.* [3] argued that providing return policies in the online platform channel has no effect on the choice between marketplace and reselling contract but does impact the manufacturer's profit across channels.

We continue the work of Alaei *et al.* [3] by studying contract model selection in the context of returns management. However, the difference is that we study the choice of the optimal contract while considering the impact of the cap-and-trade regulation. We find that manufacturers choose agency contracts at a low commission rate. Interestingly, the commission rate threshold at which manufacturers have no preference between agency contracts and reselling contracts is influenced by the firm's carbon emission intensity, the cap, and the return rate.

2.2. Return strategy

In a seminal paper, McWilliams [21] studied the impact of return strategies on retailers and concluded that MBG (money-back guarantee) makes retailers selling low-quality products more profitable, while MBG hurts retailers selling high-quality products. Balakrishnan *et al.* [5] argued that consumers buying in offline stores after browsing and searching for goods on online platforms can reduce the return rate but increase competition between online channels and offline stores, making manufacturers less profitable. Janakiraman *et al.* [13] investigated the effect of the leniency of return strategy on consumer purchase behavior and the return decision by reviewing previous studies and dividing the leniency into five dimensions: return time, money, effort paid, range, and return-exchange. They demonstrated that the leniency of the return strategy increases purchase more than return. Taleizadeh *et al.* [30], by modeling a dynamic channel that includes the consumer and the platform, in which the platform can sell goods through a cash-back website, derive a refund strategy as a support for the consumer, and offer refunds can lead to more consumers if the return rate can be accurately calculated.

Regarding whether to provide MBG, Chen and Grewal [8] studied a supply chain consisting of one manufacturer and two retailers to show that when an existing retailer offers MBG, offering MBG and not offering it could be optimal choices for a new entrant. Ohmura *et al.* [24] showed that the adoption of MBG is related to the risk propensity of supply chain participants, and the greater the risk propensity of supply chain participants, the more favorable the adoption of MBG. Considering a dual-channel scenario, Li *et al.* [15] studied whether manufacturers should provide return service in both direct channel and indirect channels through retailer resale, concluding that if the return rate is low, manufacturers will adopt a full refund/return strategy in both channels, and otherwise, manufacturers will adopt a strategy of not offering return service in either channel; for retailers, if the return rate is low, retailers prefer a full refund return strategy in the indirect channel, but otherwise, they prefer a full refund return strategy in the direct channel. Radhi and Zhang [27] further considers cross-channel returns, explores how returns affect the optimal number of orders across channels if online purchases can be returned to offline stores. Liu *et al.* [19] examines whether dual-channel retailers should allow consumers to return products in both channels and whether they should sign a return insurance contract with the manufacturer. When the customer's sensitivity factor to pricing is high (*i.e.*, demand is low) and the return rate is low, the retailer and the manufacturer should avoid entering into a contract to handle returns. However, when customer sensitivity to pricing and return rates are high, retailers and manufacturers should enter into contracts to maximize profits.

Several studies investigate the optimal leniency of a return strategy. For example, Yoo [39] stated that a lenient return strategy should be developed after the product quality is improved. Ma *et al.* [20], by constructing a model with heterogeneity in consumers' willingness to pay for product quality, concluded that the return window of decentralized channels is longer than that of centralized channels, and the return window of high-quality products is shorter than the return window for low-quality returns.

We continue to study the impact of offering a refund strategy on manufacturers. When scholars such as Janakiraman *et al.* [13] and Taleizadeh *et al.* [30] argue that offering a money-back guarantee leads to more demand; however, production leads to more carbon emissions. We study the return strategy while considering the effects of the cap-and-trade regulation, and focus on return management in the context of online platform channels. We find that under agency contract, manufacturers with low emission intensity might or might not optimally provide return service, depending on certain conditions. As for manufacturers with high emission intensity, they will provide return service under certain conditions, or they will not produce any products when carbon intensity is moderate.

2.3. Cap-and-trade regulation

This study relates to production and operation decisions under the cap-and-trade regulation. The increased environmental protection awareness among governments and the public has led to a series of carbon control policies, including carbon cap mechanisms, cap-and-trade regulation, and carbon tax policies [32].

Research work on the relationship between carbon trading prices and caps, Hua *et al.* [12] studied the optimal order quantity of firms under cap-and-trade regulation. Under the assumption of a fixed carbon price, the optimal order quantity is independent of the cap. The optimal order quantity may decrease with the increase of the cap when the cap and the carbon trading price are inversely proportional. He *et al.* [11] found that the production volume of carbon-intensive firms increases with the increase of allowances by investigating the decision problem of their production volume under a cap-and-trade regulation, assuming a fixed carbon trading price. All the above carbon trading prices are assumed to be the same. Benjaafar *et al.* [6] considered the multiperiod case where carbon emissions can be controlled by reducing the cap allocated to firms when the cap and the carbon trading price are linearly related. Xu *et al.* [37] considered a linear correlation between cap and carbon trading prices and the case where manufacturers do not have excess emission credits to sell at carbon trading prices. By studying the optimal decision for multiple products under the cap-and-trade regulation and the carbon tax policy, he concluded that the optimal production volume for each product is proportional to the cap. Amjadian and Gharaei [4] designed a multi-stage product closed-loop supply chain (CLSC) based on green manufacturing principles and quality control strategies to optimize the quantity and volume of inventory, thereby minimizing the inventory function while maximizing the reliability function.

Several scholars focus on the effect of the cap-and-trade regulation on optimal profit and supply chain coordination. For example, Ji *et al.* [14] concluded that the manufacturer's profit first increases and then decreases as the cap increases. Xu *et al.* [35] assumed that consumers have green preferences, and then supply chain coordination under the cap-and-trade regulation is achieved by designing different contractual mechanisms. Xia *et al.* [33] explored the impact of reciprocal benefits and consumers' environmental awareness on green supply chains under the cap-and-trade regulation.

We follow the assumptions of Benjaafar *et al.* [6] and Xu *et al.* [37] regarding the inverse relationship between the cap and carbon trading price. Unlike the papers mentioned above, we focus on the choice of return strategy and the choice of contracts, assuming that cap-and-trade regulation is in effect. Although previous studies have explored the choice of contract under cap-and-trade regulation, they did not consider the optimal return strategy, and our study shows that considering these together leads to new and different results (Tab. 1).

3. Model

In our model, we study the return decisions of a manufacturer or platform under cap-and-trade regulation in a model where the manufacturer sells its products through the online platform. We model the interaction

TABLE 1. Comparison between this study and its most closely related studies.

	Cap-and-trade regulation		Contract Strategy	Return Strategy
	Fixed carbon price	Linear correlation between cap and carbon price		
Hua *et al.* [12]	√			
Benjaafar *et al.* [6]		√		
Xu *et al.* [37]		√	√	
Ohmura *et al.* [24]				√
Radhi and Zhang [27]				√
Alaei *et al.* [3]			√	√
Tian *et al.* [31]			√	
Taleizadeh *et al.* [29]			√	√
This paper		√	√	√

between an online platform and a manufacturer as a Stackelberg game. We assume that the platform operates in agency or reselling model. In practice, manufacturers can choose to work with a platform that operates in reselling model or choose one using agency model, so we consider that it is the manufacturer who decides on the type (reselling or agency) of the contracts. Second, the operating model of the platform directly affects the operating decisions of the manufacturer and platform. In agency model, the manufacturer decides whether to provide return services, and the manufacturer sells the goods directly to the consumer at a price p through the platform and pays the platform a $\varphi(0 < \varphi < 1)$ proportion of the revenue, and keeps $1 - \varphi$ proportion of the revenue itself. In reselling model, the platform decides whether to provide return services, and then sells the product to the platform at the wholesale price w, and then the platform decides the retail price and sells it to the consumer. Figure 1 illustrates the model's decision tree. Depending on the manufacturer's choice between an agency contract and reselling contract in stage 1, and the choice of the manufacturer or platform between providing and not providing return services in stage 2, there are four possible subgames for stage 3, manufacturers and platforms make decisions on optimal retail and wholesale prices under each subgame in stage 3. We depict our research problem in Figure 2.

– Agency/Yes (AY): in the agency model, the manufacturer provides return services. This is the stage 3 subgame where the manufacturer chooses agency contracts and then chooses to provide return services. Here, the manufacturer sets the retail price of the product.
– Agency/No ($A\bar{\text{Y}}$): in the agency model, the manufacturer does not provide return services. In this stage 3 subgame, the manufacturer sets the retail price.
– Reselling/Yes (RY): in the reselling model, the platform provides return services. In this stage 3 subgame, the manufacturer first sets the wholesale price, then the platform responds by setting the retail price.
– Reselling/No ($R\bar{\text{Y}}$): in the reselling model, the platform does not provide return services. In this stage 3 subgame, the manufacturer first sets the wholesale price, then the platform responds by setting the retail price.

Following Xu *et al.* [37], under cap-and-trade regulation, we assume that the carbon price is $b = a_0 - b_0C$, where a_0 is the base price, b_0 is the carbon price sensitivity factor. Here, C is the carbon emission credits allocated by the government to the manufacturer $(0 < C < \frac{a_0}{b_0})$, and the carbon price formula implies that the carbon emission allowance cap is inversely related to the carbon trading price. We set the carbon emissions per unit of good produced (*i.e.*, emissions intensity) to be e_0. In addition, we assume that consumer demand under no return service is $1 - p$, the consumer demand under full refund return service is $1 - bp$, and the price factor $b(0 < b < 1)$ indicates that consumer demand can be promoted when return services are offered [22].

We summarize the notation used in this study in Table 2.

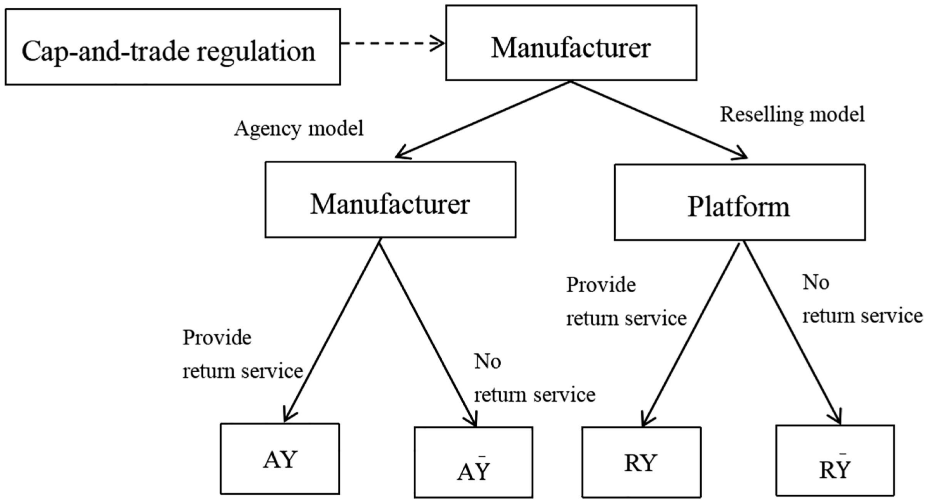


FIGURE 1. Decision tree.

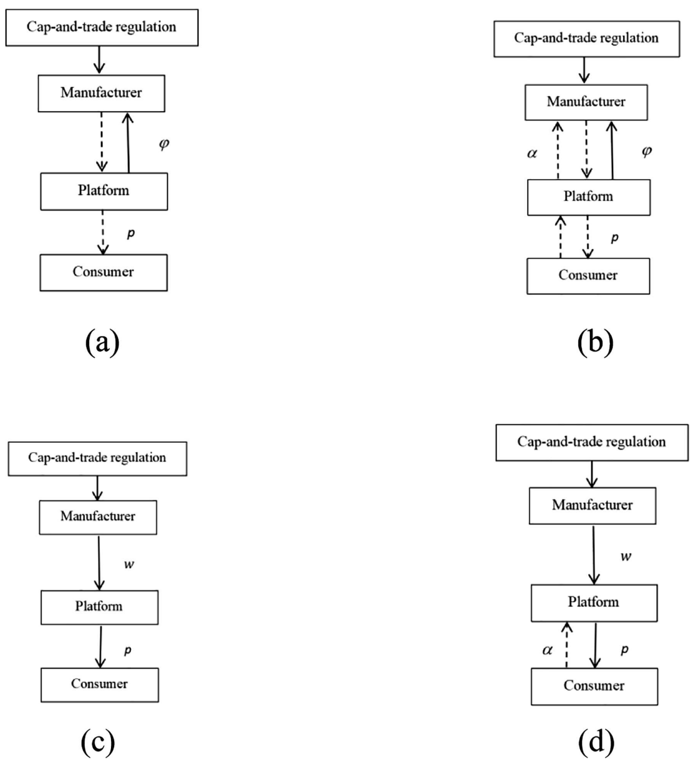


FIGURE 2. Structure of research questions. (a) Model $A\bar{Y}$. (b) Model AY. (c) Model $R\bar{Y}$. (d) Model RY.

TABLE 2. Parameters and corresponding definitions.

Parameters	
φ	Commission rate
α	Return rate
a_0	Maximum potential carbon price
b_0	Price sensitivity of the cap
C	Cap under cap-and-trade regulation
e_0	Unit product carbon emission
π	Profit of the members
Superscripts $Y, \bar{Y}$	Provide return service and not provide return service, respectively
Superscripts A, R	Agency model and reselling model, respectively
Superscript m, p	Manufacturer and platform, respectively
Superscript $*$	Denotes an optimal decision
Decision variables	
p	Retail price
w	Wholesale price

4. Results

Using backward induction, we first analyze the four possible subgames of the third stage $\{A\bar{Y}, AY, R\bar{Y}, RY\}$, then discuss the operational decision of whether the platform or manufacturer provides return services in the second stage. Then, in the next section, we examine the manufacturer's contract strategies decision in the first stage.

4.1. Platform return decision under the agency contracts

In this subsection, we analyze the manufacturer's return strategy (*i.e.*, whether or not to provide return services) in the second stage under the agency contracts. For this purpose, we first derive the equilibrium prices and profits for the $A\bar{Y}$ and AY return strategy subgames in the third stage:

In the agency model, the profits for the manufacturer and platform when the manufacturer does not provide return service in the third stage are as follows (strategy $A\bar{Y}$):

$$\begin{aligned} \pi_m^{A\bar{Y}} &= (1-\varphi)p^{A\bar{Y}}D^{A\bar{Y}} - (a_0 - b_0\ C)\Big(e_0\ D^{A\bar{Y}} - C\Big) \\ \pi_p^{A\bar{Y}} &= \varphi p^{A\bar{Y}}D^{A\bar{Y}}. \end{aligned} \tag{1}$$

Lemma 1. *In agency model, the optimal decision and profit for the manufacturer and platform when the manufacturer does not provide return service are as shown in Table 3.*

From Lemma 1, it can be obtained that under the agency contracts, if the manufacturer does not provide return services, the retail price increases with the commission rate, decreases with the cap, and increases with the manufacturer's carbon emission intensity. In addition, the commission rate interval of the subgame equilibrium increases with the cap and decreases with the manufacturer's carbon emission intensity.

In the agency model, the profits for the manufacturer and platform when the manufacturer provides return services are as follows (strategy AY):

$$\begin{aligned} \pi_m^{AY} &= (1-\varphi)(1-\alpha)p^{AY}D^{AY} - (a_0 - b_0C)\big(e_0D^{AY} - C\big) \\ \pi_p^{AY} &= \varphi p^{AY}(1-\alpha)D^{AY}. \end{aligned} \tag{2}$$

Lemma 2. *In agency model, the optimal decision and profit for the manufacturer and platform when the manufacturer provides return service is as shown in Table 4.*

TABLE 3. The optimal price and profits of the manufacturer and the platform under $A\bar{Y}$ strategy.

Equilibrium	$0 < e_0 < -\frac{1}{-a_0 + Cb_0}$ && $0 < \varphi \leq 1 - a_0e_0 + Cb_0e_0$
Retail price $p^{A\bar{Y}^*}$	$\frac{-1 + \varphi - a_0e_0 + Cb_0e_0}{2(-1 + \varphi)}$
Demand $D^{A\bar{Y}^*}$	$\frac{1}{2}\left(1 + \frac{(a_0 - Cb_0)e_0}{-1 + \varphi}\right)$
Manufacturer's profit $\pi_m^{A\bar{Y}^*}$	$\frac{1}{4}\left(1 - \varphi + \frac{(a_0 - Cb_0)(4C(-1 + \varphi) + e_0(2 - 2\varphi + (-a_0 + Cb_0)e_0))}{-1 + \varphi}\right)$
Platform's profit $\pi_p^{A\bar{Y}^*}$	$\frac{1}{4}\varphi\left(1 - \frac{(a_0 - Cb_0)^2e_0^2}{(-1 + \varphi)^2}\right)$

TABLE 4. The optimal price and profits of the manufacturer and the platform under AY strategy.

Equilibrium	$0 < e_0 < \frac{-1 + \alpha}{-ba_0 + bCb_0}$ && $0 < \varphi \leq \frac{-1 + \alpha + ba_0e_0 - bCb_0e_0}{-1 + \alpha}$
Retail price p^{AY^*}	$\frac{1}{2}\left(\frac{e_0(a_0 - b_0C)}{(\alpha - 1)(\varphi - 1)} + \frac{1}{b}\right)$
Demand D^{AY^*}	$\frac{1}{2}\left(1 + \frac{b(-a_0 + Cb_0)e_0}{(-1 + \alpha)(-1 + \varphi)}\right)$
Manufacturer's profit $\pi_m^{AY^*}$	$\frac{1}{4}\left(\frac{(-1 + \alpha)(-1 + \varphi)}{b} + (a_0 - Cb_0)\left(4C + e_0\left(-2 + \frac{b(a_0 - Cb_0)e_0}{(-1 + \alpha)(-1 + \varphi)}\right)\right)\right)$
Platform's profit $\pi_p^{AY^*}$	$-\frac{(-1 + \alpha)\varphi}{4b} + \frac{b\varphi(a_0 - Cb_0)^2e_0^2}{4(-1 + \alpha)(-1 + \varphi)^2}$

From Lemma 2, it can be obtained that under the agency contracts, if the manufacturer provides return services, the retail price increases with the commission rate, decreases with the cap, increases with the manufacturer's carbon emission intensity, and increases with the return rate. In addition, the commission rate interval of the subgame equilibrium increases with the cap, decreases with the manufacturer's carbon emission intensity, and decreases with the return rate.

Lemmas 1 and 2 lead to several interesting findings. We present these findings in Propositions 1–3.

Proposition 1. *In the agency model*

(a) *Production volume and carbon emissions increase with the increase in the cap, regardless of whether the manufacturer offers return service. The higher the manufacturer's carbon emissions per unit of product produced, the more sensitive the manufacturer is to changes in the cap.*
(b) *When the manufacturer provides return service, the higher the rate of returns, the more sensitive the manufacturer is to the cap.*

Proposition 1 shows that the optimal production volume is influenced by the cap regardless of whether the manufacturer provides return service. That is, controlling the cap can be used to control the firm's carbon emissions, which is something that previous studies have debated. Hua *et al.* [12] argued that the cap is not relevant to the production volume and carbon emissions cannot be affected by controlling the cap, while other studies show that adjusting the cap can control carbon emissions and the optimal production volume increases as the cap increases [37]. This difference may come from different assumptions about carbon trading prices. Hua *et al.* [12] assumes that carbon trading prices are fixed, an assumption that applies to volume and emissions decisions in a given time period for firms with small or moderate emission intensity, while [37] assumes that the price of carbon trading and the cap are inversely proportional to each other. We continue to adopt the [37] assumption and study the impact of the cap-and-trade regulation on the control of production volume and carbon emissions under the consideration of return management. The results of our work show that controlling the cap can control carbon emissions regardless of whether return services are provided. Moreover, when the government lowers the manufacturer's carbon cap, the manufacturer's carbon emissions decrease along with it; the more energy-intensive the manufacturer is, the more sensitive it is to the government's decision to lower the cap and the more an energy-intensive manufacturer's output decreases compared to a less energy-intensive manufacturer's output. Thus, the higher energy-intensive manufacturer's carbon emissions decrease more than the lower energy-intensive manufacturer's carbon emissions.

In addition, in the case of manufacturers providing return services, high-return-rate manufacturers are more sensitive to the government's decision to control the cap. When the government lowers the cap, high-return-rate manufacturers' carbon emissions are reduced more than low-return-rate manufacturers' carbon emissions.

Therefore, when the government lowers the cap on manufacturers' carbon emissions, the company's output will decrease as the cap is lowered, and manufacturers with higher energy consumption and higher return rate will reduce their output and carbon emissions more. Similarly, when the government increases the cap on manufacturers' carbon emissions, manufacturers with lower energy consumption and lower return rates have less production and carbon emissions growth. High-energy-consuming industries are mainly petroleum, coal, and other fuel processing industries; chemical raw materials and chemical products manufacturing industries; non-metallic mineral products industries, and ferrous metal smelting and rolling processing industries; non-ferrous metal smelting and rolling processing industries; electricity and heat production and supply industries; and other traditional industries. Low-end manufacturing through platform retailing is inextricably linked to these traditional industries; for example, chemical fiber garments consume large amounts of energy in their production and processing. Two examples of low-energy-consuming industries are new energy industries and high-tech industries, products sold through the platform include storage devices, cell phones, and more.

To maintain a balance between the goals of "carbon emission control" and "industrial upgrading and high-quality development", the government can adjust the cap for high-tech manufacturers with low energy consumption and low return rates to a higher level and the cap for Low-end manufacturers with high energy consumption and high return rates to a lower level. Manufacturers with low energy consumption or return rates will produce more, with a concomitant increase in carbon emissions. Manufacturers with high energy consumption or return rates will produce less and emit less carbon. Manufacturers with high energy consumption or return rates are more sensitive to adjustments in the cap. By controlling the cap, the government can control the extent of carbon emissions and the speed and extent of industrial transformation. In addition, in the case of manufacturers belonging to the same industry, when the cap for enterprises with low energy consumption or return rate is adjusted in a larger direction by the same amount as the cap allocated to enterprises with high energy consumption or high return rate is adjusted in a smaller direction, the reduction in carbon emissions by enterprises with high energy consumption and high return rate is higher than the increase in production or carbon emissions by enterprises with low energy consumption and return rate, which indicates that a reasonable adjustment of the cap value can effectively encourage the development of enterprises in the same industry with low energy consumption and the reduction of the industry's total carbon emissions.

Thus, controlling the cap not only controls carbon emissions but also controls industrial upgrading and achieves high-quality economic development.

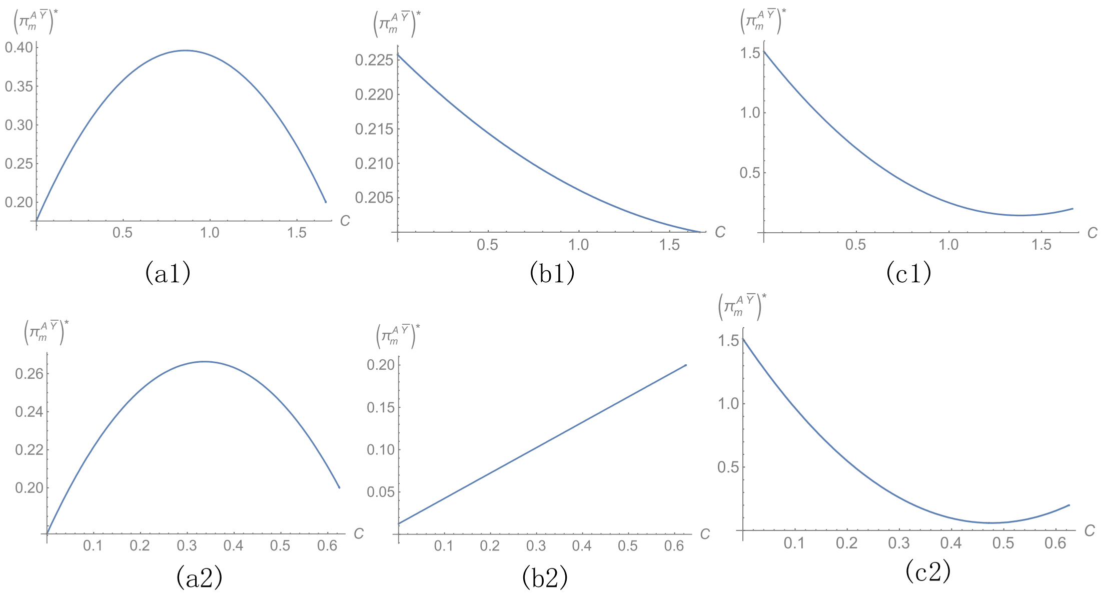


FIGURE 3. Change in the manufacturer's profit under different e_0. (a1) $b_0 = 0.3; e_0 = 0.1$ (b1) $b_0 = 0.3; e_0 = 3.3$. (c1) $b_0 = 0.3; e_0 = 6$. (a2) $b_0 = 0.8; e_0 = 0.1$. (b2) $b_0 = 0.8; e_0 = 2$. (c2) $b_0 = 0.8; e_0 = 6$.

Define

$$\tilde{C} = \begin{cases} C_1 = \frac{-2a_0+2\varphi a_0-b_0e_0+\varphi b_0e_0+a_0b_0e_0^2}{b_0(-4+4\varphi+b_0e_0^2)} & \text{Thresholds under no return service} \\ C_2 = \frac{(-1+\alpha+\varphi-\alpha\varphi)b_0e_0+a_0(-2(-1+\alpha)(-1+\varphi)+bb_0e_0^2)}{b_0(-4(-1+\alpha)(-1+\varphi)+bb_0e_0^2)} & \text{Thresholds under provision of return services} \end{cases},$$

where the manufacturer's optimal profit $\pi_m^{A\bar{Y}^*}$ and $\pi_m^{AY^*}$ are to be maximized. Then we have the following proposition about the effect of the cap C on $\pi_m^{A\bar{Y}^*}$ and $\pi_m^{AY^*}$.

Proposition 2. *In the agency model, regardless of whether the manufacturer provides return services*

(a) *When the manufacturer's carbon emission intensity e_0 is high, the manufacturer's profit first decreases, but it then increases once the cap falls below $\tilde{C}$ as the cap decreases.*
(b) *When the manufacturer's carbon emission intensity e_0 is low, the manufacturer's profit increases first, but it then decreases once the cap falls below $\tilde{C}$ as the cap decreases.*
(c) *When the carbon price factor b_0 is large and the manufacturer's carbon intensity e_0 is moderate, the manufacturer's profit decreases as the cap decreases. When the carbon price factor b_0 is small and the manufacturer's carbon intensity e_0 is moderate, the manufacturer's profit increases as the cap decreases.*

We assume that $a_0 = 0.5$, $\varphi = 0.2$, when the manufacturer does not offer returns, and we explore the change in the manufacturer's profit under different e_0 through numerical analysis.

When firms offer returns, the numerical analysis shows that firms' profits change at different e_0 similar to Figure 3.

Proposition 2 and Figure 3 indicates that the effect of the cap on manufacturer profits is similar, regardless of whether the manufacturer offers return service. When the manufacturer's carbon emission intensity is high (a high-energy-consumption manufacturer) and the cap is above a certain threshold $\tilde{C}$, lower production quantities dominate as the cap decreases, and thus the manufacturer's profits decrease as the cap decreases. However, when the cap falls below a certain threshold $\tilde{C}$, increased retail prices and gains from carbon trading dominate, and thus the manufacturer's profits increase as the cap decreases. Moreover, when the manufacturer's carbon emission intensity is low (a low-energy-consumption manufacturer) and the cap is above a certain threshold $\tilde{C}$, increases in retail price and the gains from carbon trading dominate as the cap decreases, and thus the manufacturer's profit increases as the cap decreases. However, when the cap is below a certain threshold $\tilde{C}$, the increased production quantity dominates, and the manufacturer's profit decreases as the cap decreases.

Therefore, the government needs to consider the carbon emission profit change threshold when controlling the cap. Above a certain threshold, if the government gradually reduces the carbon emission cap, the profits of high-energy-consumption enterprises gradually decrease, while the profits of low-energy-consumption enterprises gradually increase, and investors' expectations of investment returns for the high-energy-consumption industries fall. This will reduce investors' interest in investing in high-energy-consumption industries, which will slow down the development of those industries. For low-energy-consumption firms, on the other hand, above a specific threshold, the profits of low-energy-consumption enterprises are increased if the government lowers the cap on carbon emissions. This will reduce investors' interest in investing in low-energy-consumption industries. Suppose that a traditional high-energy industry firm wants to be sustainable and gain investors' favor in the context of low-carbon policies. In that case, the firm must continue to develop energy-saving technologies to achieve energy conservation and emission reduction.

In addition, when the carbon price factor is high and when the carbon intensity is moderate, manufacturers' profits keep decreasing as the government lowers the cap. When the carbon price factor is low and the carbon intensity is moderate, the manufacturer's profit increases as the government lowers the cap. This difference is due to the different carbon price factors, which result in different trends in manufacturers' profit changes from selling carbon credits with the cap. When the cap decreases, the price of carbon decreases more for high carbon price factors relative to low carbon price factors. Monotonicity occurs due to the combined effect of price and output changes and carbon price factors. Therefore, the government needs to consider the carbon price sensivity factor when controlling the cap, which will affect the change in profits of manufacturers with moderate energy consumption and thus affect the development of industries with moderate energy consumption.

Proposition 3. *When* $0 < e_0 \leq e_1$ *holds,*

(a) *if* $0 < \alpha < 1 - b$ *and* $0 < \varphi < \varphi_1$*, manufacturers prefer to provide return services;*
(b) *if* $1 - b < \alpha < 1$ *and* $0 < \varphi < \varphi_2$*, manufacturers prefer not to provide return services.*
When $e_1 < e_0 < e_2$ *holds;*
(c) *if* $0 < \alpha < 1 - ba_0e_0 + bcb_0e_0$ *and* $0 < \varphi < \varphi_1$*, manufacturers prefer to provide return services, where* $\varphi_1 = 1 + \frac{b(a_0 - Cb_0)e_0}{-1+\alpha}$, $\varphi_2 = 1 - a_0e_0 + Cb_0e_0$, $e_1 = -\frac{1}{-a_0+Cb_0}$, $e_2 = -\frac{1}{-ba_0+bCb_0}$; φ_1, φ_2 *both increase in* C *and decreases with* e_0, φ_1 *decreases with* α.

We assume that $C = 0.6$, $a_0 = 0.4$, $b_0 = 0.4$, $b = 0.2$, and we use numerical analysis to explore the conditions of manufacturers' return decision under different e_0. The results are shown in Figure 4.

From Proposition 3 and the numerical analysis results, we can see that in the agency model, the optimal decision of the low-energy-consumption manufacturer is to choose not to provide return service when the return rate is high and the commission rate is low. Manufacturers with low energy consumption should provide return services when the return rate is low and the commission rate is low. Otherwise, such manufacturers should choose to sell all of their carbon credits. In addition, the optimal decision for manufacturers with high energy consumption is not to produce and instead, sell all their carbon rights when the return rate is high. Manufacturers with high energy consumption provide return service when the return rate and commission rate are low, and do not produce when the return rate is low and the commission rate is high.

Now consider agency model as the carbon emissions per unit of product increase or the cap decreases, the smaller the critical value of the commission rate that manufacturers are indifference to whether or not to produce. (*i.e.*, the higher the carbon emissions intensity of enterprises or the lower the cap assigned to manufacturers by the government, the smaller share of profit can be charged by the platform while guaranteeing the manufacturer's

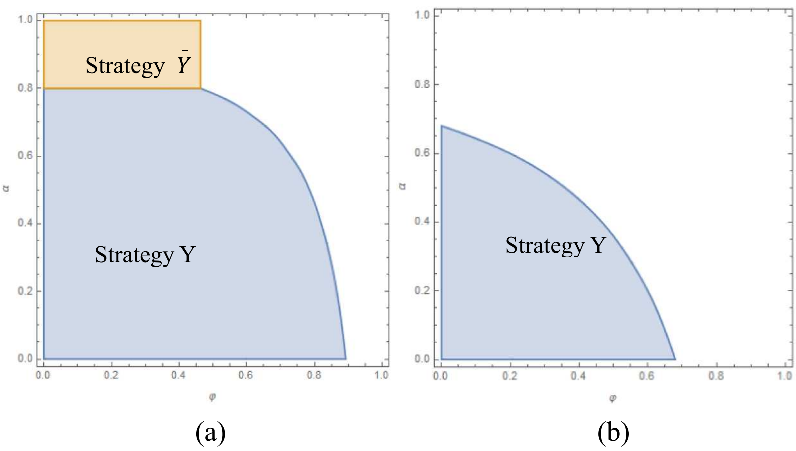


FIGURE 4. Return strategy in agency model. (a) $e_0 = 2$. (b) $e_0 = 10$. Note: (i) Strategy $\bar{Y}$: the manufacturer does not offer return services. (ii) Strategy Y: the manufacturer offer return services.

willingness to produce. Thus, the more-energy-intensive manufacturers have a more demanding condition under the cap-and-trade regulation, and the cap-and-trade regulation can effectively control the development of the industry. Furthermore, whether the manufacturer has low or high energy consumption, when the return rate is low, the manufacturer will provide return services, and the platform can charge a higher commission when the return rate is lower. That is, the lower the return rate, the companies are willing to provide return services at a higher commission rate.

4.2. Platform return decision under the reselling contracts

In this subsection, we analyze the platform's return strategy (*i.e.*, whether to provide return services) in the second stage under reselling contracts. Compared to the agency contracts, where the return decision is made by the manufacturer, the platform makes the return decision in reselling model. For this purpose, we will first derive the equilibrium prices and profits for the two $R\bar{Y}$ and RY subgames in the third stage:

In the reselling model, the profits for the manufacturer and platform when the manufacturer does not provide return service in the third stage are as follows (strategy $R\bar{Y}$):

$$\pi_m^{R\bar{Y}^*} = w^{R\bar{Y}} D^{R\bar{Y}} - (a_0 - b_0 C)\left(e_0 D^{R\bar{Y}} - C\right)$$
$$\pi_p^{R\bar{Y}^*} = \left(p^{R\bar{Y}} - w^{R\bar{Y}}\right) D^{R\bar{Y}}. \tag{3}$$

Lemma 3. *In the reselling model, the optimal decision and profit for the manufacturer and platform when the platform does not provide return services are as shown in Table 5.*

From Lemma 3, it can be obtained that under reselling contracts, if the platform does not provide return service, the retail and wholesale prices decrease with the cap and increase with the manufacturer's carbon emission intensity. Also, the carbon intensity interval of the subgame equilibrium increases with the cap.

In the reselling model, the platform provides return services in the third stage with the following profits for the manufacturer and platform (strategy RY):

$$\pi_m^{RY} = w^{RY} D^{RY} - (a_0 - b_0 C)\left(e_0 D^{RY} - C\right)$$
$$\pi_p^{RY} = (p(1-\alpha) - w) w^{RY}. \tag{4}$$

TABLE 5. The optimal price and profits of the manufacturer and the platform under $R\bar{Y}$ strategy.

Equilibrium	$0 < e_0 \leq -\frac{1}{-a_0 + Cb_0}$
Retail price $p^{R\bar{Y}^*}$	$\frac{1}{4}(3 + (a_0 - Cb_0)e_0)$
Wholesale price $w^{R\bar{Y}^*}$	$\frac{1}{2}(1 + a_0e_0 - Cb_0e_0)$
Demand $D^{R\bar{Y}^*}$	$\frac{1}{4}(1 + (-a_0 + Cb_0)e_0)$
Manufacturer's profit $\pi_m^{R\bar{Y}^*}$	$\frac{1}{8}(1 + (a_0 - Cb_0)(8C + e_0(-2 + (a_0 - Cb_0)e_0)))$
Platform's profit $\pi_p^{R\bar{Y}^*}$	$\frac{1}{16}(-1 + (a_0 - Cb_0)e_0)^2$

TABLE 6. The optimal price and profits of the manufacturer and the platform under RY strategy.

Equilibrium	$0 < e_0 \leq \frac{-1 + \alpha}{-ba_0 + bCb_0}$
Retail price p^{RY^*}	$\frac{3}{4b} - \frac{(a_0 - Cb_0)e_0}{4(-1 + \alpha)}$
Wholesale price w^{RY^*}	$\frac{1 - \alpha + b(a_0 - Cb_0)e_0}{2b}$
Demand D^{RY^*}	$\frac{1}{4}\left(1 + \frac{b(a_0 - Cb_0)e_0}{-1 + \alpha}\right)$
Manufacturer's profit $\pi_m^{RY^*}$	$-\frac{-1 + \alpha}{8b} + \frac{(a_0 - Cb_0)(8C(-1 + \alpha) + e_0(2 - 2\alpha + b(-a_0 + Cb_0)e_0))}{8(-1 + \alpha)}$
Platform's profit $\pi_p^{RY^*}$	$-\frac{(-1 + \alpha + b(a_0 - Cb_0)e_0)^2}{16b(-1 + \alpha)}$

Lemma 4. *In the reselling model, the platform provides return services in the third stage, and the optimal profit for the manufacturer and the platform are as shown in Table 6.*

From Lemma 4, it can be obtained that under the reselling contracts, if the platform provides return services, the retail price decreases with the cap, increases with the manufacturer's carbon emission intensity, and increases with the return rate. The wholesale price decreases with the cap, increases with the manufacturer's carbon emission intensity, and decreases with the return rate. Also, the carbon intensity interval of the subgame equilibrium increases with the cap and decreases with the return rate.

Lemmas 3 and 4 lead to several interesting findings. We state these findings in Propositions 4–6.

Proposition 4. *In the reselling model, the following hold:*

(a) *The production volume and carbon emissions increase with increasing cap, regardless of whether the platform provides return services. Moreover, the higher the manufacturer's carbon emissions per unit of product produced, the more sensitive the manufacturer is to changes in the cap.*

(b) *When the platform provides return services, the higher return rate, the more sensitive the manufacturer is to the cap.*

Proposition 4 is similar to Proposition 1 in that it shows a similar effect of government control of the cap on production volume and carbon emissions in the agency and reselling model, so we will not repeat the previous analysis here.

Define $C_3 = \frac{(-1+\alpha)b_0e_0+a_0(-4+4\alpha+bb_0e_0^2)}{b_0(-8+8\alpha+bb_0e_0^2)}$. Here, the manufacturer's optimal profit $\pi_m^{R\bar{Y}^*}$ and $\pi_m^{RY^*}$ can be maximized. Then we have the proposition about the effect of carbon emission C on $\pi_m^{R\bar{Y}^*}$ and $\pi_m^{RY^*}$.

The changes in the manufacturer's profit with respect to the cap C in the reselling model, where the platform does not provide a return service, are roughly similar to those changes with respect to C in the agency model. Those changes with C when the platform provide return services are described in Proposition 5.

Proposition 5. *In the reselling model, if the platform provides return services.*

(a) *When the manufacturer's carbon emission intensity e_0 is high, the manufacturer's profit first decreases as the cap decreases but then increases once the cap falls below C_3.*
(b) *When the manufacturer's carbon emissions intensity e_0 is low, the manufacturer's profit first increases as the cap decreases but then decreases once the cap falls below C_3.*
(c) *When the carbon price factor b_0 and the price factor of demand b is low, or when the carbon price factor b_0 is high, the manufacturer's profit decreases as the government lowers the cap if the manufacturer's carbon emission intensity is moderate. If the carbon price factor b_0 is low and the price factor of demand b is high, the manufacturer's profit increases as the government lowers the cap when the carbon emission intensity is moderate.*

We assume that $a_0 = 0.5$, $\alpha = 0.35$. When the manufacturer provides returns, we explore the change in the manufacturer's profit by numerical analysis under different e_0.

Proposition 5 and Figure 5 shows that the impact of the cap on manufacturer profits when the platform provides return services in the reselling model. Propositions 5(a) and 5(b) indicate that the effect of the cap on manufacturer profits when manufacturers have high and low carbon emissions intensity. We argue that as the cap decreases, the combined effects of lower demand, higher wholesale prices, and the gains from selling carbon credits make the manufacturer's profit subsequently decrease at first and then increase for high-energy-consumption manufacturers, but the profit increases at first and then decreases for low-energy-consumption manufacturers.

Proposition 5(c) shows that if the carbon price factor is high, the manufacturer's profit decreases with cap reductions, the reasons are similar to those in the agency model. If the carbon price factor is low and the demand price factor is low, the lower retail price when reducing the cap does not cause a substantial reduction in the demand, and the lower potential to sell more carbon emission credits dominates the position. Thus, under the combined effect of carbon trading proceeds, output, and retail price, the manufacturer's profit decreases with the reduction of the cap. But when the carbon price factor is low and the demand price factor is high, the reduction of the cap will cause a more significant reduction of demand, and selling more carbon emission credits dominates the position, so under the combined effect of carbon trading gains, output, and retail price, the manufacturer's profit increases with the reduction of the cap.

Therefore, consider the case that the government considers the changes in profits of manufacturers who enter into reselling contracts with platforms that provide return services when controlling carbon emissions through controlling the cap. For this case, we argue that the government needs to pay attention to the threshold for the change in the direction of profits of high- and low-energy-consuming manufacturers. Also, we believe that the government needs to consider the carbon price sensitivity factor and consumer demand sensitivity in the case of returns when considering the direction of variation in profits of moderate-energy-consuming manufacturers with the cap.

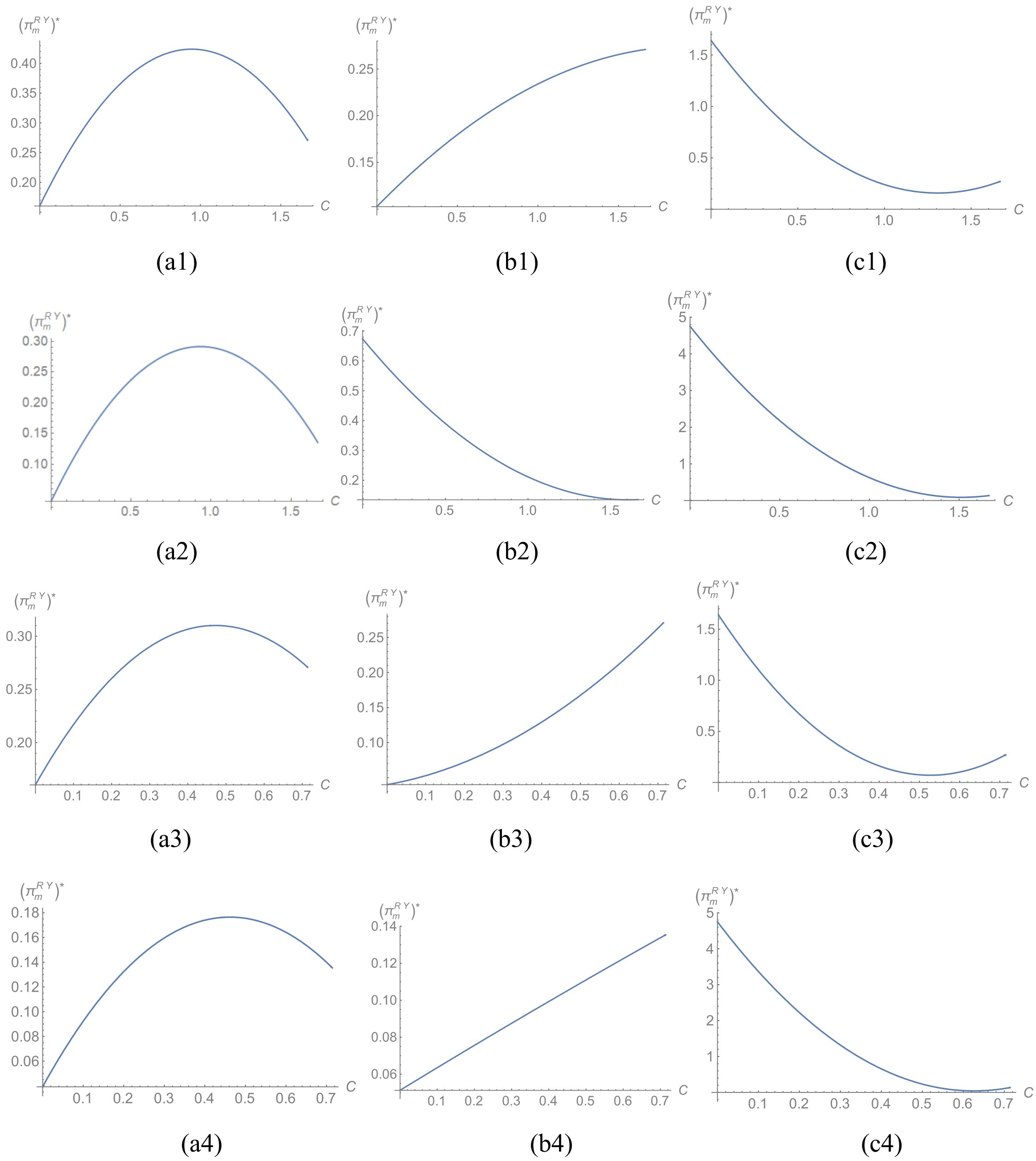


FIGURE 5. Change in the manufacturer's profit at different values of e_0. (a1) $b_0 = 0.3$; $b = 0.3$; $e_0 = 1$. (b1) $b_0 = 0.3$; $b = 0.3$; $e_0 = 7$. (c1) $b_0 = 0.3$; $b = 0.3$; $e_0 = 15$. (a2) $b_0 = 0.3$; $b = 0.6$; $e_0 = 1$. (b2) $b_0 = 0.3$; $b = 0.6$; $e_0 = 7$. (c2) $b_0 = 0.3$; $b = 0.6$; $e_0 = 15$. (a3) $b_0 = 0.7$; $b = 0.3$; $e_0 = 1$. (b3) $b_0 = 0.7$; $b = 0.3$; $e_0 = 6$. (c3) $b_0 = 0.7$; $b = 0.3$; $e_0 = 15$.

Proposition 6. *In the reselling model, the following hold:*
When $0 < e_0 \le e_1$,

(a) *if* $0 < \alpha < 1 - b$, *the platform prefers to provide return services;*
(b) *if* $1 - b < \alpha < 1$, *the platform prefers not to provide return services.*
When $e_1 < e_0 < e_2$,
(c) *if* $0 < \alpha < 1 - ba_0e_0 + bCb_0e_0$, *the platform prefers to provide return services where* $e_1 = -\frac{1}{-a_0+Cb_0}$, $e_2 = -\frac{1}{-ba_0+bCb_0} \cdot e_1$, e_2 *both increase in* C.

In addition to the above results, the platform's profit is the same regardless of whether the platform chooses to provide return services, and the manufacturer's output is 0; all carbon rights are sold.

Considering the cap-and-trade regulation, in the reselling model. From Propositions 6(a) and 6(b), if the platform cooperates with a low-energy and high-return-rate manufacturer, it is optimal for the platform to not provide return service; but when the platform cooperates with a low-energy and low-return-rate manufacturer, the platform should provide return service. From Proposition 6(c), if the platform cooperates with a high-energy-consumption and low-return-rate manufacturer, it is optimal for the platform to provide return services.

5. Comparison of the agency and reselling models

In this section, after considering the case of the optimal return strategy, we compare the optimal equilibrium results in the agency the reselling model, resulting in the following proposition.

Proposition 7. *Assume* $0 < e_0 \le e_1$ *holds:*

(a) *if* $0 < \alpha < 1 - b$ *and* $0 < \varphi < \varphi_3$, *there is more output in agency model;*
(b) *if* $1 - b < \alpha < 1$ *and* $0 < \varphi < \varphi_4$, *there is more output in agency model.*
When $e_1 < e_0 < e_2$ *holds;*
(c) *if* $0 < \alpha < 1 - ba_0e_0 + bCb_0e_0$ *and* $0 < \varphi < \varphi_3$, *there is more output in agency model where* $\varphi_3 = -1 + \frac{2(-1+\alpha)}{-1+\alpha+b(-a_0+Cb_0)e_0}, \varphi_4 = -1 + \frac{2}{1+(a_0-Cb_0)e_0}$, $e_1 = -\frac{1}{-a_0+Cb_0}$, $e_2 = -\frac{1}{-ba_0+bCb_0}$, *and* φ_3, φ_4 *both increase in* C *and decreases with* e_0, φ_3 *decreases with* α.

Therefore, after considering the case of the optimal return strategy for cap-and-trade regulation, regardless of whether the platform or the manufacturer provides return services, we argue that firms produce more and generate higher carbon emissions in the agency model when the commission is low. Also, the higher the cap, the higher the commission rate that enables manufacturers to produce more as well as generate higher carbon emissions in the agency model. That is, manufacturers have higher output and higher carbon emissions in the agency model, even with a higher commission rate.

Proposition 8. *When* $0 < e_0 \le e_1$ *holds;*

(a) *if* $0 < \alpha < 1 - b$ *and* $0 < \varphi < \varphi_5$, *manufacturers prefer the agency model;*
(b) *if* $1 - b < \alpha < 1$ *and* $0 < \varphi < \varphi_6$, *manufacturers prefer the agency model.*
When $e_1 < e_0 < e_2$ *holds;*
(c) *if* $0 < \alpha < 1 - ba_0e_0 + bcb_0e_0$ *and* $0 < \varphi < \varphi_5$, *manufacturers prefer the agency model where* $\varphi_5 = \frac{1}{4(-1+\alpha)^2}((-1+\alpha+b(a_0-Cb_0)e_0)(3(-1+\alpha)+b(-a_0+Cb_0)e_0) - \sqrt{((-1+\alpha+b(a_0-Cb_0)e_0)^2((-1+\alpha)^2+b(a_0-Cb_0)e_0(6-6\alpha+b(a_0-Cb_0)e_0)))}, \varphi_6 = \frac{1}{4}(3+(a_0-Cb_0)e_0(-2+(-a_0+Cb_0)e_0) - \sqrt{(1+(-a_0+Cb_0)e_0)^2(1+(a_0-Cb_0)e_0(6+(a_0-Cb_0)e_0))}); e_1 = -\frac{1}{-a_0+Cb_0}, e_2 = -\frac{1}{-ba_0+bCb_0}; \varphi_5$ *and* φ_6 *increase as* C *increases and decrease as* e_0 *increases;* φ_5 *decreases as* α *increases.*

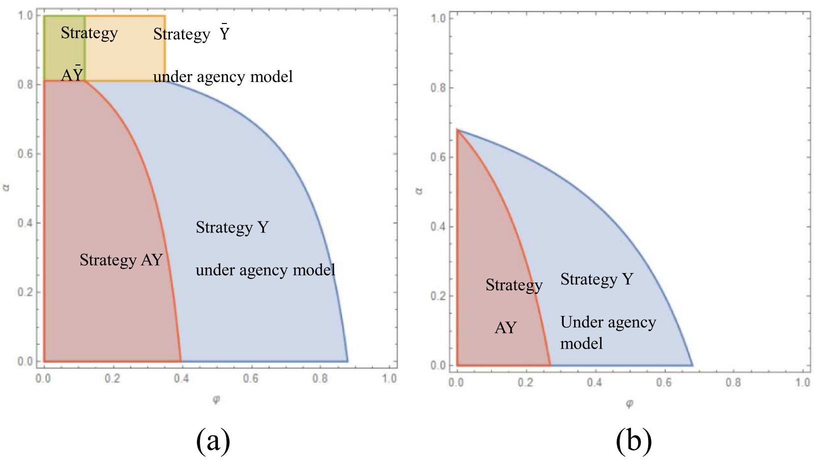


FIGURE 6. Contract strategies selection at different values of e_0. (a) $e_0 = 2$. (b) $e_0 = 10$. Note: (i) Strategy $\bar{Y}$ under agency model: the manufacturer does not offer return services if select agency model. (ii) Strategy $A\bar{Y}$: the manufacturer ultimately selects an agency model and does not offer return services. (iii) Strategy Y under agency model: the manufacturer offers return services if select agency model. (iv) Strategy AY: the manufacturer ultimately selects an agency model and offer return services.

Proposition 8 shows that after considering the optimal return condition, manufacturers should choose agency contracts when the commission rate is low, regardless of whether returns are offered. The critical value of the commission rate at which manufacturers agency contracts and reselling contracts are equally beneficial decreases as the government lowers the cap; decreases as the manufacturer's energy consumption increases; and decreases as the return rate increases when return services are offered. Thus, when the government lowers the cap, the manufacturer's choice of agency contracts becomes more demanding, and the manufacturer is only willing to choose the agency contracts if it then gives the platform a lower commission rate. Also, manufacturers with higher energy consumption will choose agency contracts only if the platform commission rate is lower. In the case of providing return services, with higher return rates, the manufacturers will choose agency contracts only if the platform commission rate is lower.

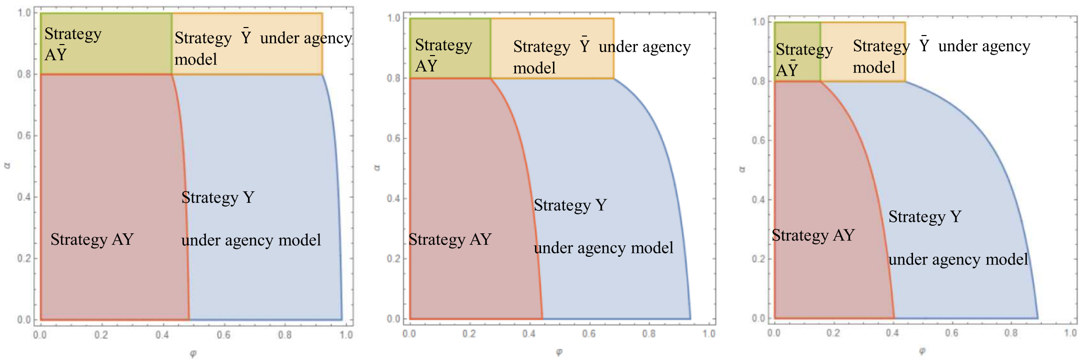
We assume $C = 0.6, a_0 = 0.4,\ b_0 = 0.4,\ b = 0.2$, and explore the firm's return decision conditions under different e_0 by numerical analysis. Figure 6 shows the results.

We assume that $e_0 = 2,\ a_0 = 0.4,\ b_0 = 0.4,\ b = 0.2$, and explore the conditions of firms' return decisions under different C by numerical analysis. See Figure 7.

As shown in the Figures 6 and 7, the manufacturer chooses the agency contracts at a low commission rate, and as the manufacturer's energy consumption e_0 increases and as C decreases, the manufacturer chooses the agency contracts with a decreasing range of commission rates, and with the manufacturer providing return services, the return rate and the commission rate threshold are negatively correlated. Therefore, we believe that it is optimal for the manufacturer to choose an agency contract with a low commission rate, and the manufacturer needs to consider its own energy consumption, the cap by government allocated, and the return rate in the case of having return services when choosing the contract strategies.

6. EXTENSION

In this section, we extend the basic model to analyze the return strategies and contract strategies selection of decision-makers under cap-and-trade regulation while also considering the return costs and production costs.



(a) (b) (c)

FIGURE 7. Contract strategies selection at different values of C. (a) $C = 0.9$ (b) $C = 0.6$. (c) $C = 0.3$.

TABLE 7. Profit formulas considering return cost.

Contract	Manufacturer profit	Platform profit
Agency	$\pi_m^{AY} = (1-\varphi)(1-\alpha)p^{AY}D^{AY} - \alpha D^{AY}t - (a_0 - b_0\ C)(e_0 D^{AY} - C)$	$\pi_p^{AY} = \varphi p^{AY}(1-\alpha)D^{AY}$
Reselling	$\pi_m^{RY} = w^{RY}D^{RY} - (a_0 - b_0 C)\left(e_0 D^{RY} - C\right)$	$\pi_p^{RY} = \left(p(1-\alpha) - w^{RY}\right)D^{RY} - \alpha D^{RY}t$

6.1. Return costs

We can add a return cost per unit of returned product to the basic model. Let t be the return cost per unit of returned product, which is borne by different parties under different contract strategies. Under the agency contracts, the total return cost αDt is borne by the manufacturer, while under the reselling contracts, the total return cost αDt is carried out by the platform. When returns are not offered, the profit formulas for the manufacturer and the platform are the same as in the basic model. When returns are offered, the profit equations for the manufacturer and the platform are as depicted in Table 7.

First, we explore how considering return cost impacts firms' return strategy under agency contracts. We assume $C = 0.6, a_0 = 0.4$, $b_0 = 0.4$, $b = 0.2$ to explore the conditions of firms' return decision under agency contracts for different t and e_0. Figure 8 shows the numerical analysis results.

As shown in Figure 8, under the agency contracts, as the cost of returns increases, the manufacturer chooses to provide return service under more demanding conditions. Meanwhile, with different values of t, manufacturers with low energy consumption have optimal choices as follows: (1) provide return services when the return rate is high and the commission rate is small; (2) provide return services when the return rate is low and the commission rate is small; (3) provide return services if the return rate is medium and the commission rate is small; (4) not provide return services when the return rate is medium and the commission rate is moderate; (5) sell all carbon emission credits in other cases. The optimal choices for manufacturers with high energy consumption are (1) sell all carbon emission credit when the return rate is high, or (2) provide return service if the return rate and commission rate are both low.

Second, we consider how the return cost impacts the contract strategies selection of the firm. We assume that $C = 0.6, a_0 = 0.4$, $b_0 = 0.4$, $b = 0.2, e_0 = 2$ to explore the selection of different contract strategies by numerical analysis using different values of t. Figure 9 shows the results.

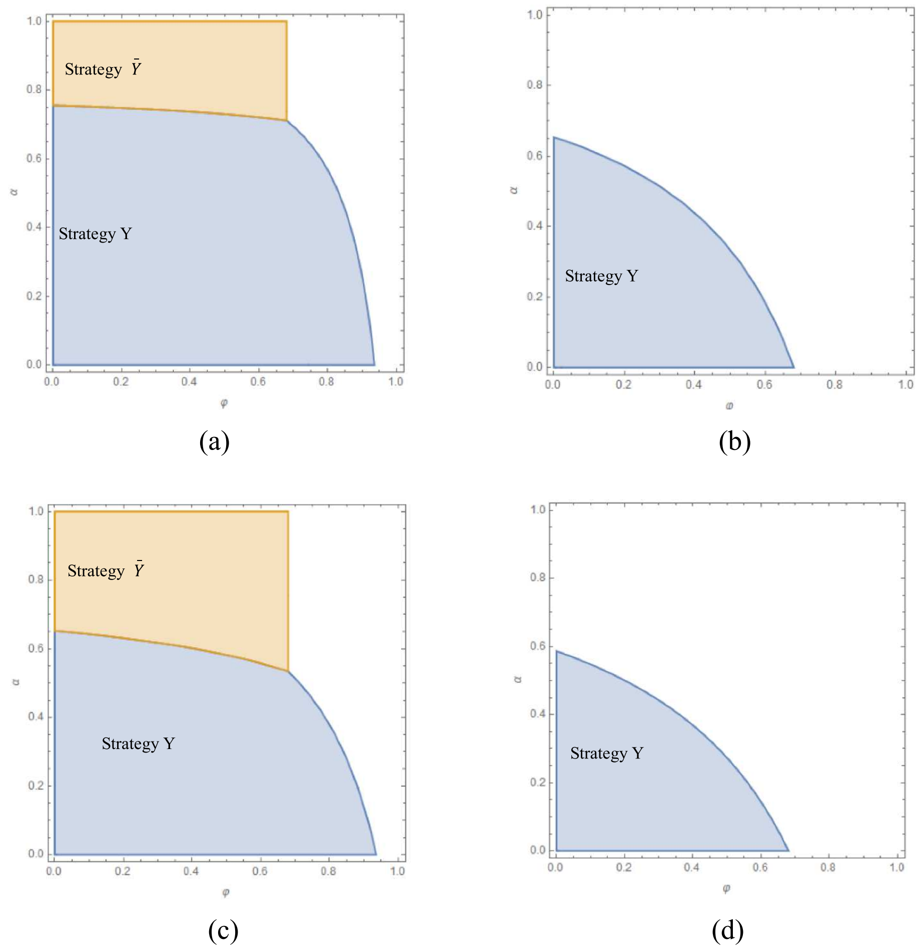


FIGURE 8. Return strategy in agency model under consideration of return cost. (a) $t = 0.2, e_0 = 2$. (b) $t = 0.2, e_0 = 10$. (c) $t = 0.8, e_0 = 2$. (d) $t = 0.8, e_0 = 10$.

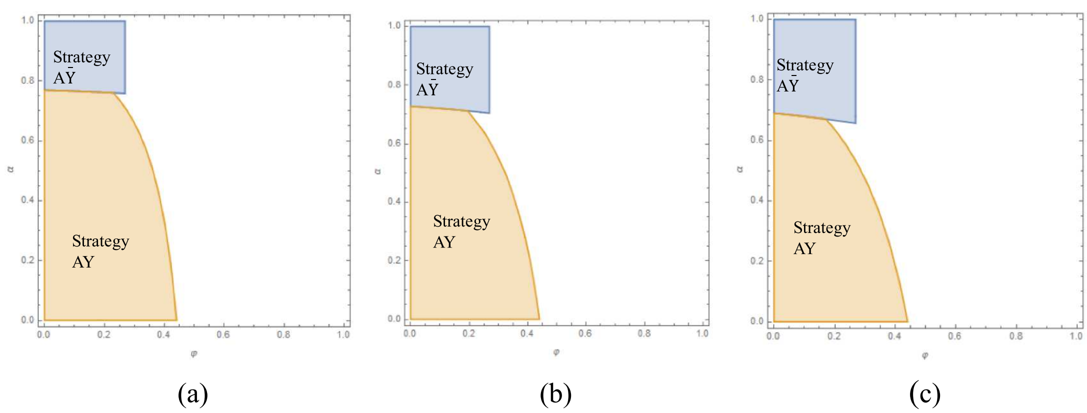


FIGURE 9. Contract strategies selection at different values of t. (a) $t = 0.2$. (b) $t = 0.5$. (c) $t = 0.8$.

TABLE 8. Profit formula considering production cost.

Agency Model	The manufacturer does not offer return services ($A\bar{Y}$)	$\pi_m^{A\bar{Y}} = ((1-\varphi)p^{A\bar{Y}} - m)D^{A\bar{Y}} - (a_0 - b_0C)\left(e_0D^{A\bar{Y}} - C\right)$ $\pi_p^{AN} = \varphi p^{A\bar{Y}} D^{A\bar{Y}}$
	The manufacturer offers return services (AY)	$\pi_m^{AY} = ((1-\varphi)(1-\alpha)p^{AY} - m)D^{AY} - (a_0 - b_0C)(e_0D^{AY} - C)$ $\pi_p^{AY} = \varphi p^{AY}(1-\alpha)D^{AY}$
Reselling Model	The platform does not offer return services ($R\bar{Y}$)	$\pi_m^{R\bar{Y}} = (w^{R\bar{Y}} - m)D^{R\bar{Y}} - (a_0 - b_0C)\left(e_0D^{R\bar{Y}} - C\right)$ $\pi_p^{R\bar{Y}} = \left(p^{R\bar{Y}} - w^{R\bar{Y}}\right)D^{R\bar{Y}}$
	The platform offers return services (RY)	$\pi_m^{RY} = (w^{RY} - m)D^{RY} - (a_0 - b_0C)(e_0D^{RY} - C)$ $\pi_p^{RY} = \left(p^{RY}(1-\alpha) - w^{RY}\right)D^{RY}$

As shown in Figure 9, the results of the numerical analysis show that manufacturers are still willing to select the agency model at a low commission rate when the cost of returns is considered, and that the indifference point for manufacturers' selection between the agency and reselling contracts decreases as the government lowers the cap. That point also decreases as the manufacturers' energy consumption increases.

The results for this extended model are similar to the relevant findings in Sections 4 and 5, indicating that the basic model's results are robust.

6.2. Production costs

Next, we extend the basic model by assuming that the production cost per unit of product is m, and the production cost is borne by the manufacturer. Table 8 shows the profits of the manufacturer and platform.

First, we explore the impact of considering production cost on firms' return strategy under agency contracts. We assume $C = 0.6, a_0 = 0.4$, $b_0 = 0.4$, $b = 0.2$ to explore the conditions of firms' return decisions under agency contracts at different m and e_0 by numerical analysis. The results appear in Figure 10.

As seen in Figure 10, under the agency contracts, as the production cost increases, the manufacturer is willing to produce under more demanding conditions. In the case of low production cost, manufacturers with low energy consumption have the following optimal choices: (1) not provide return service when the return rate is high and the commission rate is small; (2) provide return service when the return rate is low and the commission rate is small; (3) not produce in the other cases of return rate and commission rate. Manufacturers with high energy consumption (1) offer return services when return rate are low and commission rates are low, and (2) do not produce in other cases of returns and commission rates.

Consider the case of high production costs. Manufacturers (1) will offer return services if commission rates are small and the return rates are low, and (2) do not produce in other cases of returns and commission rates. Manufacturers will produce only under more stringent conditions as the manufacturer's carbon intensity increases.

Thus, the return strategy for platforms in reselling model is similar to Section 4 when we consider the production cost, so the analysis of those results is not repeated here.

Second, we use numerical analysis to show how considering production cost impacts the firm's contract strategies selection. We assume that $C = 0.6, a_0 = 0.4$, $b_0 = 0.4$, $b = 0.2, e_0 = 2$ to explore the selection of different contract strategies. The results for different values of m appear in Figure 11.

As seen in Figure 11, the numerical analysis results show that when considering production costs, manufacturers choose agency contracts at low commission rates. As the production cost increases, the smaller the critical value of the commission rate at which the manufacturer is indifferent between the agency and reselling

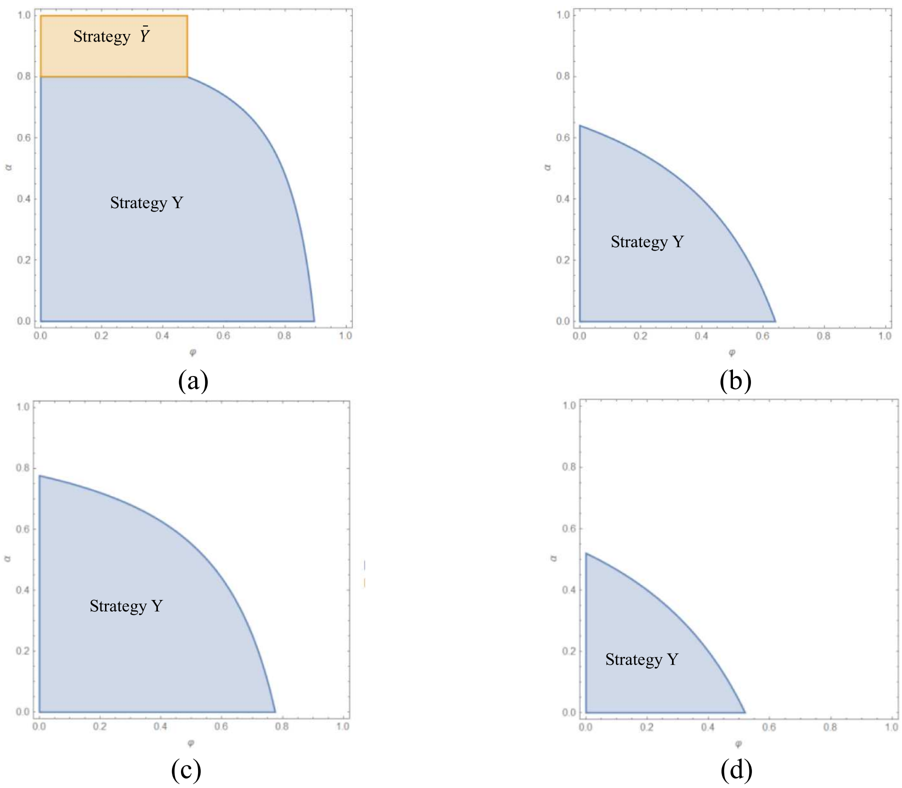


FIGURE 10. Return strategy in agency model under consideration of production cost. (a) $m = 0.2, e_0 = 2$. (b) $m = 0.2, e_0 = 10$. (c) $m = 0.8, e_0 = 2$. (d) $m = 0.8, e_0 = 10$.

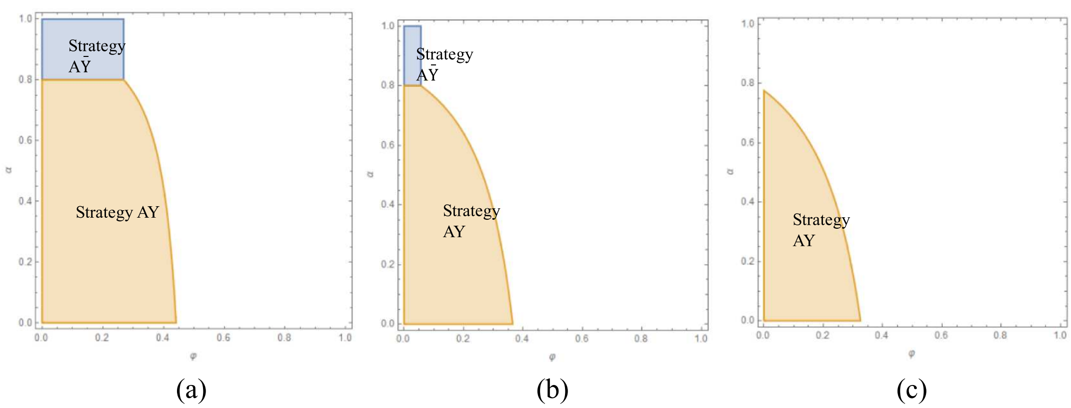


FIGURE 11. Contract strategies selection for different values of m. (a) $m = 0.2$. (b) $m = 0.5$. (c) $m = 0.8$.

contracts. This means that when the production cost is higher, the manufacturer will choose the agency contract only if the platform set a lower commission rate.

7. Conclusion

7.1. Main results

In this study, we explore the issues of manufacturers' contract strategies choices and manufacturers' or platforms' return strategies under cap-and-trade regulation, where manufacturers can enter into either agency contracts or reselling contracts with platforms. For both the agency and reselling contracts, we explore the optimal return strategies (whether to provide return service) of the manufacturer or platform under cap-and-trade regulation. This study analyzes the impact of important parameters on the manufacturer's decision, and then further compares the two types of contract from the perspective of profit maximization of the manufacturer.

Analysis of the impact of government implementation of cap-and-trade regulation on controlling carbon emissions yielded the following results. Implementing the cap-and-trade regulation can control carbon emissions. Some previous studies have argued that controlling caps does not control carbon emissions, while others have argued that it does, and we continue to consider the return management context. For the agency and reselling models, we show that production volume and carbon emissions decrease with the reduction of the cap, regardless of whether the manufacturer or the platform provides return services. Manufacturers with high energy consumption will be more sensitive to government initiatives to lower the carbon cap, cutting more production and thus reducing more carbon emissions, than manufacturers with low energy consumption. Government adjustments of the cap help control the output of high-energy-consuming manufacturers who produce similar products. In addition, in the case of platforms or manufacturers providing return services, manufacturers with high return rates are more sensitive to government initiatives to reduce the carbon cap than manufacturers with low return rates.

Previous studies on the relationship between manufacturers and caps are controversial. Ji *et al.* [14] argue that under aggregate control and trading system allocation, manufacturers' profits increase and then decrease as the allocation cap increases, while Xu *et al.* [37] argue that the optimal profits of low-energy-consuming manufacturers increase and then decrease with the cap increasing and that the optimal profits of high-energy-consuming manufacturers increase with the cap increasing. Our findings are different from previous scholars. By analyzing the relationship between the cap and manufacturers' optimal profits under the cap-and-trade regulation, we show the following. (1) For both the agency and reselling models, the high-energy-consuming manufacturers' profit decreases and then increases with decreasing cap; the low-energy-consuming manufacturers' profit increases first and then decreases with the reduction of the cap. (2) In the agency model, regardless of whether the return service is provided, (a) when the carbon price factor is high, the profits of manufacturer with moderate carbon emission intensity decrease as the cap decreases; and (b) when the carbon price factor is low, the profits of manufacturer with moderate carbon emission intensity increase as the cap decreases. (3) In the reselling model, when the platform does not provide return services, manufacturer profit changes due to cap changes are similar to those in the agency model. The situation when the platform provides return services is more complicated: (a) when the carbon price factor and price factor of demand are both low; or when the carbon price factor is high, the profits of manufacturer with moderate carbon emission intensity decreases as the government lowers the cap; (b) when the carbon price factor is low and the demand price factor is high, the profits of manufacturer with moderate carbon emission intensity increases as the government lowers the cap.

Regarding the selection aspect of the MBG strategy, Ohmura *et al.* [24] argue that adopting MBG is related to the risk propensity of supply chain participants. Considering a dual-channel context, Li *et al.* [15] argues that manufacturers will adopt a full refund return strategy in both channels if the return rate is low. Unlike previous scholars, we consider the impact of cap-and-trade regulation on manufacturers' return strategies. We arrive at the following conclusions.

(1) In the agency model, (1a) A manufacturer with low energy consumption will choose not to provide return services when the return rate is high and the commission rate is low; it will choose to provide return services when the return rate is low and the commission rate is low. (1b) A manufacturer with high energy consumption will not produce and will sell all carbon credits when the return rate is high, but it will provide return services in the case of a low return rate and a low commission rate. (1c) Whether or not offer return services, as carbon emissions per unit of product produced increase or the cap decreases, the threshold value of the commission rate at which manufacturers are indifference to whether or not to produce is decreasing. Manufacturers with low energy consumption can survive with or without providing return services under suitable conditions, and companies with high energy consumption can survive by providing return services only if the return rate is low and the commission rate is low. Also, the higher energy consumption of the company, the more demanding conditions for the manufacturer to produce, rather than just selling its cap.
(2) For the reselling model, the results are as follows. (2a) If the manufacturer cooperating with the platform is a low-energy-consuming firm, when the return rate is high, it is optimal for the platform not to provide return services, but when the return rate is low, it is optimal for the platform to provide return services. (2b) If the manufacturer is a high-energy-consuming firm, it does not produce when the return rate is high, but it is optimal for the platform to provide return services when the return rate is low. (2c) The lower the cap allocated by the government, the more willing the platform is to work with low-energy-consumption manufacturers.

Hagiu *et al.* [10] argue that the reselling model is optimal when there are spillovers and network effects of marketing activities across products, leading to unfavorable expectations of supplier participation. Liu *et al.* [19] argue that platforms prefer the agency model when the potential market size is moderate. This paper compares the two contracts with considering cap-and-trade regulation. strategies yield the following conclusions for the manufacturer's selection of agency and reselling contracts. (1) Consider the production volume and carbon emissions. This study concludes that when both the agency model and reselling model have output, regardless of whether the platform or the manufacturer provides return services, when the commission rate is low, the production volume will be higher in the agency model than in the reselling model. This means that a particular manufacture's carbon emissions generated in the agency model will be higher than in the reselling model when the commission rate is low. (2) Manufacturers should choose agency contracts when the commission rate is low, regardless of whether they provide return services. The commission rate threshold marking a manufacturer's indifference between agency and reselling contracts decreases as the government lowers the cap, decreases as the manufacturer's carbon emissions per unit of product increase, and decreases as the return rate increases when return services are provided. In other words, the lower the cap, the higher the energy consumption of the firm, as well as the higher the product return rate, so the firm is only willing to choose the agency contracts if the platform set a low commission rate.

This study considered the cost of return and production in model extensions. The results for both extensions verify that the conclusions of this paper are robust.

7.2. Managerial insights

From the government's perspective, firstly, to reduce carbon emissions, the government can strategically focus on manufacturers within the same industry, especially those with high carbon emissions and a higher return rate for providing returns. Such manufacturers, being more sensitive to government decisions on cap reduction, can be effective targets for carbon reduction policies. Second, when dealing with manufacturers across different industries, the government can consider adjusting caps differently. For low-energy-consuming high-tech manufacturers, raising the cap may stimulate increased production, while lowering the cap for high-energy-consuming low-end manufacturers can curb their output and carbon emissions. This approach facilitates overall carbon reduction and industrial upgrading. Furthermore, while adjusting caps to influence industrial dynamics, the government must exercise caution. Lowering the cap for high-energy-consuming manufacturers can decrease their profits, but this adjustment must be controlled to prevent unintended consequences. Factors like the carbon price coefficient and demand sensitivity in return scenarios should be considered for medium-energy-consuming manufacturers when adjusting caps.

From the manufacturer's standpoint, a strategic choice may involve collaborating with a platform operating under an agency model, particularly when confronted with a low commission rate. Within the agency framework, a manufacturer with low energy consumption might refrain from offering return services in instances of high return rates coupled with a low commission rate, while opting to provide such services when facing a low return rate with a correspondingly low commission rate. Conversely, a high-energy-consuming manufacturer may extend return services in scenarios featuring a low return rate and a low commission rate. As an alternative strategy, a high-energy-consuming manufacturer might engage in an agency contract at a commission rate lower than that negotiated by a low-energy-consuming counterpart. Acceptance of a platform's request for a higher commission rate may be contingent upon an augmented government-allocated cap. Furthermore, in cases involving return services, manufacturers experiencing lower return rates may also consider entering into an agency contract with an elevated commission rate offered by the platform.

From the platform's vantage point, those operating under a reselling model might opt to collaborate with low-energy manufacturers characterized by a high return rate, without necessarily providing a return service. Alternatively, platforms may choose to partner with manufacturers exhibiting low return rates and extend return services.

In the future, scholars could extend this work by considering the following research perspectives. First, future research could explore the entire spectrum of environmental problems arising from returns, including secondary packaging, logistics, and disposal of defective products. This holistic approach will shed light on the complete environmental impact of returns in e-commerce platforms. Second, considering the distinct nature of offline channels in handling returns, future research could explore the dynamics of dual-channel returns, accounting for spillover effects and the direct handling of returned products in offline channels. Third, scholars can continue to delve into return strategies under aggregate control and trading regimes, such as return window duration, return shipping insurance, returned product handling, and partial refunds. In addition, consumer attitudes toward environmental protection may also influence the return strategies of manufacturers or platforms under cap-and-trade regulation, suggesting another avenue for extending this research.

Appendix A.

Proof of Lemma 1. We obtain the first derivations of $\pi_m^{A\bar{Y}}$ withrespect to $p^{A\bar{Y}}$

$$\frac{\partial \pi_m^{A\bar{Y}}}{\partial p^{A\bar{Y}}} = \left(-1 + 2p^{AN}\right)(-1 + \varphi) + (a_0 - Cb_0)e_0.$$

Let $\frac{\partial \pi_m^{A\bar{Y}}}{\partial p^{A\bar{Y}}} = 0$, we have

$$p^{A\bar{Y}^*} = \frac{1}{2} - \frac{(a_0 - Cb_0)e_0}{2(-1 + \varphi)}.$$

Substituting it into equation (1), considering a range of demand greater than 0, we can easily obtain the optimal decisions shown in Lemma 1. □

Proof of Lemma 2. The method of proof of Lemma 2 is similar to that of Lemma 1, by using the method of proof of Lemma 1, we can obtain Lemma 2, which is not overstated here. □

Proof of Proposition 1. For the manufacturer does not offer return services, by taking the first order derivative of the equilibrium demand D^{AN^*} with respect to C, we have:

$$\frac{\partial D^{A\bar{Y}^*}}{\partial C} = -\frac{b_0 e_0}{2(-1 + \varphi)}$$

we obtain the first derivations of $\frac{\partial D^{A\bar{Y}^*}}{\partial C}$ with respect to e_0 and the first derivations of $\frac{\partial (e_0 D^{A\bar{Y}^*})}{\partial C}$ with respect to e_0

$$\frac{\partial D^{A\bar{Y}^*}}{\partial C \partial e_0} = -\frac{b_0}{2(-1+\varphi)} > 0; \quad \frac{\partial (e_0 D^{A\bar{Y}^*})}{\partial C \partial e_0} = -\frac{b_0 e_0}{-1+\varphi} > 0.$$

Similarly, for the manufacturer offer return services, we have:

$$\frac{\partial D^{AY^*}}{\partial C} = \frac{bb_0 e_0}{2(-1+\alpha)(-1+\varphi)} > 0; \quad \frac{\partial D^{AY^*}}{\partial C \partial e_0} = -\frac{bb_0}{2(-1+\alpha)(-1+\varphi)} > 0$$

$$\frac{\partial \big(e_0 D^{AY^*}\big)}{\partial C \partial e_0} = \frac{bb_0 e_0}{(-1+\alpha)(-1+\varphi)} > 0; \quad \frac{\partial D^{AY^*}}{\partial C \partial \alpha} = -\frac{bb_0 e_0}{2(-1+\alpha)^2(-1+\varphi)} > 0.$$

□

Proof of Proposition 2. For the manufacturer does not offer return services, as it can be seen in Lemma 1, when $0 < e_0 < -\frac{1}{-a_0 + Cb_0}$ && $0 < \varphi < 1 - a_0 e_0 + Cb_0 e_0$, the optimal profit of the manufacturer is

$$\pi_m^{A\bar{Y}^*} = \frac{1}{4}\left(1 - \varphi + \frac{(a_0 - Cb_0)(4C(-1+\varphi) + e_0(2 - 2\varphi + (-a_0 + Cb_0)e_0))}{-1+\varphi}\right)$$

where we discuss the variation of the manufacturer's profit with the cap in this case

$$\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} = \frac{(-1+\varphi)b_0 e_0 + a_0(-2 + 2\varphi + b_0 e_0^2) + C(-4(-1+\varphi)b_0 - b_0^2 e_0^2)}{2(-1+\varphi)}.$$

Let $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} = 0$, we have

$$C_1 = \frac{(-1+\varphi)b_0 e_0 + a_0(-2 + 2\varphi + b_0 e_0^2)}{b_0(-4 + 4\varphi + b_0 e_0^2)}.$$

Suppose that $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} = \frac{CA_1 + B_1}{2(-1+\varphi)}$. We can obtain that

$$A_1 = (-4(-1+\varphi)b_0 - b_0^2 e_0^2)$$
$$B_1 = (-1+\varphi)b_0 e_0 + a_0(-2 + 2\varphi + b_0 e_0^2)$$
$$E_1 = 2\sqrt{-\frac{-1+\varphi}{b_0}}$$
$$E_2 = \frac{2 - 2\varphi}{a_0}$$
$$E_3 = \frac{2a_0}{b_0}.$$

When $b_0 > -\frac{a_0^2}{-1+\varphi}$ and $E_1 < e_0 < E_2$, that is $A_1 < 0$ and $B_1 < 0$, the distribution of $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C}$ is positive correlation line with positive intercept, then we have $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} > 0$.

When $0 < b_0 < -\frac{a_0^2}{-1+\varphi}$ and $E_2 < e_0 < E_1$, that is $A_1 > 0$ and $B_1 > 0$, the distribution of $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C}$ is negative correlation line with negative intercept, then we have $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} < 0$.

When $0 < b_0 \leq -\frac{a_0^2}{-1+\varphi}$ and $e_0 > E_3$; or when $b_0 > \frac{a_0^2}{-1+\varphi}$ an $e_0 > E_2$; that is $A_1 < 0$ and $B_1 > 0$, the distribution of $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C}$ is positive correlation line with negative intercept, then we have if $C_1 < C < \frac{a_0}{b_0}$, $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} > 0$; if $0 < C < C_1$, $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} < 0$.

When $0 < b_0 \le -\frac{a_0^2}{-1+\varphi}$ and $0 < e_0 < E_2$; or when $b_0 > \frac{a_0^2}{-1+\varphi}$ and $0 < e_0 < E_3$; that is $A_1 > 0$ and $B_1 < 0$, the distribution of $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C}$ is negative correlation line with positive intercept, then we have if $C_1 < C < \frac{a_0}{b_0}$, $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} < 0$; if $0 < C < C_1$, $\frac{\partial \pi_m^{A\bar{Y}^*}}{\partial C} > 0$.

For the manufacturer providing return services, the method is the same as above, the manufacturer's profit varies with the cap in similar way as above, which is not overstated here. □

Proof of Proposition 3. In the agency model, when the manufacturer does not offer return service, the optimal profit of the manufacturer is

$$\pi_m^{A\bar{Y}^*} = \begin{cases} \frac{1}{4}\Big(1-\varphi+\frac{(a_0-Cb_0)(4C(-1+\varphi)+e_0(2-2\varphi+(-a_0+Cb_0)e_0))}{-1+\varphi}\Big) & \text{if } 0<e_0<-\frac{1}{-a_0+Cb_0}, 0<\varphi<1-a_0e_0+Cb_0e_0 \\ C(a_0-Cb_0) & \text{else.} \end{cases}$$

In the agency model, when the manufacturer offers return service, the optimal profit of the manufacturer is

$$\pi_m^{AY^*} = \begin{cases} \frac{1}{4}\Big(\frac{(-1+\alpha)(-1+\varphi)}{b}+(a_0-Cb_0)\Big(4C+e_0\Big(-2+\frac{b(a_0-Cb_0)e_0}{(-1+\alpha)(-1+\varphi)}\Big)\Big)\Big) & \text{if } 0<e_0<\frac{-1+\alpha}{-ba_0+bCb_0}, 0<\varphi<\frac{-1+\alpha+ba_0e_0-bCb_0e_0}{-1+\alpha} \\ C(a_0-Cb_0) & \text{else.} \end{cases}$$

After a comparison of the profits of the manufacturer (offer and not offer returns) under different conditions, we obtained the following intervals. In the agency model, it is apparent that the manufacturer will earn more profit when the manufacturer offer return service if $\pi_m^{A\bar{Y}^*} < \pi_m^{AY^*}$, that is when $0 < e_0 < -\frac{1}{-a_0+Cb_0}$ && $0 < \alpha < 1-b$ && $0 < \varphi < \varphi_1$; or when $-\frac{1}{-a_0+Cb_0} < e_0 < -\frac{1}{-ba_0+bCb_0}$ && $0 < \alpha < 1-ba_0e_0+bCb_0e_0$ && $0 < \varphi < \varphi_1$. It is apparent that the manufacturer will earn more profit when the manufacturer does not offer return service if $\pi_m^{A\bar{Y}^*} > \pi_m^{AY^*}$, that is $0 < e_0 < -\frac{1}{-a_0+Cb_0}$ && $1-b < \alpha < 1$ && $0 < \varphi < \varphi_2$ where, $\varphi_1 = 1+\frac{b(a_0-Cb_0)e_0}{-1+\alpha}$, $\varphi_2 = 1-a_0e_0+Cb_0e_0$. □

Proof of Lemma 3. Given w^{RN}, we obtain the first derivations of $\pi_p^{R\bar{Y}}$ with respect to $p^{R\bar{Y}}$

$$\frac{\partial \pi_p^{R\bar{Y}}}{\partial p^{R\bar{Y}}} = 1-2p+w^{R\bar{Y}}.$$

Let $\frac{\partial \pi_p^{R\bar{Y}}}{\partial p^{R\bar{Y}}} = 0$, we have

$$p^{R\bar{Y}} = \frac{1+w^{R\bar{Y}}}{2}.$$

Substituting it into equation (4), we find that the manufacturer's wholesale price w^{RN} satisfies:

$$\frac{\partial \pi_m^{R\bar{Y}}}{\partial w^{R\bar{Y}}} = \frac{1}{2}\Big(1-2w^{R^*}+(a_0-Cb_0)e_0\Big) = 0.$$

We can then obtain $w^{R\bar{Y}^*} = \frac{1}{2}(1+a_0e_0-Cb_0e_0)$, $p^{R\bar{Y}^*} = \frac{1}{4}(3+(a_0-Cb_0)e_0)$, substituting $w^{R\bar{Y}^*}$ and $p^{R\bar{Y}^*}$ into equation (3), consider a range of demand greater than 0, we can easily obtain the optimal decisions shown in Lemma 3. □

Proof of Lemma 4. The method of proof of Lemma 4 is similar to that of Lemma 3, by using the method of proof of Lemma 3, we can obtain Lemma 4, which is not overstated here. □

Proof of Proposition 4. For the platform does not provide return services, by taking the first order derivative of the equilibrium demand D^{RN^*} with respect to C, we have:

$$\frac{\partial D^{R\bar{Y}^*}}{\partial C} = \frac{b_0 e_0}{4} > 0.$$

We obtain the first derivations of $\frac{\partial D^{R\bar{Y}^*}}{\partial C}$ with respect to e_0 and the first derivations of $\frac{\partial\left(e_0 D^{R\bar{Y}^*}\right)}{\partial C}$ with respect to e_0.

$$\frac{\partial D^{R\bar{Y}^*}}{\partial C \partial e_0} = \frac{b_0}{4} > 0; \quad \frac{\partial (e_0 D^{R\bar{Y}^*})}{\partial C \partial e_0} = \frac{b_0 e_0}{2} > 0.$$

Similarly, for the platform offer return services, we have:

$$\frac{\partial D^{RY^*}}{\partial C} = -\frac{b b_0 e_0}{4(-1+\alpha)} > 0; \quad \frac{\partial D^{RY^*}}{\partial C \partial e_0} = -\frac{b b_0}{4(-1+\alpha)} > 0$$
$$\frac{\partial\left(e_0 D^{RY^*}\right)}{\partial C \partial e_0} = -\frac{b b_0 e_0}{2(-1+\alpha)} > 0; \quad \frac{\partial D^{RY^*}}{\partial C \partial \alpha} = \frac{b b_0}{4(-1+\alpha)^2} > 0.$$

□

Proof of Proposition 5. For the platform that does not provide return services, the manufacturer's profit varies with the cap in a similar way as that of Proposition 2, the method of proof is similar to that of Proposition 2, which is not overstated here.

For the platform provide return services, as it can be seen in lemma, when $0 < e_0 < \frac{-1+\alpha}{-ba_0+bCb_0}$, the optimal profit of the manufacturer is

$$\pi_m^{RY^*} = -\frac{T_1}{8b(-1+\alpha)}$$

where $T_1 = (-1+\alpha)^2 + b(a_0 - Cb_0)(-8C(-1+\alpha) + 2(-1+\alpha)e_0 + b(a_0 - Cb_0)e_0^2)$, then we discuss the variation of the manufacturer's profit with the cap in this case $\frac{\partial \pi_m^{RY^*}}{\partial C} = -\frac{T_1}{8b(-1+\alpha)}$, where $T_1 = (-1+\alpha)^2 + b(a_0 - Cb_0)(-8C(-1+\alpha) + 2(-1+\alpha)e_0 + b(a_0 - Cb_0)e_0^2)$.

Let $\frac{\partial T_1}{\partial C} = 0$, we have

$$C_3 = \frac{(-1+\alpha)b_0 e_0 + a_0(-4+4\alpha+b b_0 e_0^2)}{b_0(-8+8\alpha+b b_0 e_0^2)}.$$

Suppose that $\frac{\partial \pi_m^{RY^*}}{\partial C} = -\frac{T_1}{8b(-1+\alpha)} = -\frac{CA_2+B_2}{8b(-1+\alpha)}$, we can obtain that

$$A_2 = 2bb_0(-8+8\alpha+bb_0e_0^2)$$
$$B_2 = -2b(-1+\alpha)b_0e_0 - 2ba_0(-4+4\alpha+bb_0e_0^2)$$
$$E_4 = 2\sqrt{2}\sqrt{-\frac{-1+\alpha}{bb_0}}$$
$$E_5 = \frac{2-2\alpha}{ba_0}$$
$$E_6 = \frac{4a_0}{b_0}.$$

When $b_0 > -\frac{2a_0^2}{-1+\alpha}$ and $E_4 < e_0 < E_5$; or when $0 < b_0 \le -\frac{2a_0^2}{-1+\alpha}$ and $0 < b < \frac{b_0-\alpha b_0}{2a_0^2}$ and $E_4 < e_0 < E_5$. That is $A_2 > 0$ and $B_2 > 0$, the distribution of $\frac{\partial \pi_m^{RY^*}}{\partial C}$ is positive correlation line with positive intercept; then we have $\frac{\partial \pi_m^{RY^*}}{\partial C} > 0$.

When $0 < b_0 < -\frac{2a_0^2}{-1+\alpha}$ and $\frac{b_0-\alpha b_0}{2a_0^2} < b < 1$ and $E_5 < e_0 < E_4$. That is $A_2 < 0$ and $B_2 < 0$, the distribution of $\frac{\partial \pi_m^{RY^*}}{\partial C}$ is negative correlation line with negative intercept, then we have $\frac{\partial \pi_m^{RY^*}}{\partial C} < 0$.

When $0 < b_0 < -\frac{2a_0^2}{-1+\alpha}$ and $0 < b \leq \frac{b_0-\alpha b_0}{2a_0^2}$ and $e_0 > E_5$; or when $b_0 \geq -\frac{2a_0^2}{-1+\alpha}$ and $e_0 > E_5$; or when $0 < b_0 < -\frac{2a_0^2}{-1+\alpha}$ and $\frac{b_0-\alpha b_0}{2a_0^2} < b < 1$ and $e_0 > E_6$. That is $A_2 > 0$ and $B_2 < 0$, the distribution of $\frac{\partial \pi_m^{RY^*}}{\partial C}$ is positive correlation line with negative intercept; then we have if $C_3 < C < \frac{a_0}{b_0}$, $\frac{\partial \pi_m^{RY^*}}{\partial C} > 0$; if $0 < C < C_3$, $\frac{\partial \pi_m^{RY^*}}{\partial C} < 0$.

When $0 < b_0 < -\frac{2a_0^2}{-1+\alpha}$ and $0 < b \leq \frac{b_0-\alpha b_0}{2a_0^2}$ and $0 < e_0 < E_6$; or when $b_0 \geq -\frac{2a_0^2}{-1+\alpha}$ and $0 < e_0 < E_6$; or when $0 < b_0 < -\frac{2a_0^2}{-1+\alpha}$ and $\frac{b_0-\alpha b_0}{2a_0^2} < b < 1$ and $0 < e_0 < E_5$. That is $A_2 < 0$ and $B_2 > 0$, the distribution of $\frac{\partial \pi_m^{RY^*}}{\partial C}$ is negative correlation line with positive intercept; then we have if $C_3 < C < \frac{a_0}{b_0}$, $\frac{\partial \pi_m^{RY^*}}{\partial C} < 0$; if $0 < C < C_3$, $\frac{\partial \pi_m^{RY^*}}{\partial C} > 0$. □

Proof of Proposition 6. In the reselling model, when the platform does not offer return service, the optimal profit of the platform is

$$\pi_p^{R\bar{Y}^*} = \begin{cases} \frac{1}{16}(-1+(a_0-Cb_0)e_0)^2 & \text{if } 0 < e_0 < -\frac{1}{-a_0+Cb_0} \\ 0 & \text{else.} \end{cases}$$

In the reselling model, when the platform offers return service, the optimal profit of the platform is

$$\pi_p^{RY^*} = \begin{cases} -\frac{(-1+\alpha+b(a_0-Cb_0)e_0)^2}{16b(-1+\alpha)} & \text{if } 0 < e_0 < \frac{-1+\alpha}{-ba_0+bCb_0} \\ 0 & \text{else.} \end{cases}$$

After a comparison of the profits of the platform (offer and not offer returns) under different conditions, we obtained the following intervals. In the reselling model, it is apparent that the platform will earn more profit when the platform does not offer return service if $\pi_p^{R\bar{Y}^*} > \pi_p^{RY^*}$, that is $0 < e_0 < -\frac{1}{-a_0+Cb_0}$ && $1-b < \alpha < 1$. It is apparent that the platform will earn more profit when the platform offer return service if $\pi_p^{R\bar{Y}^*} < \pi_p^{RY^*}$, that is when $0 < e_0 < -\frac{1}{-a_0+Cb_0}$ && $0 < \alpha < 1-b$; or when $-\frac{1}{-a_0+Cb_0} < e_0 < -\frac{1}{-ba_0+bCb_0}$ && $0 < \alpha < 1 - ba_0e_0 + bCb_0e_0$. □

Proof of Proposition 7. The manufacturer's demand in the agency model is described in Lemmas 1 and 2; the manufacturer's profit in the reselling model is described in Lemmas 3, 4 and Proposition 6.

It is apparent that the manufacturer will have more output in the agency model if $D^{Ai^*} > D^{Ri^*}$,

$$D^{Ai^*} = \begin{cases} D^{A\bar{Y}^*} & \text{if the manufacturer does not provide return services in the agency model} \\ D^{AY^*} & \text{if the manufacturer provide return services in the agency model} \end{cases}$$

$$D^{Ri^*} = \begin{cases} D^{R\bar{Y}^*} & \text{if the platform does not provide return services in the reselling model} \\ D^{RY^*} & \text{if the platform provide return services in the reselling model.} \end{cases}$$

In the agency model, when the platform does not offer return service, the demand is

$$D^{A\bar{Y}^*} = \begin{cases} \frac{1}{2}\left(1+\frac{(a_0-Cb_0)e_0}{-1+\varphi}\right) & \text{if } 0 < e_0 < -\frac{1}{-a_0+Cb_0} \text{ and } 0 < \varphi \leq 1 - a_0e_0 + Cb_0e_0 \\ 0 & \text{else.} \end{cases}$$

In the agency model, when the manufacturer offers return service, the optimal profit of the manufacturer is

$$D^{AY^*} = \begin{cases} \frac{1}{2}(1+\frac{b(-a_0+Cb_0)e_0}{(-1+\alpha)(-1+\varphi)}) & \text{if } 0 < e_0 < \frac{-1+\alpha}{-ba_0+bCb_0} \text{ and } 0 < \varphi \leq \frac{-1+\alpha+ba_0e_0-bCb_0e_0}{-1+\alpha} \\ 0 & \text{else.} \end{cases}$$

In the reselling model, when the platform does not offer return service, the demand is

$$D^{R\bar{Y}^*} = \begin{cases} \frac{1}{4}(1+(-a_0+Cb_0)e_0) & \text{if } 0<e_0<-\frac{1}{-a_0+Cb_0} \\ 0 & \text{else.} \end{cases}$$

In the reselling model, when the manufacturer offers return service, the optimal profit of the manufacturer is

$$D^{RY^*} = \begin{cases} \frac{1}{4}\left(1+\frac{b(a_0-Cb_0)e_0}{-1+\alpha}\right) & \text{if } 0<e_0<\frac{-1+\alpha}{-ba_0+bCb_0} \\ 0 & \text{else.} \end{cases}$$

After a comparison of the demands of different contract strategies, we obtained the following intervals. That is when $0<e_0\leq -\frac{1}{-a_0+Cb_0}$ && $0<\alpha<1-b$ && $0<\varphi<\varphi_3$; or when $0<e_0\leq -\frac{1}{-a_0+Cb_0}$ && $1-b<\alpha<1$ && $0<\varphi<\varphi_4$; or when $-\frac{1}{-a_0+Cb_0}<e_0\leq -\frac{1}{-a_0+Cb_0}$ && $0<\alpha<1-ba_0e_0+bCb_0e_0$ && $0<\varphi<\varphi_3$. The manufacturer will have more output in the agency model.

Where $\varphi_3=-1+\frac{2(-1+\alpha)}{-1+\alpha+b(-a_0+Cb_0)e_0}$, $\varphi_4=-1+\frac{2}{1+(a_0-Cb_0)e_0}$. □

Proof of Proposition8. The manufacturer's profit in the agency model is described in Lemmas 1, 2 and Proposition 3; the manufacturer's profit in the reselling model is described in Lemmas 3, 4 and Proposition 6.

It is apparent that the manufacturer will earn more profit with the agency model if $\pi_m^{Ai^*}>\pi_m^{Ri^*}$,

$$\pi_m^{Ai^*} = \begin{cases} \pi_m^{A\bar{Y}^*} & \text{if the manufacturer does not provide return services} \\ \pi_m^{AY^*} & \text{if the manufacturer provide return services} \end{cases}$$

$$\pi_m^{Ri^*} = \begin{cases} \pi_m^{R\bar{Y}^*} & \text{if the platform does not provide return services} \\ \pi_m^{RY^*} & \text{if the platform provide return services.} \end{cases}$$

In the agency model, $\pi_m^{A\bar{Y}^*}$ and $\pi_m^{AY^*}$ are described in Proposition 3. $\pi_m^{R\bar{Y}^*}$ and $\pi_m^{RY^*}$ as shown below.

In the reselling model, when the platform does not offer return service, the optimal profit of the manufacturer is

$$\pi_m^{R\bar{Y}^*} = \begin{cases} \frac{1}{8}(1+(a_0-Cb_0)(8C+e_0(-2+(a_0-Cb_0)e_0))) & \text{if } 0<e_0<-\frac{1}{-a_0+Cb_0} \\ C(a_0-Cb_0) & \text{else.} \end{cases}$$

In the reselling model, when the platform offers return service, the optimal profit of the manufacturer is

$$\pi_m^{RY^*} = \begin{cases} -\frac{-1+\alpha}{8b}+\frac{(a_0-Cb_0)(8C(-1+\alpha)+e_0(2-2\alpha+b(-a_0+Cb_0)e_0))}{8(-1+\alpha)} & \text{if } 0<e_0<\frac{-1+\alpha}{-ba_0+bCb_0} \\ C(a_0-Cb_0) & \text{else.} \end{cases}$$

After a comparison of the profits of the manufacture of different contract strategies, we obtained the following intervals. That is when $0<e_0\leq -\frac{1}{-a_0+Cb_0}$ && $0<\alpha<1-b$ && $0<\varphi<\varphi_5$; or when $0<e_0\leq -\frac{1}{-a_0+Cb_0}$ && $1-b<\alpha<1$ && $0<\varphi<\varphi_6$; or when $-\frac{1}{-a_0+Cb_0}<e_0\leq -\frac{1}{-ba_0+bCb_0}$ && $0<\alpha<1-ba_0e_0+bCb_0e_0$ && $0<\varphi<\varphi_5$. The manufacturer will earn more profit with the agency mode.

Where $\varphi_5=\frac{1}{4(-1+\alpha)^2}((-1+\alpha+b(a_0-Cb_0)e_0)(3(-1+\alpha)+b(-a_0+Cb_0)e_0)-\sqrt{((-1+\alpha+b(a_0-Cb_0)e_0)^2((-1+\alpha)^2+b(a_0-Cb_0)e_0(6-6\alpha+b(a_0-Cb_0)e_0)))}$, $\varphi_6=\frac{1}{4}(3+(a_0-Cb_0)e_0(-2+(-a_0+Cb_0)e_0)-\sqrt{(1+(-a_0+Cb_0)e_0)^2(1+(a_0-Cb_0)e_0(6+(a_0-Cb_0)e_0))})$; $e_1=-\frac{1}{-a_0+Cb_0}$, $e_2=-\frac{1}{-ba_0+bCb_0}$;

$$\frac{\partial\varphi_5}{\partial e_0}=\frac{b(a_0-Cb_0)(-1+\alpha+b(-a_0+Cb_0)e_0)}{2(-1+\alpha)^2} + \frac{b(a_0-Cb_0)((-1+\alpha)^3+b(a_0-Cb_0)e_0(5(-1+\alpha)^2+b(a_0-Cb_0)e_0(3(-1+\alpha)+b(-a_0+Cb_0)e_0)))}{2(-1+\alpha)^2\sqrt{\begin{array}{l}(-1+\alpha)^4+b(a_0-Cb_0)e_0(-4(-1+\alpha)^3+b(a_0-Cb_0)e_0\\(-10(-1+\alpha)^2+b(a_0-Cb_0)e_0(4-4\alpha+b(a_0-Cb_0)e_0)))\end{array}}}<0$$

$$\frac{\partial\varphi_5}{\partial C} = -\frac{bb_0e_0(-1+\alpha+b(-a_0+Cb_0)e_0)}{2(-1+\alpha)^2} - \frac{bb_0e_0\big((-1+\alpha)^3+b(a_0-Cb_0)e_0\big(5(-1+\alpha)^2+b(a_0-Cb_0)e_0(3(-1+\alpha)+b(-a_0+Cb_0)e_0)\big)\big)}{2(-1+\alpha)^2\sqrt{\begin{array}{c}(-1+\alpha)^4+b(a_0-Cb_0)e_0\\ \big(-4(-1+\alpha)^3+b(a_0-Cb_0)e_0\big(-10(-1+\alpha)^2+b(a_0-Cb_0)e_0(4-4\alpha+b(a_0-Cb_0)e_0)\big)\big)\end{array}}} > 0$$

$$\frac{\partial\varphi_5}{\partial\alpha} = \frac{b(a_0-Cb_0)e_0}{2(-1+\alpha)^3}(1-\alpha+b(a_0-Cb_0)e_0 + \frac{-(-1+\alpha)^3+b(a_0-Cb_0)e_0(-5(-1+\alpha)^2+b(a_0-Cb_0)e_0(3-3\alpha+b(a_0-Cb_0)e_0))}{\sqrt{\begin{array}{c}(-1+\alpha)^4+b(a_0-Cb_0)e_0(-4(-1+\alpha)^3\\ +b(a_0-Cb_0)e_0(-10(-1+\alpha)^2+b(a_0-Cb_0)e_0(4-4\alpha+b(a_0-Cb_0)e_0)))\end{array}}} < 0$$

$$\frac{\partial\varphi_6}{\partial e_0} = -\frac{1}{2}(a_0-Cb_0)(1+(a_0-Cb_0)e_0) - \frac{(a_0-Cb_0)(1+(a_0-Cb_0)e_0(-5+(a_0-Cb_0)e_0(3+(a_0-Cb_0)e_0)))}{2\sqrt{1+(a_0-Cb_0)e_0(4+(a_0-Cb_0)e_0(-10+(a_0-Cb_0)e_0(4+(a_0-Cb_0)e_0)))}} < 0$$

$$\frac{\partial\varphi_6}{\partial C} = \frac{1}{2}b_0e_0\left(1+a_0e_0-Cb_0e_0+\frac{1+(a_0-Cb_0)e_0(-5+(a_0-Cb_0)e_0(3+(a_0-Cb_0)e_0))}{\sqrt{1+(a_0-Cb_0)e_0(4+(a_0-Cb_0)e_0(-10+(a_0-Cb_0)e_0(4+(a_0-Cb_0)e_0)))}}\right) > 0.$$

□

Funding

This research was financially supported by Anhui Philosophy and Social Science Foundation (AHSKY2021D147).

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