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Altruistic Preference Models of Low-Carbon E-Commerce Supply Chain

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Abstract: With the gradual popularity of online sales and the enhancement of consumers' low-carbon awareness, the low-carbon e-commerce supply chain (LCECSC) has developed rapidly. However, most of the current research on LCECSC assumes that the decision-making body is rational, and there is less research on the irrational behavior of the e-platform altruistic preference. Therefore, aiming at the LCECSC composed of a single e-platform and a single manufacturer, this paper establishes two basic models with or without altruistic preference. Additionally, this paper combines the characteristics of online sales and assumes that altruistic preference is a proportional function of commission, then establishes a commission-based extended model with altruistic preference to further explore the influence of commission on its altruistic preference. The current literature does not consider this point, nor does it analyze the influence of other parameters on the degree of altruism preference. By comparing the optimal decisions and numerical analysis among the models, the following conclusions can be drawn that: (1) different from the traditional offline supply chain, the profit of the dominator e-platform is lower than the profit of the follower manufacturer; (2) when the consumers' carbon emission reduction elasticity coefficient increases, service level, sales price, carbon emission reduction, sales, supply chain members profits, and system profit increase, ultimately improving economic and environmental performances; (3) the altruistic preference behavior of the e-platform is a behavior of 'profit transferring'. The moderate altruistic preference is conducive to the stable operation and long-term development of LCECSC.

Keywords: e-commerce platform; altruistic preference; low-carbon e-commerce supply chain

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1. Introduction

Greenhouse gases are still a common challenge faced by human society today. Effectively responding to smog and the greenhouse effect, and accelerating the enhancement of the low-carbon economy, has become an urgent international issue [1,2]. In terms of government, various countries introduced relevant requirements and policies to promote the enhancement of energy conservation and emission reduction [3,4]. For instance, in 2016, the new U.S. policy required a higher vehicle emission standard; in 2017, China launched a national carbon emissions trading system; in 2018, Germany issued the 'High-Tech Strategy 2025', which included climate protection and emission reductions of greenhouse gases. For consumers, with the enhancement of low-carbon awareness, environmentally friendly and energy-saving products are gradually recognized and favored. While consumers are concerned about the functional value of the products, they are also concerned about their low-carbon attributes [5,6]. To meet customers' low-carbon demand, Land Rover developed carbon labels for every car and invests more in emission reduction technologies; In 2018, Wal-Mart launched the global '1 Billion-Ton Emission Reduction Project'; INM and IKEA required their suppliers to provide carbon labels. Under the dual promotion of government emission reduction policies and consumers' low-carbon demand, how enterprises should determine their emission reduction levels to assume social responsibility is of paramount importance [7,8].

In recent years, with the vigorous development of logistics and information technology, many manufacturers rely on the e-platform to sell low-carbon products, which forms the low-carbon e-commerce supply chain (LCECSC). The LCECSC can effectively reduce enterprise costs and improve information sharing between enterprises in order to achieve win-win results [9]. However, the service level of the e-platform affects consumer satisfaction, which makes service another important factor affecting consumers' purchasing decisions [10]. High-quality service can help the platform obtain more sales opportunities in the fierce competing e-commerce market [11]. Therefore, in the fierce competition of homogeneous products, discussing the impact of service on sales in LCECSC is of paramount importance.

Besides, in the operation of LCECSC, the e-platform occupies the dominant position due to its large customer base, network infrastructure, and other resources [12]. Generally speaking, the manufacturer possesses absolute channel power in the traditional supply chain [13,14], but plays the following role in LCECSC. The change in the role makes the manufacturer pay more attention to fairness and even refuse to cooperate with the e-platform when feeling injustice. Therefore, the fairness of decision-making has become a key factor affecting the operation of the supply chain [15,16]. For this reason, to ensure the stability and coordination of the system, the e-platform, while pursuing its profit maximization, also pays attention to the manufacturer's profit and carries out altruistic preferences. Given the importance of altruistic preference to the stable and long-term operation of the system, which forces e-platforms to adopt altruistic preference behavior. For example, Suning.com carries out commission refund activities for various categories such as 3C digital products and automotive supplies. When the manufacturer's sales reach the specified value, the e-platform will refund half or even the full annual commission to increase the enthusiasm of the manufacturer in sales.

However, extant research pays less attention to the altruistic preferences in LCECSC. For example, Wan et al. [17] studied the influence of decision-makers' altruism preference and consumers' low-carbon awareness on an online and offline environmentally friendly hotel supply chain. Feng et al. [18] designed profit distribution rules considering the retailer's altruistic preference behavior. Because of this, incorporating carbon emission reduction and service into the demand function, this paper studies the influence of altruistic preference of the e-platform on decision-making. This paper mainly solves these problems:

(1) When the manufacturer and the e-platform form a Stackelberg game relationship, what are the optimal decisions in basic models where the e-platform considering sltruistic preference or not?
(2) Considering the increase of consumers' low-carbon awareness, what is the impact of the consumers' elasticity coefficient of carbon emission reduction on LCECSC decision-making?
(3) By comparing whether the e-platform considers altruistic preferences, is it beneficial to the operation of LCECSC for the e-platform to consider altruistic preferences? Since commission will affect the degree of altruistic preference of the e-platform, an extended model is established after endogenizing the influence of commissions on altruistic preference. How does LCECSC's decision-making differ between the commission-based extended model with altruistic preference and the basic model without altruistic preference?

The difference between this paper and previous papers is mainly in these two aspects:

Firstly, considering the development of low-carbon awareness and e-commerce environment, by contrast with the research of Xia et al. [19], this paper incorporates carbon emission reduction and service into the demand function to establish models, which makes the conclusions more consistent with reality. Research has shown that consumers' low-carbon preference can effectively improve the efficiency of LCECSC operations. Therefore, the manufacturer must actively promote environmentally friendly low-carbon products and cultivate a low-carbon consumer market as soon as possible in the form of 'small profits and high sales'. In the long run, the initial investment of the manufacturer will bring huge economic and environmental performances.

Secondly, considering the e-platform's altruistic preference, two basic models with or without altruistic preference are established, and the influence of altruistic preference on the LCECSC members and system is analyzed. Besides, this paper establishes a commission-based extended model with altruistic preference to directly explore the influence of commission on altruistic preference. It is found that the e-platform's altruistic preference is not enough to compensate for the loss caused by the increase in commission. The current literature does not consider such influence and does not analyze the influence of other parameters on the degree of altruistic preference [20].

The remaining parts of this paper are arranged as follows: Section 2 is a literature review and Section 3 is the model description and hypothesis. The establishment and calculation of the two basic models with or without altruistic preference are in Section 4. Section 5 is the establishment and analysis of the commission-based extended model with altruistic preference; Section 6 is numerical analysis of Basic models (4) and Extended model (5). The conclusions of this paper are given in Section 7.

2. Literature Review

Research on 'low-carbon economy' and e-commerce is still the focus of today's enterprises and academia. This paper reviews relevant literature from three aspects: the low-carbon supply chain (LCSC), the e-commerce supply chain (ECSC), and the altruistic preference.

The first is the research on the issue of LCSC. The development of LCSC can help reduce the total carbon emission and excessive resource consumption, as well as environmental pollution [21]. At present, research on LCSC mainly focuses on three aspects: government regulations [22,23], government subsidies for emission reduction [24–26], and consumers' low-carbon preference [27,28]. The government regulations include three categories: carbon restrictions [29–31], carbon taxes [32–35], and carbon trading plans [36–38]. For example, Kang et al. [39] studied behavior of LCSC members and the government's low-carbon policy strategy. They found that the government should control carbon trading prices instead of controlling carbon emission caps to achieve the purpose of energy conservation and emission reduction. Wang et al. [34] explored the interaction between government policies and business operations. They found that under the carbon tax policy, supply chain members with partial pricing power can increase the environmental performance and profitability of the supply chain. Li et al. [40] explored the influence of carbon emission reduction costs on system decision-making under the carbon tax policy. Aiming at carbon emission reduction technology and cost in production and operation, Wang et al. [20] discussed the influence of government subsidies on low-carbon e-commerce closed-loop supply chain operation decisions, which concluded that government subsidies can improve system operation efficiency and the total social surplus. Then, J. Zhao et al. [41] explored the impact of different subsidies and different subsidy targets on profit transfer. In response to consumers' increasing preference for low-carbon products, Hong and Guo [42] found that when the manufacturer shares the retailer's marketing cost, the manufacturer's profit is higher, and as consumers' low carbon awareness increases, this result is even more significant. Ji et al. [28] found that online direct sales channels will increase the carbon emission reduction level and system profit when consumers with low-carbon preferences. With the advancement of low-carbon technology and low-carbon concepts, the concept and application of green supply chains have gradually become popular. The green supply chain not only maintains low carbon, but also includes reasonable planning, storage, circulation and processing, etc., and is committed to reducing the impact of logistics on the environment. For green supplier selection, Li and Wei [43] proposed two types of multi-criteria decision making based on generalized Pythagorean fuzzy weighted

Heronian mean (GPFWHM) operator and Pythagorean fuzzy weighted geometric Heronian mean (PFWGHM) operator to help companies choose green suppliers scientifically and reasonably to achieve steady development in the market; Wei et al. [44] extended the distance from average solution (EDAS) method to multiple attribute group decision making (MAGDM) with PLTSs, and found that this method has good discrimination in evaluating the performance of green suppliers. However, most of the aforementioned research focused on the offline traditional low-carbon supply chains and green supplier selection, and did not involve the influence of e-commerce development on LCECSC. This paper establishes the model of LCECSC to analyze the low-carbon product pricing, which is in line with the current background of the rapid development of e-commerce.

The second is the research on ECSC. ECSC was generated from the retail industry [42,45] and gradually spread to other industries such as fresh food and agricultural products [46]. Research on ECSC has always been a hot topic in academia. Siddiqui and Raza [12] concluded that the development of ECSC is mainly divided into two stages. (1) The first stage mainly studies the integration of supply chain management and e-commerce: Garcia and Grabot [47] pointed out that e-platforms are increasingly focusing on relationship improvement as the performance of ECSC is closely related to the quality of partnerships; Ma and Xie [48] compared a dual-channel supply chain under uncertain demand and conducted a complexity analysis; Shao [49] studied the impact of transportation costs on the decision-making of the platform and the manufacturer in ECSC, then found that the platform is unprofitable when the manufacturer prefers free shipping. (2) The second stage mainly studies the operation and optimization of ECSC: Panda et al. [50] discussed the pricing of high-tech products in the online and offline dual-channel supply chain, then designed a revenue-sharing coordination mechanism to achieve supply chain coordination; Jia and Li [51] studied the channel selection of the manufacturer when the e-platform can choose to provide services and self-operated stores, then found that the commission will affect the preferred mode of both the manufacturer and the e-platform; Yan et al. [52] found that the e-platform providing financing services can expand the market share of the e-platform and increase the profitability of the system.

However, the above research did not consider the psychology of supply chain members, especially the fairness concern caused by the role change of members after the joining of the e-platform. Loch and Wu [53] first conducted an empirical study on the 'altruistic preference' behavior, and the research showed that most supply chain members with social responsibility will consider 'profit transferring', thereby further improving the enterprise's reputation. Xia et al. [54] incorporated consumers' low-carbon awareness and the e-platform's altruistic preference into the two-echelon supply chain, then found that both of them have a significant impact on enterprises' utilities and profits. Specifically, the price decreases with the reciprocal behavior of the manufacturers and the retailers, and the best emission reduction level is conversely. Huang et al. [55] and Fan et al. [1] have shown that altruistic preference effectively weakens the double marginalization effect of decentralized decision-making. However, it can be found that the aforementioned literature is quite different from the research content of this paper. First, the aforementioned literature mainly studies the influence of altruistic preference in offline sales on supply chain decision-making, which is quite different from the LCECSC dominated by the e-platform studied in this paper. Second, this paper considers consumers' low-carbon preferences and e-platform altruistic preference, and further incorporates the manufacturer's carbon emission reduction level and the e-platform service level into the decision function, which makes the research conclusions more realistic business operations. Third, this paper combines the characteristics of online sales and assumes that altruistic preference is a proportional function of commission, then establishes a commission-based extended model with altruistic preference to further explore the influence of commission on its altruistic preference. The current literature does not consider this point, nor does it analyze the influence of other parameters on the degree of altruism preference. Additionally, unlike Xia et al. [54] adopting the Nash game, considering that with the rapid development of the network economy, the dominant position of e-platforms has become more stable. This paper assumes that the manufacturer and the e-platform constitute Stackelberg, which is dominated by the e-platform. The game relationship is more in line with the actual environment of online sales.

3. Model Illustration and Assumptions

Consider the LCECSC consisting of a dominator e-platform and a follower manufacturer; the model structure can be seen in Figure 1. The manufacturer produces low-carbon products and releases product information such as sales prices by the e-platform; consumers browse products through the computer page or mobile phone software of the e-platform to obtain the actual product pictures, specifications, instructions for use, and other relevant information. Then combining with the evaluation of other consumers, consumers purchase the corresponding product on demand and hand over the payment to the e-platform, which will generate the corresponding order. After the order is generated, the manufacturer mails the product to consumers through self-operated or third-party logistics, then the consumer signs for the receipt after receiving and examining the products. Finally, the e-platform deducts the corresponding commission from the payment and passes the remaining payment to the manufacturer to complete the product transaction. This model structure is reasonable and common. First, from the actual situation, Taobao (www.taobao.com, accessed on 13 July 2021), Amazon (www.amazon.com, accessed on 13 July 2021), Suning.com (www.suning.com, accessed on 13 July 2021) and other websites are cooperating with manufacturers in this mode. Second, from the perspective of theoretical analysis, most of the literature uses this type of model for supply chain decision analysis, such as Han and Wang [10], but the difference is that the product sold in this model is a low-carbon product.

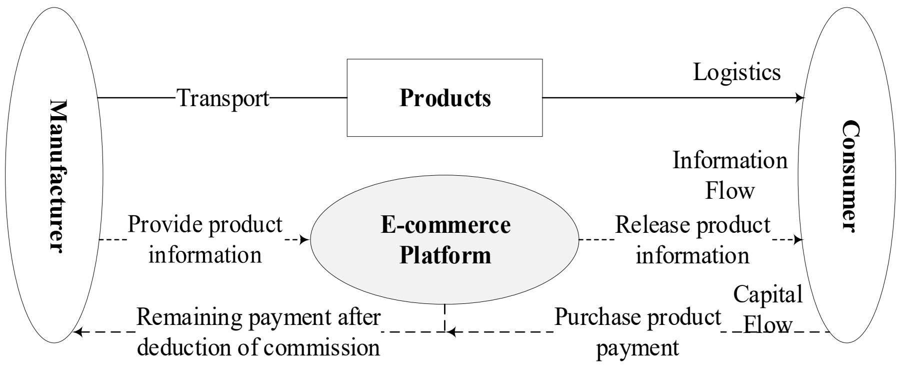


Figure 1. The model structure of the low-carbon e-commerce supply chain (LCECSC).

The commission is the main source of the e-platform's profit, and the amount of commission charged for different categories of products is also different. The e-platform will provide the manufacturer with different service items based on the amount of commission charged, such as self-service network services, product advertising, worry-free return and exchange, enterprise procurement, and other special services. JD (www.jd.com, accessed on 13 July 2021) and Suning (www.suning.com, accessed on 13 July 2021) all use this charging model.

Besides, entering the e-platform following the entry rules formulated by the platform, the manufacturer also needs to pay a fixed platform fee such as a deposit and website alliance promotion fee. These fees do not need to be paid again within a short period after one payment, which is a fixed cost. Therefore, for the convenience of calculation, this fixed cost is ignored and it does not affect the model conclusions.

The paper selects general low-carbon products for research. The e-platform provides services for the manufacturer, and the service level directly affects consumers' willingness to buy and further affects sales. Therefore, this paper takes the service as the main influencing variable and incorporates it into the model for analysis. For ease of description, the parameters involved in the model are shown in Table 1.

Table 1. Notation.

Symbol	Description
	Parameters
t	Carbon emission reduction cost parameter, $t > 0$
ρ	The commission charged by the e-platform for units selling low-carbon products, $0 < \rho < p$
k	Service cost parameter, $k > 0$
α	The potential maximum demand in the market, $\alpha > 0$
β	Elasticity coefficient of the sales price, $\beta > 0$, where $\beta > max\{\lambda, \gamma\}$, this shows that consumers are most concerned about sales price, followed by the service level and the carbon emission reduction level.
γ	The service level elasticity coefficient, $\gamma > 0$
λ	The carbon emission reduction elasticity coefficient, $\lambda > 0$
θ	The e-platform's altruistic preference coefficient, $0 \le \theta \le 1$
	Decision variables
h	The manufacturer's carbon emission reduction level
p	The sales price of unit low-carbon products
s	The service level
	Derived Functions
π_m	The manufacturer's profit
π_e	The e-platform's profit
π	The LCECSC's profit, $\pi = \pi_m + \pi_e$

In this paper, based on the reality and rationality of model construction, the basic assumptions of the following models are given:

(1) Suppose that in an LCECSC composed of a single manufacturer and a single e-platform, the e-platform is the leader and the manufacturer is the follower. The two constitute a Stackelberg game relationship, that is, a two-stage complete information dynamic game.

(2) According to the research of Nair and Narasimhan [56], the carbon emission reduction cost of the manufacturer is assumed as $C_m(h) = th^2/2$, and the market demand for low-carbon products is $q = \alpha - \beta p + \gamma s + \lambda h$

(3) According to the hypothesis of Han and Wang [10], the cost of the e-platform to provide service is assumed as $C_e(s) = ks^2/2$.

According to the above parameters setting and related assumptions, the manufacturer's profit can be expressed by the following equation:

$$\pi_m = (p - \rho)q - th^2/2 = (p - \rho)(\alpha - \beta p + \gamma s + \lambda h) - th^2/2 \tag{1}$$

In Equation (1), the first term is the revenue of product sales, and the second term is carbon emission reduction cost.

The e-platform's profit can be expressed as:

$$\pi_e = \rho q - ks^2/2 = \rho(\alpha - \beta p + \gamma s + \lambda h) - ks^2/2 \tag{2}$$

In Equation (2), the first term is the commission revenue charged from the manufacturer, the second term is the cost of the e-platform to provide the service.

The profit of the LCECSC system can be expressed as:

$$\pi = pq - th^2/2 - ks^2/2 = \rho(\alpha - \beta p + \gamma s + \lambda h) - th^2/2 - ks^2/2 \tag{3}$$

The overall profit of the LCECSC system is the sum of the manufacturer's profit and the e-platform's profit. In Equation (3), the first term is the revenue of products sales, the second term is the carbon emission reduction cost, and the third term is the sales service cost.

Because the research and development and manufacturing of low-carbon products consume high costs for the manufacturer, the price of low-carbon products has become an important factor restricting consumer purchases. Therefore, in order to make the model more realistic, it is assumed that the elasticity coefficient of the sales price is large enough, that is, $2kt\beta - t\gamma^2 - k\lambda^2 > 0$. The constraint indicates that consumers are more sensitive to product price than the service level and the degree of carbon emission. Moreover, this constraint can ensure that the optimal decisions are positive, and each model has a unique optimal decision.

4. Basic Model

4.1. The Basic Model without Altruistic Preference

In the basic model where the e-platform without considering altruistic preference, each supply chain member makes the decision with the goal of maximizing its own profit. The dominator e-platform and the follower manufacturer constitute a Stackelberg game relationship. When making decisions, the manufacturer and the e-platform choose their own strategies based on the other's possible decisions to ensure that they maximize their profits, so as to achieve a Nash equilibrium. That is to say, the dominator e-platform first decides service level s, then the follower manufacturer decides carbon emission reduction level h and the sales price p, after that, the e-platform adjusts the service level s according to the manufacturer's decisions. Repeat the above process until the Nash equilibrium is reached. In this paper, referring to the research of Zhang and Wang [4], Fan et al. [1], Yuyin and Jinxi [25], to solve the optimal decision under the Stackelberg game relationship, the reverse induction method is used. The solution process is as follows:

According to the manufacturer's profit function Equation (1), a Hessian matrix $H = \begin{vmatrix} -2\beta & \lambda \\ \lambda & -t \end{vmatrix}$ can be obtained. Because $-2\beta < 0$, and $\begin{vmatrix} -2\beta & \lambda \\ \lambda & -t \end{vmatrix} > 0$, the optimal decisions of π_m exists. Through $\frac{\partial \pi_m}{\partial p} = 0$ and $\frac{\partial \pi_m}{\partial h} = 0$, we can get the response functions of sales price and carbon emission reduction level:

$$p = \frac{t(\alpha + s\gamma + \beta\rho) - \lambda^2\rho}{2t\beta - \lambda^2} \tag{4}$$

$$h = \frac{\lambda(\alpha + s\gamma + \beta\rho)}{2t\beta - \lambda^2} \tag{5}$$

Substitute Equations (4) and (5) into the decision function of the e-platform. Because of $\frac{\partial^2 \pi_e}{\partial s^2} = -k < 0$, the service level of the e-platform can be solved by $\frac{\partial \pi_e}{\partial s} = 0$:

$$s^{D*} = \frac{t\beta\gamma\rho}{k(2t\beta - \lambda^2)} \tag{6}$$

when Equation (6) is substituted into Equations (4) and (5), the carbon emission reduction level and the manufacturer's sales price can be obtained. Then we can obtain the optimal manufacturer's profit and the optimal e-platform's profit, and the LCECSC system as shown in Table 2.

Table 2. The optimal decision and corresponding profit under the basic model.

Basic Model	Title 2
Basic model without altruistic preference	$p^{D*}=\frac{t\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{k\left(2t\beta-\lambda^2\right)^2}+\rho;$ $h^{D*}=\frac{\lambda\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{k\left(2t\beta-\lambda^2\right)^2};$ $s^{D*}=\frac{t\beta\gamma\rho}{k\left(2t\beta-\lambda^2\right)};$ $q^{D*}=\frac{t\beta\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{k\left(2t\beta-\lambda^2\right)^2};$ $\pi_m^{D*}=\frac{t\left[t\beta\gamma^2\rho+k(\alpha-\beta\rho)\left(2t\beta-\lambda^2\right)\right]^2}{2k^2\left(2t\beta-\lambda^2\right)^3};$ $\pi_e^{D*}=\frac{t\beta\rho\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{2k\left(2t\beta-\lambda^2\right)^2};$ $\pi^{D*}=\pi_m^{D*}+\pi_e^{D*}$
Basic model with altruistic preference	$p^{A*}=\frac{t(1-\theta)\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{\left(2t\beta-\lambda^2\right)\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]}+\rho;$ $h^{A*}=\frac{(1-\theta)\lambda\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{\left(2t\beta-\lambda^2\right)\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]};$ $s^{A*}=\frac{t\gamma[\theta(\alpha-\beta\rho)+\beta\rho(1-\theta)]}{k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta};$ $q^{A*}=\frac{t\beta(1-\theta)\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{\left(2t\beta-\lambda^2\right)\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]};.$ $\pi_m^{A*}=\frac{t(1-\theta)^2\left[t\beta\gamma^2\rho+k(\alpha-\beta\rho)\left(2t\beta-\lambda^2\right)\right]^2}{2\left(2t\beta-\lambda^2\right)\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]^3};$ $\pi_e^{A*}=\frac{t\beta(1-\theta)\left[t\beta\gamma^2\rho+k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{\left(2t\beta-\lambda^2\right)\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]}-\frac{kt^2\gamma^2[\theta(\alpha-\beta\rho)+\beta\rho(1-\theta)]^2}{2\left[k(1-\theta)\left(2t\beta-\lambda^2\right)-t\gamma^2\theta\right]^2};$ $\pi^{A*}=\pi_m^{A*}+\pi_e^{A*}$

Proposition 1. *s^{D*}, p^{D*}, and h^{D*} increase with the increase of λ; q^{D*} increases with λ; π_m^{D*} and π_e^{D*} increase with λ.*

Proof. $\frac{\partial s^{D*}}{\partial\lambda}=\frac{2t\beta\gamma\lambda\rho}{k\left(2t\beta-\lambda^2\right)}>0$, similarly, $\frac{\partial p^{D*}}{\partial\lambda}>0$, $\frac{\partial h^{D*}}{\partial\lambda}>0$, $\frac{\partial\pi_m^{D*}}{\partial\lambda}>0$, $\frac{\partial\pi_e^{D*}}{\partial\lambda}>0$

From Proposition 1, we can see that when the e-platform does not consider altruistic preference, the service level, carbon emission reduction level, sales price, the market demand, and the profits of supply chain members are positively related to λ. The increase of λ means that consumers' low-carbon awareness increases. To meet consumer demand, the manufacturer continues to increase h^{D*}, then the manufacturer increases sales price to compensate for the increased carbon emission reduction cost. The increase in the sales prices brings an increase in the manufacturer's profit, making the manufacturer willing to pay more for improving h^{D*}. At the same time, the increased sales price causes a decline in consumer surplus, making the e-platform improve service level to attract more customers. Consumers who prefer low-carbon products are very likely to pay a higher price for the better service and low-carbon products, indicating that market demand will actually increase and the e-platform's profit will increase accordingly.

In addition, it is worth noting that increasing the sales price of low-carbon products is not good for increasing consumer surplus. Hence, only those consumers with strong low-carbon awareness will favor low-carbon products. Therefore, the manufacturer and the e-platform should increase the promotion of low-carbon products and cultivate a low-carbon consumer market as soon as possible to offset the negative impact of increased sales prices. □

Proposition 2. *s^{D*}, p^{D*}, and π_e^{D*} increase with the increase of ρ; h^{D*}, q^{D*}, and π_m^{D*} decrease with ρ. When $\rho\le\rho'$, π^{E*} increases with ρ; when $\rho>\rho'$, π^{E*} decreases with ρ, where $\rho'=\frac{kt\alpha\gamma^2\left(2t\beta-\lambda^2\right)}{\beta\left[k^2\left(2t\beta-\lambda^2\right)^2+kt\gamma^2\left(2t\beta-\lambda^2\right)-t^2\gamma^4\right]}$.*

The proof is similar to Proposition 1.

From Proposition 2, we can see that sales price, the service level, and the profit of the e-platform are positively related to the commission, while the carbon emission reduction level, sales, and the profit of the manufacturer are negatively related to the commission. It is easy to understand that relying on its dominant position, the e-platform can increase the unit commission. The higher commission makes the e-platform can increase the service level to expand the consumer group, which in turn improves the status of the e-platform, forming a virtuous circle. But for the manufacturer, the higher commission means the loss of its profit. To alleviate the loss of its profit, the manufacturer saves costs by reducing carbon emission reduction levels and increase profit by increasing sales price. For the supply chain system, when $\rho \leq \rho'$, as the increase of commission, the system's profit increases; when $\rho > \rho'$, the system's profit decreases. This indicates that when the commission is low, the e-platform's profit increases faster than the manufacturer's profit decreases, while the e-platform's profit increases less than the manufacturer's profit decreases when the commission is high. This suggests that e-platform should set reasonable commissions, because while considering its own profits, it must also consider the revenues of the manufacturer and the system.

Proposition 3. $\pi_m^{D*} > \pi_e^{D*}$

Proof. $\frac{\pi_m^{D*}}{\pi_e^{D*}} = \frac{\left[t\beta\gamma^2\rho + k\left(2t\beta - \lambda^2\right)(\alpha - \beta\rho)\right]^2}{k\beta(2t\beta - \lambda^2)\rho[t\beta\gamma^2\rho + 2k(2t\beta - \lambda^2)(\alpha - \beta\rho)]}$, order $A = k(2t\beta - \lambda^2)(\alpha - \beta\rho)$, $\left[t\beta\gamma^2\rho + A\right]^2 - k\beta\left(2t\beta - \lambda^2\right)\rho\left[t\beta\gamma^2\rho + 2A\right] = A^2 - 2\beta\rho A\left(2kt\beta - t\gamma^2 - k\lambda^2\right) - t\beta^2\gamma^2\rho^2\left(2kt\beta - t\gamma^2 - k\lambda^2\right)$ can be obtained. Because $\alpha \gg \beta\rho$, $\frac{\pi_m^{D*}}{\pi_e^{D*}} > 1$ can be get. That is $\pi_m^{D*} > \pi_e^{D*}$.

Proposition 3 indicates that in LCECSC, the dominator e-platform's profit is lower than the follower manufacturer's, which is different from the conclusion that the dominant player in the traditional offline supply chain is more profitable [57]. This is because the e-platform, although dominant in LCECSC, is essentially a shared platform, whose main profit is the commission charged from the manufacturer. Moreover, the commission is often less to ensure the manufacturer's enthusiasm for cooperation. According to the assumption of Liu et al. [58], the commission charging standard of most e-platforms currently does not exceed 30% of the sales price. Therefore, in terms of the system composed of a single follower manufacturer and a single dominator e-platform, the e-platform's profit is less than the manufacturer's. The e-platform needs to cultivate the platform's goodwill and achieve profitability by attracting more manufacturers to settle in. □

4.2. The Basic Model with Altruistic Preference

In recent years, the decision made by the e-platform to maximize its profit has sometimes hurt the manufacturer's profit. In China's '618', 'Double 11' and other large-scale online shopping promotion activities, the e-platform frequently makes unauthorized decisions and damages the decision-making power of the manufacturer to gain market share and attract customers, which leads to repeated conflicts. In September 2017, China Bestseller's menswear brand SELECTED JD store was closed, and its other brands, Only, Vero Moda, and Jack and Jones have also withdrawn from JD. In the earlier '618', clothing brands Libo and Qigege directly announced the closure of their JD stores because JD forced them to participate in the promotion and disturbed the price system. The manufacturer's withdrawal from the e-platform not only harms their own profits but also reduces the credibility of the e-platform. Under this circumstance, to stabilize the operation of the supply chain and prevent the chain from breaking, the e-platform must pay attention to the manufacturer's profit and make appropriate 'profit transferring' to the manufacturer. In LCECSC, this kind of profit-transferring preference decision is particularly important. For low-carbon product manufacturers, the manufacturing and development of low-carbon products require more investment. However, by contrast with the traditional offline supply chain where manufacturers play dominant roles, manufacturers play follower roles in LCECSC, so the manufacturers' profits are lower and the pressure to produce low-carbon products becomes greater. In this case, on the one hand, e-platforms need to maintain a good cooperative relationship with manufacturers. On the other hand, e-platforms need to respond to the requirements of low-carbon development and increase manufacturers' enthusiasm for emission reduction. Therefore, e-platforms will pay attention to the follower manufacturers' profits and concede to manufacturers.

In LCECSC, the altruistic preference adopted by the e-platform to maintain system stability is not the mutual altruism between the e-platform and the manufacturer, but the pure altruism of the e-platform [17,59]. In the actual LCECSC, e-platforms have a huge customer base and occupy a dominant position, relying on economies of scale to achieve large-scale profits, while manufacturers not only face the problem of losing the right to speak but also of being less profitable. Therefore, this paper only considers the pure altruistic behavior of the e-platform to concede to the manufacturer and increase the willingness of the manufacturer to cooperate.

When the e-platform considers altruistic preference, the manufacturer still makes decisions to maximize its profit. The e-platform takes the manufacturer's profit as the reference for its decision, then maximize its utility to make decision. Drawing on the altruistic preference function given by Katok et al. [60] and Loch and Wu [53], the utility function of altruistic preference of the e-platform can be shown as:

$$U_e = \pi_e - \theta(\pi_e - \pi_m) \tag{7}$$

where θ is the altruistic preference coefficient of the e-platform. The smaller θ, the less the e-platform concerns about the manufacturer's profit, and vice versa. At this time, the e-platform makes decisions intending to maximize its utility. The dominator e-platform and the follower manufacturer still constitute a Stackelberg game. The optimal decision can be obtained by the reverse induction method, which is shown in Table 2.

The proof is similar to Section 4.1.

In reality, the e-platform only considers the altruistic preference when its own profit is guaranteed. Therefore, in the optimal decisions, it must be satisfied that $s^{A*} > 0$, $p^{A*} > 0$, $h^{A*} > 0$, and $\pi_e^{A*} > 0$, then $0 \leq \theta < \overline{\theta}$ can be got. Therefore, the feasible range of the degree of altruistic preference is $0 \leq \theta < \overline{\theta}$. Under this condition, the relevant conclusions are analyzed below. Among them, $\overline{\theta} = \frac{k(2t\beta - \lambda^2)}{2kt\beta + t\gamma^2 - k\lambda^2}$, and $0.5 < \overline{\theta} < 1$.

Proposition 4. *s^{A*}, p^{A*}, h^{A*}, and q^{A*} increase with the increase of θ; π_m^{A*} and U_e^{A*} increase with θ; π_e^{A*} decreases with θ.*

The proof is similar to Proposition 1.

Proposition 4 indicates that the higher the altruistic preference coefficient, the higher the service level, sales price, carbon emission reduction level, and market demand. The profit of the manufacturer also increases with the altruistic preference coefficient, but the profit of the e-platform decreases. This is because the e-platform focuses on the manufacturer's profit and increases sales by improving service level, and ultimately achieves an increase in the manufacturer's profit. However, the e-platform with altruistic preference has caused its profit to decline due to the increase in service costs. It can also be seen from Proposition 4 that due to the altruistic preference of the e-platform, the manufacturer invests more funds to increase the carbon emission reduction level and sales price.

It is worth noting that although the increase in commission in Proposition 2 also increases the service level and sales price, it is different from the increase caused by the altruistic preference here. In Proposition 2, the e-platform aims to increase its profit to increase commission, thereby improving service level to attract consumers. In this proposition, increasing altruistic preference means that the e-platform considers both its profit and the manufacturer's, and actively improves the service level to increase the market share, thereby improving the platform's reputation.

Proposition 5. *When* $0 \leq \theta \leq 0.5$, π^{A*} *is increase with the increase of* θ*; when* $0.5 \leq \theta \leq \overline{\theta}$, π^{A*} *is decrease with* θ, *where* $\overline{\theta} = \frac{k(2t\beta-\lambda^2)}{2kt\beta+t\gamma^2-k\lambda^2}$.

Proof. $\frac{\partial \pi^{A*}}{\partial \theta} = \frac{t^2(1-2\theta)\left[t\beta\gamma^3\rho+k\gamma(\alpha-\beta\rho)(2t\beta-\lambda^2)\right]^2}{(2t\beta-\lambda^2)[k(1-\theta)(2t\beta-\lambda^2)-t\gamma^2\theta]^3}$, binding conditions $2t\beta-\lambda^2>0$, $0 \leq \theta < \frac{k(2t\beta-\lambda^2)}{2kt\beta+t\gamma^2-k\lambda^2}$, when $0 \leq \theta \leq 0.5$, $\frac{\partial \pi^{A*}}{\partial \theta} \geq 0$ can be get; when $0.5 < \theta \leq \overline{\theta}$, $\frac{\partial \pi^{A*}}{\partial \theta} < 0$.

Proposition 5 indicates that the changes in system profit are related to the value of θ. When $0 \leq \theta \leq 0.5$, as θ increases, the manufacturer increases its enthusiasm for cooperation due to the altruistic preference adopted by the e-platform. The e-platform and the manufacturer work closely together to promote the efficient operation of LCECSC, then the manufacturer's and the system profits increase. When $\theta = 0.5$, the system reached the highest profit. Therefore, when $0 \leq \theta \leq 0.5$, the altruistic preference behavior is conducive to the overall operation of LCECSC. However, when the degree of altruistic preference exceeds $0.5(0.5 < \theta \leq \overline{\theta})$, the altruistic preference reduces the system profit and is not conducive to the cooperation between the e-platform and the manufacturer. Altruistic preference is the 'profit transferring' action that transfers the e-platform's profit to the manufacturer, which conflicts with the reality that the e-platform hopes to maximize its profit. Therefore, the e-platform in real life is often forced by the manufacturer and external pressures to engage in altruistic preference behavior, and the altruistic preference coefficient generally less than 0.5. □

5. Extended Model

5.1. The Commission-Based Extended Model with Altruistic Preference

With the increase in the commission, the e-platform's profit increases, while the manufacturer's decreases. From Proposition 3, it can be seen that the manufacturer's profit is higher than the e-platform's, which reduces the profit gap between the two parties in the supply chain. Furthermore, the e-platform's altruistic preference degree increases, which means that there is a proportional relationship between θ and ρ. For example, JD has a commission rate of 12%, which is much higher than other similar platforms, but it invests in building warehouses and logistics to improve distribution efficiency and increase consumers' platform loyalty.

Therefore, in this extended model, assuming that the altruistic preference coefficient is positively related to the commission to analyze the impact of commission on altruistic preference, that is $\theta = l\rho + f$. In actual operation, the commission generally does not exceed 30% of the sales price [58], so this paper assumes that $\rho \leq 0.6p$. On this basis, the optimal decision under altruistic preference is solved as follows:

$$p^{E*} = \frac{t(1-f-l\rho)\left[t\beta\gamma^2\rho+k(2t\beta-\lambda^2)(\alpha-\beta\rho)\right]}{[k(2t\beta-\lambda^2)-(f+l\rho)(2kt\beta+t\gamma^2-k\lambda^2)](2t\beta-\lambda^2)}+\rho$$

$$h^{E*} = \frac{\lambda(1-f-l\rho)\left[t\beta\gamma^2\rho+k(2t\beta-\lambda^2)(\alpha-\beta\rho)\right]}{[k(2t\beta-\lambda^2)-(f+l\rho)(2kt\beta+t\gamma^2-k\lambda^2)](2t\beta-\lambda^2)}$$

$$s^{E*} = \frac{t\gamma[(f+l\rho)(\alpha-2\beta\rho)+\beta\rho]}{k(2t\beta-\lambda^2)-(f+l\rho)(2kt\beta+t\gamma^2-k\lambda^2)}$$

$$q^{E*} = \frac{t\beta(1-f-l\rho)\left[t\beta\gamma^2\rho+k(2t\beta-\lambda^2)(\alpha-\beta\rho)\right]}{k(2t\beta-\lambda^2)^2}$$

$$\pi_m^{E*} = \frac{t\left[t\beta\gamma^2\rho+k(\alpha-\beta\rho)(2t\beta-\lambda^2)\right]^2}{2k^2(2t\beta-\lambda^2)^3}$$

$$\pi_e^{E*} = \frac{t\beta\rho\left[t\beta\gamma^2\rho+k(2t\beta-\lambda^2)(\alpha-\beta\rho)\right]}{2k(2t\beta-\lambda^2)^2}$$

$$\pi^{E*} = \pi_m^{D*} + \pi_e^{D*}$$

Proposition 6. *s^{E*}, p^{E*}, and π_e^{E*} increase with the increase of ρ; h^{E*}, q^{E*}, and π_m^{E*} decrease with ρ.*

Proof. The first derivative proof of s^{E*}, p^{E*} about ρ is the same as Proposition 1.

Order $\frac{\partial h^{E*}}{\partial \rho} = 0$, $\rho_1 = \rho''$, $\rho_2 = \rho'''$ can be get, where,

$$\begin{aligned}&\rho''\\&= \left\{l\beta\left(2kt\beta - t\gamma^2 - k\lambda^2\right)\left[k\left(2t\beta - \lambda^2\right) - f\left(2kt\beta + t\gamma^2 - k\lambda^2\right)\right]\right.\\&\left.+\sqrt{[kl\alpha(2t\beta - \lambda^2) + f\beta](2kt\beta + t\gamma^2 - k\lambda^2) - \beta(2kt\beta - k\lambda^2 - f)(2kt\beta - t\gamma^2 - k\lambda^2)}\right\}\\&/\left[l^2\beta\left(2kt\beta - t\gamma^2 - k\lambda^2\right)\left(2kt\beta + t\gamma^2 - k\lambda^2\right)\right]\end{aligned}$$

$$\begin{aligned}&\rho'''\\&= \left\{l\beta\left(2kt\beta - t\gamma^2 - k\lambda^2\right)\left[k\left(2t\beta - \lambda^2\right) - f\left(2kt\beta + t\gamma^2 - k\lambda^2\right)\right]\right.\\&\left.+\sqrt{[kl\alpha(2t\beta - \lambda^2) + f\beta](2kt\beta + t\gamma^2 - k\lambda^2) - \beta(2kt\beta - k\lambda^2 - f)(2kt\beta - t\gamma^2 - k\lambda^2)}\right\}\\&/\left[l^2\beta\left(2kt\beta - t\gamma^2 - k\lambda^2\right)\left(2kt\beta + t\gamma^2 - k\lambda^2\right)\right]\end{aligned}$$

But $\rho''' < 0$, the conditions are not met, discard it.

From $\rho \le 0.5p$, $\rho \le \overline{\rho}$ can be get, where $\overline{\rho} = \frac{t(1-f-l\rho)\left[t\beta\gamma^2\rho + k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)\right]}{3[k(2t\beta-\lambda^2)-(f+l\rho)(2kt\beta+t\gamma^2-k\lambda^2)](2t\beta-\lambda^2)}$.

And $\rho'' > \overline{\rho}$, when $\rho \le \overline{\rho} < \rho''$, $\frac{\partial h^{E*}}{\partial \rho} \le 0$ can be obtained; therefore, when $\rho \le \overline{\rho}$, h^{E*} is negatively correlated with ρ.

In the same way, it can be proved that when $\rho \le \overline{\rho}$, q^{E*}, π_m^{E*} are negatively correlated with ρ. □

From Proposition 6, it can be concluded that under the assumption of $\theta = l\rho + f$, the higher the commission, the higher the service level and the sales price, which is consistent with Proposition 2. But the higher the commission, the lower the carbon emission reduction level, the sales, and the manufacturer's profit, which is consistent with Proposition 2 but contrary to Proposition 4. This shows that altruistic preference is not enough to make up for the loss due to increased commission. Therefore, to maintain the stable operation of the system, the e-platform should appropriately reduce the commission, which is more obvious in the operation of some large-scale e-platforms with strong strength and abundant funds. For example, Tophatter, a new e-platform in the United States that focuses on mobile auction shopping, has achieved a 30-fold breakthrough in daily sales by reducing its commission rate by 50%.

5.2. Comparative Analysis between Models

With the increase in the commission, the e-platform's profit increases, while the manufacturer's decreases. From Proposition 3, it can be seen that the manufacturer's profit is higher than the e-platform's, which reduces the profit gap between the two parties in the supply chain. Furthermore, the e-platform's altruistic preference degree increases, which means that there is a proportional relationship between θ and ρ. For example, JD has a commission rate of 12%, which is much higher than other similar platforms, but it invests in building warehouses and logistics to improve distribution efficiency and increase consumers' platform loyalty.

Comparing the optimal decision in the extended model and the basic model without altruistic preference, conclusion 1 can be obtained.

Conclusion 1. *$s^{E*} \ge s^{D*}$, $p^{E*} \ge p^{D*}$, $h^{E*} \ge h^{D*}$, $q^{E*} \ge q^{D*}$.* (ii) *$\pi_m^{E*} \ge \pi_m^{D*}$, $\pi_e^{E*} \le \pi_e^{D*}$, $\pi^{E*} \ge \pi^{D*}$.*

Proof. $s^{E*} - s^{D*} = \frac{t\gamma(f+l\rho)\left[k\left(2t\beta-\lambda^2\right)(\alpha-\beta\rho)+t\beta\gamma^2\rho\right]}{k(2t\beta-\lambda^2)[k(2t\beta-\lambda^2)(1-f-l\rho)-t\gamma^2(f+l\rho)]} \geq 0$, similarly, $p^{E*} \geq p^{D*}$ $h^{E*} \geq h^{D*}$, $q^{E*} \geq q^{D*}$, $\pi_m^{E*} \geq \pi_m^{D*}$, $\pi_e^{E*} \leq \pi_e^{D*}$,$\pi^{E*} \geq \pi^{D*}$. □

From Conclusion 1(i), it can be concluded that compared with the basic model where the e-platform does not adopt altruistic preference, the service level, sales price, the carbon emission reduction level, and sales are higher in the extended model. This is because the e-platform adopts altruistic preference by improving the service level, and the manufacturer increases the carbon emission reduction level, which increases sales price. However, the positive impact of service level and carbon emission reduction level on sales is stronger than the negative impact due to the increase in the sales price, which leads to an increase in sales. This means the e-platform adopts altruistic preference is conducive to the system operation, that is the e-platform with the right to speak should also consider the manufacturer's profit while considering its own profit. The e-platform must realize that only high-quality products and high-quality services can maintain consumer traffic and increase consumer loyalty, thereby enhancing economic and environmental performances.

From Conclusion 1(ii), it can be seen that, compared with the basic model without altruistic preference, the manufacturer's and system profits are higher, and the e-platform's profit is lower in the extended model. Also, although the e-platform's adoption of an altruistic preference is not conducive to increasing its own profit, it is conducive to the system operation.

6. Numerical Analysis

To further analyze the relationship between decision variables and parameters in the models, the following analysis was carried out in combination with numerical examples. Matlab software was used for numerical analysis. Similar to Zhang and Wang [4], Fan et al. [1], Zhao et al. [29], low-carbon products are considered for numerical analysis with the following parameter values, that is $\alpha = 100$, $\beta = 2$, $\gamma = 1$, $\lambda = 1$, $\rho = 6$, $t = 3$, $k = 2$, and taking $\theta(\theta \in [0,\ 0.7])$ as the independent variable. In "Model Illustration and Assumptions" and "The Basic Model with Altruistic Preference", two main constraints were proposed, that is $2kt\beta - t\gamma^2 - k\lambda^2 > 0$ and $0 \leq \theta < \overline{\theta}$, where $\overline{\theta} = \frac{k\left(2t\beta-\lambda^2\right)}{2kt\beta+t\gamma^2-k\lambda^2}$, and $0.5 < \overline{\theta} < 1$. The values of the parameters should satisfy these two constraints. Considering that the optimal decision should have practical meaning, the values of the parameters also ensured that the optimal decisions were positive.

When $\alpha = 100$, $\beta = 2$, $\gamma = 1$, $\lambda = 1$, $\rho = 6$, $t = 3$, and $k = 2$, $2kt\beta - t\gamma^2 - k\lambda^2 = 19$ (satisfying $2kt\beta - t\gamma^2 - k\lambda^2 > 0$), and $\overline{\theta} = \frac{k\left(2t\beta-\lambda^2\right)}{2kt\beta+t\gamma^2-k\lambda^2} = 0.88$ (satisfying $0.5 < \overline{\theta} < 1$). According to $0 \leq \theta < \overline{\theta}$, $\theta(\theta \in [0,\ 0.7])$ is reasonable. Therefore, draw the changing graphs of the decision variables in the basic models with the altruistic preference coefficient, which are shown in Figure 2.

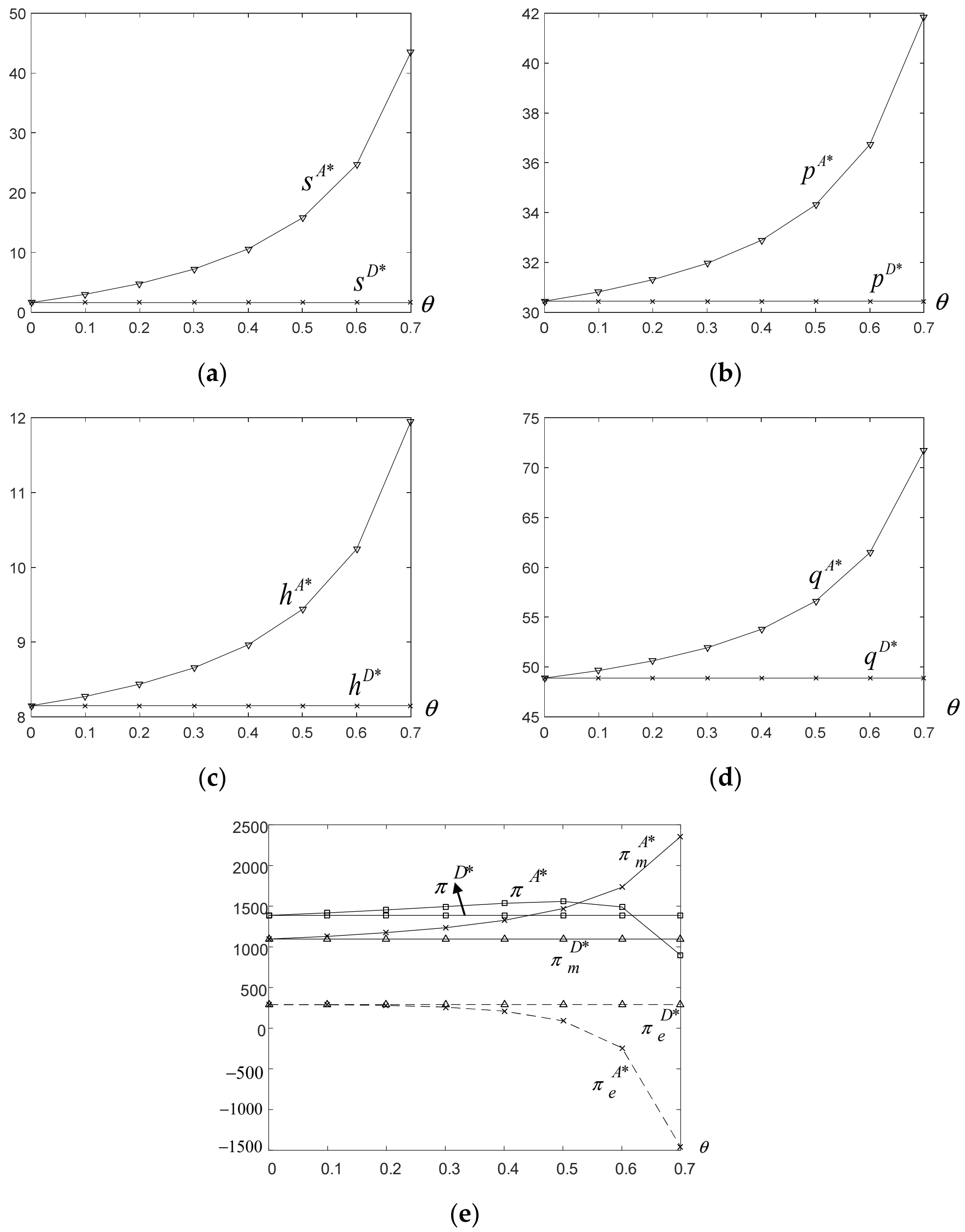


Figure 2. Changing graphs of the decision variables in the basic models with the altruistic preference coefficient: (**a**) the changes of s over θ; (**b**) the change of p over θ; (**c**) the changes of h over θ; (**d**) the changes of q over θ; (**e**) the changes of profits over θ.

According to Figure 2, in the basic models, all decision variables change in the same direction as the altruistic preference coefficient, and the manufacturer's profit is also the same, but the e-platform's profit is opposite. This is consistent with Proposition 4. The higher the e-platform's attention to the manufacturer, the higher the service level. At this time, the manufacturer increases the carbon emission reduction level, then the sales will increase accordingly. The altruistic preference behavior is to transfer part of the e-platform's profit to the manufacturer. Therefore, while the manufacturer's profitability increases, the e-platform's decreases, and when the altruistic preference coefficient is too large, the profit of the e-platform is even negative. It means that the e-platform should adopt altruistic preference within an acceptable range. According to the change of the system profit in Figure 2e when $\theta < 0.5$, the system profit increases accordingly, which can improve the cooperation enthusiasm of the manufacturer and promote the cooperation between supply chain members. When $\theta = 0.5$, the system profit reaches the maximum. But when $\theta > 0.5$, the e-platform's profit is excessively damaged, and the altruistic preference is not conducive to the system operation.

Next, assuming $f = 1/30$ and $l = 0$, $\rho(\rho \in [0, 20])$ is taken as the independent variable. The values of the parameters in this part need to meet two main constraints, that is $2kt\beta - t\gamma^2 - k\lambda^2 > 0$ and $\rho \le 0.6p$. The values of the parameters should satisfy these two constraints. Considering that the optimal decision should have practical meaning, the values of the parameters also ensure that the optimal decisions are positive.

When $\alpha = 100$, $\beta = 2$, $\gamma = 1$, $\lambda = 1$, $t = 3$, $k = 2$, $f = 1/30$, $l = 0$, and taking $\rho(\rho \in [0, 20])$, $2kt\beta - t\gamma^2 - k\lambda^2 = 19$ (satisfying $2kt\beta - t\gamma^2 - k\lambda^2 > 0$), and according to $\rho \le 0.6p$, ρ should satisfy $\rho \le 22.71$, so $\rho \in [0, 20]$ is reasonable. Therefore, graphs of the changes of each variable in the extended model and the basic model without altruistic preference are drawn, as shown in Figure 3.

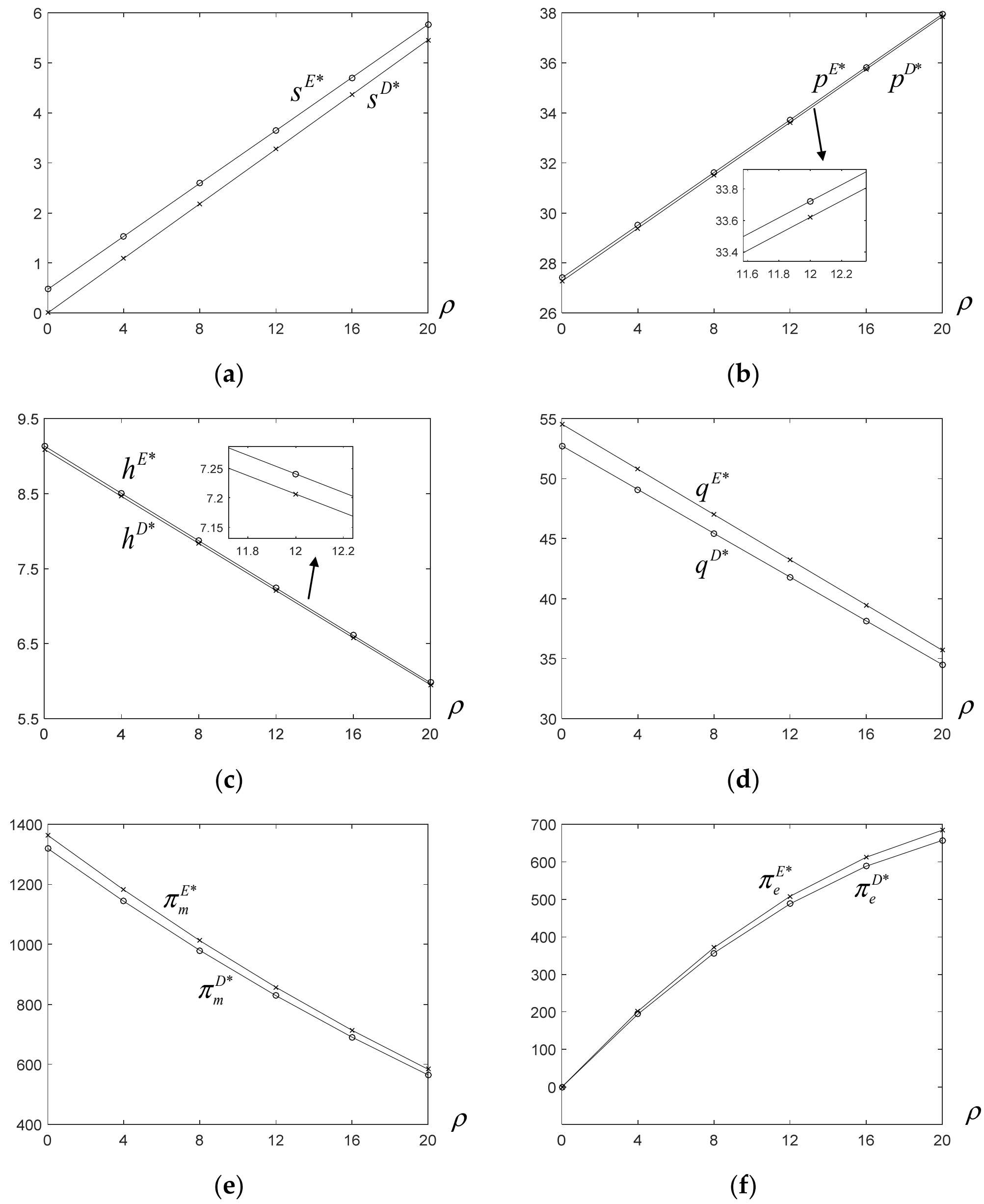
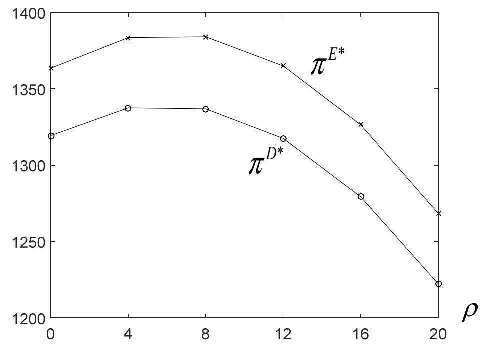


Figure 3. *Cont.*



(**g**)

Figure 3. Graphs of the changes of each variable in the extended model and the basic model without altruistic preference: (**a**) the changes of s over ρ; (**b**) the changes of p over ρ; (**c**) the changes of h over ρ; (**d**) the changes of q over ρ; (**e**) the changes of the manufacturer profits over ρ; (**f**) the changes of the e-platform's profit over ρ; (**g**) the changes of the systems' profits over ρ.

As can be seen from Figure 3, when $\rho \in [0, 20]$, in the extended model and the basic model without altruistic preference, the changes of variables with the commission are consistent with Proposition 2. Moreover, compared with the basic model without altruistic preference, the variables in the extended model are higher, and in particular the service level is much higher. This is because the altruistic preference is reflected in improving service levels to attract more consumers. In addition, when the commission is not high, the difference between the optimal decisions in the two models is larger, but with the increase of the commission, the difference becomes smaller. This indicates that when the commission is too high, the altruistic preference behavior of the e-platform does not significantly promote the system operation. Therefore, the e-platform should choose a reasonable commission.

It is worth noting that compared with the basic model without altruistic preference, the e-platform's profit is lower in the commission-based extended model (Conclusion 1). But the difference between the two models is very small from Figure 3e, and as the commission increases, the difference becomes smaller. This shows that in the commission-based extended model with altruistic preference, the e-platform always implements an altruistic preference based on ensuring its own profit.

7. Conclusions

In recent years, with the improvement of low-carbon awareness and the popularity of e-commerce, the manufacturer has settled in the e-platform to sell low-carbon products, which puts the manufacturer at a disadvantage in LCECSC. In this context, research on the altruistic preference of the e-platform, the dominant player in LCECSC, has become a new focus. This paper establishes two basic models with or without altruistic preference. On this basis, endogenizing the influence of commission on the degree of altruistic preference, the commission-based extended model with altruistic preference is established, then the optimal decisions of the three models are analyzed. The research shows:

(1) By contrast with the conclusion that the dominant player has the highest profit in the traditional supply chain, in the LCECSC system composed of a dominator e-platform and a follower manufacturer, the e-platform's profit is lower than the manufacturer's (Proposition 3). This is because the e-platform is a shared platform that generates economies of scale by serving many manufacturers. However, the e-platform serves a single manufacturer, and its profit is lower than the manufacturer's profit.

(2) With the improvement of consumers' carbon emission reduction elasticity coefficient, service level, sales price, carbon emission reduction level, sales, supply chain members profits, and system profit all have a rising trend. This is because demand drives production and consumers' preference for low-carbon products encourages the manufac-

turer to spend more on carbon emission reduction. It also makes the e-platform increase the service level, further increasing the sales price and sales, then improves economic and environmental performances.

Although the increase in the carbon emission reduction level causes an increase in sales prices, the sales does not decrease due to the increase in sales price. The main reason is that compared with the negative impact of sales price on sales, the increase in carbon emission reduction level and service level has a greater positive impact on sales. This is an important difference between low-carbon products and traditional products (Proposition 1).

(3) In the model with altruistic preference, when $\theta < 0.5$, system profit is positively related to θ. The service level, sales price, the carbon emission reduction level, and the manufacturer's profit increase with θ increases, but the e-platform's profit decreases. This means that the e-platform's moderate altruistic preference behavior ($\theta < 0.5$) is not conducive to the growth of its profit, but it is conducive to the development of LCECSC.

Through the research of this paper, we can obtain these theoretical and practical implications:

Theoretical implications: first, this paper considers the altruistic preference of the e-platforms when discussing the sales of low-carbon products, which has guiding significance for the research of irrational behaviors in online sales. Second, after constructing two basic model with or without altruistic preference, this paper further constructs an extended model of altruistic preference as a proportional function of commission, which enriches the theoretical basis of research on low-carbon product sales and altruistic preference.

Practical implications: (1) through the conclusion that the improvement of consumers' carbon emission reduction elasticity can improve the economic and environmental benefits of the supply chain, we can conclude that the dominant e-platform must not only actively promote low-carbon products but also increase consumers' low-carbon awareness. (2) Since the appropriate profit-making behavior of the e-platform is conducive to the development of LCECSC, the e-platform can benefit the manufacturer and attract consumers by improving service levels. This kind of profit-making behavior can not only enhance the willingness of manufacturers to cooperate, but also ensure a good shopping experience for consumers, thereby promoting the healthy and sustainable development of LCECSC. (3) Although the increase in the carbon emission reduction level has led to an increase in product price, the sales of low-carbon product have not declined due to the increase in prices. Therefore, the follower manufacturer should promote environmentally friendly low-carbon products and cultivate a low-carbon consumer market in the form of 'small profits but quick turnover'. In the long run, the manufacturer's initial investment will bring huge economic and environmental performance improvements.

The research has certain limitations and we will explore them, mainly as follows:

(1) The paper only considers the impact of carbon emission reduction and altruistic preference on LCECSC's decision-making. Carbon trading mechanisms, carbon tax, and other environmental policies will also have an impact on LCECSC's decisions and operation. Research on this aspect will be our next research direction.
(2) The paper only considers the LCECSC composed of a single manufacturer and a single e-platform. In reality, the e-platform often cooperates with multiple manufacturers. Research on this "one-to-many" LCECSC will be more practical and instructive.
(3) The paper only considers the impact of economic and environmental benefits, and does not consider other factors that affect the sustainable development of the supply chain, such as consumer surplus. This will be our next research direction.

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