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Sales Mode Selection and Information-Sharing Strategy for Green E-Commerce Supply Chain

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Abstract

With the rapid development of E-commerce platforms (EPs) and the accumulation of consumer data, demand information sharing has become increasingly important in green supply chains. However, the interaction between selling mode selection and information-sharing strategies remains insufficiently explored. This study develops a game-theoretic model for a green supply chain consisting of a manufacturer and an EP to examine selling modes and information-sharing decisions under reselling and agency modes. The results indicate that information sharing is highly dependent on information accuracy. Specifically, when information accuracy exceeds a threshold, the manufacturer no longer purchases demand information because the marginal benefit cannot compensate for the acquisition cost. Under the reselling mode, the EP shares information only when information accuracy falls within an intermediate range, whereas under the agency mode, it always chooses to share information due to additional information-sharing revenue. Moreover, the manufacturer prefers the agency mode when the service cost performance factor is below the critical threshold and switches to the reselling mode otherwise. Information sharing consistently improves environmental performance, while the preferred selling mode depends on the service cost performance factor. The extension further shows that introducing an information collection cost narrows the information-sharing region and weakens the EP's incentive to share information.

Keywords: green supply chain; sales mode; information-sharing; service level

1. Introduction

The continuous growth of the economy has been accompanied by a significant increase in environmental problems, which have attracted considerable attention from various stakeholders, including consumers, enterprises, and governments [1,2]. In recent years, there has been a marked shift in consumer preferences towards green products. In response to this market shift, a large number of manufacturers have proactively implemented green technologies and sustainable materials in their production processes. The primary objectives of these initiatives are to improve the sustainability of their products and to strengthen competitiveness. By 2025, world-leading enterprises such as Schneider and Siemens are expected to further increase investment in green product development [3]. Similarly, enterprises such as Xiaomi and Midea have also laid out green product lines, launching home appliances and digital products equipped with environmental protection technologies. These initiatives, which are committed to sustainable development, have

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not only received widespread attention from consumers but have also further stimulated market demand through the creation of green value.

Over the past decades, digital technologies have advanced rapidly, and E-commerce has experienced robust growth. These two factors have contributed significantly to the prosperity of digital retailing [4,5]. It is widely acknowledged that E-commerce has become an indispensable component of the economy. Consequently, the management of green supply chains faces more stringent demands than ever before [6]. The green E-commerce supply chain, abbreviated as GESC, is characterized by two prevailing sales modes: agency and reselling. Typical examples of the agency mode include Taobao and Pinduoduo, while Zappos is a representative case of the reselling mode. In the agency mode, E-commerce platforms (EPs) act as intermediaries that connect manufacturers directly with consumers. Manufacturers are responsible for all aspects of customer service and share a certain proportion of their revenue with the EPs in accordance with prior agreements [7]. By comparison, under the reselling mode, EPs are responsible for selling products to consumers [8]. Therefore, analyzing the decision-making logic behind sales mode selection in the E-commerce environment is of great practical and theoretical value.

In GESC systems, many manufacturers lack demand-side information support, making it difficult to dynamically adjust production activities efficiently. In contrast, EPs can obtain valuable market information, which leads to information asymmetry among GESC members. With the continuous advancement of Internet technologies, many EPs have integrated advanced data collection and analysis tools [9], thereby accumulating rich datasets. For example, JD Business Intelligence, launched by JD.com, integrates multidimensional consumer information such as browsing, purchasing, and evaluation behaviors to provide accurate market insights for merchants. After mastering this core market demand information, EPs are motivated to share this information with manufacturers to increase profits [10]. With more accurate information, manufacturers can improve product development, reduce demand uncertainty, and enhance supply chain performance. Amazon opens core data to Procter & Gamble, such as consumers' green consumption preferences and purchasing behaviors of environmentally friendly products [11], helping Procter & Gamble more accurately align with market demand, promote green product R&D and green supply chain optimization, and achieve efficient matching of supply and demand. However, some studies indicate that information sharing may lead to the double marginalization effect [12], which can weaken the EP's willingness to share information. For manufacturers, the benefits of acquiring demand information may also fail to offset the associated acquisition cost. More importantly, the value of information sharing may differ across sales modes because reselling and agency modes involve different pricing rights and revenue structures. Under the reselling mode, the EP earns a retail margin, whereas under the agency mode, it earns commission revenue. These differences can change the incentives of both parties to share or acquire demand information. Therefore, information-sharing decisions should be examined jointly with sales mode selection in GESCs.

In light of the above background, this study aims to explore how strategic choices regarding sales modes and information sharing affect pricing decisions, firm profitability, and the level of environmental improvement in GESCs. Specifically, this study addresses the following research questions:

(1) Under different sales modes, how should the manufacturer and the EP formulate optimal operational decisions?
(2) How do the green cost performance factor, service cost performance factor, and information accuracy determine the information-sharing strategies adopted by supply chain members?
(3) Which sales mode is more beneficial for each member of the supply chain?

(4) How do different sales modes and information sharing states affect the level of environmental improvement?

To address the above questions, we build a GESC model comprising one EP and one manufacturer. This analytical model is constructed to examine the impacts of various sales formats and information-sharing scenarios on the two parties, provide strategic guidance for green supply chain members, and support decision-making regarding product pricing, green degree, and the EP's service level.

This study provides three main contributions. First, it reveals how information accuracy jointly determines the information-sharing incentives of the manufacturer and the EP under different sales modes, identifying the conditions under which information sharing can be achieved. Second, it shows how green and service cost performance factors shape the potentially different sales mode preferences of the manufacturer and the EP. Third, it demonstrates that information sharing consistently improves environmental performance across sales modes, while the environmental advantage of a particular sales mode depends on operational conditions. These findings provide new insights into the interaction among sales mode selection, information sharing, and environmental performance in GESCs.

The structure of the rest of this paper is arranged as follows: Section 2 presents a literature review from two distinct angles. Section 3 outlines the core research questions, along with the mathematical model and key assumptions. Section 4 develops and analyzes optimal pricing and information-sharing strategies under various sales channel configurations. Section 5 compares the reselling and agency models to identify firms' preferred sales formats and information-sharing practices. Section 6 extends the baseline model by incorporating information collection costs. Finally, Section 7 summarizes the main findings, discusses managerial implications, and presents the limitations and directions for future research.

2. Literature Review

This study systematically reviews the relevant literature from two main perspectives: the selection of sales modes in GESCs and green information sharing.

2.1. Selection of Sales Modes in GESCs

Against the backdrop of the rapid growth of E-commerce platforms (EPs) as the primary channel for consumer purchases, comparison and selection between reselling and agency modes have become core research topics in E-commerce operations [13,14]. Previous studies have conducted systematic analyses of the decision-making logic of these two modes by incorporating multiple influencing factors, including brand externalities [15], logistics service capabilities [16,17], differences in channel power structures [18], blockchain technology applications [19], upstream and downstream market competition [6,20], and commission rate pricing mechanisms [21]. This stream of literature primarily explores how these factors shape the channel preferences of manufacturers, EPs, and end consumers. Meanwhile, some studies have examined the impact of the two EP sales modes on other supply chain decisions. For example, He et al. [22] compared human and AI customer service strategies under different sales modes.

In recent years, channel cooperation mode selection between green manufacturers and EPs has emerged as a fast-growing research stream [23]. Existing studies generally show that neither the agency mode nor the reselling mode is always optimal; instead, their relative advantages depend on specific market and operational conditions. Cheng et al. [24] found that high-quality store brands do not necessarily prompt EPs to introduce them and that the two parties often have conflicting preferences regarding sales modes. Zhang and Hou [25] showed that manufacturers should choose the agency mode when

the commission rate is low and the reselling mode when it is high. Similarly, Yi et al. [26] found that the agency mode is optimal under significant positive spillover effects, whereas stronger negative spillover leads to a preference for reselling. These findings suggest that commission rates and spillover effects may reverse firms' sales mode preferences. Other studies have emphasized technology, market response, and environmental policies. Peng et al. [27] indicated that EPs tend to introduce high-end private brands when cost-effectiveness is high and that this tendency is stronger under the agency mode. Yang [28] found that, under a cap-and-trade mechanism, EPs' green investment benefits the entire supply chain, whereas manufacturers tend to select the EP sales mode when they are in a weaker position or possess cost advantages. Zhao et al. [29] showed that manufacturers have stronger incentives to adopt blockchain technology under the agency mode and that the commission rate affects this decision in dual-channel settings. Deng and Zhang [30] demonstrated that manufacturers prefer online direct selling or dual-channel modes when online reviews are highly effective but tend to choose traditional reselling when such effectiveness is low. Shang et al. [31] further showed that government subsidies and carbon taxes alter pricing structures and that centralized decision-making is not always optimal.

Overall, previous studies have identified various factors that may affect sales mode selection, but their conclusions differ because they focus on different contractual, technological, competitive, and environmental conditions. Although some studies incorporate green factors, EP service levels are rarely considered together with green operational decisions. Consequently, how green factors and service factors jointly affect the potentially conflicting sales mode preferences of manufacturers and EPs remains insufficiently explored.

2.2. Green Information Sharing

In GESCs, existing studies have examined how various factors influence information-sharing strategies between manufacturers and EPs, including product quality and pricing [32], blockchain technology applications [33,34], eco-label selection [34], spillover effects [35], channel intrusion [36], and information inference mechanisms [37]. Some studies have also extended information disclosure analysis to E-commerce hybrid channels. However, previous studies have reached different conclusions regarding the value of information sharing. Wang et al. [38] showed that a complete information-sharing strategy can promote Pareto improvements among GESC members, enabling all participants to benefit. This result emphasizes the coordination value of information sharing. In contrast, Zhao et al. [37] found that when information asymmetry is large or demand is low, firms may be unwilling to share information. Moreover, first-mover advantage is not always guaranteed and depends on factors such as information gaps, inference ability, and sharing strategies. Thus, information sharing may improve supply chain performance, but such benefits are conditional rather than universal.

In competitive market environments, existing research has examined how inter-supply chain competition and horizontal competition among manufacturers affect information-sharing strategies and has clarified the conditions under which information sharing is feasible. Ha et al. [12] proposed that when GESC members share demand information, competing supply chains respond strategically, and sales mode choices depend on retailer competition and manufacturers' cost optimization capabilities. Their analysis also indicates that information sharing may intensify the double marginalization effect and therefore does not necessarily benefit the information provider. Liu et al. [39] focused on information-sharing decisions among multiple original equipment manufacturers in competitive settings. Other studies have further explored the boundary conditions of information sharing. Yu and Cao [40] and Lin et al. [41] showed that when demand un-

certainty increases or environmental investment efficiency is low, EPs are less willing to share information.

These studies demonstrate that the effect of information sharing depends on the balance between its coordination benefits and its potential profit losses or acquisition costs. Nevertheless, most studies examine information sharing under a given channel structure. Although some studies incorporate information accuracy, few compare how information accuracy affects the sharing incentives of manufacturers and EPs under both reselling and agency modes. Moreover, green factors, service factors, and information accuracy have rarely been integrated to examine their combined effects on sales decisions, mode selection, and environmental performance.

2.3. Distinctions Between Our Work and Existing Literature

This study differs from the existing literature in several important aspects. First, although prior studies on sales mode selection in GESCs have examined various influencing factors, few have jointly considered green factors and EP service levels. As a result, the interaction between service operations and channel decisions has not been fully captured. Second, although some studies on green information sharing incorporate information accuracy, they generally do not integrate green factors, service factors, and information accuracy within a unified framework, nor do they analyze their combined effects on sales mode selection and operational decisions. To address these gaps, this study develops a GESC model consisting of one manufacturer and one EP and integrates different information sharing states and sales modes into a unified analytical framework. It systematically examines their joint effects on pricing decisions, information-sharing strategies, profitability, and environmental improvement levels. Specifically, this study explores the interaction among information accuracy, green cost performance, and service cost performance in shaping sales mode selection and information-sharing decisions. It also reveals how environmental improvement levels vary under different strategic combinations. This work contributes to the literature by providing a more comprehensive analysis of multi-dimensional decision-making in green supply chains and offering practical insights for supply chain members. We summarize the representative studies that are most relevant to this paper in Table 1.

Table 1. Summary of the relevant literature.

	Sales Modes Selection	Green Supply Chain	Information Sharing	Platform Service
Li et al. [10]		√		√
Huang et al. [19]	√		√	
Yan et al. [20]	√	√		
Peng et al. [27]	√			√
Quadir and Raj [42]		√	√	
Chen et al. [43]	√	√	√	
Chen et al. [44]	√		√	
Li et al. [45]		√	√	
Jiao and Deng [46]	√	√	√	
This paper	√	√	√	√

3. Problem Description and Assumptions

3.1. Problem Description

We consider a GESC consisting of one manufacturer and one EP. The manufacturer produces green products, while the EP provides two sales modes: reselling and agency [11,47]. Under the reselling mode, the EP acts as a retailer by purchasing products at a wholesale price and reselling them to consumers to earn a margin. Under the agency mode, the EP serves as an intermediary: the manufacturer sells products directly to consumers through the platform and determines retail prices, while the EP earns revenue through a commission charged on sales.

EPs can accumulate large amounts of consumer data, including purchasing records and browsing behavior. By analyzing such data, EPs can extract valuable market information and sell it to manufacturers, thereby improving demand forecasting accuracy and assisting production planning [27]. However, two key issues arise. On the one hand, after obtaining precise demand information, manufacturers' decisions may affect the EP's profit, and thus the EP must decide whether to share information. On the other hand, although accurate information can benefit manufacturers, acquiring such information incurs costs; therefore, manufacturers must decide whether to purchase it.

To capture the joint effects of sales modes and information sharing, four models are considered: (reselling, no sharing), (reselling, sharing), (agency, no sharing), and (agency, sharing) (see Figure 1).

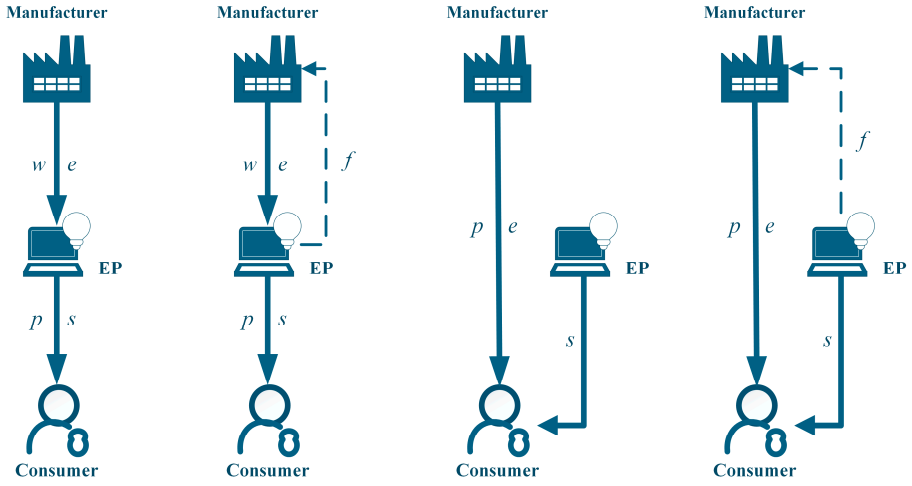


Figure 1. Structures of four models in a GESC.

3.2. Assumptions

The relevant symbols used in this study and their definitions are listed in the following Table 2.

The four models are based on the following assumptions. Consistent with prior studies [4], all supply chain members are assumed to be fully rational and aim to maximize their own profits.

Demand information: Since EPs can easily obtain consumers' purchasing records and browsing traces, we assume that the cost of data processing is negligible [47]. After data processing, the EP observes a noisy demand signal $f = a + \varepsilon$, where the noise term ε follows a normal distribution $(0, n)$. Market demand is assumed to be uncertain, which is set as $a = a_0 + \theta$ [42,48], where a_0 is the basic demand, and the random variable θ represents demand fluctuations, following a normal distribution $(0, v)$. And then, we have $E(a|f) = \frac{n}{v+n}a_0 + \frac{v}{v+n}f$ and $E((f - a_0)^2) = v + n$. We define the information accuracy as $t = \frac{v}{v+n} \in [0, 1]$, where v represents the variance of market demand uncertainty, and

n represents the variance of the noise term. Accordingly, $A = E[a|f] = (1-t)a_0 + tf$. A larger t indicates a smaller relative noise level and thus more accurate demand information. In the subsequent analysis, t is treated as an exogenous parameter rather than a random variable, and different values of t represent different levels of information accuracy.

Table 2. Symbols and meanings.

Symbols	Meanings
a	Market size
a_0	Basic demand
f	Demand signal
ε	The noise error term of the demand signal
t	Information accuracy
α	Commission rate charged by the EP
θ	Uncertain random variable captured by the EP
k	Consumers' sensitivity coefficient of green products
b	Consumers' sensitivity coefficient of retail price
r	Consumers' sensitivity coefficient of service level
ξ	The manufacturer's sensitivity coefficient of information fees
β	Green degree investment cost coefficient
μ	Service-level investment cost coefficient
α	Commission rate under the agency mode
φ	Green cost performance factor
ψ	Service cost performance factor
e^i	Green degree of green products in the model i, $i \in \{RN, RI, AN, AI\}$
p^i	Retail price of green products in the model i, $i \in \{RN, RI, AN, AI\}$
w^i	Wholesale price of the green product in the model i, $i \in \{RN, RI, AN, AI\}$
s^i	Service level of the EP in the model i, $i \in \{RN, RI, AN, AI\}$
q^i	Demand of green products in the model i, $i \in \{RN, RI, AN, AI\}$
π_M^i	Profit of the manufacturer in the model i, $i \in \{RN, RI, AN, AI\}$
π_E^i	Profit of the EP in the model i, $i \in \{RN, RI, AN, AI\}$
EI^i	Environmental improvement level in the model i, $i \in \{RN, RI, AN, AI\}$

Consumer demand: Following the standard specification in the literature [49], the baseline demand function is given by $q = a - bp$. In the E-commerce context, both the EP's service level and the product's green degree positively affect demand [50], and thus demand is modeled as $q = a - bp + ke + rs$. In the absence of information-sharing, the manufacturer cannot observe the demand signal and instead estimates market size based on historical data; in this case, demand is given by $q = a_0 - bp + ke + rs$. Since price typically has a stronger impact on demand than other factors, we maintain the standard assumption that $k < b$ and $r < b$ [43,51].

Cost structure: To acquire the demand information from the EP, the manufacturer must pay a corresponding information fee. The information acquisition cost is assumed to be ξt^2, where $\xi > 0$ [52]. The EP incurs costs for service provision, while the manufacturer incurs costs for green investment in product development. The service cost is given by μs^2 [12,50], and the green investment cost is specified as βe^2 [52,53].

Environmental improvement level. Following Li et al. [45], we define the environmental improvement level (EI) as the aggregate environmental benefit generated by the green products sold in the market. Specifically, the green degree e represents the environmental improvement of a unit green product relative to a conventional product, whereas q represents the quantity of green products consumed. Accordingly, the environmental improvement level is defined as $EI = eq$.

Commission rate: EPs usually set a unified commission rate for product categories and announce it publicly, which is consistent with the actual situation, and will not adjust

such rates individually for a certain manufacturer. According to the decisions of EPs such as JD and Taobao, the commission rate satisfies $\alpha \in (0, 0.3)$.

Decision-making sequence: We follow Lin et al. [41]. First, the EP decides whether to share information, after which the manufacturer decides whether to purchase the information. Under the reselling mode, the manufacturer first determines the wholesale price (w) and the product greenness level (e), and the platform subsequently determines the retail price (p) and the service level (s). Under the agency mode, the manufacturer first determines the retail price (p) and the product greenness level (e), after which the platform determines the service level (s). The detailed sequence of events is illustrated in Figure 2.

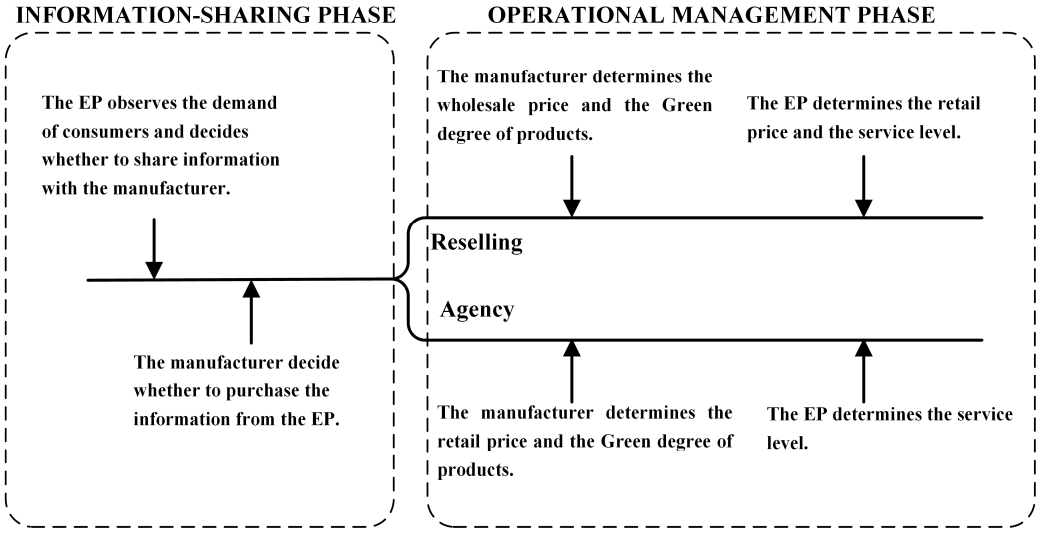


Figure 2. Decision-making sequence of the manufacturer and the EP in a GESC.

4. Equilibrium Analysis and Information-Sharing Strategies

In this section, we derive the equilibrium outcomes under the four models. For analytical convenience, we denote $A = E[a|f] = a_0(1-t) + tf$, $B = 8b\beta\mu - \mu k^2 - 2\beta r^2$, and $C = 4b\beta\mu + \alpha k^2\mu - k^2\mu - 2\alpha\beta r^2$. According to the assumptions, A, B, and C are all positive.

4.1. Decisions of GESC Members Under Reselling Mode

4.1.1. Scenario Without Information-Sharing (Model *RN*)

In the *RN* model, the manufacturer first decides the wholesale price of products and the green degree of products, and then the EP sets the retail price of products and its own service level. The optimization problem is formulated as

$$\max_{w^{RN}, e^{RN}} \Pi_M^{RN} = w^{RN} E[q^{RN}] - \beta^{RN} (e^{RN})^2,$$
$$s.t. \begin{cases} \max\limits_{p^{RN}, s^{RN}} \Pi_P^{RN} = (p^{RN} - w^{RN}) E[q^{RN}|f] - \mu^{RN} (s^{RN})^2, \\ E[q^{RN}] = a_0 - bp^{RN} + ke^{RN} + rs^{RN}, \\ E[q^{RN} \mid f] = A - bp^{RN} + ke^{RN} + rs^{RN}. \end{cases}$$

4.1.2. Scenario with Information-Sharing (Model *RI*)

In the *RI* model, the manufacturer sets the wholesale price and optimal product green degree first, then the EP decides the retail price and EP service level. The mathematical formulation of this optimization problem is given by

$$\max_{w^{RI},e^I} \Pi_M^{RI} = w^{RI}E[q^{RI}] - \beta^{RI}(e^{RI})^2,$$
$$s.t.\begin{cases} \max\limits_{p^{RI},s^{RI}} \Pi_P^{RI} = (p^{RI} - w^{RI})E[q^{RI}|f] - \mu^{RI}(s^{RI})^2, \\ E[q^{RI} \mid f] = A - bp^{RI} + ke^{RI} + rs^{RI}. \end{cases}$$

Using backward induction, the equilibrium solutions of the two models are obtained, as reported in Table 3. See Appendix A for the detailed solution process.

Table 3. The optimal outcomes in the models *RN* and *RI*.

	Model *RN*	**Model *RI***
e^{R^*}	$\frac{a_0 k\mu}{B}$	$\frac{Ak\mu}{B}$
w^{R^*}	$\frac{a_0\beta(4b\mu-r^2)}{bB}$	$\frac{A\beta(4b\mu-r^2)}{bB}$
p^{R^*}	$\frac{A\beta(6b\mu-r^2)}{bB}$	$\frac{A\beta(6-r^2)}{bB}$
s^{R^*}	$\frac{A\beta r}{B}$	$\frac{A\beta r}{B}$
$E[\Pi_M^{R^*}]$	$\frac{{a_0}^2\beta\mu}{B}$	$\frac{{a_0}^2\beta\mu}{B} + \frac{tv\beta\mu}{B} - \xi t^2$
$E[\Pi_P^{R^*}]$	$\frac{\beta^2{a_0}^2\mu(4b\mu-r^2)}{B^2} + \frac{tv\mu}{(4b\mu-r^2)}$	$\frac{\beta^2{a_0}^2\mu(4b\mu-r^2)}{B^2} + \frac{\beta^2tv\mu(4b\mu-r^2)}{B^2} + \xi t^2$
$E[EI^{R^*}]$	$\frac{2{a_0}^2b\beta k\mu^2}{B^2}$	$\frac{2{a_0}^2b\beta k\mu^2}{B^2} + \frac{2tvb\beta k\mu^2}{B^2}$

Analyzing the equilibrium results of the models *RN* and *RI* under the reselling mode, we have the following conclusions:

Proposition 1. *Under the reselling mode, regardless of whether information-sharing occurs, the equilibrium results satisfy*

(1) $\frac{\partial w^{Rj^*}}{\partial k} > 0$, $\frac{\partial e^{Rj^*}}{\partial k} > 0$, $\frac{\partial p^{Rj^*}}{\partial k} > 0$, $\frac{\partial s^{Rj^*}}{\partial k} > 0$, $\frac{\partial E[\Pi_M^{Rj^*}]}{\partial k} > 0$, $\frac{\partial E[\Pi_P^{Rj^*}]}{\partial k} > 0$;

(2) $\frac{\partial w^{Rj^*}}{\partial \beta} < 0$, $\frac{\partial e^{Rj^*}}{\partial \beta} < 0$, $\frac{\partial p^{Rj^*}}{\partial \beta} < 0$, $\frac{\partial s^{Rj^*}}{\partial \beta} < 0$, $\frac{\partial E[\Pi_M^{Rj^*}]}{\partial \beta} < 0$, $\frac{\partial E[\Pi_P^{Rj^*}]}{\partial \beta} < 0$;

(3) $\frac{\partial w^{Rj^*}}{\partial r} > 0$, $\frac{\partial e^{Rj^*}}{\partial r} > 0$, $\frac{\partial p^{Rj^*}}{\partial r} > 0$, $\frac{\partial s^{Rj^*}}{\partial r} > 0$, $\frac{\partial E[\Pi_M^{Rj^*}]}{\partial r} > 0$, $\frac{\partial E[\Pi_P^{Rj^*}]}{\partial r} > 0$;

(4) $\frac{\partial w^{Rj^*}}{\partial \mu} < 0$, $\frac{\partial e^{Rj^*}}{\partial \mu} < 0$, $\frac{\partial p^{Rj^*}}{\partial \mu} < 0$, $\frac{\partial s^{Rj^*}}{\partial \mu} < 0$, $\frac{\partial E[\Pi_M^{Rj^*}]}{\partial \mu} < 0$, $\frac{\partial E[\Pi_P^{Rj^*}]}{\partial \mu} < 0$, $j \in \{N, I\}$.

See Appendix B for a proof of Proposition 1. Proposition 1 indicates that market operation decisions under the reselling mode are affected by consumers' sensitivity coefficient of green products, green degree investment cost coefficient, consumers' sensitivity to service level, and service-level investment cost coefficient. All these equilibrium results rise with the increase in consumers' sensitivity coefficient to green products and service level, and fall with the rise of the cost coefficients of green degree investment and service-level investment.

When consumers' sensitivity coefficient of green products decreases and the green degree investment cost coefficient increases, the manufacturer is unwilling to improve the product's green degree, which directly affects the online sales performance of products on the EP. Therefore, the manufacturer and the EP are motivated to reduce the wholesale price and retail price to stabilize product sales. However, the increase in demand brought by the price reduction is offset by the negative effect of reduced green degree, resulting in a downward trend in the final product demand and thus a decline in the profits of both the manufacturer and the EP. Industrial practices demonstrate that consumers' sensitivity coefficient to green products and the cost coefficient of green degree investment are core factors driving the performance improvement of GESCs. Through continuous product innovation and brand building, Tesla has increased consumers' preference for new energy vehicles. In

2023, Tesla's global vehicle deliveries reached 1.81 million units, which substantiates the strong appeal of green consumption preferences to demand [54].

When consumers' sensitivity coefficient of service level decreases and the service-level investment cost coefficient increases, the EP faces excessive service cost pressure and is unwilling to provide a high service level, which will affect the sales volume of products on the EP. As analyzed above, both the manufacturer and the EP are motivated to reduce the wholesale price and sales price to stabilize sales. However, the increase in demand brought by the price reduction is offset by the negative effect of reduced service level, and the final product demand still shows a downward trend, leading to a decline in the profits of both the manufacturer and the EP.

Proposition 2. *Under the reselling mode, the information-sharing strategies are given as*

(1) if $t \in [t_1, 1]$, *the EP will share information (i.e.,* $E[\Pi_P^{RI^*}] \geq E[\Pi_P^{RN^*}]$*);*

(2) if $t \in [0, t_2]$, *the manufacturer will purchase information (i.e.,* $E[\Pi_M^{RI^*}] \geq E[\Pi_M^{RN^*}]$*);*

(3) if $t \in [t_1, t_2]$, *information-sharing is achieved in the GESC (i.e.,* $E[\Pi_P^{RI^*}] \geq E[\Pi_P^{RN^*}]$ *and* $E[\Pi_M^{RI^*}] \geq E[\Pi_M^{RN^*}]$*), where* $t_1 = \frac{\mu v}{\xi(4b\mu - r^2)} - \frac{\beta^2 \mu v (4b\mu - r^2)}{\xi B^2}$ *and* $t_2 = \frac{\beta \mu v}{\xi B}$.

See Appendix B for a proof of Proposition 2. Proposition 2 indicates the willingness of the manufacturer and the EP to share information under different ranges of information accuracy. From the perspective of EP, when information accuracy t is in a low range $[0, t_1]$, the information fee charged by the EP on the manufacturer fails to fully offset the profit erosion caused by the double marginalization effect; thus, the EP lacks the motivation to engage in information-sharing. Shang et al. [52] argued that retailers sharing private information will benefit manufacturers but harm themselves, so a scenario without information-sharing is the optimal choice for the GESC members. We find that as the accuracy of information continues to improve, the value of information also increases. When $t > t_1$, the EP can collect a higher information fee from the manufacturer, which can fully cover the loss from the double marginalization effect and yield additional profits, so a share-information strategy will be adopted by the EP. From the perspective of the manufacturer, when information accuracy t is at a low level $[0, t_2]$ but with low information acquisition costs, the manufacturer still benefits relative to the no-information case. However, as information accuracy t increases, the cost of obtaining information becomes prohibitive when $t > t_2$, which exceeds the benefits brought by the information itself. Therefore, the manufacturer chooses not to obtain information from the EP.

Given the large number of exogenous variables involved in the analysis, this study follows the approach of Qin et al. [55] by defining $\varphi = \frac{k^2}{\beta}$ and $\psi = \frac{r^2}{\mu}$ to denote the green cost performance factor and service cost performance factor, respectively. Larger values of the two composite parameters mean that each additional unit of investment in green degree and service level can increase demand more. We define variable $\Phi_1 = t_2 - t_1$ to characterize the interval of information-sharing under the reselling mode, which leads us to the following corollary:

Corollary 1. *The range of information-sharing under the reselling mode satisfies* $\frac{\partial \Phi_1}{\partial \varphi} > 0$ *and* $\frac{\partial \Phi_1}{\partial \psi} > 0$.

See Appendix B for a proof of Corollary 1. Corollary 1 shows how the range of information-sharing under the reselling mode changes with the green cost performance factor and service cost performance factor. Higher green cost performance factor and higher service cost performance factor will expand the range of information accuracy for achieving information-sharing. To gain a clearer understanding of how the green cost

performance factor and service cost performance factor affect information-sharing, this study follows the parameter settings of prior literature [12,44] and assigns values as follows: $a_0 = 2$, $b = 1$, $v = 1$, $\xi = 0.6$, $k = 0.8$, $\beta = 0.5$, $r = 0.8$, $\mu = 0.5$. Then, the impact of the green cost performance factor φ and service cost performance factor ψ on the range Φ_1 of information-sharing is shown in the following Figures 3 and 4, respectively.

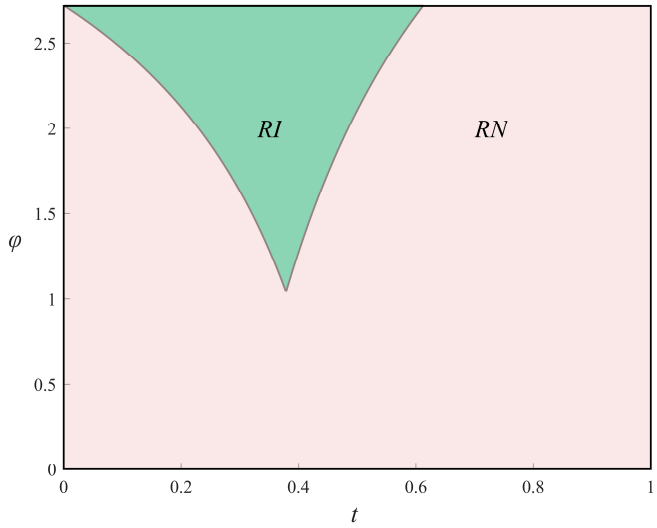


Figure 3. Impact of green cost performance on information-sharing strategy under the reselling mode.

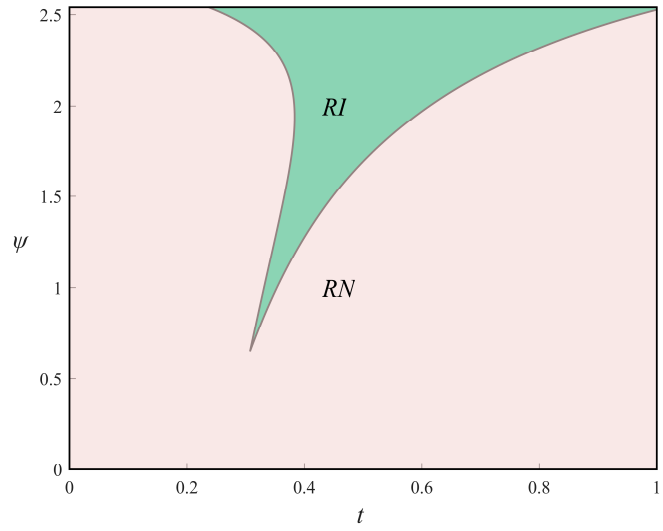


Figure 4. Impact of service cost performance on information-sharing strategy under the reselling mode.

As shown in Figure 3, the range of information accuracy for achieving information-sharing expands with the increase in the green cost performance factor. This is because when the green cost performance factor rises, enhancing the product's green degree can notably boost the sales volume of green products. Moreover, according to Proposition 1, the price of green products will also rise, leading to a substantial increase in the revenues of both the EP and the manufacturer. Even if the information accuracy decreases, the loss caused by the double marginalization effect when the EP shares information is still acceptable. Likewise, as information accuracy improves, the manufacturer retains the capacity to acquire information. It can also be found from Figure 3 that, when the green cost performance factor is at a low level, information-sharing will not be achieved no matter how the information accuracy changes. When the information accuracy is high, even if the green cost performance factor is increased, information-sharing will not be achieved. Due

to the low-cost performance factor, the manufacturer is unwilling to improve the product's green degree, the revenues of the EP and the manufacturer are low, the EP is unwilling to share information, and the manufacturer is also unwilling to purchase information. When the information accuracy is high, the EP is willing to share information, but due to the high cost required for purchasing, even if the green cost performance factor is high, the manufacturer is still unwilling to purchase information.

Similarly, Figure 4 shows that the range of information accuracy for achieving information-sharing expands with the increase in the service cost performance factor. As analyzed for the green cost performance factor, when the service cost performance factor increases, the increased revenues of the EP and the manufacturer make the EP willing to share information and the manufacturer able to purchase information. Different from Figure 3, when the information accuracy is low, even if the service cost performance factor is increased, information-sharing will not be achieved. This is because when the information accuracy is low, even if the service cost performance factor increases, the revenue brought by the EP's information-sharing cannot make up for the loss caused by the double marginalization effect. Comparing Figures 3 and 4, the manufacturer is more affected by the green cost performance factor, while the EP is more affected by the service cost performance factor.

Proposition 3. *Under the reselling mode, the product's green degree and environmental improvement level satisfy the following relationships:* $E[e^{RN^*}] = E[e^{RI^*}]$ *and* $E[EI^{RN^*}] < E[EI^{RI^*}]$.

See Appendix B for a proof of Proposition 3. From Proposition 3, we can see that under the reselling mode, information-sharing cannot improve the product's green degree but can increase the environmental improvement level. Although information-sharing cannot improve the product's green degree, it can reduce the variance of the green degree from v to vt, which can improve the stability and effectiveness of the product's green degree. As a form of cooperation between manufacturers and EPs, information-sharing helps align production plans with market demand for both parties, thereby enhancing overall coordination efficiency. This means that all stakeholders in the GESC can promote continuous environmental improvement and enhance environmental sustainability by carrying out information-sharing cooperation or improving the level of cooperation.

4.2. Decisions of GESC Members Under Agency Mode

4.2.1. Scenario Without Information-Sharing (Model AN)

In the AN model, the manufacturer first decides the retail price and green degree of products, after which the EP sets its own service level. The optimization problem is expressed as

$$\max_{p^{AN},e^{AN}} \Pi_M^{AN} = (1-\alpha)p^{AN}E[q^{AN}] - \beta^{AN}(e^{AN})^2,$$
$$s.t.\begin{cases} \max\limits_{s^{AN}} \Pi_P^{AN} = \alpha p^{AN}E[q^{AN}|f] - \mu^{AN}(s^{AN})^2, \\ E[q^{AN}] = a_0 - bp^{AN} + ke^{AN} + rs^{AN}, \\ E[q^{AN} \mid f] = A - bp^{AN} + ke^{AN} + rs^{AN}. \end{cases}$$

4.2.2. Scenario with Information-Sharing (Model AI)

Similarly, in the model AI, the manufacturer first sets the retail price and optimal green degree of products, and then the EP decides the corresponding EP service level. The optimization problem is expressed as

$$\max_{p^{AI},e^{AI}} \Pi_M^{AI} = (1-\alpha)p^{AI}E[q^{AI}] - \beta^{AI}(e^{AI})^2,$$
$$s.t.\begin{cases} \max_{s^{AI}} \Pi_P^{AI} = \alpha p^{AI}E[q^{AI}|f] - \mu^{AI}(s^{AI})^2, \\ E[q^{AI} \mid f] = A - bp^{AI} + ke^{AI} + rs^{AI}. \end{cases}$$

By adopting backward induction, the equilibrium solutions in the models AN and AI under the agency mode can be obtained, which are shown in the following Table 4.

Table 4. The optimal outcomes in the models AN and AI.

	Model *AN*	**Model *AI***
e^{A^*}	$\frac{a_0 k\mu(1-\alpha)}{C}$	$\frac{Ak\mu(1-\alpha)}{C}$
p^{A^*}	$\frac{2a_0\beta\mu}{C}$	$\frac{2A\beta\mu}{C}$
s^{A^*}	$\frac{a_0\beta\alpha r}{C}$	$\frac{A\beta\alpha r}{C}$
$E[\Pi_M^{A^*}]$	$\frac{{a_0}^2\ \beta\ \mu(1-\alpha)}{C}$	$\beta\ \mu(1-\alpha)\frac{{a_0}^2+tv}{C} - \xi t^2$
$E[\Pi_P^{A^*}]$	$\frac{{a_0}^2\alpha\beta^2\mu\ (4b\mu-3\alpha r^2)}{C^2}$	$\alpha\beta^2\mu(4b\mu-3\alpha r^2)\frac{{a_0}^2+tv}{C^2} + \xi t^2$
$E[EI^{A^*}]$	$\frac{{a_0}^2\beta k\mu(4b\mu-3\alpha r^2+\alpha r^2)(1-\alpha)}{2C^2}$	$\beta k\mu(1-\alpha)(4b\mu-3\alpha r^2+\alpha r^2)\frac{{a_0}^2+tv}{2C^2}$

The following part conducts sensitivity analysis and comparative analysis of the equilibrium results in the models AN and AI.

Proposition 4. *Under the agency mode, regardless of whether information-sharing occurs, the equilibrium results satisfy*

(1) $\frac{\partial e^{Aj^*}}{\partial k} > 0$, $\frac{\partial p^{Aj^*}}{\partial k} > 0$, $\frac{\partial s^{Aj^*}}{\partial k} > 0$, $\frac{\partial E[\Pi_M^{Aj^*}]}{\partial k} > 0$, $\frac{\partial E[\Pi_P^{Aj^*}]}{\partial k} > 0$;

(2) $\frac{\partial e^{Aj^*}}{\partial \beta} < 0$, $\frac{\partial p^{Aj^*}}{\partial \beta} < 0$, $\frac{\partial s^{Aj^*}}{\partial \beta} < 0$, $\frac{\partial E[\Pi_M^{Aj^*}]}{\partial \beta} < 0$, $\frac{\partial E[\Pi_P^{Aj^*}]}{\partial \beta} < 0$;

(3) $\frac{\partial e^{Aj^*}}{\partial r} > 0$, $\frac{\partial p^{Aj^*}}{\partial r} > 0$, $\frac{\partial s^{Aj^*}}{\partial r} > 0$, $\frac{\partial E[\Pi_M^{Aj^*}]}{\partial r} > 0$, $\frac{\partial E[\Pi_P^{Aj^*}]}{\partial r} > 0$;

(4) $\frac{\partial e^{Aj^*}}{\partial \mu} < 0$, $\frac{\partial p^{Aj^*}}{\partial \mu} < 0$, $\frac{\partial s^{Aj^*}}{\partial \mu} < 0$, $\frac{\partial E[\Pi_M^{Aj^*}]}{\partial \mu} < 0$, $\frac{\partial E[\Pi_P^{Aj^*}]}{\partial \mu} < 0$, $j \in \{N, I\}$.

See Appendix B for a proof of Proposition 4. Proposition 4 indicates that market operation decisions under the agency mode are also affected by consumers' sensitivity coefficient of green products, green degree investment cost coefficient, consumers' sensitivity coefficient of service level, and service-level investment cost coefficient. These decisions increase with the increase in consumers' sensitivity coefficient of green products and consumers' sensitivity coefficient of service level, and decrease with the increase in green degree investment cost coefficient and service-level investment cost coefficient. As for the effects of the two green-related parameters k and β on the optimal results of GESC, the reasons are consistent with Proposition 1 and will not be repeated here.

Next, by analyzing the effect of the two service-related parameters r and μ, we find that unlike the reselling mode, the EP does not directly participate in product sales, but product sales volume is still affected by the service level. When consumers' sensitivity coefficient of service level decreases and the service-level investment cost coefficient increases, consumers' desire to purchase products decreases, and the EP faces excessive service cost pressure and is unwilling to provide a high service level. To stabilize product sales volume, the manufacturer is motivated to reduce the product price to stabilize sales. However, the increase in demand brought by the price reduction is offset by the negative effect of reduced service level, and the final product demand still shows a downward trend, leading to a decline in the profits of both the EP and the manufacturer.

Proposition 5. *Under the agency mode, the information-sharing strategies are given as*

(1) the EP is consistently willing to share information (i.e., $E[\Pi_P^{AI^*}] \geq E[\Pi_P^{AN^*}]$*);*

(2) if $t \in (0, t_3]$*, the manufacturer tends to purchase information (i.e.,* $E[\Pi_M^{AI^*}] \geq E[\Pi_M^{AN^*}]$*);*

(3) if $t \in [0, t_3]$*, information-sharing is achieved in the GESC (i.e.,* $E[\Pi_P^{AI^*}] \geq E[\Pi_P^{AN^*}]$ *and* $E[\Pi_M^{AI^*}] \geq E[\Pi_M^{AN^*}]$*), where* $t_3 = \frac{\beta\,\mu(1-\alpha)v}{\xi C}$.

See Appendix B for a proof of Proposition 5. Proposition 5 indicates that under the agency mode, the EP is always willing to share information with the manufacturer regardless of changes in information accuracy. This is because the EP does not directly participate in product sales and will not generate the double marginalization effect. The EP's only source of profit is the fixed proportion of commission. When information is not shared with the manufacturer, the EP cannot obtain additional profits from information-sharing. However, when information-sharing is achieved, regardless of the information accuracy, the EP can always obtain additional profits from information-sharing, so the EP is willing to share information. From the perspective of the manufacturer, when the information accuracy t is at a low level $[0, t_3]$, the benefits of purchasing information are greater than the required cost, and the manufacturer is profitable. When the information accuracy t is higher than the threshold t_3, the cost of the manufacturer purchasing information is high, exceeding the value of the information itself, so the manufacturer chooses not to purchase information.

Denoting $\Phi_2 = t_3 - 0 = t_3$ to represent the range of information-sharing under the agency mode, then we derive the following corollary:

Corollary 2. *The range of information-sharing under the agency mode satisfies* $\frac{\partial \Phi_2}{\partial \varphi} > 0$ *and* $\frac{\partial \Phi_2}{\partial \psi} > 0$.

See Appendix B for a proof of Corollary 2. Corollary 2 shows how the range of information-sharing under the agency mode changes with the green cost performance factor and service cost performance factor. Higher green cost performance factor and higher service cost performance factor will expand the range of information accuracy for achieving information-sharing. For better analysis, we conduct numerical simulation with $\alpha = 0.25$, and the results are shown in the following Figures 5 and 6.

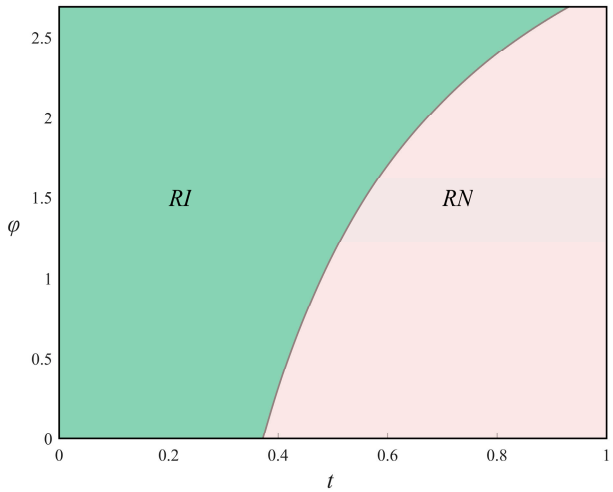


Figure 5. Impact of green cost performance on information-sharing strategy under the agency mode.

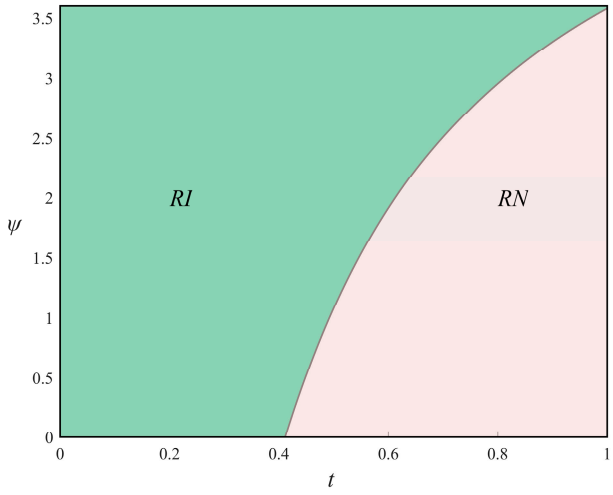


Figure 6. Impact of service cost performance on information-sharing strategy under the agency mode.

As shown in Figures 5 and 6, the range of information accuracy for achieving information-sharing under the agency mode expands with the increase in the green cost performance factor and service cost performance factor. The reasons are roughly the same as those described in Corollary 1. Then, under the same green cost performance factor and service cost performance factor, comparing with Corollary 1, we find that the range of information-sharing achieved under the agency mode is larger. By comparing Figures 5 and 6, under the same range of information-sharing, the green cost performance factor is smaller than the service cost performance factor. This is because, under the agency mode, the manufacturer determines the product's green degree and directly sells products to consumers, which is conducive to improving the manufacturer's decision-making efficiency and earning more profits, so the manufacturer is more able to purchase information.

Proposition 6. *Under the agency mode, the product's green degree and environmental improvement level satisfy the following relationships:* $E[e^{AN^*}] = E[e^{AI^*}]$ *and* $E[EI^{AN^*}] < E[EI^{AI^*}]$.

See Appendix B for a proof of Proposition 6. Similar to the scenario in the reselling mode, Proposition 6 indicates that, under the agency mode, information-sharing cannot improve the product's green degree but is conducive to increasing the environmental improvement level. The reason is the same as Proposition 3: information-sharing helps better coordinate the production and demand of both parties, promote continuous environmental improvement, and enhance environmental sustainability.

5. Sales Mode Comparison and Selection

This section focuses on discussing the differences in operational decisions, equilibrium profits, and environmental improvement levels between the reselling and agency modes. The conditions for manufacturers to select the optimal sales mode from the standpoints of supply chain performance and environmental protection are explored.

Proposition 7. *The optimal service levels and green degrees under different sales modes satisfy*

(1) *if* $0 < \varphi \le 4b$, *then* $s^{Rj^*} \ge s^{Aj^*}$; *if* $4b < \varphi < \frac{2b}{\alpha} - \frac{1-\alpha}{2\alpha\beta}$, *then* $s^{Rj^*} < s^{Aj^*}$;

(2) *if* $0 < \psi \le 2b$, *then* $e^{Rj^*} \le e^{Aj^*}$; *if* $2b < \psi < 4b - \frac{\varphi}{2}$, *then* $e^{Rj^*} > e^{Aj^*}$, $j \in \{N, I\}$.

See Appendix B for a proof of Proposition 7. From Proposition 7(1), we can find that when the green cost performance factor is not very large (i.e., $0 < \varphi \le 4b$), the optimal service level under the reselling mode is higher than that under the agency mode. This

indicates that under the reselling mode, since the EP sells products to consumers and has the right to prioritize determining product marginal returns, it needs to match a higher service level to respond to demand. Under the agency mode, the EP only receives a fixed proportion of commission, so the service pressure is relatively small, and it can maintain the status quo. For example, JD provides next-day delivery, on-site return and exchange, and free replacement services for its self-operated products [56].

Proposition 7(2) reveals that when the service cost performance factor is small (i.e., $0 < \psi \leq 2b$), the product's green degree under the reselling mode is lower than that under the agency mode. This is because a small service cost performance factor makes the EP unwilling to maintain a high service level. Since the manufacturer directly transacts with consumers under the agency mode, it is more vulnerable to the impact of reduced sales volume. To ensure sales volume, the manufacturer will maintain a higher product green degree than under the reselling mode.

Proposition 8. *The manufacturer's expected profits under different sales modes satisfy*

(1) *if* $0 < \psi \leq 2b$, *then* $E[\pi_M^{Rj^*}] < E[\pi_M^{Aj^*}]$;

(2) *if* $2b < \psi < 4b - \frac{\varphi}{2}$, *then* $E[\pi_M^{Rj^*}] \geq E[\pi_M^{Aj^*}]$, $j \in \{N, I\}$.

See Appendix B for a proof of Proposition 8. When the service cost performance is at a high level (i.e., $2b < \psi < 4b - \frac{\varphi}{2}$), the product pricing by the manufacturer under the reselling mode is higher, and the manufacturer's expected profit is also higher than that under the agency mode regardless of fluctuations in the commission rate charged by the EP. At this time, in a sound system environment, both the manufacturer and the EP can earn more profits by setting high prices. On the contrary, when the service cost performance is low, the opposite conclusion is drawn. Due to the EP's low service cost performance, it is unwilling to maintain a higher service level and cannot effectively attract demand. To obtain higher returns, the manufacturer will choose to set a relatively low product sales price. Market demand is significantly positively affected by the low price, and the manufacturer gains more benefits under the agency mode. For example, some electronic manufacturers choose JD self-operated mode, which has a high service level [57]. We also find that the upper limit of $2b < \psi < 4b - \frac{\varphi}{2}$ is affected by the green cost performance factor. When the green cost performance factor is too large, the manufacturer will decide to adopt the agency mode, independent of other influencing factors. Owing to the large green cost performance factor, enhancing the product's green degree can yield substantial benefits for the manufacturer. Compared with the reselling mode, manufacturers can more conveniently control product pricing directly and thus obtain higher profits under the agency mode.

Based on the above parameter settings, we take $t = 0.1$ and $t = 0.7$ to describe the impacts of sales mode on the EP's profit, which are shown in the following Figure 7.

Figure 7a shows that when information accuracy and the service cost performance factor are small, the EP prefers the agency mode, regardless of whether information is shared. Due to the small information accuracy and service cost performance factor, the EP is unwilling to share information and improve service levels and is more willing to obtain profits by collecting fixed commissions. As shown in Figure 7b, when information accuracy is high, the EP can obtain higher information fees and has the right to prioritize determining product marginal returns to gain more marginal benefits.

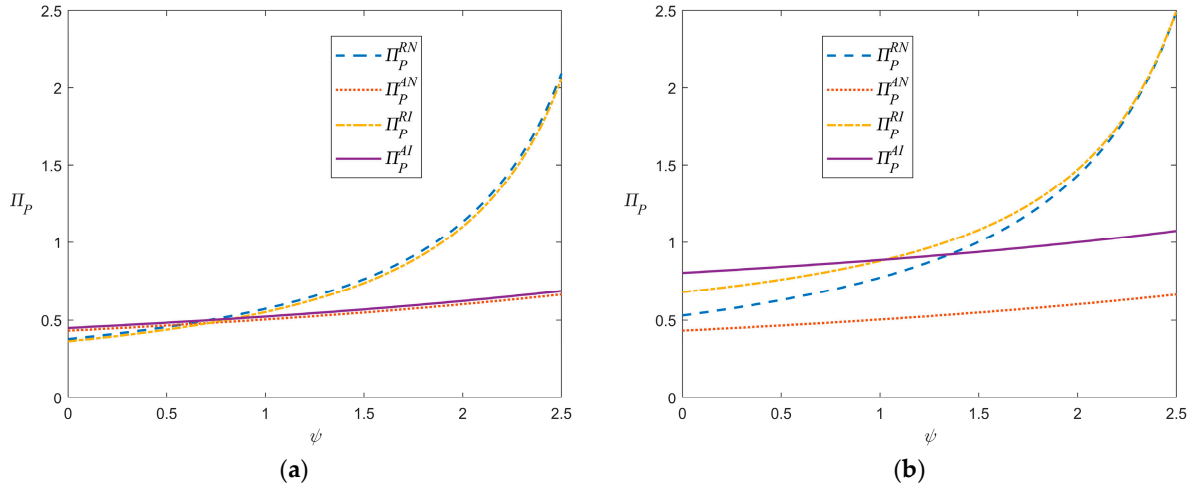


Figure 7. EP's profits under different sales modes. (**a**) $t = 0.1$. (**b**) $t = 0.7$.

Combined with Proposition 8, when the EP's service cost performance is high, both the manufacturer and the EP tend to choose the reselling mode. At this time, the EP can effectively attract consumers, and both parties can profit from the huge market demand, achieving a win–win situation with a more stable cooperation mode. Therefore, manufacturers choosing EPs with high service cost performance factors can not only maximize their own returns but also achieve a win–win cooperation with the EP.

Since information accuracy t does not affect the threshold of ψ, under the above parameter settings, we only take $t = 0.5$ to describe the impact of ψ on the environmental improvement level, which is described in the following Figure 8.

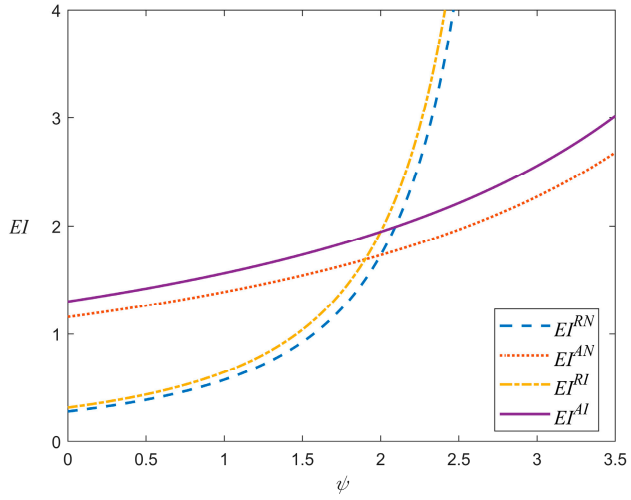


Figure 8. Impact of ψ on the environmental improvement level ($t = 0.5$).

Figure 8 illustrates that when the service cost performance factor is small, the environmental improvement level under the agency mode is higher. Combined with Proposition 7, since the green degree under the reselling mode is low at this time, the product sales volume decreases, and the environmental improvement level is lower than that under the agency mode. Conversely, when the service cost performance factor is high, the environmental improvement level under the reselling mode becomes higher. By observing Figure 8, we also observe that, irrespective of the sales mode adopted, the environmental improvement level without information-sharing is lower than that with information-sharing. In short, information-sharing is conducive to environmental improvement, which further validates Propositions 3 and 6.

6. Extension

In the baseline model, we assume that the EP can collect information at no additional cost. In practice, however, information collection typically requires the EP to devote resources to data cleaning, data analytics, and data security management. Therefore, in this section, we extend the baseline model by incorporating the cost of information collection and examine how such a cost affects the EP's information-sharing decision. Following Huang et al. [41], we assume that the EP incurs a fixed information collection cost F.

Specifically, the platform first determines whether to collect information. When the EP chooses to share information, it must collect the relevant information in advance and incur the fixed information collection cost F. In contrast, when the EP chooses not to share information, it does not collect information and hence incurs no such cost. Accordingly, when information-sharing is implemented, the EP's profits under the reselling and agency modes are, respectively, $\Pi_P^{RI} = (p^{RI} - w^{RI})E[q^{RI}|f] - \mu^{RI}(s^{RI})^2 - F$ and $\Pi_P^{AI} = \alpha p^{AI}E[q^{AI}|f] - \mu^{AI}(s^{AI})^2 - F$; all other model settings remain the same as those in the baseline model.

For a given information-sharing strategy, we compare the EP's profits with and without information-sharing under the reselling and agency modes to characterize the conditions under which the EP is willing to share information. Specifically, under the reselling mode, the EP shares information when $t \in [t_1^F, t_2]$, whereas under the agency mode, the information-sharing region is $t \in [t_3^F, t_3]$, where $t_1^F = \frac{\sqrt{v^2\mu^2(\frac{\beta^2(4b\mu-r^2)}{B^2} - \frac{1}{4b\mu-r^2})^2 + 4\xi F} - v\mu(\frac{\beta^2(4b\mu-r^2)}{B^2} - \frac{1}{4b\mu-r^2})}{2\xi}$, and $t_3^F = \frac{\sqrt{(\frac{\alpha v\mu\beta^2(4b\mu-3\alpha r^2)}{C^2})^2 + 4\xi F} - \frac{\alpha v\mu\beta^2(4b\mu-3\alpha r^2)}{C^2}}{2\xi}$.

Compared with the baseline model, introducing an information collection cost narrows the parameter regions in which the EP is willing to share information. The intuition is that the fixed collection cost reduces the platform's net benefit from information-sharing. Consequently, the EP chooses to share information only when the incremental benefit generated by information-sharing is sufficiently large to compensate for the additional collection cost. Thus, the information collection cost raises the threshold for information-sharing and weakens the EP's incentive to share information.

7. Conclusions

In the digital economy era, information is a core enterprise resource. Using big data and cloud computing, EPs can directly reach consumer terminals and mine high-value demand information from massive transaction data. With GESC as the research context, this study explores manufacturers' optimal sales decisions and demand information-sharing strategies under the reselling mode and agency mode from the dual perspectives of manufacturers and EPs. This study incorporates product green degree and EP service level as decision variables, analyzes the impacts of the green cost performance factor and service cost performance factor on information-sharing decisions, compares the effects of different sales modes on the strategic choices of both supply and demand sides, and finally verifies the impacts of different strategy combinations on the environmental performance of the supply chain. On this basis, core research conclusions and management implications are drawn.

7.1. Main Research Findings

Under the two sales models studied in this paper, market operation decisions are affected by consumers' sensitivity coefficient of green products, green degree investment cost coefficient, consumers' sensitivity coefficient of service level, and service-level investment cost coefficient. These decisions rise with the growth of consumers' sensitivity coefficient

to green products and service level and decline with the increase in the cost coefficients of green degree investment and service-level investment.

In the reselling mode, due to the combined impact of the double marginalization effect and information accuracy, the manufacturer chooses not to purchase information under high information accuracy conditions. On the contrary, the EP will not share information. This is consistent with the conclusion of Li et al. [10]. Under the agency mode, the double marginalization effect does not exist, so the EP will choose to share information regardless of information accuracy, while the manufacturer will not purchase information with high accuracy. It is also concluded in this study that the feasible region of information-sharing is jointly affected by a number of different factors. Under both sales modes, the feasible interval of information-sharing widens with the increase in the green cost performance factor. Under the reselling mode, when the accuracy of information is relatively low, even if the service cost performance factor is improved, information-sharing will not be achieved. Under the agency mode, for the same range of information-sharing, the green cost performance factor is smaller than the service cost performance factor.

When the service cost performance is at a high level, the product pricing under the reselling mode is higher, and its expected profit is also higher than that under the agency mode, regardless of fluctuations in the commission rate. At this time, both the manufacturer and the EP can obtain more profits by setting high prices in a sound system environment. When the service cost performance is low, the opposite conclusion is drawn. For the EP perspective, when information accuracy is high, it can obtain higher information fees and has the right to prioritize determining product marginal returns to gain more marginal benefits. When the EP's service cost performance is high, both the manufacturer and the EP tend to choose the reselling mode to achieve a win–win cooperation.

Different combinations of sales modes and information-sharing states affect the environmental improvement level. Across all sales modes considered, the degree of environmental improvement is noticeably greater under information-sharing than in the scenario with no information exchange. When the service cost performance factor is small, the environmental improvement level under the agency mode is higher. Conversely, when the service cost performance factor is high, the environmental improvement level under the reselling mode is higher. Furthermore, the extension analysis shows that introducing information collection costs raises the threshold for information-sharing and narrows the feasible sharing region, thereby weakening the EP's incentive to share information.

7.2. Management Implications

Manufacturers should ensure their choice of sales mode accurately matches the service cost performance level of their cooperative EPs, prioritizing cooperation with EPs with high service cost performance factors under the reselling mode to expand market share through the EPs' high service levels. If cooperative EPs have weak service capabilities, they should opt for the agency mode to stabilize returns by independently controlling pricing strategies and strengthening green investments. For information purchase decisions, they need to dynamically evaluate the balance between information accuracy and acquisition costs, strictly deciding whether to purchase information within the feasible information accuracy range based on the accounting results of their own benefits and costs, and avoiding acquisition costs exceeding benefits due to excessively high information accuracy. Meanwhile, GESC members should attach importance to improving green cost performance, reducing green investment costs through technological innovation or strengthening the market communication of product green attributes.

EPs need to optimize their operational strategies based on their own information, aligning with manufacturers' dominant sales mode choices. If they possess massive and

accurate consumer data with high information accuracy, when manufacturers choose the reselling mode, they can maximize returns through information-sharing fees and the price difference between procurement and sales. If information accuracy is low, when manufacturers adopt the agency mode, they can rely on stable commission income to reduce operational risks. Service investment needs to be deeply coordinated with the mode selected by manufacturers: when manufacturers choose the reselling mode, EPs should increase service investment, strengthening service levels by improving logistics timeliness and optimizing after-sales support to attract continuous cooperation from manufacturers and help products enhance premium space; when manufacturers adopt the agency mode, EPs can optimize the service cost structure to meet consumers' basic service needs under reasonable investment control.

For the GESCs as a whole, all members should establish a win–win information-sharing system, clarifying the reasonable sharing mechanism of information fees, green investments, and service costs. GESC members can expand the feasible range of information-sharing by jointly improving green cost performance and service cost performance. Meanwhile, GESC members need to fully recognize the environmental value of information-sharing. Even if there are short-term information acquisition costs, in the long run, the increased environmental improvement level brought by information-sharing will promote the sustainable development of GESCs.

7.3. Research Limitations and Future Directions

This study is carried out based on the GESC structure of a single manufacturer and a single EP. In the future, the complexity of GESCs can be expanded by breaking the single-subject assumption, introducing competitive scenarios with multiple manufacturers or multiple EPs, and analyzing differentiated information disclosure and sales mode selection. Actual variables such as government policies (e.g., carbon taxes, green subsidies), consumer heterogeneity, and information security costs can be incorporated to quantify their impacts on sales decisions and environmental improvement. Additionally, combined with new models such as blockchain technology and joint green R&D, future research can explore how technology changes the logic of information-sharing and the benefit distribution and decision coordination under new forms of cooperation.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Calculation Processes and Results

Before calculating the profits and optimal solutions of the EP and the manufacturer, it is necessary to clarify how the member holding information in the GESC should use information to determine the market size. Specifically, if the manufacturer does not hold

relevant information, its estimated market size is $E[a] = a_0$; if the manufacturer holds relevant information, its estimated market size is $E[a|f] = a_0(1-t) + tf = A$. Given that $E[E[a]] = a_0$, $E[E[a|f]] = a_0$ and $(E[a\,|\,f])^2 = A^2 = {a_0}^2 + tv$, the profits of the manufacturer and the EP under different information-sharing states in the two sales modes are as follows:

Proof of the Model RN

Using the backward induction method, we first calculate the Hessian matrix H_1^{RN} of π_P^{RN} with respect to p^{RN} and s^{RN}, which is expressed as $H_1^{RN} = \begin{bmatrix} \frac{\partial^2 \pi_P^{RN}}{\partial p^{RN2}} & \frac{\partial^2 \pi_P^{RN}}{\partial p^{RN} \partial s^{RN}} \\ \frac{\partial^2 \pi_P^{RN}}{\partial s^{RN} \partial p^{RN}} & \frac{\partial^2 \pi_P^{RN}}{\partial s^{RN2}} \end{bmatrix}$.

From the assumptions $b, \mu, r > 0$, we have $\frac{\partial^2 \pi_P^{RN}}{\partial p^2} = -2b < 0$ and $\begin{bmatrix} \frac{\partial^2 \pi_P^{RN}}{\partial p^{RN2}} & \frac{\partial^2 \pi_P^{RN}}{\partial p^{RN} \partial s^{RN}} \\ \frac{\partial^2 \pi_P^{RN}}{\partial s^{RN} \partial p^{RN}} & \frac{\partial^2 \pi_P^{RN}}{\partial s^{RN2}} \end{bmatrix}$ $= 4b\mu - r^2$. To ensure the availability of equilibrium solutions in this model, we only consider the case when $\frac{r^2}{\mu} < 4b$. Under this case, H_1^{RN} is a negative definite matrix, from $\frac{\partial \pi_P^{RN}}{\partial p^{RN}} = 0$ and $\frac{\partial \pi_P^{RN}}{\partial s^{RN}} = 0$, we obtain $p^{RN} = \frac{2A\mu + 2ek\mu + 2b\mu w - wr^2}{4b\mu - r^2}$ and $s^{RN} = \frac{r(A+ek-bw)}{4b\mu - r^2}$. Since the manufacturer does not obtain information, we have $p^{RN} = \frac{2a_0\mu + 2ek\mu + 2b\mu w - wr^2}{4b\mu - r^2}$ and $s^{RN} = \frac{r(a_0+ek-bw)}{4b\mu - r^2}$.

Substituting p^{RN} and s^{RN} into π_M^{RN}, and then we calculate the Hessian matrix H_2^{RN} of π_M^{RN} with respect to w^{RN} and e^{RN}, which is given as $H_2^{RN} = \begin{bmatrix} \frac{\partial^2 \pi_M^{RN}}{\partial w^{RN2}} & \frac{\partial^2 \pi_M^{RN}}{\partial w^{RN} \partial e^{RN}} \\ \frac{\partial^2 \pi_M^{RN}}{\partial e^{RN} \partial w^{RN}} & \frac{\partial^2 \pi_M^{RN}}{\partial e^{RN2}} \end{bmatrix}$.

From the above assumption $\frac{r^2}{\mu} < 4b$, we have $\frac{\partial^2 \pi_M^{RN}}{\partial w^2} = -\frac{4b^2\mu}{4b\mu - r^2} < 0$ and $\begin{vmatrix} \frac{\partial^2 \pi_M^{RN}}{\partial w^2} & \frac{\partial^2 \pi_M^{RN}}{\partial w \partial e} \\ \frac{\partial^2 \pi_M^{RN}}{\partial e \partial w} & \frac{\partial^2 \pi_M^{RN}}{\partial e^2} \end{vmatrix} = \frac{4b^2\mu\,(8b\beta\mu - \mu k^2 - 2\beta r^2)}{(4b\mu - r^2)^2} > 0$. To ensure the availability of equilibrium solutions in this model, we only consider the case when $\frac{r^2}{\mu} < 4b - \frac{k^2}{2\beta}$. Under this case, H_2^{RN} is a negative definite matrix. From $\frac{\partial \pi_M^{RN}}{\partial w^{RN}} = 0$ and $\frac{\partial \pi_M^{RN}}{\partial e^{RN}} = 0$, we have $w^{RN^*} = \frac{a_0\beta\,(4b\mu - r^2)}{b\,(8b\beta\mu - \mu k^2 - 2\beta r^2)}$ and $e^{RN^*} = \frac{r(A+ek-bw)}{4b\mu - r^2}$. Substituting w^{RN^*} and e^{RN^*} into p^{RN} and s^{RN}, we can obtain the optimal results of all decision variables. In this model, we assume that $\frac{r^2}{\mu} < 4b - \frac{k^2}{2\beta}$, which holds in the study.

The solution process for the other three models RI, AN, and AI are similar to that for the model RN, so the detailed proof processes are omitted. □

Appendix B. Proofs of Propositions and Corollaries

Proof of Proposition 1. From the above assumption $\frac{r^2}{\mu} < 4b - \frac{k^2}{2\beta}$, we have $B = 8b\beta\mu - \mu k^2 - 2\beta r^2 > 0$ and $4b\mu - r^2 > 0$ are satisfied.

Deriving the first-order partial derivatives of all equilibrium results with regard to parameter k, we have $\frac{\partial w^{RN^*}}{\partial k} = \frac{2a_0\beta k\mu\,\left(4b\mu - r^2\right)}{b\,B^2} > 0$, $\frac{\partial s^{RN^*}}{\partial k} = \frac{2a_0k^2\mu^2}{B^2} + \frac{a_0\mu}{B} > 0$, $\frac{\partial p^{RN^*}}{\partial k} = \frac{2a_0\beta k\mu\,\left(6b\mu - r^2\right)}{b\,B^2} > 0$, $\frac{\partial s^{RN^*}}{\partial k} = \frac{2a_0\beta k\mu r}{B^2} > 0$, $\frac{\partial E[\pi_M^{RN^*}]}{\partial k} = \frac{2{a_0}^2\beta k\mu^2}{B^2} > 0$, $\frac{\partial E[\pi_P^{RN^*}]}{\partial k} = \frac{4{a_0}^2\beta^2k\mu^2\,\left(4b\mu - r^2\right)}{B^3} > 0$, $\frac{\partial w^{RI^*}}{\partial k} = \frac{2A\beta k\mu\,\left(4b\mu - r^2\right)}{b\,B^2} > 0$, $\frac{\partial s^{RI^*}}{\partial k} = \frac{2Ak^2\mu^2}{B^2} + \frac{A\mu}{B} > 0$, $\frac{\partial p^{RI^*}}{\partial k} = \frac{2A\beta k\mu\,\left(6b\mu - r^2\right)}{b\,B^2} > 0$, $\frac{\partial s^{RI^*}}{\partial k} = \frac{2A\beta k\mu r}{B^2} > 0$, $\frac{\partial E[\pi_M^{RI^*}]}{\partial k} = \frac{2{a_0}^2\beta k\mu^2}{B^2} + \frac{2tv\beta k\mu^2}{B^2} > 0$, $\frac{\partial E[\pi_P^{RI^*}]}{\partial k} = \frac{4{a_0}^2\beta^2k\mu^2\,\left(4b\mu - r^2\right)}{B^3} + \frac{4tv\beta^2k\mu^2\,\left(4b\mu - r^2\right)}{B^3} > 0$.

Similarly, by finding the first-order derivatives of each equilibrium result with respect to β, r and μ, we obtain Proposition 1. □

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Proof of Proposition 2. Under the reselling mode, comparing the profits of the manufacturer and the EP between the scenario with and without information-sharing, we have

(1) $E[\pi_M^{RI^*}] - E[\pi_M^{RN^*}] = \frac{tv\beta\mu}{4b\mu - r^2} - \xi t^2$, if $t \le \frac{\beta\mu v}{(8b\beta\mu - \mu k^2 - 2\beta r^2)\xi}$, then $E[\pi_M^{RI^*}] \ge E[\pi_M^{RN^*}]$, otherwise, $E[\pi_M^{RI^*}] < E[\pi_M^{RN^*}]$.
Solving the inequality for t (information accuracy), the range of t for the manufacturer to be willing to purchase information is derived as $\left(0, \frac{\beta\mu v}{(8b\beta\mu - \mu k^2 - 2\beta r^2)\xi}\right]$.

(2) $E[\pi_P^{RI}] - E[\pi_P^{RN}] = \frac{\beta^2 tv\mu(4b\mu - r^2)}{(8b\beta\mu - \mu k^2 - 2\beta r^2)^2} + \xi t^2 - \frac{tv\mu}{4b\mu - r^2} \ge 0$, if
Solving the inequality for t, the range of t for the EP to be willing to share information is derived as $\left[\frac{\mu v}{\xi\ (4b\mu - r^2)} - \frac{\beta^2\mu v(4b\mu - r^2)}{\xi(8b\beta\mu - \mu k^2 - 2\beta r^2)^2}, 1\right)$.

To realize information-sharing in the green supply chain, both the manufacturer and the EP must be willing to participate. Thus, the range of t for information-sharing is the intersection of the two ranges above: $\left[\frac{\mu v}{\xi(4b\mu - r^2)} - \frac{\beta^2\mu v(4b\mu - r^2)}{\xi(8b\beta\mu - \mu k^2 - 2\beta r^2)^2}, \frac{\beta\mu v}{(8b\beta\mu - \mu k^2 - 2\beta r^2)\xi}\right]$. □

Proof of Corollary 1. By calculating the partial derivative of $t_2 - t_1$ with respect to φ, $\frac{\partial(t_2 - t_1)}{\partial\varphi} = \frac{v\mu^2(16b\mu - \mu\varphi - 4r^2)}{\xi(8b\mu - \mu\varphi - 2r^2)^3}$. Since $8b\mu - \mu\varphi - 2r^2 > 0$, we have $\frac{\partial(t_2 - t_1)}{\partial\varphi} > 0$.

By calculating the partial derivative of $t_2 - t_1$ with respect to φ, $\frac{\partial(t_2 - t_1)}{\partial\psi} = \frac{v}{\xi}\frac{[(8b\mu - \mu\varphi - 2r^2) + \beta(4b - \psi)]^2(8b\mu + k^2 - 2\beta\psi)}{(8b\mu - \mu\varphi - 2r^2)^3(4b - \psi)^2}$. Since $8b\beta - k^2 - 2\beta\psi > 0$, we have $\frac{\partial(t_2 - t_1)}{\partial\psi} > 0$. □

Proof of Proposition 3. Calculate the expected green degree and expected environmental improvement amount under different information-sharing states in the reselling mode:

(1) Expected green degree: $E[e^{RN}] = \frac{a_0 k\mu}{8b\beta\mu - \mu k^2 - 2\beta r^2}$, $E[e^{RI}] = \frac{a_0 k\mu}{8b\beta\mu - \mu k^2 - 2\beta r^2}$.
Thus, $E[e^{RI}] = E[e^{RN}]$.

(2) Expected environmental improvement amount:

$$E[EI^{RN}] = E[e^{RN}q^{RN}] = \frac{2{a_0}^2 b\beta k\mu^2}{(8b\beta\mu - \mu k^2 - 2\beta r^2)^2},$$

$$E[EI^{RI}] = E[e^{RI}q^{RI}] = \frac{2{a_0}^2 b\beta k\mu^2}{(8b\beta\mu - \mu k^2 - 2\beta r^2)^2} + \frac{2tvb\beta k\mu^2}{(8b\beta\mu - \mu k^2 - 2\beta r^2)^2}.$$

Thus, $E[EI^{RI}] - E[EI^{RN}] = \frac{2tvb\beta k\mu^2}{(8b\beta\mu - \mu k^2 - 2\beta r^2)^2} > 0$, and Proposition 3 is proved. □

Proof of Proposition 4. Since the proof of Proposition 4 follows a similar logic to Proposition 1, its detailed derivation is omitted for brevity. □

Proof of Proposition 5. Compare the profits of the manufacturer and the EP under different information-sharing states (information-sharing vs. no sharing) in the agency mode:

(1) For the manufacturer: The profit difference between information-sharing (model AI) and information non-sharing (model AN) is $E[\pi_M^{AI}] - E[\pi_M^{AN}] = \frac{tv\beta\ \mu\ (1-\alpha)}{4b\beta\mu + \alpha k^2\mu - k^2\mu - 2\alpha\beta r^2} - \xi t^2 \ge 0$.
Solving the inequality for t, the range of t for the manufacturer to be willing to purchase information is derived as $\left(0, \frac{\beta\ \mu(\alpha-1)v}{(k^2\ \mu - 4\ b\ \beta\ \mu + 2\ \alpha\ \beta\ r^2 - \alpha\ k^2\ \mu)\xi}\right]$.

(2) For the EP: The profit difference between information-sharing (model AI) and information non-sharing (model AN) is $E[\pi_P^{AI}] - E[\pi_P^{AN}] = \frac{tv\alpha\beta^2\mu(4b\mu - 3\alpha r^2)}{(4b\beta\mu + \alpha k^2\mu - k^2\mu - 2\alpha\beta r^2)^2} + \xi t^2 \ge 0$.

Solving the inequality for t, the range of t for the EP to be willing to purchase information is derived as $(0, 1)$.

To realize information-sharing, the range of t is the intersection of the two ranges, i.e., $\left(0, \frac{\beta\ \mu(\alpha-1)v}{(k^2\ \mu-4\ b\ \beta\ \mu+2\ \alpha\ \beta\ r^2-\alpha\ k^2\ \mu)\xi}\right]$. □

Proof of Corollary 2. By calculating the partial derivative of $t_3 - 0$ with respect to φ, $\frac{\partial t_3-0}{\partial \varphi} = \frac{v\mu^2(1-\alpha)^2}{\xi(4b\mu+\alpha\varphi\mu-\varphi\mu-2\alpha r^2)^2}$. Since $4b\mu + \alpha\varphi\mu - \varphi\mu - 2\alpha r^2 > 0$, we have $\frac{\partial(t_2-t_1)}{\partial \varphi} > 0$.

By calculating the partial derivative of $t_3 - 0$ with respect to ψ, $\frac{\partial(\partial t_3-0)}{\partial \psi}$ $= \frac{2\alpha\beta v^2(1-\alpha)}{\xi(4b\beta+\alpha k^2-k^2-2\alpha\beta\psi)^2}$. Since $4b\beta + \alpha k^2 - k^2 - 2\alpha\beta\psi > 0$, we have $\frac{\partial(t_2-t_1)}{\partial \psi} > 0$. □

Proof of Proposition 6. Calculate the expected green degree and expected environmental improvement amount under different information-sharing states in the agency mode:

(1) Expected green degree: $E[e^{AN}] = \frac{a_0 k\mu\ (1-\alpha)}{4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2}$, $E[e^{AI}] = \frac{a_0 k\mu\ (1-\alpha)}{4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2}$. Thus, $E[e^{AN}] = E[e^{AI}]$.

(2) Expected environmental improvement amount: $E[EI^{AN}] = E[e^{AN}q^{AN}]$ $= \frac{{a_0}^2\beta k\mu\left(4b\mu-3\alpha r^2+\alpha r^2\right)\ (1-\alpha)}{2(4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2)^2}$, $E[EI^{AI}] = E[e^{AI}q^{AI}] = \frac{{a_0}^2\beta k\mu\left(4b\mu-3\alpha r^2+\alpha r^2\right)\ (1-\alpha)}{2(4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2)^2} + \frac{tv\beta k\mu\left(4b\mu-3\alpha r^2+\alpha r^2\right)\ (1-\alpha)}{2(4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2)^2}$.

The difference between the two is $E[EI^{AI}] - E[EI^{AN}] = \frac{2tvb\beta k\mu^2}{(4b\beta\mu+\alpha k^2\mu-k^2\mu-2\alpha\beta r^2)^2} > 0$. Thus, $E[EI^{AI}] > E[EI^{AN}]$. □

Proof of Proposition 7. Compare the optimal green degree and optimal service level between the reselling mode and the agency mode:

(1) Difference in optimal green degree: $E[e^{Rj^*}] - E[e^{Aj^*}] = \frac{a_0 k}{8b\beta-k^2+2\beta\psi} - \frac{a_0 k\ (1-\alpha)}{k^2-4\ b\beta+2\alpha\beta\psi-\alpha k^2}$. Solve for $2b < \psi < 4b - \frac{\varphi}{2}$ based on $E[e^{Rj^*}] - E[e^{Aj^*}] > 0$.

(2) Difference in optimal service level: $E[s^{Rj^*}] - E[s^{Aj^*}] = \frac{a_0 r}{8b\mu-\mu\varphi-2r^2} - \frac{a_0\alpha r}{\varphi\mu-4\ b\mu+2\alpha r^2-\alpha\varphi\mu}$. Solve for $\varphi < 4b$ based on $E[s^{Rj^*}] - E[s^{Aj^*}] > 0$. □

Proof of Proposition 8. Compare the manufacturer's expected profits between the reselling mode and the agency mode under different information-sharing states:

(1) When information is not shared (RN vs. AN models): $E[\pi_M^{RN}] - E[\pi_M^{AN}] = \frac{{a_0}^2\beta}{8b\beta-k^2-2\beta\psi} - \frac{{a_0}^2\ \beta\ (1-\alpha)}{4b\beta+\alpha k^2-k^2-2\alpha\beta\psi}$. Solve for $0 < \psi \le 2b$ based on $E[\pi_M^{RN}] \le E[\pi_M^{AN}]$.

(2) When information is shared (RI vs. AI models): $E[\pi_M^{RI}] - E[\pi_M^{AI}] = \frac{{a_0}^2\beta+tv\beta}{8b\beta-k^2-2\beta\psi} - \frac{{a_0}^2\ \beta\ (1-\alpha)+tv\beta\ (1-\alpha)}{4b\beta+\alpha k^2-k^2-2\alpha\beta\psi}$. Solve for $0 < \psi \le 2b$ based on $E[\pi_M^{RI}] \le E[\pi_M^{AI}]$. □

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