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COORDINATION OF SUPPLY CHAIN CONSIDERING CONSUMERS' GREEN PREFERENCE UNDER REDUCED PACKAGING STRATEGY

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Abstract. The rapid development of e-commerce has led to a surge in packaging, which poses a significant threat to the environment, especially overpackaging. Studying how to reduce packaging problems in e-commerce is the need for optimal decision-making in supply chains and optimal allocation of resources, and it is also the focus of this paper. Therefore, supply chain coordination considering reduced packaging strategies under consumers' green preferences and green brand and good image is studied. First, a supply chain model with integrated packaging and secondary packaging is established, which can consider consumers' green preferences. Then three models of decentralized decision-making, centralized decision-making and introduction of contract are constructed. Finally, the correctness of the model is verified by numerical analysis, and the influence of different parameters on the model is studied. We find that revenue sharing and cost sharing contracts enable supply chains to achieve coordination while reducing packaging. With the increase of the proportion of consumers with green preferences, especially when the consumers with green preferences in the market exceed the threshold (e.g. about 0.5 in numerical analysis), the strategy of reducing packaging can help the supply chain increase profits.

1. **Introduction.** The express service industry has played an increasingly important role in the economy and society. However, a large number of packaging has caused unnecessary waste of resources and unavoidable environmental pollution. According to Eurostat, the per capita annual production of packaging waste in the

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EU-28 is 163kg. Germany and Italy top the list of countries with around 200kg of packaging waste per capita per year [31]. 36% of municipal solid waste comes from packaging in Europe [32]. China Post Office said that the actual recycling rate of express packaging is less than 10%, and most of them are directly sent to landfills.

Moreover, the increasing popularity of e-commerce has further promoted the growth of express packaging, which has also further increased environmental pressures and challenges [11, 22]. In particular, the overpackaging of products has become a major source of pollution and global environmental concern [4, 8, 9, 33]. E-commerce express packages use excessive packaging measures to ensure the safety of goods, and e-commerce retailers tend to overuse packaging materials to satisfy customers. The total amount of shipping packaging used in Germany e-commerce in 2018 was about 830,000 tons of paper and 34,000 tons of light packaging [50]. According to statistics, the new incremental part of domestic waste in Guangzhou, China is mainly the waste packaged by e-commerce, accounting for 90% of the increase. Overpackaging not only undermines environmental sustainability but also affects supply chain costs [25]. Packaging imposes high costs in the supply chain, with the packaging industry consuming around 40% of plastics and 50% of paper in Europe [5]. Studying how to reduce express packaging problems in e-commerce is the need for optimal decision-making in supply chains and optimal allocation of resources, and it is also the focus of this paper.

With the increasing environmental awareness, many e-commerce platforms have begun to promote integrated packaging for pollution avoidance and resource savings. Such as Suning launched the "drifting box" plan, using recyclable integrated packaging boxes to replace traditional cartons. In addition, reducing the use of packaging from the source is a more effective measure to solve the packaging problem. Amazon's "non packaged transportation (PFS) plan" advocates the green concept of non express packaging and distribution. Detergent manufacturers have been exploring ways to increase product density and reduce packaging weight to achieve a reduction in logistics packaging for online orders [26]. Multinational companies such as Nestle are committed to the commercialization of 100% bio based recyclable bottles for still water [27]. UNEP [30] reported that more than 60 countries have introduced bans and taxes to curb disposable plastic packaging waste. If the product's packaging can fully consider product safety issues, it can directly use the primary packaging for distribution, and there is no need for secondary packaging in the e-commerce express link. This should be the optimal path to green packaging. This paper studies reduction packaging strategies and the corresponding supply chain optimization decisions.

Consumers are willing to pay a certain premium to buy green products, which shows that green products are more and more popular with the public [6, 16, 43]. Consumers' purchase preference is an important factor affecting the integration of product packaging and e-commerce logistics distribution packaging. Some consumers with environmental awareness will be more willing to buy products without secondary packaging, and ordinary consumers are more inclined to buy products with secondary packaging for product safety reasons or other reasons. There are two types of consumers in the market at the same time. In order to better meet the diverse needs of customers, this paper considers the optimization and coordination of the supply chain when selling products with secondary packaging and integrated green packaging. Further, many studies have shown that enterprises adopting marketing methods to promote green, establish brand image and low-carbon goodwill can effectively influence demand and gain consumer recognition [17, 49]. For example, companies such as Gree and Midea actively put advertisements to promote the high energy efficiency of green products and successfully affect consumers' purchase decisions. In this paper's research, the green brand effect is also taken into account in the decision-making of supply chain cost input, product pricing, and contract coordination.

Promoting integrated green packaging and realizing the reduction of packaging in e-commerce logistics requires close coordination and cooperation between retail e-commerce and manufacturers. The linkage between upstream and downstream of the supply chain and joint efforts are the key to promoting reduced packaging and guiding consumer demand. Manufacturers and retailers need to jointly design, develop and promote the primary packaging that meets the requirements of integrated packaging. By establishing a coordination contract, the supply chain can achieve coordination, which helps to create a green supply chain brand image, improve consumers' recognition of integrated packaging, and provide a reference for the Green Governance of packaging. Under the above background, it raises the question of how to design the contract to coordinate the supply chain's coordination with the reduced packaging. Few literatures focus on supply chain coordination from this perspective.

Therefore, the contributions of this paper to literature are in the following aspects:

(1) This paper studies the influence of consumers' green preferences on the decision-making of reduced packaging and the optimal decision-making of the supply chain.

(2) The contract is introduced to enable retailers and manufacturers to work together to design, invest and promote reduced packaging. Research the interaction between green supply chain green brand and good image and consumers' green preferences to maximize the profits of supply chain members.

(3) In this paper, we investigate the impact of brand image on consumer demand, product pricing, and supply chain coordination. On this basis, the reduction packaging strategy that can realize the optimal supply chain is given.

Based on this, this paper studies supply chain coordination considering reduced packaging strategies under consumers' green preferences. On the other hand, we propose a coordination mechanism. The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 is devoted to model formulation and analysis. Numerical examples and discussions of results are presented in Section 4. Finally, conclusions are offered in Section 5.

2. **Literature review.** The literature related to this study mainly includes the following three streams: green packaging decisions in the supply chain, the influence of consumers' green preferences on supply chain decisions, and green supply chain coordination.

With the rapid growth of e-commerce, a massive amount of packaging waste draws attention of scholars, especially the over-packaging in e-commerce. The research on packaging in supply chain focuses on supply chain cost, product pricing, etc. Meherishi et al. [26] researched the pricing issues for three forms of express packaging, disposable primary packaging, disposable protective packaging, and returnable secondary packaging, in a two-stage supply chain. In terms of supply chain costs, packaging affects supply chain costs such as transportation, inventory carrying, order processing, and lot sizing costs [42]. McDonald [24] and Sohrabpour, Oghazi, and Olsson [36] researched how economical packaging can improve supply chain cost efficiency from an operational and supply chain management perspective. Accorsi, Cascini, Cholette, Manzini, and Mora [1] compared single-use packaging and multi-purpose plastic packaging in the fruit and vegetable supply chain and found lower costs for suppliers and farmers, but higher costs borne by distribution centers and customers. Błażejewski, Walker, Muazu, and Rothman [2] studied the milk supply chain using reusable stainless steel agitators and reusable glass bottles and compared it with the current supply chain using disposable HDPE bottles. The study shows that if the reuse scheme is adopted, the greenhouse gas emissions can be reduced by about 6.5 tons (about 65% reduction) of carbon dioxide equivalent per year. In addition to the study of integrated packaging, sustainable packaging and product mobility decision-making in the food and beverage supply chain, there are few studies on integrated packaging and product mobility decision-making in other products [6, 25]. Meherishi et al. [25] suggested that the interaction of products and packaging systems is not adequately considered in supply chain management.

Consumers are increasingly turning to green preferences, such as biodegradable and compostable packaging, and there is an increasing demand for sustainable packaging of products [3]. Many studies have shown that consumers' green preferences have affected their purchasing behavior. Research shows that changes in consumer preference characteristics are a significant factor in motivating supply chain members to undertake green efforts and implement green operating policies [14, 35, 39, 41]. Z. L. Liu, Anderson, and Cruz [21] showed that firms with superior low-carbon operations would benefit from consumers' green preferences. Y. Wang and Hou [44]findings showed that consumers' green preferences significantly affect the green level of products and the optimal decision-making of supply chain members, and have complex effects on the adjustment speed of the supply chain. Identification of consumers' green preferences helps to gain additional market shares and affects the operations and profit of the supply chain [6, 13, 14]. Peng, Pang, and Cong [34] introduced a consumers' preference coefficient in the price function and researched how it affects emission reduction decisions. Xie et al. [46] used the value co-creation (VCC) theory to establish a research model to study consumer preferences for overpackaging solutions, and they found the relationship among consumer preference, government policy and combined packaging. Mahmoudi and Parviziomran [23] reviewed reusable packaging and deliver insights and potential opportunities for the future. A few articles study the impact of consumers' green preferences on supply chain decisions considering shared express packaging.

Further, the presence of green consumers also has the potential to force supply chains and enterprises to transform to meet their needs and preferences. Consumers' green preferences will also affect the supply chain members' green R D investment. Consumers know little about manufacturing technology, but they still want to adopt environmentally friendly manufacturing processes and environmentally friendly packaging (such as biodegradability and recyclability) [28]. Tong, Mu, Zhao, Mendis, and Sutherland [40] showed that consumer sensitivity to carbon-reduction technologies affects manufacturers' R D spending and retailers' promotion of low-carbon products. Xia, Hao, Qin, Ji, and Yue [45] indicated that consumers' green preferences promote the improvement of corporate incentive mechanisms, and guide supply chain members to invest in emission reduction technology investment, which is beneficial to increasing the profits of supply chain members. It showed that few studies focus on the impact of consumers' behavior on the economic impacts of reusable packaging. They thought future research could focus on coordinating the packages and consumers' demands.

An efficient supply chain system seeks to integrate the activities of each supply chain member. There is a growing awareness of the adverse environmental and social impacts of packaging, which is of interest to various stakeholders in the supply chain. Achieving sustainable packaging in supply chains requires cooperation amongst the players and coordinated internal and external changes in organizations within the supply chain [12]. Ghosh and Shah [13] showed the relationship between cost-sharing contracts and greenness level, price, and profit of the supply chain. Heydari, Govindan, and Aslani [15] studied the coordination problem of the green supply chain and adopted the Stackelberg game method to study the optimal pricing decision and coordination strategy of the green supply chain. Taleizadeh, Alizadeh-Basban, and Sarker [38] used three coordination contracts to reduce the price of green products and improve supply chain profits. Lin, Fan, Tan, and Zhu [19]investigated the complex dynamic pricing decision in the green supply chain, and coordinated the supply chain with a side-payment self-executing contract. Yang and Chen [47] investigated the impact of revenue-sharing and cost-sharing on manufacturers' carbon reduction efforts and the profitability of their supply chains, considering consumer environmental awareness and carbon taxes. Q. Li, Xiao, and Qiu [18]designed a revenue-sharing contract to enhance the green supply chain players' performance. Peng et al. [34] integrate yield uncertainty and consumers' low-carbon preference in supply chain and propose a revenue-sharing with subsidy on emission reduction (RSS) contract to coordinate Supply Chain. Q. Wang et al. [43] studied joint carbon reduction coordination mechanisms and compared the impact of different contracts on the profits of green supply chain members. Considering consumers' low carbon preference, R. Fan, Lin, and Zhu [10] established the Stackelberg and the vertical Nash game models. The results show that consumers' low carbon preference narrows the stable region of the system. Moreover, consumer sensitivity to supply chain greening levels positively impacts supply chain performance [48]. Liu, Li, Anwar, and Zhang [20] found that consumers' low carbon preference can benefit supply chain companies, and carbon emission reduction cost-sharing increases retailers' order quantity and profits, thus there is an incentive for two supply chain members to cooperate.

This research is an extension of coordination for supply chain with reduced packaging. Our work contributes to the literature concerning the influence of consumers' green preferences on the decision-making of reduced packaging, and the coordination mechanism covering the measures of the reduction packaging is investigated. In this paper, the interaction between green brand and good image and consumers' green preferences to maximize the profits of supply chain members.

3. **Model formulation and analysis.**

3.1. **Question description and model formulation.** This paper studies the supply chain decision-making and coordination based on the reduced packaging strategy, influenced by consumers' green preferences and products' green brand and good image. In order to reduce the amount of packaging and avoid excessive packaging, we provide customers with packaging that can be shared between production and retail e-commerce distribution in the e-commerce retail link, i.e., integrated

TABLE 1. Notations for parameters and variables

Parameter	Definition
θ	Proportion of consumers without green preference
d_0	Total market demand
α	Influence coefficient of price on demand
r	Influence coefficient of integrated packaging green efforts on demand
e	Integrated packaging green effort cost
β	Influence coefficient of integrated packaging green efforts on green preferences consumer demand
λ	Integrated packaging green effort coefficient
q_t	Increased demand for secondary packaging products
q_e	Demand for integrated packaging products
f	Packaging handling fee for secondary packaging product
p_t	Price of the second packaging product
p_e	Price of the integrated packaging product
w_t	Wholesale prices for secondary packaging product
w_e	Wholesale prices for integrated packaging product
c_t	Cost of secondary packaging product
c_e	Cost of integrated packaging product
π_R	Retailer profit
π_M	Manufacturer profit
π	Supply chain profit

packaging. Products are delivered in the original packaging at the time of manufacture, and no secondary packaging is required for retail. At the same time, in order to meet the diversified needs of ordinary customers, products with secondary packaging can also be provided when customers provide additional packaging costs f. The design of primary packaging may be less optimal for e-commerce distribution [5], so integrated packaging requires manufacturers to invest in research and development, which is called the manufacturer's integrated packaging green effort $\frac{1}{2}\lambda e^2$, where λ is green effort coefficient, and e is green effort cost. In the existing literature, such cost patterns are usually expressed in the form of a quadratic function such as Q. Wang et al. [43], Nordhaus [29], d'Aspremont and Jacquemin [7].The higher the efforts of integrated packaging, the higher the green degree of packaging.

With the development of the concept of green consumption, the number of consumers with green consumption preferences in the market continues to increase, and the influence of the green brand and good image created by enterprises on market demand is also gradually increasing. So manufacturers strive to improve integrated packaging green efforts to enhance the green brand and good image of the enterprise and supply chain, thereby increasing the market demand for the product. The green brand and good image has some impact on all consumer needs, the extent of which is related to integrated packaging green efforts. It has a indirect impact on the needs of consumers with non-green preferences. Here we assume that its impact is re , where r is the impact coefficient of integrated efforts on demand. For green preferences consumers, it has a direct impact. We assume that its impact is $re + \frac{1}{2}\beta\lambda e^2$ based on Sun et al. [37], Ji et al. [16], where β is influence coefficient of integrated packaging efforts on green preferences consumer demand.

The following notations defined in Table 1 are used in this paper:

The market demand is divided into two parts, the demand for secondary packaging products qt and the demand for integrated packaging products qe. Its expressions are shown in the following Eqs. (1) and (2), respectively.

$$q_t = \theta d_0 - \alpha p_t + re \tag{1}$$

$$q_e = (1-\theta)d_0 - \alpha p_e + re + \frac{1}{2}\beta\lambda e^2 \tag{2}$$

where θ is the proportion of consumers without green preferences, $\theta = (0,1)$. θ decreases gradually with the increase of consumers' preference for green, and finally reaches 0. α is influence coefficient of price on demand. p_t is price of the second packaged product. p_e is price of the integrated packaging product. e is integrated packaging effort cost. r is influence coefficient of integrated packaging efforts on demand. β is influence coefficient of integrated packaging efforts on green preferences consumer demand. From the Comparison of Eqs. (1) and (2), it can be seen that q_e has one more item $\frac{1}{2}\beta\lambda e^2$ than q_t, which is due to the contribution of integrated packaging efforts to the demand.

The retailer's profit π_R and the manufacturer's profit π_M are composed of the profit of the integrated packaging product and the profit of the second packaging product. According to the market demand and price, we can obtain the retailer's profit π_R, the manufacturer's profit π_M, and the supply chain's profit π, respectively, as shown in the following Eqs. (3) (4) (5).

$$\pi_R = q_t(p_t - w_t + f) + q_e(p_e - w_e) \tag{3}$$

$$\pi_M = q_t(w_t - c_t) + q_e(w_e - c_e) - \frac{1}{2}\lambda e^2 \tag{4}$$

$$\pi = \pi_R + \pi_M \tag{5}$$

where $q_t(p_t - w_t + f)$ is the profit of retail e-commerce selling products requiring secondary packaging, and $q_e(p_e - w_e)$ is the profit of retail e-commerce selling integrated packaging products. $q_t(w_t - c_t)$ is the profit obtained by the manufacturer from selling products requiring secondary packaging. $q_e(w_e - c_e)$ is the profit obtained by the manufacturer from selling integrated packaging products, and $\frac{1}{2}\lambda e^2$ is the cost of integrated packaging efforts paid by the manufacturer to reduce packaging.

According to the economic activity, we can get the constraints:

$$\begin{aligned}
&p_t > w_t > c_t \\
&p_e > w_e > c_e \\
&0 < \theta < 1 \\
&0 < \alpha < 1 \\
&r > 0, e > 0, f > 0.
\end{aligned}$$

3.2. **Decentralized decision.** Decentralized decision occurs when manufacturers and retailers make separate decisions. As manufacturers have an absolute position in the market, retailers are following. Therefore, when decentralizing decision, the retailer makes the optimal decision first. Manufacturers then make their own optimal decisions based on the retailer's optimal decision results.

The first is the retailer's sole optimal decision about its own profit. p_t and p_e are the optimal control variables of the retailer's profit, so the first order derivative of retailer's profit Eq. (3) with respect to p_t and p_e, respectively

$$\frac{\partial \pi_R}{\partial p_t} = er + \theta d_0 - \alpha p_t - \alpha\left(f + p_t - w_t\right) = er + \theta d_0 - \alpha\left(f + 2p_t - w_t\right) \tag{6}$$

$$\frac{\partial \pi_R}{\partial p_e} = er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 - \alpha p_e - \alpha\left(p_e - w_e\right) = er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 - \alpha\left(2p_e - w_e\right) \quad (7)$$

In order to optimize the profit of retailers, p_t and p_e need to meet the conditions of the optimal value of the Hessian matrix. The Hessian matrix is as follows $\frac{\partial^2 \pi_R}{\partial p_t^2} = -2\alpha$, $\frac{\partial^2 \pi_R}{\partial p_e^2} = -2\alpha$, $\frac{\partial^2 \pi_R}{\partial p_t \partial p_e} = \frac{\partial^2 \pi_R}{\partial p_e \partial p_t} = 0$.

Because $\begin{bmatrix} \frac{\partial^2 \pi_R}{\partial p_t^2} & \frac{\partial^2 \pi_R}{\partial p_t \partial p_e} \\ \frac{\partial^2 \pi_R}{\partial p_e \partial p_t} & \frac{\partial^2 \pi_R}{\partial p_e^2} \end{bmatrix} = \begin{bmatrix} -2\alpha & 0 \\ 0 & -2\alpha \end{bmatrix}$, the first-order principal subtype is less than 0, the second-order principle subtype is greater than 0, and the matrix is a semi-negative definite matrix, the retailer's profit has a maximum value.

Let $\frac{\partial \pi_R}{\partial p_t^D} = 0$ and $\frac{\partial \pi_R}{\partial p_e^D} = 0$, we can get

$$p_t^D = \frac{-\alpha f + er + \theta d_0 + \alpha w_t}{2\alpha} \quad (8)$$

$$p_e^D = \frac{2er + e^2\beta\lambda + 2(1-\theta)d_0 + 2\alpha w_e}{4\alpha} \quad (9)$$

Bringing Eqs. (8) and (9) into Eq. (3), the optimal value of the retailer's profit is obtained, but w_t and w_e are determined by the manufacturer's optimal decision.

After the retailer makes the optimal decision, the manufacturer starts the optimal decision. First, Eq. (8) and Eq. (9) are brought into Eq. (4). Since w_t and w_e are the control variables of the manufacturer's profit, the first derivative of the manufacturer's profit function with respect to w_t and w_e, respectively, is as follows:

$$\frac{\partial \pi_M}{\partial w_t} = er + \theta d_0 - \frac{1}{2}\alpha(w_t - c_t) + \frac{1}{2}(\alpha f - er - \theta d_0 - \alpha w_t) \quad (10)$$

$$\frac{\partial \pi_M}{\partial w_e} = er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 - \frac{1}{2}\alpha(w_e - c_e) + \frac{1}{4}(-2er - e^2\beta\lambda - 2d_0 + 2\theta d_0 - 2\alpha w_e) \quad (11)$$

To make the manufacturer's profit reach the optimal value, w_t and w_e should satisfy the condition that the optimal value of the Hessian matrix exists. The Hessian matrix is $\frac{\partial^2 \pi_M}{\partial w_t^2} = -\alpha$, $\frac{\partial^2 \pi_M}{\partial w_e^2} = -\alpha$, $\frac{\partial^2 \pi_M}{\partial w_t \partial w_e} = \frac{\partial^2 \pi_M}{\partial w_e \partial w_t} = 0$.

Because $\begin{bmatrix} \frac{\partial^2 \pi_M}{\partial w_t^2} & \frac{\partial^2 \pi_M}{\partial w_t \partial w_e} \\ \frac{\partial^2 \pi_M}{\partial w_e \partial w_t} & \frac{\partial^2 \pi_M}{\partial w_e^2} \end{bmatrix} = \begin{bmatrix} -\alpha & 0 \\ 0 & -\alpha \end{bmatrix}$, the first-order principal subtype is less than 0, the second-order principle subtype is greater than 0, and the matrix is a semi-negative definite matrix, the manufacturer's profit has a maximum value. Solving for $\frac{\partial \pi_M}{\partial w_t^D} = 0$ and $\frac{\partial \pi_M}{\partial w_e^D} = 0$, we get

$$w_t^D = \frac{\alpha f + er + \alpha c_t + \theta d_0}{2\alpha} \quad (12)$$

$$w_e^D = \frac{2er + e^2\beta\lambda + 2(1-\theta)d_0 + 2\alpha c_e}{4\alpha} \quad (13)$$

Then bringing Eq. (12) and Eq. (13) into Eq. (8) and Eq. (9), that is, the optimal profit of the retailer with decentralized decision is obtained, the expression

$$\begin{cases} p_t^D = \frac{3er + 3\theta d_0 + \alpha c_t - \alpha f}{4\alpha} \\ p_e^D = \frac{6er + 3e^2\beta\lambda + 6(1-\theta)d_0 + 2\alpha c_e}{8\alpha} \end{cases} \quad (14)$$

According to the constraints, the range of some parameters is inferred:

$$p_t > w_t > c_t \rightarrow er + \theta d_0 - 3\alpha f - \alpha c_t > 0$$
$$p_e > w_e > c_e \rightarrow 2er + e^2\beta\lambda + 2(1-\theta)d_0 - 2\alpha c_e > 0.$$

When $er + \theta d_0 - 3\alpha f - \alpha c_t > 0$, $p_t^D > w_t^D > c_t$ is established.

When $2er + e^2\beta\lambda + 2(1-\theta)d_0 - 2\alpha c_e > 0$, $p_e^D > w_e^D > c_e$ is established.

Bringing Eqs. (12)-(14) into Eqs. (3)-(5), we obtain the optimal value of profits for manufacturers, retailers, and supply chains, as follows:

$$\pi_R = \frac{1}{64\alpha}\left(\begin{array}{l} e^4\beta^2\lambda^2 + 8\alpha f\theta d_0 + 4\alpha^2\left(f^2 + c_e^2 + c_t^2\right) + 4er\left(2\alpha f + 2er + e^2\beta\lambda + 2d_0\right) \\ +4e^2\beta\lambda d_0\left(1-\theta\right) + 4d_0^2\left(1 - 2\theta + 2\theta^2\right) \\ -4\alpha c_e(2re + e^2\beta\lambda + 2(1-\theta)d_0) - 8\alpha c_t(\alpha f + er + \theta d_0) \end{array}\right) \tag{15}$$

$$\pi_M = \frac{1}{32\alpha}\left(\begin{array}{l} e^4\beta^2\lambda^2 + 8\alpha f\theta d_0 + 4\alpha^2(f^2 + c_e^2 + c_t^2) + 4er(2\alpha f + 2er + e^2\beta\lambda + 2d_0) \\ -16\alpha e^2\lambda + 4e^2\beta\lambda d_0(1-\theta) + 4d_0^2(1 - 2\theta + 2\theta^2) \\ -4\alpha c_e(2er + e^2\beta\lambda + 2(1-\theta)d_0) - 8\alpha c_t(\alpha f + er + \theta d_0) \end{array}\right) \tag{16}$$

$$\pi = \frac{1}{64\alpha}\left(\begin{array}{l} 3e^4\beta^2\lambda^2 + 24\alpha f\theta d_0 + 12\alpha^2(f^2 + c_e^2 + c_t^2) + 12er(2\alpha f + 2er + e^2\beta\lambda + 2d_0) \\ -32\alpha e^2\lambda + 12e^2\beta\lambda d_0(1-\theta) + 12d_0^2(1 - 2\theta + 2\theta^2) \\ -12\alpha c_e(2er + e^2\beta\lambda + 2(1-\theta)d_0) - 24\alpha c_t(\alpha f + er + \theta d_0) \end{array}\right) \tag{17}$$

3.3. **Centralized decision.** When manufacturers and retailers adopt centralized decision, the supply chain profit function is

$$\pi = q_t(p_t + f - c_t) + q_e(p_e - c_e) - \frac{1}{2}\lambda e^2 \tag{18}$$

The derivative of Eq. (18) for p_t and p_e are obtained

$$\frac{\partial \pi}{\partial p_t} = er + \theta d_0 - \alpha\left(f + 2p_t - c_t\right) \tag{19}$$

$$\frac{\partial \pi}{\partial p_e} = er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 - \alpha\left(2p_e - c_e\right) \tag{20}$$

p_t, $p_e$needs to satisfy the condition that the Hessian matrix has the optimal value to can get the optimal solution for the supply chain' profit. The Hessian matrix is as follows, $\frac{\partial^2\pi}{\partial p_t^2} = -2\alpha$, $\frac{\partial^2\pi}{\partial p_e^2} = -2\alpha$, $\frac{\partial^2\pi}{\partial p_t\partial p_e} = \frac{\partial^2\pi}{\partial p_e\partial p_t} = 0$.

Because $\left[\begin{array}{cc} \frac{\partial^2\pi}{\partial p_t^2} & \frac{\partial^2\pi}{\partial p_t\partial p_e} \\ \frac{\partial^2\pi}{\partial p_e\partial p_t} & \frac{\partial^2\pi}{\partial p_e^2} \end{array}\right] = \left[\begin{array}{cc} -2\alpha & 0 \\ 0 & -2\alpha \end{array}\right]$, the first-order principal subtype is less than 0, the second-order principal subtype is greater than 0, the matrix is a semi-negative definite matrix, and the profit of the supply chain has a maximum value. Let Eq.(19) and Eq.(20) be equal to zero, we get

$$p_t^C = \frac{er + \theta d_0 - \alpha f + \alpha c_t}{2\alpha} \tag{21}$$

$$p_e^C = \frac{2er + e^2\beta\lambda + 2(1-\theta)d_0 + 2\alpha c_e}{4\alpha} \tag{22}$$

Bringing the optimal p_t^C and p_e^C (Eqs. (21) and (22)) into the total supply chain profit (Eq. (18)), the optimal value of the total supply chain profit can be obtained,

$$\begin{aligned} \pi = &-\frac{e^2\lambda}{2} + (er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 + \frac{1}{4}(-2er - e^2\beta\lambda - 2\alpha c_e - 2d_0 \\ &+ 2\theta d_0))(\frac{2er + e^2\beta\lambda + 2\alpha c_e + 2d_0 - 2\theta d_0}{4\alpha} - w_e) + (er + \frac{1}{2}e^2\beta\lambda \end{aligned} \tag{23}$$

$$+(1-\theta)d_0+\frac{1}{4}(-2er-e^2\beta\lambda-2\alpha c_e-2d_0+2\theta d_0))(w_e-c_e)$$
$$+(er+\theta d_0+\frac{1}{2}(\alpha f-er-\alpha c_t-\theta d_0)(f+\frac{-\alpha f+er+\alpha c_t+\theta d_0}{2\alpha}-w_t)$$
$$+(er+\theta d_0+\frac{1}{2}(\alpha f-er-\alpha c_t-\theta d_0))(w_t-c_t)$$

By comparing with the optimal profit of the supply chain under decentralized decision-making, we can know that the optimal profit of the supply chain under centralized decision-making is greater than that under decentralized decision-making. The details are as follows: Subtracting Eq. (17) from Eq. (23), we can get

$$\Delta\pi=\frac{1}{64\alpha}\left(\begin{array}{l} e^4\beta^2\lambda^2+4e^3r\beta\lambda+8e^2r^2+8e\alpha fr+4\alpha^2f^2+4\alpha^2c_e^2+4\alpha^2c_t^2 \\ +4d_0\left(e^2\beta\lambda\left(1-\theta\right)+2er+2\alpha f\theta+\left(1+2\theta^2-2\theta\right)d_0\right) \\ -4\alpha c_e\left(e^2\beta\lambda+2er+2\left(1-\theta\right)d_0\right)-8\alpha c_t\left(er+\alpha f+\theta d_0\right) \end{array}\right).$$

Because $er+\theta d_0-3\alpha f-\alpha c_t>0$, $2er+e^2\beta\lambda+2(1-\theta)d_0-2\alpha c_e>0$, we obtain $\frac{er+\theta d_0-3\alpha f}{\alpha}>c_t$, $\frac{2er+e^2\beta\lambda+2(1-\theta)d_0}{2\alpha}>c_e$. Bring it into $\Delta\pi$, and you can calculate $\Delta\pi\geq af^2$. $\Delta\pi\geq 0$, that is, the supply chain profit of centralized decision is greater than that of decentralized decision.

3.4. **Introducing contract.** In order to make the profits of retailers and manufacturers in the supply chain under decentralized decision the same as under centralized decision, revenue-sharing and cost-sharing contracts are introduced here, where w_{tr}, w_{er}, a_t, and a_e are contract parameters. The retailer profit and manufacturer profit with contracts are as follows:

$$\pi_{RC}=q_t(a_tp_t-w_{tr}+f)+q_e(a_ep_e-w_{er}) \tag{24}$$

$$\pi_{MC}=q_t((1-a_t)p_t+w_{tr}-c_t)+q_e((1-a_e)p_e+w_{er}-c_e)-\frac{1}{2}\lambda e^2 \tag{25}$$

The derivative of Eq. (24) for p_t and p_e are obtained

$$\frac{\partial\pi_{RC}}{\partial p_t}=a_t(er+\theta d_0-\alpha p_t)-\alpha\left(f+a_tp_t-w_{tr}\right) \tag{26}$$

$$\frac{\partial\pi_{RC}}{\partial p_e}=a_e(er+\frac{1}{2}e^2\beta\lambda+(1-\theta)d_0-\alpha p_e)-\alpha\left(a_ep_e-w_{er}\right) \tag{27}$$

Since p_t and p_e satisfy the conditions for the existence of the optimal value of the Hessian matrix, the retailer's profit has an optimal value. The solution of Hessian matrix is consistent with the above description, so it not be shown. Let Eqs. (26)-(27) is equal to zero, p_t^I and p_e^I can be obtained

$$p_t^I=\frac{a_ter+a_t\theta d_0-\alpha f+\alpha w_{tr}}{2a_t\alpha} \tag{28}$$

$$p_e^I=\frac{2a_eer+a_ee^2\beta\lambda+2a_e(1-\theta)d_0+2\alpha w_{er}}{4a_e\alpha} \tag{29}$$

Let p_t^I and p_e^I under introducing decision be the same as p_t^C, p_t^C under the centralized decision, that is, Eq. (28) is equal to Eq. (21), Eq. (29) is equal to Eq. (22), and a system of equations is obtained

$$\left\{\begin{array}{l} p_t^I=p_t^C \\ p_e^I=p_e^C \end{array}\right. \tag{30}$$

We get the results of w_{tr} and w_{er} from Eq. (30), as follows

$$\begin{aligned} w_{tr} &= f - a_t f + a_t c_t \\ w_{er} &= a_e c_e \end{aligned} \tag{31}$$

Finally, Eqs. (28), (29), and (31) are brought into Eq. (24) and (25), and the profit of the retailer, the profit of the manufacturer, and the profit of the supply chain are obtained.

$$\begin{aligned} \pi_{RC} =&(a_t f - a_t c_t + \frac{-\alpha f + a_t er + \alpha(f - a_t f + a_t c_t) + a_t\theta d_0}{2\alpha})(er + \theta d_0 \\ &- \frac{-\alpha f + a_t er + \alpha(f - a_t f + a_t c_t) + a_t\theta d_0}{2a_t}) \\ &+ (-a_e c_e + \frac{2a_e er + a_e e^2\beta\lambda + 2\alpha a_e c_e + 2a_e d_0(1-\theta)}{4\alpha})(er + \frac{1}{2}e^2\beta\lambda \\ &+ (1-\theta)d_0 - \frac{2a_e er + a_e e^2\beta\lambda + 2\alpha a_e c_e + 2a_e d_0(1-\theta)}{4a_e}) \end{aligned} \tag{32}$$

$$\begin{aligned} \pi_{MC} =& -\frac{e^2\lambda}{2} + (er + \theta d_0 - \frac{-\alpha f + a_t er + \alpha(f - a_t f + a_t c_t) + a_t\theta d_0}{2a_t})((1-a_t)f \\ &- (1-a_t)c_t + \frac{(1-a_t)(-\alpha f + a_t er + \alpha(f - a_t f + a_t c_t) + a_t\theta d_0)}{2\alpha a_t}) \\ &+ (er + \frac{1}{2}e^2\beta\lambda + (1-\theta)d_0 \\ &- \frac{2a_e er + a_e e^2\beta\lambda + 2\alpha a_e c_e + 2a_e d_0(1-\theta)}{4a_e})((-1+a_e)c_e \\ &+ \frac{(1-a_e)(2a_e er + a_e e^2\beta\lambda + 2\alpha a_e c_e + 2a_e d_0(1-\theta))}{4\alpha a_e}) \end{aligned} \tag{33}$$

$$\begin{aligned} \pi &= \pi_{RC} + \pi_{MC} \\ &= \frac{1}{16\alpha}\left(\begin{array}{l} e^4\beta^2\lambda^2 + 8\alpha f\theta d_0 + 4\alpha^2(f^2 + c_e^2 + c_t^2) \\ +4er(2\alpha f + 2er - 2\alpha er + e^2\beta\lambda + 2d_0) + \\ 4e^2\beta\lambda d_0(1-\theta) + 4d_0^2(1 - 2\theta + 2\theta^2) \\ -4\alpha c_e(2er + e^2\beta\lambda + 2(1-\theta)d_0) - 8\alpha c_t(\alpha f + er + \theta d_0) \end{array}\right) \end{aligned} \tag{34}$$

4. **Numerical analysis.** Next, the correctness of the model would be verified by numerical analysis. Moreover, through parameter sensitivity analysis, we tried to reveal the management laws of the model and provide a scientific basis for guiding

TABLE 2. Comparison of different decision-making cases

	w_t, w_e	p_t	p_e	π_R	π_M	π
Centralized decision	—	30.5	43	—	—	2106.2
Decentralized decision	35.5, 43.0	47.75	58.5	537.8	1030.6	1568.4
Introduction contract	3.8, 3.0	30.5	43	597.3	1508.9	2106.2

management. Some parameters in this section are as follows: θ=0.5, d_0=100, α=1, r=5, e=3, β=0.2, λ=10, f=5, w_t=60, w_e=65, c_t=1, c_e=12.

4.1. **Analysis of the contract.** Table 2 shows the different values of w_t, w_e, p_t, p_e, π_R, π_M, and π in the three cases of decentralized decision, centralized decision, and introducing contract. In centralized decision and introducing contract, the values (i.e., p_t, p_e) are the same. It shows that the model after the introduction of revenue-sharing and cost-sharing contracts achieves supply chain coordination.

The p_t, p_e in decentralized decision are 1.566 and 1.360 times that in the introduced contract, respectively. Obviously, according to the market demand function Eq.(1) and Eq. (2), the reduction of prices p_t and p_e can increase market demand and help to improve profits. Moreover, the w_t and w_e in the introduction contract are much smaller than that in the decentralized decision, only abound 10.7% and 7.0%. In other words, the retailer's profit of a single item increases rapidly because the difference between p_t and w_t, as well as p_e and w_t, becomes larger in introducing contract. At the same time, the manufacturer's profit of a single commodity is reduced. However, the π_R, π_M in introducing contract are larger than that in decentralized decision, about 11.1%, and 46.4%. Therefore, manufacturers and retailers support the scheme of introducing contracts based on maximizing overall benefits.

4.2. **Sensitivity analysis of the parameters.** In this section, we apply sensitivity analysis to study the effects of parameters e, r, and green preferences consumer share $1-\theta$ on optimal pricing under decentralized and centralized decision-making in the supply chain and optimal profits for manufacturers and retailers.

Fig 1 shows the impact of the proportion of consumers with green preferences $1-\theta$ on the optimal p_e under decentralized decision and introducing contract. The optimal price p_e of integrated packaging increases linearly with the increase of $1-\theta$. It shows that with the increase of customers' green preferences, the market demand for integrated green packaging increases, and the optimal price of products with integrated packaging will increase rapidly. The p_e under decentralized decision is always greater than that under the introduction contract. However, the gap of p_e between decentralized decision and introduction contract is increase. That is, p_e is more sensitive to $1-\theta$ in the decentralized decision. Fig 2 shows the proportion of consumers without green preferences $1-\theta$ on the optimal p_t under decentralized decision and introducing contract. Increased price p_t of products with secondary packaging products decreases linearly with the increase of $1-\theta$. The p_t under decentralized decision is also always greater than that under the introduction contract, like p_e. the gap of p_t between decentralized decision and introduction contract decreases.

Fig 3 and 4 show the impact of r on the optimal p_e, and the optimal p_t under decentralized decision and introducing contract, respectively. The p_e and p_t under introducing contract are respectively smaller than that under decentralized contract,

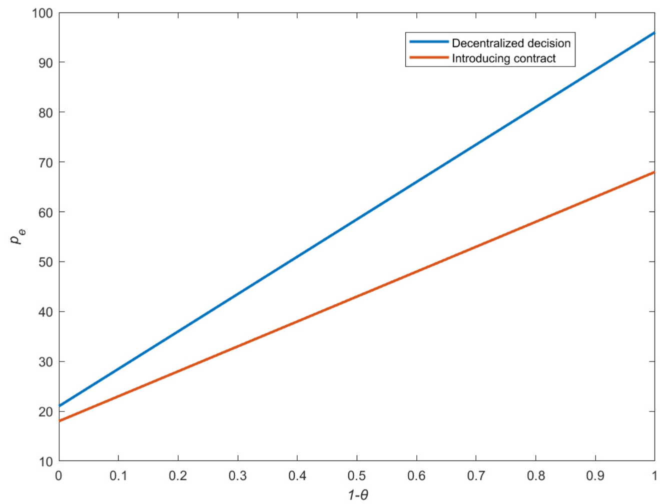

FIGURE 1. Impact of $1-\theta$ on optimal p_e

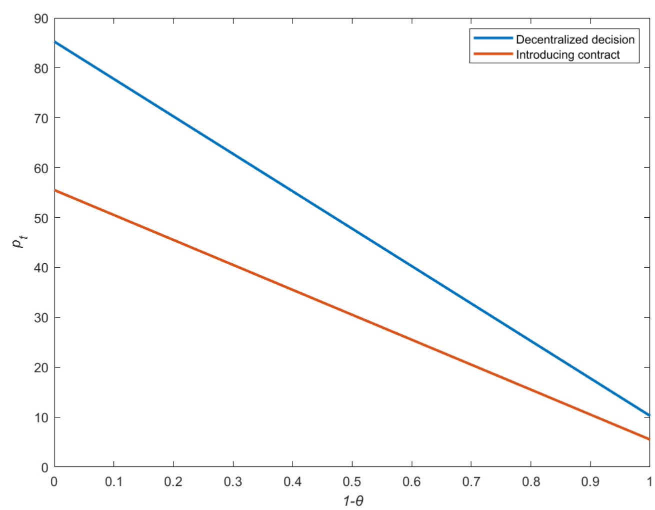

FIGURE 2. Impact of $1-\theta$ on optimal p_t

that is, the cooperation is beneficial to reduce the price. According to Eqs (1) and (2), the reduction of price p_e and p_t will increase market demand q_t and q_e, so the profits of retailers and manufacturers may increase.

Fig 5 and Fig 6 show the impact of integrated packaging green effort cost e on the optimal p_e, and the optimal p_t under decentralized decision and introducing contract, respectively. The optimal price of the products with both integrated packaging and secondary packaging increase as integrated packaging green effort

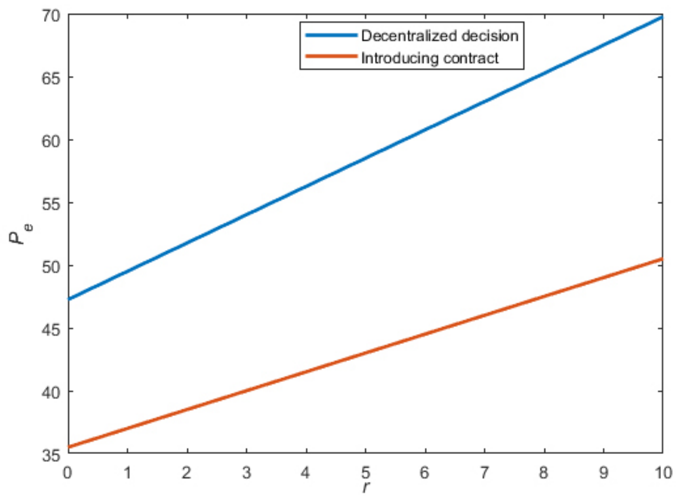

FIGURE 3. Impact of r on optimal p_e

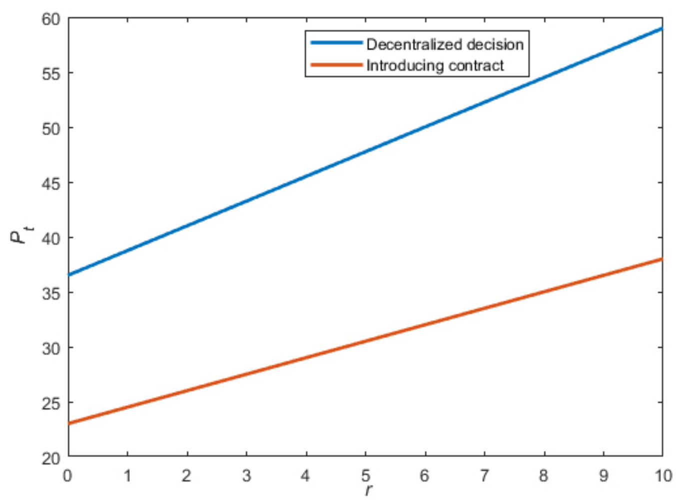

FIGURE 4. Impact of r on optimal p_t

increase, but the former increases nonlinearly, while the latter increases linearly. The p_e and p_t under introducing contract are respectively smaller than that under decentralized contract, that is, the cooperation is beneficial to reduce the price.

Fig 7 is proportion of consumers with green preferences $1-\theta$ on π_R under decentralized decision and introducing contract. With the increase of $1-\theta$, π_R first decreases gradually, reaching the minimum value, and then increases gradually. π_R under introducing contract is always larger than that under decentralized decision. When $1-\theta$ =0.6, π_R under introducing contract is the minimum value 585.1, which

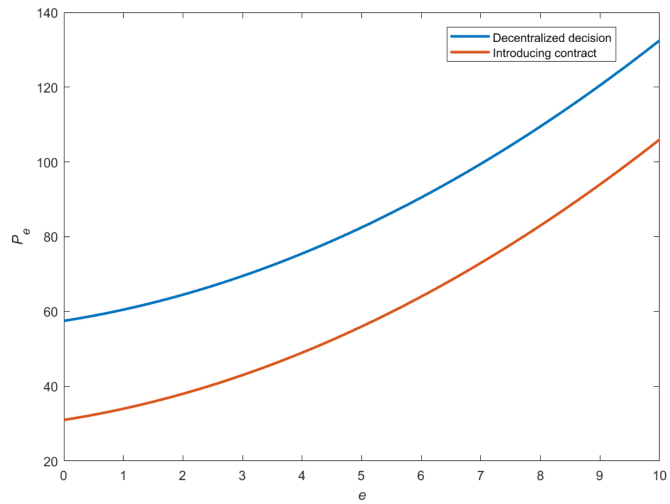

FIGURE 5. Impact of integrated packaging green effort cost e on optimal p_e

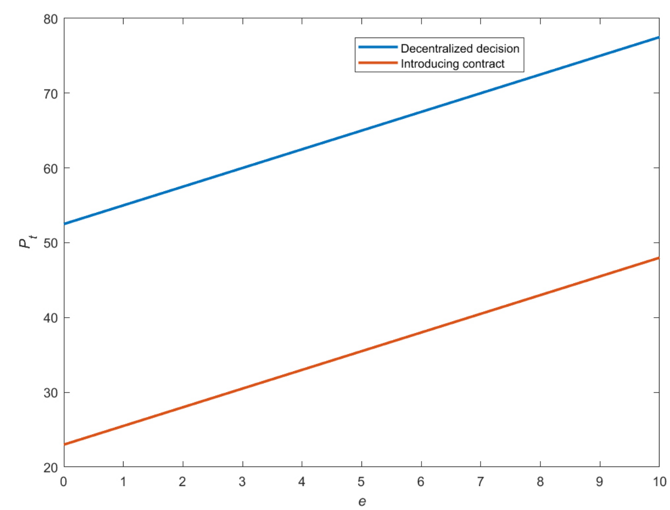

FIGURE 6. Impact of integrated packaging green effort cost e on optimal p_t

is 54.6% of $\pi_R|_{1-\theta=0}$ ($\pi_R|_{1-\theta=x}$ represents the value of π_R when $1-\theta=x$) and 72.1% of $\pi_R|_{1-\theta=1}$. While $1-\theta$=0.55, π_R under decentralized decision is the minimum value 536.6, which is 60.0% of $\pi_R|_{1-\theta=0}$ and 66.5%of $\pi_R|_{1-\theta=1}$. We can draw the conclusion that $\pi_R|_{1-\theta<0.15}$ under introducing contract, $\pi_R|_{1-\theta<0.10}$ under decentralized decision is greater than $\pi_R|_{1-\theta=1}$. In the sense of management, the initial green preferences may lead to the decline of retailers' profits.

Fig 8 is the proportion of consumers with green preferences $1-\theta$ on π_M under decentralized decision and introducing contract. The change law of π_M with $1-\theta$ is similar to that of π_R with $1-\theta$. Only $\pi_{M|1-\theta=1}/\pi_{M|1-\theta=0}$ is less than $\pi_{R|1-\theta=1}/\pi_{R|1-\theta=0}$. It indicates that the profit reduction of the manufacturer is small.

Overall, when the proportion of consumers with green preferences in the market is less than half, the profits of retailers (and manufacturers) tend to decline as the value of $1-\theta$ increases. When the proportion of consumers with green preferences exceeds Halfway through, the retailer's and the manufacturer's profit gradually rises as the value of $1-\theta$ increases. At present, with the improvement of public awareness of environmental protection, the proportion of consumers with green preferences in the market will inevitably continue to increase. Supply chain members need to adapt to the development trend and improve the green brand and good image of the supply chain through green packaging, product research and development, design, and promotion, to attract more ordinary consumers to change to consumers with green preferences, thereby improving the overall profit of itself and the supply chain. In addition, compared with decentralized decision-making, the profits of both retailers and manufacturers have improved after the introduction of contracts, and the introduction of contracts has slowed down the magnitude of profit fluctuations caused by changes in $1-\theta$ values, especially for manufacturers, which effect is more obvious.

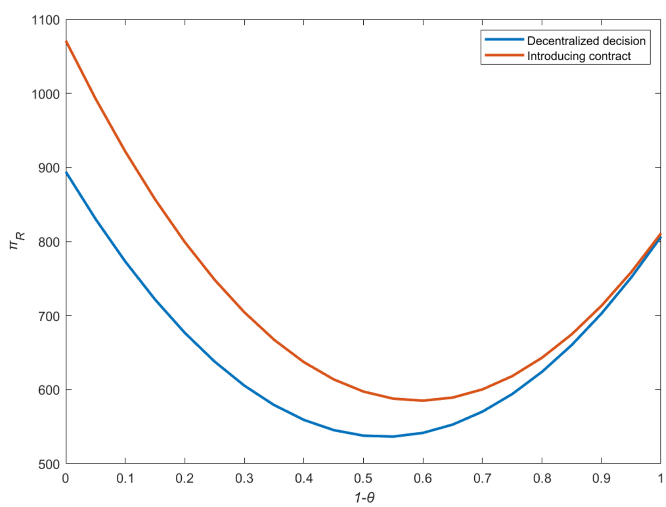

FIGURE 7. Impact Green preferences $1-\theta$ on π_R

Impact of integrated packaging effort cost e on π_R under decentralized decision and introducing contract is shown in Fig 9. π_R increases nonlinearly as e increases, and π_R under introducing contracts is larger than π_R under decentralized contracts. There is an interesting phenomenon, in $e=(6,8)$, the difference between the two is the smallest, which may be caused by the high cost of e.

Impact of integrated packaging effort cost e on π_M under decentralized decision and introducing contract is shown in Fig 10. π_M under introducing contracts is

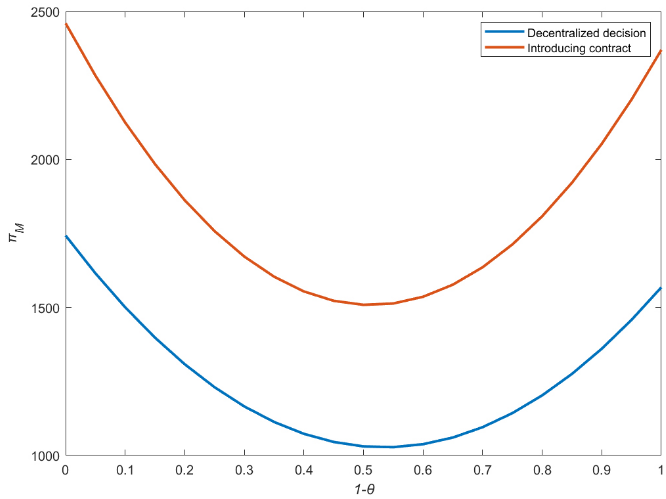

FIGURE 8. Impact Green preferences $1-\theta$ on π_M

larger than π_M under decentralized contracts. Therefore, introducing contract is a wise decision of the manufacturer based on the maximum profit. π_R increases nonlinearly as e increases, and the larger e, the greater $\pi_{M|e=10}/\pi_{M|e=0} = 10.3$ under introducing contract. While $\pi_{M|e=0} = -210$ under the decentralized decision, it means that when e=0, the profit π_M is negative. Profit π_M under decentralized decision is positive only when e=2. That is to say, if the profit π_M is positive, the e under decentralized decision is greater than the e (e=0) under introducing contract. Moreover, manufacturers' increased green packaging efforts can increase profits for both manufacturers and retailers, and the rate of profit improvement is lower when green efforts are small, and increases when green efforts are large.

Fig 11 and Fig 12 show influence coefficient of integrated packaging efforts r on π_R , π_M under decentralized decision and introducing contract, respectively. In Figs. 11 and 12, π_R and π_M increase rapidly with the increase of r. Obviously, it is a situation of small profits but quick turnover in management science to earn more profits. The π_R and π_M under introducing contract are respectively larger than that under decentralized contract, that is, the cooperation is beneficial to increase the profit.

The influence of brand image on demand is positively related to the profits of manufacturers and retailers. The greater the influence of the brand image, the greater the profits of supply chain members. After the contract's introduction, the profit increase is gradually greater than that under dispersion. The influence of brand image on manufacturer's profit increase is greater than that on retailer's profit. Retailers will be more keen to promote and publicize the green behavior of reduced packaging, thereby increasing their own profits. Under introducing contract, the average growth rate of retailer's profit within $r = (0, 10)$ is 54.3, and the average growth rate of retailer's profit within $r = (0, 10)$ of decentralized decision-making is 49.3. Under introducing contract, the average growth rate of manufacturers' profits

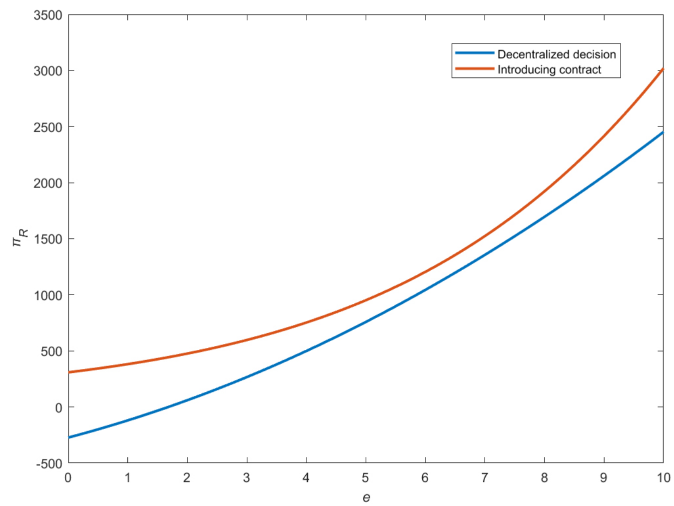

FIGURE 9. Impact of integrated packaging effort cost e on π_R

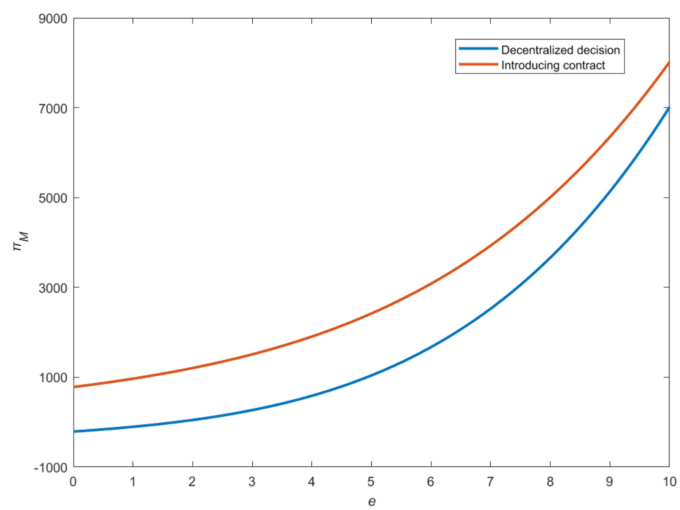

FIGURE 10. Impact of integrated packaging effort cost e on π_M

within $r = (0, 10)$ is 142.2, and decentralized decision-making manufacturers' profits within $r = (0, 10)$ are 98.3.

5. **Conclusions.** This paper studies the supply chain coordination considering the strategy of reducing packaging under the green preferences of consumers. We draw the following conclusions:

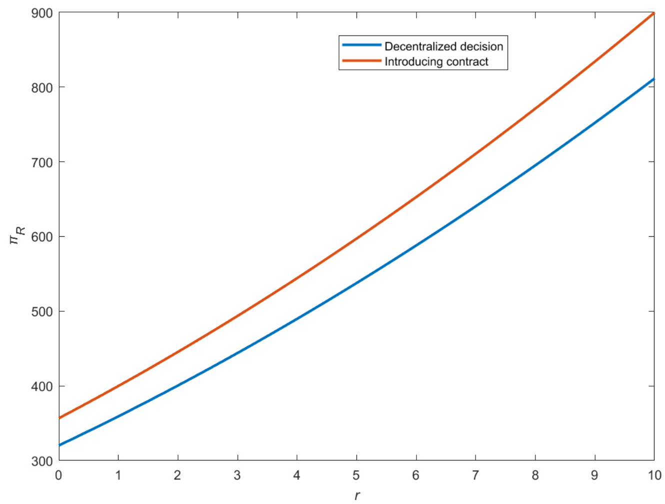

FIGURE 11. Impact of r on on π_R

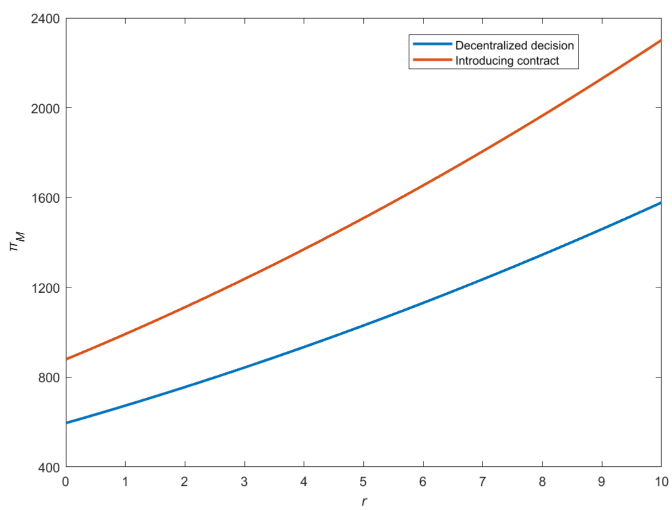

FIGURE 12. Impact of r on on π_M

1. The revenue-sharing and cost-sharing contracts enable coordination of supply chains considering reduced packaging strategies. At the same time, the introduction of the contract can optimize the price of integrated packaging and secondary packaging products, and improve supply chain profits.

2. With the increasing proportion of consumers with green preferences, especially when more than half of the consumers with green preferences in the market, adopting the strategy of reducing packaging can help the supply chain increase profits.

Supply chain members need to continuously improve the integrated packaging green efforts to improve profits.

3. The impact of integrated packaging green efforts on manufacturers' profits is greater than that on retailers' profits. Green brand and good image praise affect the consumers' green preference and further increase supply chain profits. The greater the influence of brand image and good reputation, the faster the profits of the supply chain will increase.

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REFERENCES

[1] R. Accorsi, A. Cascini, S. Cholette, R. Manzini and C. Mora, Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study, *Int. J. Prod. Econ.*, **152** (2014), 88-101.

[2] T. Błażejewski, S. R. J. Walker, R. I. Muazu and R. H. Rothman, Reimagining the milk supply chain: Reusable vessels for bulk delivery, *Sustain. Prod. Consum.*, **27** (2021), 1030-1046.

[3] Z. Boz, V. Korhonen and C. Koelsch Sand, Consumer considerations for the implementation of sustainable packaging: A review, *Sustainability*, **12** (2020), 2192.

[4] K. Chueamuangphan, P. Kashyap and C. Visvanathan, Packaging waste from E-commerce: Consumers' awareness and concern, *Sustainable Waste Management: Policies and Case Studies*, **(**2020), 27-41.

[5] P. M. Coelho, B. Corona, R. ten Klooster and E. Worrell, Sustainability of reusable packaging-Current situation and trends. Resource, *Conservation* & *Recycling: X*, **(**2020), 100037.

[6] J. Cong, T. Pang and H. Peng, Optimal strategies for capital constrained low-carbon supply chains under yield uncertainty, *J. Clean. Prod.*, **256** (2020), 120339.

[7] C. d'Aspremont and A. Jacquemin, Cooperative and noncooperative R & D in duopoly with spillovers, *Am. Econ. Rev.*, **78** (1988), 1133-1137.

[8] H. Duan, G. Song, S. Qu, X. Dong and M. Xu, Post-consumer packaging waste from express delivery in China, *Resour. Conserv. Recycl.*, **144** (2019), 137-143.

[9] S. Escursell, P. Llorach-Massana and M. B. Roncero, Sustainability in e-commerce packaging: A review, *J. Clean. Prod.*, **280** (2021), 124314.

[10] R. Fan, J. Lin and K. Zhu, Reducing the cost of demand uncertainty through accurate response to early sales, *Oper. Res.*, **44** (1996), 87-99.

[11] W. Fan, M. Xu, X. Dong and H. Wei, Considerable environmental impact of the rapid development of China's express delivery industry, *Resour. Conserv. Recycl.*, **126** (2017), 174-176.

[12] J. García-Arca, J. C.Prado-Prado and A. T. G. P. Garrido, "Packaging logistics": Promoting sustainable efficiency in supply chains, *Int. J. Phys. Distr. Log.*, **4** (2014), 325-346.

[13] D. Ghosh and J. Shah, Supply chain analysis under green sensitive consumer demand and cost sharing contract, *Int. J. Prod. Econ.*, **164** (2015), 319-329.

[14] J. He, Y. Lei and X. Fu, Do consumer's green preference and the reference price effect improve green innovation? A theoretical model using the food supply chain as a case, *Int. J. Environ. Res. Public. Health.*, **16** (2019), 5007.

[15] J. Heydari, K. Govindan and A. Aslani, Pricing and greening decisions in a three-tier dual channel supply chain, *Int. J. Prod. Econ.*, **217** (2019), 185-196.

[16] J. Ji, Z. Zhang and L. Yang, Carbon emission reduction decisions in the retail-/dual-channel supply chain with consumers' preference, *J. Clean. Prod.*, **141** (2017), 852-867.

[17] N. Li, M. Deng, H. Mou, et al., Government participation in supply chain low-carbon technology R&D and green marketing strategy optimization, *Sustainability.*, **14** (2022), 8342.

[18] Q. Li, T. Xiao and Y. Qiu, Price and carbon emission reduction decisions and revenue-sharing contract considering fairness concerns, *J. Clean. Prod.*, **190** (2018), 303-314.

[19] J. Lin, R. Fan, X. Tan and K. Zhu, Dynamic decision and coordination in a low-carbon supply chain considering the retailer's social preference, *Socio-Econ. Plan. Sci.*, **77** (2021), 101010.

[20] M. Liu, Z. Li, S. Anwar and Y. Zhang, Supply chain carbon emission reductions and coordination when consumers have a strong preference for low-carbon products, *Environ. Sci. Pollut. Res. Int.*, **28** (2021), 19969-19983.

[21] Z. Liu, T. D. Anderson and J. M. Cruz, Consumer environmental awareness and competition in two-stage supply chains, *Eur. J. Oper. Res.*, **218** (2012), 602-613.

[22] S. Lu, L. Yang, W. Liu and L. Jia, User preference for electronic commerce overpackaging solutions: Implications for cleaner production, *J. Clean. Prod.*, **258** (2020), 120936.

[23] M. Mahmoudi and I. Parviziomran, Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management, *Int. J. Prod. Econ.*, **228** (2020), 107730.

[24] C. M. McDonald, Integrating packaging and supply chain decisions: Selection of economic handling unit quantities, *Int. J. Prod. Econ.*, **180** (2016), 208-221.

[25] L. Meherishi, S. A. Narayana and K. Ranjani, Sustainable packaging for supply chain management in the circular economy: A review, *J. Clean. Prod.*, **237** (2019), 117582.

[26] L. Meherishi, S. A. Narayana and K. Ranjani, Integrated product and packaging decisions with secondary packaging returns and protective packaging management, *Eur. J. Oper. Res.*, **292** (2021), 930-952.

[27] Nestlé Waters France launches new formats of 100% recycled plastic bottles for its VITTEL®, HEPAR® and CONTREX® brands, https://naturalmineralwaterseurope.org/members/nestle-waters-france-launches-new-formats-of-100-recycled-plastic-bottles/.

[28] A. T. Nguyen, L. Parker, L. Brennan and S. Lockrey, A consumer definition of eco-friendly packaging, *J. Clean. Prod.*, **252** (2020), 119792.

[29] W. D. Nordhaus, To slow or not to slow: The economics of the greenhouse effect, *Econ. J.*, **101** (1991), 920-937.

[30] G. Oberoi and A. Garg, Single-Use plastics: A roadmap for sustainability?, *Supremo. Amicus.*, **24** (2021), 585.

[31] Packaging waste statistics, *Eurostat*, (2017), http://ec.europa.eu/eurostat/statisticsexplained/index.php/Packaging_waste_statistics.

[32] Packaging waste statistics, *Eurostat*, (2019), http://ec.europa.eu/eurostat/statisticsexplained/index.php/Packaging_waste_statistics.

[33] H. Pålsson, F. Pettersson and L. W. Hiselius, Energy consumption in e-commerce versus conventional trade channels-Insights into packaging, the last mile, unsold products and product returns, *J. Clean. Prod.*, **164** (2017), 765-778.

[34] H. Peng, T. Pang and J. Cong, Coordination contracts for a supply chain with yield uncertainty and low-carbon preference, *J. Clean. Prod.*, **205** (2018), 291-302.

[35] T. N. Phan and K. Baird, The comprehensiveness of environmental management systems: The influence of institutional pressures and the impact on environmental performance, *J. Environ. Manage.*, **160** (2015), 45-56.

[36] V. Sohrabpour, P. Oghazi and A. Olsson, An improved supplier driven packaging design and development method for supply chain efficiency, *Packag. Technol. Sci.*, **29** (2016), 161-173.

[37] L. Sun, X. Cao, M. Alharthi, et al., Carbon emission transfer strategies in supply chain with lag time of emission reduction technologies and low-carbon preference of consumers, *J. Clean. Prod.*, **264** (2020), 121664.

[38] A. A. Taleizadeh, N. Alizadeh-Basban and B. R. Sarker, Coordinated contracts in a two-echelon green supply chain considering pricing strategy, *Comput. Ind. Eng.*, **124** (2018), 249-275.

[39] Y. Tian, J. Ma, L. Xie, T. Koivumäki and V. Seppänen, Coordination and control of multi-channel supply chain driven by consumers' channel preference and sales effort, *Chaos Solitons Fractals*, **132** (2020), 109576, 20 pp.

[40] W. Tong, D. Mu, F. Zhao, et al., The impact of cap-and-trade mechanism and consumers' environmental preferences on a retailer-led supply Chain, *Resour. Conserv. Recycl.*, **142** (2019), 88-100.

[41] M. A. Ülkü and J. Hsuan, Towards sustainable consumption and production: Competitive pricing of modular products for green consumers, *J. Clean. Prod.*, **142** (2017), 4230-4242.

[42] K. Verghese and H. Lewis, Environmental innovation in industrial packaging: A supply chain approach, *Int. J. Prod. Res.*, **45** (2007), 4381-4401.

[43] Q. Wang, D. Zhao and L. He, Contracting emission reduction for supply chains considering market low-carbon preference, *J. Clean. Prod.*, **120** (2016), 72-84.

[44] Y. Wang and G. Hou, A duopoly game with heterogeneous green supply chains in optimal price and market stability with consumer green preference, *J. Clean. Prod.*, **255** (2020), 120161.

[45] L. Xia, W. Hao, J. Qin, et al., Carbon emission reduction and promotion policies considering social preferences and consumers' low-carbon awareness in the cap-and-trade system, *J. Clean. Prod.*, **195** (2018), 1105-1124.

[46] G. Xie, L. Huang, C. Apostolidis, et al., Assessing consumer preference for overpackaging solutions in e-commerce, *Int. J. Env. Res. Pub. He.*, **18** (2021), 7951.

[47] H. Yang and W. Chen, Retailer-driven carbon emission abatement with consumer environmental awareness and carbon tax: Revenue-sharing versus cost-sharing, *Omega.*, **78** (2018), 179-191.

[48] C. Zhang, Y. Liu and G.Han, Two-stage pricing strategies of a dual-channel supply chain considering public green preference, *Comput. Ind. Eng.*, **151** (2021), 106988.

[49] Z. Zhang and L. Yu, Dynamic optimization and coordination of cooperative emission reduction in a dual-channel supply chain considering reference low-carbon effect and low-carbon goodwill, *Int. J. Environ. Res. Public. Health.*, **18** (2021), 539.

[50] T. Zimmermann and R. Bliklen, Single-use vs. reusable packaging in e-commerce: Comparing carbon footprints and identifying break-even points, *GAIA.*, **29** (2020), 176-183.

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