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Decisions and Coordination in E-Commerce Supply Chain under Logistics Outsourcing and Altruistic Preferences

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Abstract: Considering the peculiarities of logistics in the electronic commerce (e-commerce) supply chain (ESC) and e-commerce platform's altruistic preferences, a model including an e-commerce platform, third-party logistics service provider, and manufacturer is constructed. Based on this, three decision models are proposed and equilibrium solutions are obtained by the Stackelberg game. Then, an "altruistic preference joint fixed-cost" contract is proposed to maximize system efficiency. Finally, numerical analysis is used to validate the findings of the paper. The article not only analyzes and compares the optimal decisions under different ESC models, but also explores the intrinsic factors affecting the decisions. This paper finds that the conclusions of dual-channel supply chains or traditional supply chains do not necessarily apply to ESC, and that the effect of altruistic behavior under ESC is influenced by consumer preferences. Moreover, there is a multiparty win–win state for ESC, and this state can be achieved through the "altruistic preference joint fixed-cost" contract. Therefore, the findings of this paper contribute to the development of an e-commerce market and the cooperation of ESC members.

Keywords: electronic commerce supply chain; altruistic preference; third-party logistics service provider; sales promotion service level

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1. Introduction

Currently, with the tremendous advances in Internet technology, online shopping has become increasingly popular among consumers. According to CNNIC (cnnic.com), Chinese online shopping users reached 649 million in 2019, with a penetration rate of 76.2% and transaction value of RMB 6.66 trillion yuan. Meanwhile, many manufacturers have entered electronic commerce (e-commerce) platforms (as e-platforms) [1], and entrusted logistics operators to deliver their products to consumers, which has promoted the emergence of the electronic commerce supply chain (ESC) consisting of e-platforms, manufacturers, and logistics operators. Compared to the traditional supply chain, the ESC breaks through the limitations of time and geography, which makes the ESC more convenient for consumers [2]. Moreover, the ESC eliminates the intermediate steps and transaction costs [3], making the online products more price competitive and the ESC more competitive than the traditional supply chain [4].

The ESCs' growth underscores the growing prominence of logistics. Unlike shopping in brick-and-mortar stores, there is often a spatial separation between consumers and products in online shopping, which makes logistics necessary in ESC [5]. In ESCs, consumers' satisfaction and loyalty are highly influenced by logistics, especially the speed and quality of delivery [6]. Therefore, many e-commerce companies regard logistics as an important advantage of sustainable competitiveness [7]. According to Chen and Hua [8], the ESC's logistics model can be broadly divided into self-built logistics of e-platforms and logistics outsourcing. In this model of logistics outsourcing, e-platform cooperates with the third-party logistics service provider (TPLSP), which has two advantages compared to self-built logistics. On the one hand, the logistics outsourcing model can save e-platforms' costs associated with the logistics system construction and transportation, which can allow e-platforms to focus on their strengths [9]. On the other hand, by cooperating with different TPLSPs, e-platforms can achieve both speedy delivery of products with time-sensitive requirements and low-cost delivery of ordinary products, which can cater to the different service preferences of consumers. Logistics outsourcing can increase the flexibility of logistics services and ultimately achieve ESC cost reduction and performance improvement [10].

However, the entry of TPLSPs has created higher requirements for cooperation with ESCs. On the one hand, e-commerce platforms need to consider more factors when providing sales promotion services (SP-services) such as product promotion, online customer service and after-sales service, various payment methods. On the other hand, in ESCs e-platforms have a large customer base and a well-developed management system, which generally gives them greater power in collaboration. In the process of maximizing their own profits, e-platforms are sometimes in conflict with subordinate manufacturers and TPLSPs. For example, in July 2017, JD (WWW.JD.COM) announced a unilateral suspension of cooperation with TTK Express, followed by the inclusion of YTO Express, Express-Mail Services, Best Express, and Depp on the non-recommended list (The report can be viewed from http://www.ebrun.com/20170801/240633.shtml). Additionally, in the second half of 2017, numerous household and apparel companies exited JD due to infringement of their rights by the platform (Reported on https://news.cngold.org/c/2017-10-30/c5430025.html). This tit-for-tat between e-platforms and subordinate companies is detrimental. Therefore, to minimize the profits lost due to conflicts within ESC, e-platforms are beginning to consider the interests of their partners. That is, e-platforms have an altruistic preference in working with subordinate firms in ESC [11]. For example, in 2019, JD launched the "JD Group Buy" plan, which formulated a series of preferential policies for merchants who promote group buying. Ultimately, these preferential policies not only brought an increase in turnover for merchants, but also led to an increase in the merchants and users of JD platform (Available from http://mjbbs.jd.com/thread-166161-1-1.html). Coincidentally, SUNING (www.suning.com) implemented subsidies for partners and logistics operators in 2018's Double 11 online shopping festival, thus fulfilling the promise of no higher price for consumers. This subsidy strategy contributed to the product sales growth of SUNING and formed a win-win situation (Accessed from http://news.sohu.com/20181112/n555099979.shtml). These practices not only illustrate the complexities of competitive cooperation in ESCs but also provide a context for the introduction of altruistic preferences in ESC research.

Logistics outsourcing increase the complexity of ESC operations, and the altruistic preferences of e-platforms affect the decisions and profits of ESC participants. Therefore, based on existing studies, the study aims to answer the following questions.

(1) What factors will influence TPLSP's decision? What pricing strategy should the TPLSP adopt? How does consumer preference for logistics services price affect sales and the profit of TPLSP?

(2) What are the motivations for e-platforms to implement altruistic behavior? How does the e-platform's altruistic preference influence ESC members' decisions? Is altruistic preference conducive to increasing the e-platform's profits?

(3) Considering the altruistic preference of the e-platform, how should the coordination mechanism be designed for maximum ESC efficiency and profitability? What factors would affect the feasible scope of a coordination mechanism?

The contributions of the study are the following.

Firstly, TPLSPs and e-platforms are rarely considered as the decision maker in existing studies on ESCs [12]. This paper constructs an ESC model consisting of a manufacturer, a TPLSP, and an e-platform, and makes decisions about the e-platform's sales promotion services level, logistics services price, and sales price. This study finds that improved consumer preference for the sales promotion service level can make ESC members more profitable, but increased consumer preference for logistics services prices can decrease profits. Moreover, the sales price in centralized decision-making is not the lowest, but higher than that in a decentralized model where ESC members are completely rational, which differs from the findings of traditional and dual-channel supply chains [13,14].

Secondly, unlike the studies on altruistic preferences in traditional offline and dual-channel supply chains [15,16], this paper considers altruistic preferences of the e-platform for manufacturer and TPLSP. The study found that e-platform's altruistic preferences enhance the profits of subordinated companies and the ESC system while harming her own profits. Additionally, the altruistic preferences on different subordinate firms have an effect on consumer preferences. When consumers have a higher desire for the low sales price, e-platform's altruistic behavior for TPLSP is more effective. Conversely, when consumers have a higher desire for low logistics services price, e-platform's altruistic behavior for manufacturer exerts better results.

Thirdly, most of the existing literature adopts the common coordination approach of revenue-sharing or cost-sharing to achieve optimal decisions in the supply chain. In contrast, altruistic preferences are used as the coordination tool to design the contract of "altruistic preference joint fixed-cost" to achieve ESC coordination. Furthermore, increased consumer preference for sales price and the sales promotion service cost coefficient narrow the feasible scope of the contract, while the improvement in consumer preference for sales promotion service level widens the feasibility range.

The study is structured as follows: the literature review is presented in Section 2. Section 3 gives model descriptions and assumptions. In Section 4, three decision models for ESC are constructed. A coordination mechanism is proposed in Section 5. Numerical simulation is given in Section 6. Finally, Section 7 gives conclusions and management insights.

2. Literature Review

The literature is reviewed in the following three streams.

2.1. Logistics Outsourcing in Supply Chains

The logistics outsourcing model in the supply chain has been extensively studied by scholars. Liu and Lyons [17] assess the relationship between service capability and performance of third-party logistics providers using the UK and Taiwan as examples. Raut et al. [18] identify criteria for evaluating and selecting third-party logistics through a fuzzy multi-criteria decision approach. Tsai et al. [19] examine potential risk factors that may lead to the breakdown of logistics outsourcing relationships. For the fresh produce supply chain, Cai et al. [20] show that logistics outsourcing has a significant impact on supply chain performance. Based on this, Yu and Xiao [21] investigate service levels and pricing decisions for fresh produce under logistics outsourcing. Based on the product life cycle, Shen et al. [22] explore the role of logistics services in global supply chains and examine the impact of the seller's and buyer's transport mode choices on the supply chain. Lou et al. [23] discuss the retailer's choice of logistics model in a retailer-led supply chain and research the changes in logistics service levels following logistics outsourcing. Niu and Mu [24] study the outsourcing structure options for original equipment manufacturers and logistics service providers with sustainable outcomes.

The above literature provides the basis for the study of logistics outsourcing in ESCs. Unlike logistics in the traditional supply chain, logistics in ESC becomes a major factor in online product sales [25,26], customer satisfaction, and purchase intention [27,28], and e-commerce marketplace [14]. Therefore, should a logistics outsourcing model be adopted in ESC? How will logistics outsourcing affect ESC? These questions need to be addressed urgently. To address the mismatch between logistics operators' capacity and ESC product sales, Liu et al. [29] achieve improved ESC performance through option contracts, while Zhang et al. [30] study the expansion decisions of logistics operators. Considering direct online sales of multi-generational products by manufacturers, Jia et al. [31] discuss service pricing strategies of logistics service providers. Considering online retailers, Rai et al. [32] propose adjustment strategies for traditional third-party logistics providers, while Xu et al. [7] examine the determination of logistics service levels in ESCs and research the effect of logistics models on e-retailers' purchase intentions. However, e-platforms are not regarded as ESC decision-makers in the aforementioned studies, and an ESC that includes the independent e-platform as a decision-maker is the subject of this paper. Considering the independent e-platform, Song and He [33] construct the fresh produce ESC consisting of community convenience shop, fresh produce e-commerce firm, and TPLSP, to study logistics pricing and designed the coordination mechanism, but they have significant industry limitations. On the basis that sellers can self-select TPLSP or the e-platform's logistics, Qin et al. [34] address the impact of the service level of third-party logistics providers on the effectiveness of sharing logistics services between the platform and the seller. However, the logistics model discussed by Qin et al. [34] is different from this paper. This paper examines the cooperation, rather than competition, between TPLSP and the e-platform.

2.2. Altruistic Preferences in Supply Chains

Both altruistic preferences and fairness concerns are common limited rational decision-making behaviors in supply chains, but their starting points, ideas, and roles are different. The differences are presented in Table 1.

Table 1. Differences between altruistic preferences and fairness concerns.

	Altruistic Preferences	**Fairness Concerns**
Starting point	To enhance collaboration with other players and improve system performance.	To improve their own profits.
Intrinsic cause	Driven by fairness norms (economic view) and compassion (psychological view).	The pursue for fairness.
Results	General benefits for supply chain development.	Generally not conducive to supply chain development.
Minds	Self-sacrifice makes a community.	Sacrifice himself to punish others.
Representative Document	Simon [35]; Bowles [36]; Loch and Wu [37].	Fehr and Schmidt [38]; Cui et al. [39]; Ho and Zhang [40].

Currently, fairness concerns have been studied more generally than altruistic preferences. Research on altruistic preferences focuses on experimental economics [41], with relatively few involvements in supply chains. Loch and Wu [37] integrate altruistic preferences into supply chains for the first time and show that most supply chain firms consider altruistic preferences when they include social responsibility as an important factor in business decisions. Ge and Hu [42] propose a basic form of the altruistic preference utility function, which is a weighted function of altruistic preference subject profit and system profit. Wang et al. [43] find that system coordination can be implemented through the logistics service integrator's altruistic preferences. Liu et al. [44] show that altruistic preferences favor the profits of decision-makers only if the coefficient of altruistic preferences is within a certain range. Lin [45] examine the effect of altruistic preferences on integrated channel decisions and refine the revenue-sharing mechanism to achieve system coordination. Huang et al. [46] discover that the greenness of products under manufacturer's altruistic preference is higher than that without altruistic preference. Similarly, Fan et al. [47] discover that retailers' altruistic preferences can contribute to reducing carbon emissions and increasing manufacturers' profits, but the behavior is detrimental to the retailers. Considering the online sales channel in the study of altruistic preferences in the supply chain, Xu and Wang [48] find that altruistic preferences can help resolve channel conflicts between offline and online retailers.

The above studies on altruistic preferences focus on offline traditional supply chains, but only Xu and Wang [48] examine a dual-channel supply chain. However, the ESC of an e-platform as a decision-making entity has different characteristics from other supply chains. In ESC, e-platforms act as information platforms and dominate ESC. In cooperation with other enterprises, e-platforms often use their dominance to make rules that favor their own profits. Such rules usually lead to a loss of profits for the subordinated firms, which often leads to conflicts in the ESC. Therefore, in order to stabilize ESC operations, e-platforms use altruistic behavior towards the subordinated companies in ESC. Moreover, the adoption of altruistic behavior by e-platforms in ESCs differs from traditional and dual-channel supply chains, which makes the study of e-platforms' altruistic preferences in ESCs highly practical significance. It should be mentioned that Wang et al. [49] also include altruistic preferences in ESC. However, the difference is that Wang et al. [49] focus on the effect of recyclers' altruistic preferences on low-carbon closed-loop ESC, while this paper investigates the effect of e-platforms' altruistic preferences on ESC under logistics outsourcing.

2.3. Coordination Mechanism in Electronic Commerce Supply Chains (ESCs)

For the supply chain with an online channel, Chen et al. [50] find that both the two-part tariff or profit-sharing contract can achieve system coordination in dual-channel supply chain. Under the carbon allowances and trading policy, Xu et al. [16] adopt the price discount contract to improve the efficiency of the dual-channel system. Ranjan and Jha [51] increase green product levels and achieve green dual-channel system coordination through residual profit secondary distribution. Considering the e-platform as a decision-maker, Zhang et al. [52] and Zhong et al. [53] achieve the coordination of a leader-follower structure of e-commerce logistics system and a three-stage logistics service ESC using the revenue-sharing contract. Wang et al. [49] coordinate green ESC with manufacturer's fairness concern through a cost-sharing joint-commission contract and find that an improvement in consumer green preferences could increase the feasible scope of the contract. Most of the existing literature adopts the common coordination approach of revenue-sharing or cost-sharing to achieve system coordination in supply chains. In contrast, the study uses altruistic preferences as the coordination tool to design the contract to achieve ESC coordination.

2.4. Contributions of This Study

The main contributions of this paper are as follows. First, most of the existing literature studies logistics outsourcing in traditional or dual-channel supply chains and does not consider the cooperation between independent e-platforms and TPLSPs. However, most e-platforms currently work with TPLSPs to diversify their logistics services, such as eBay (www.ebay.com), Amazon (www.amazon.cn), Taobao (www.taobao.com), etc. Therefore, this paper examines the impact of logistics outsourcing on decision making and coordination in an ESC dominated by e-platforms, which extends the scope of logistics outsourcing research. Second, this paper considers the limited rationality of decision-makers by including the altruistic preferences of e-platforms for manufacturers and TPLSPs, which broadens the study of altruistic preferences in ESCs. Third, this paper provides new ideas for supply chain coordination. Instead of using the common cost-sharing or benefit-sharing models, the paper uses the altruistic preference coefficient as an adjustment tool to achieve ESC coordination.

3. Model Illustration and Assumptions

The Taobao platform, for example, does not set up self-managed logistics but rather sets up the "Cainiao Network" with logistics partners (Retrieved from https://www.cainiao.com/). Currently, manufacturers can only choose logistics providers from the

"Cainiao Network" and outsource their transportation business in Taobao. In this paper, the model is set up based on such platforms and the model structure is shown in Figure 1: ESC consists of a manufacturer, an e-platform (called she), and a TPLSP (called he). The manufacturer produces and sells the product through the e-platform. Consumers obtain product information from e-platform and make a purchase. Then, the e-platform automatically generates order and transmits it to the manufacturer. The manufacturer then processes the order and entrusts the product to the TPLSP for delivery, after which the consumer inspects and signs for the product. Once the order is complete, e-platform transfers the payment to the manufacturer and deducts a percentage of the payment as the commission, while TPLSP receives the postage paid as remuneration for the logistics service.

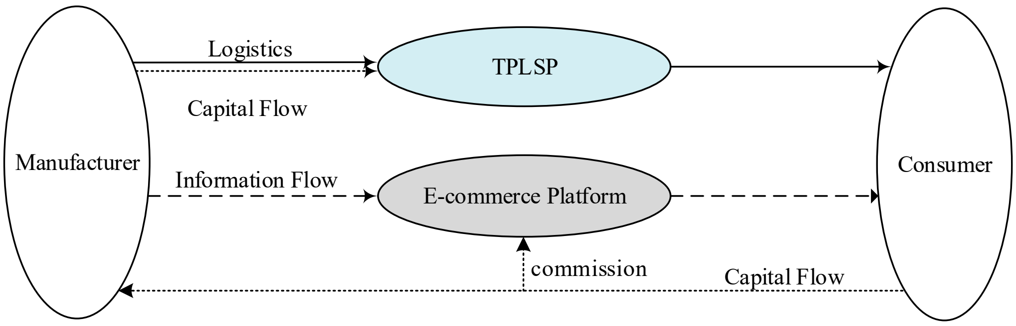


Figure 1. Model structure of electronic commerce supply chain (ESC) under logistics outsourcing.

In the actual ESC, the e-platform sets the rules and manufacturers that meet the requirements can enter the e-platform. There are two main categories of charges paid by manufacturers to e-platforms. (1) Entry fees. Manufacturers of different industries and sizes need to pay different entry fees when first cooperated with the e-platform. Such fees do not change with the actual sales and are considered as fixed costs. To avoid the trivial case, entry fees are not considered in model analysis. (2) Commission. E-platforms provide sales promotion services related to the products for manufacturers, such as product promotion, online customer service and after-sales service, and various payment methods (Accessed from https://fuwu.taobao.com/?spm=a1z13.fuwu-indext-2018.54321-ddsy.1.22a25acaj6FOTv). Therefore, e-platforms earn commissions based on a percentage of product sales, with commission rates typically less than 30%. The notations are illustrated in Table 2.

The model assumes the following:

(1) In ESC, e-platform is a dominant enterprise, manufacturer and TPLSP are subordinated enterprises. Additionally, the TPLSP is only responsible for the logistics and does not participate in other operational decisions.

(2) The e-platform receives the commission depending on a certain percentage of product sales. Therefore, total commission charged by e-platform is ρpq.

(3) It is assumed that product demand is associated with SP-service level, sales price, and logistics services price. According to assumptions of Tang et al. [54], product demand is:

$$q = \alpha - \beta p - \delta p_l + \gamma s \tag{1}$$

(4) Assume that $c'(s) > 0, c''(s) < 0$, following Liu et al. [55], the cost function for SP-services is:

$$C(s) = ks^2/2 \tag{2}$$

(5) Assuming $0 < \delta < \gamma \leq \beta \leq 2\delta \ll \alpha$, this suggests that consumers preferences for sales price are higher than consumers preferences for SP-services or logistics services price. Meanwhile, the sensitivity of consumers to different variables will not change too much, that is, $\beta < 2\delta$.

(6) To make the decisions positive, assume that $4k\beta > \gamma^2$.

Table 2. Notations description.

Notations	Description
c	Unit cost of production for the manufacturer
p	Unit sales price for product (decision variable for manufacturer)
ρ	Commission rate, $0 < \rho < 1$
p_l	Unit logistics service price for the product (decision variable for TPLSP)
s	sales promotion service (SP-service) level (decision variable for the e-platform)
k	SP-service cost coefficient, $k > 0$
α	The market saturation, $\alpha > 0$
β	Sales price elasticity coefficient, $\beta > 0$
γ	SP-service level elasticity coefficient, $\gamma > 0$
δ	Logistics service price elasticity coefficient, $\delta > 0$
v	Unit transport cost of the product, $v > 0$
q	Market demand for the product
$\theta_i (i = 1, 2)$	Altruistic preference coefficient of the e-platform, $0 \leq \theta_i \leq 1$
e, m, l	Decision maker: e represents the e-platform, m represents the manufacturer, l represents TPLSP.
D, F, C	Model: D represents the decentralized model without altruistic preferences, F represents the decentralized model with the e-platform's altruistic preferences, C represents the centralized model.
π_i^n	Profit of decision maker i under model n, $i = e, m, l,\ n$=D, F, C
π^n	Total profit of ESC system under model $n,\ n$=D, F, C
$C(s)$	The cost of SP-services for the e-platform

To analyze the impact of e-platform's altruistic preferences on decision-making, three decision models are constructed. The first is the decentralized decision model where ESC members are completely rational, the second is the decentralized decision model where the e-platform has altruistic preferences, and the third is centralized decision model under logistics outsourcing. The differences between the three decision models are shown in Figure 2.

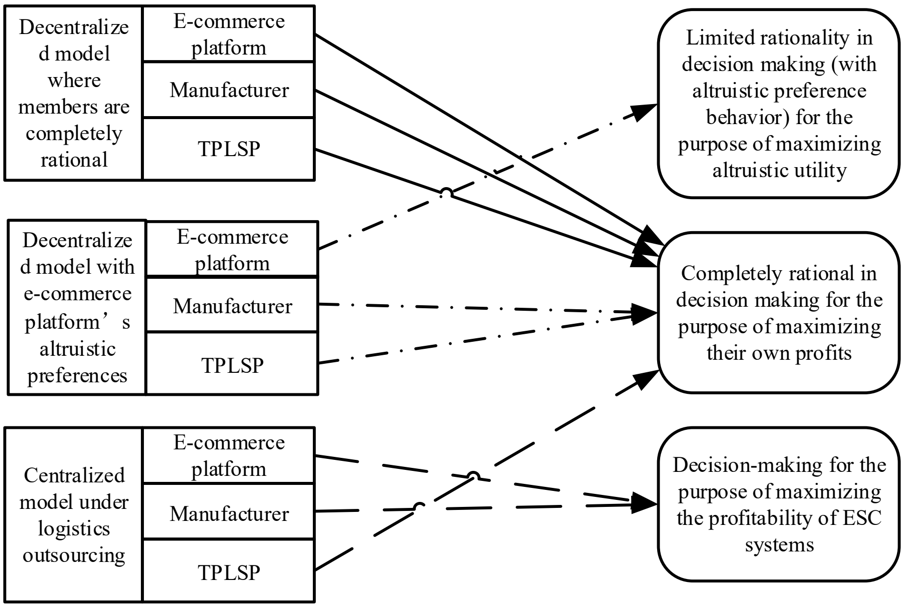


Figure 2. Decision makers' objectives for different decision models.

4. Model Formulation and Equilibrium Solutions

4.1. Decentralized Model where ESC Members are Completely Rational (Case 1)

The logistics outsourcing model in the supply chain has been extensively studied by scholars. Liu and Lyons [17] assess the relationship between service capability and performance of third-party logistics providers using the UK and Taiwan as examples. Raut et al. [18] identify criteria for e-manufacturer's profit is:

$$\pi_m = (p - \rho p - c)q \tag{3}$$

The E-platform's profit is

$$\pi_e = \rho p q - ks^2/2 \tag{4}$$

The TPLSP's profit is

$$\pi_l = (p_l - v)q \tag{5}$$

The ESC's profit is

$$\pi = (p + p_l - c - v)q - ks^2/2 \tag{6}$$

In this case, ESC members' decision-making is that, e-platform first determines s, manufacturer then decides p, TPLSP finally sets p_l. The equilibrium solutions can be obtained by backward induction. Based on Equation (5), by solving $\partial\pi_l/\partial p_l = 0$, the reaction function is:

$$p_l = \frac{\alpha - p\beta + s\gamma + v\delta}{2\delta} \tag{7}$$

Substituting Equation (7) into Equation (1) and calculating $\partial\pi_m/\partial p = 0$, the reaction function is:

$$p = \frac{\alpha + c\beta + s\gamma - v\delta - \alpha\rho - s\gamma\rho + v\delta\rho}{2\beta(1-\rho)} \tag{8}$$

By substituting Equation (8) into Equation (7), the reaction function of p_l is:

$$p_l = \frac{\alpha(1-\rho) + (s\gamma + 3v\delta)(1-\rho) + c\beta}{4\delta(1-\rho)} \tag{9}$$

Substituting Equations (8) and (9) into Equation (2), the SP-service level can be obtained by $\partial\pi_e/\partial s = 0$,

$$s^{D*} = \frac{\alpha\gamma\rho - v\gamma\delta\rho}{4k\beta - \gamma^2\rho} \tag{10}$$

Substituting s^{D*} into Equations (8) and (9), p^{D*} and p_l^{D*} can be derived separately. Based on this, market demand, profits of each decision maker and ESC can also be solved. Equilibrium solutions are presented in Table 3.

Table 3. Optimal decisions in different models.

ESC Models	Optimal Decisions
Case 1	$p^{D*} = \frac{4k[(\alpha-v\delta)(1-\rho)+c\beta]-c\gamma^2\rho}{2(1-\rho)(4k\beta-\gamma^2\rho)}$ $p_l^{D*} = \frac{v(3k\beta-\gamma^2\rho)}{4k\beta-\gamma^2\rho} + \frac{\beta\{4k[\alpha(1-\rho)-c\beta]+c\gamma^2\rho\}}{4\delta(1-\rho)(4k\beta-\gamma^2\rho)}$ $s^{D*} = \frac{\alpha\gamma\rho-v\gamma\delta\rho}{4k\beta-\gamma^2\rho}$ $q^{D*} = \frac{\beta\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}}{4(1-\rho)(4k\beta-\gamma^2\rho)}$ $\pi_m^{D*} = \frac{\beta\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta)]\}^2}{8(1-\rho)(4k\beta-\gamma^2\rho)^2}$ $\pi_e^{D*} = \frac{4k\rho[(\alpha-v\delta)^2(1-\rho)^2-c^2\beta^2]+c^2\beta\gamma^2\rho^2}{8(1-\rho)^2(4k\beta-\gamma^2\rho)}$ $\pi_l^{D*} = \frac{\beta^2\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}^2}{16\delta(1-\rho)^2(4k\beta-\gamma^2\rho)^2}$ $\pi^{D*} = \pi_m^{D*} + \pi_e^{D*} + \pi_l^{D*}$
Case 2	$s^{F*} = \frac{\gamma\{[\beta\theta_2+2\delta(\theta_1+\rho-\theta_1\rho)](\alpha-v\delta)(1-\rho)-c\beta[\beta\theta_2+2\delta\theta_1(1-\rho)]\}}{(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}}$ $p^{F*} = \frac{4k\delta[(\alpha-v\delta)(1-\rho)+c\beta]-c\gamma^2[\delta(2\theta_1-2\theta_1\rho+\rho)+\beta\theta_2]}{(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}}$ $p_l^{F*} = v + \frac{c\beta\gamma^2\rho+4k\beta((\alpha-v\delta)(1-\rho)-c\beta)}{2(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}}$ $q^{F*} = \frac{\beta\delta\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}}{2(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}}$ $\pi_m^{F*} = \frac{\beta\delta^2\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}^2}{2(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}^2}$ $\pi_e^{F*} = \frac{\beta\delta\rho\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}\{4k\delta[(\alpha-v\delta)(1-\rho)+c\beta]-c\gamma^2[\delta(2\theta_1-2\theta_1\rho+\rho)+\beta\theta_2]\}^2}{2(1-\rho)^2\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}^2} - \frac{k\gamma^2\{c\beta[2\delta(1-\rho)\theta_1+\beta\theta_2]-(\alpha-v\delta)(1-\rho)[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}^2}{2(1-\rho)^2\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}^2}$ $\pi_l^{F*} = \frac{\beta^2\delta\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}^2}{4(1-\rho)^2\{8k\beta\delta-\gamma^2[2\delta(\theta_1+\rho-\theta_1\rho)+\beta\theta_2]\}^2}$ $\pi^{F*} = \pi_m^{F*} + \pi_e^{F*} + \pi_l^{F*}$
Case 3	$p^{C*} = \frac{2k\alpha+2ck\beta-c\gamma^2-2kv\delta}{4k\beta-\gamma^2}$ $s^{C*} = \frac{\gamma(\alpha-c\beta-v\delta)}{4k\beta-\gamma^2}$ $p_l^{C*} = v + \frac{k\beta(\alpha-c\beta-v\delta)}{(4k\beta-\gamma^2)\delta}$ $q^{C*} = \frac{k\beta(\alpha-c\beta-v\delta)}{4k\beta-\gamma^2}$ $\pi_l^{C*} = \frac{k^2\beta^2(\alpha-c\beta-v\delta)^2}{(4k\beta-\gamma^2)^2\delta}$ $\pi^{C*} = \frac{k(\alpha-c\beta-v\delta)^2[2k\beta(\beta+2\delta)-\gamma^2\delta]}{2\delta(4k\beta-\gamma^2)^2}$

Proposition 1. *p^{D*}, p_l^{D*}, s^{D*}, q^{D*}, π_m^{D*}, π_e^{D*}, π_l^{D*}, and π^{D*} have positive correlations with γ.*

See Appendix A for proof.

As consumer preferences for SP-services increase, e-platforms will increase their SP-services level to attract more customers. Meanwhile, the manufacturer and the TPLSP will increase the price of product and logistics services respectively, to maximize their profits. Moreover, the market demand will increase due to the larger influence of SP-services than the sales price and logistics services price. Proposition 1 shows that the increase in consumer preference for SP-service makes ESC members and systems more profitable.

Proposition 2. p^{D*}, p_l^{D*}, s^{D*}, q^{D*}, π_m^{D*}, π_e^{D*}, π_l^{D*}, and π^{D*} *have negative correlations with* δ.

The proof is similar to Proposition 1.

When consumers' preferences for logistics services price increase, both logistics services price and the sales price will decrease. Meanwhile, the e-platform maximizes revenue by lowering the SP-services level. However, there is a very limited scope for a reduction in the logistics services price. The positive impact of logistics services price reductions on consumers is less than the negative impact of reduced SP-service level, which decreases market demand. This not only shows that consumer preference for logistics services price narrows the profitability of ESC but also indicates that the fragmentation of decision-makers in the decentralized model harms ESC.

Proposition 3. *When* $(1-\frac{\beta}{2\delta}) < \rho$, $\pi_l^{D*} > \pi_m^{D*} > \pi_e^{D*}$; *When* $0 < \rho < (1-\frac{\beta}{2\delta})$, $\pi_m^{D*} > \pi_l^{D*} > \pi_e^{D*}$.

See Appendix B for proof.

When a higher commission rate ($\rho > 1-\frac{\beta}{2\delta}$) is set, the manufacturer's profits are lower than the TPLSP's profit; conversely, the manufacturer's profit will be higher. Meanwhile, the e-platform gains the lowest profit among ESC members, which is because only one manufacturer is considered in this model. In practice, e-platforms are shared with many manufacturers. For instance, JD has more than 200,000 third-party contracted merchants in 2019 (According to JD at https://lai.jd.com/#/). However, e-platforms often create rules that harm merchants to expand their own revenues, which can easily lead to supply chain disruptions. For example, SF Express stopped cooperating with "Cainiao Network" in 2017 due to dissatisfaction with the excessively low profit margins it was given. In the 2018 "618 e-commerce festival", Tmall and JD forced LeEco to subsidize prices for consumers, thus causing LeEco's discontent. Based on this situation, in order to maintain their reputation and attract more merchants, an increasing number of e-platforms generate altruistic preferences in the cooperation process. The impact of altruistic preferences on ESCs is analyzed in the following section.

4.2. Decentralized Model with E-Platform's Altruistic Preferences (Case 2)

When dominating ESCs, some e-platforms have set up overbearing terms that seriously harm the interests of TPLSPs and manufacturers. This has aroused the discontent of many manufacturers and TPLSPs, and adversely affects the reputation of e-platforms (The report can be referred to as https://36kr.com/p/5084979.html). In this situation, on the one hand, some manufacturers and TPLSPs terminate their cooperation with e-platforms, which makes the e-platforms less competitive; on the other hand, some manufacturers and TPLSPs reduce their operating costs by a lower logistics services, which results in longer logistics transit times, higher express damage rates, and lower product quality. Therefore, to prevent the negative effects of supply chain conflicts on their own profits and reputation, some e-platforms implement altruistic preference behavior, which is intended to increase the willingness of manufacturers and TPLSPs to cooperate with e-platforms, and contribute to the stability of ESCs.

When an e-platform has altruistic preferences, she will be concerned about the equity of earnings of subordinate firms in ESC, that is, she will take the profits of TPLSP and manufacturer into account when making decisions. In this paper, the utility function constructed by Loch and Wu [37] is adopted, and the e-platform's utility function with altruistic preferences is:

$$U_e^F = \pi_e + \theta_1 \pi_m + \theta_2 \pi_l \quad (11)$$

where $0 \leq \theta_1,\ \theta_2 \leq 1$. θ_1 denotes the coefficient of the e-platform's altruistic preference for manufacturer and θ_2 represents the coefficient of e-platform's altruistic preference for TPLSP. The closer the $\theta_i(i = 1,2)$ to 0, the lower the altruistic preference degree of e-platform; the nearer the $\theta_i(i = 1,2)$ to 1, the higher the altruistic preference degree of e-platform.

In this model, the e-platform's decision function is the utility function. By a backward induction method (similar to the solution procedure in Section 4.1), equilibrium solutions can be derived as presented in Table 3.

The range of altruistic preference coefficients is analyzed below. In practice, the e-platform will only consider the altruistic preference on the premise that she gets a positive profit, which means that $s^{F*} > 0$, $p^{F*} > 0$, $p_l^{F*} > 0$, $\pi_e^{F*} > 0$ must be guaranteed. Therefore, θ_1 and θ_2 need to satisfy:

$$2\delta(1-\rho)\theta_1 + \beta\theta_2 < 2\delta(1-\rho)$$

That is, the results of the model are robust when $2\delta(1-\rho)\theta_1 + \beta\theta_2 < 2\delta(1-\rho)$ is satisfied. This paper analyzes the relevant results under this condition. Through further computational analysis, Propositions 4–5 can be derived.

Proposition 4. *(1) s^{F*}, p^{F*}, p_l^{F*}, q^{F*}, π_m^{F*}, π_l^{F*}, and π^{F*} have positive correlations with θ_1. π_e^{F*} has a negative correlation with θ_1; (2) s^{F*}, p^{F*}, p_l^{F*}, q^{F*}, π_m^{F*}, π_l^{F*}, and π^{F*} have positive correlations with θ_2. π_e^{F*} has a negative correlation with θ_2.*

The proof is similar to Proposition 1.

When the altruistic preference of an e-platform for a manufacturer or TPLSP increases, the e-platform will increase its SP-services level to attract more consumers. Meanwhile, manufacturer and TPLSP will increase the sales price and logistics services price, respectively, to further expand their profits. Moreover, altruistic preference behaviors of the e-platform for a manufacturer and TPLSP help increase market demand, which can make it more profitable for the manufacturer and TPLSP. However, e-platform invests more in SP-service, which results in a loss of her profits. As a result, e-platforms are often reluctant to adopt altruistic preference behaviors or to adopt altruistic preference behaviors with smaller preference coefficients.

Proposition 5. *When $\beta > 2\delta(1-\rho)$, $\frac{\partial p^{F*}}{\partial\theta_1} < \frac{\partial p^{F*}}{\partial\theta_2}$, $\frac{\partial s^{F*}}{\partial\theta_1} < \frac{\partial s^{F*}}{\partial\theta_2}$, $\frac{\partial p_l^{F*}}{\partial\theta_1} < \frac{\partial p_l^{F*}}{\partial\theta_2}$, $\frac{\partial q^{F*}}{\partial\theta_1} < \frac{\partial q^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_m^{F*}}{\partial\theta_1} < \frac{\partial \pi_m^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_e^{F*}}{\partial\theta_1} < \frac{\partial \pi_e^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_l^{F*}}{\partial\theta_1} < \frac{\partial \pi_l^{F*}}{\partial\theta_2}$, $\frac{\partial \pi^{F*}}{\partial\theta_1} < \frac{\partial \pi^{F*}}{\partial\theta_2}$; The opposite comparative results are reached when $\beta < 2\delta(1-\rho)$.*

See Appendix C for proof.

The effect of the two altruistic preference behaviors of an e-platform is dependent on consumers' sensitivity to sales price and logistics services price. When consumers have a higher desire for sales price ($\beta > 2\delta(1-\rho)$), e-platform's altruistic preference for TPLSP is more effective. This is because, in this case, the altruistic preference behavior of the e-platform towards the manufacturer indirectly leads the manufacturer to increase sales price, which will thus deviate from the consumer's pursuit for low-priced products and weaken the effect of the altruistic preference behavior. Conversely, when consumers have a higher desire for a logistics services price ($\beta < 2\delta(1-\rho)$), the altruistic behavior for the manufacturer exert better effects. In actual operations, consumers are more responsive to a logistics services price [14], so the e-platform's altruistic preference for the manufacturer is more favorable to the ESC.

4.3. Centralized Decision Model under Logistics Outsourcing (Case 3)

Under this model, manufacturer and e-platform all make decisions with the aim of maximizing ESC profits. In this case, the TPLSP is an outsourcing company and is not involved in non-logistics decisions within the ESC. The decision function of the manufacturer and e-platform is:

$$\max_{p,s} \pi = (p - c)q - ks^2/2 \tag{12}$$

The profit function for TPLSP is:

$$\pi_l = (p_l - v)q \tag{13}$$

In this case, the TPLSP remains a subordinate firm in the system, and e-platform joins forces with manufacturer to become the dominant alliance in ESC. The sequence of decisions between enterprises is that manufacturer and e-platform first determine p and s based on the market demand. the TPLSP then determines the logistics services price p_l according to the decisions of the manufacturer and e-platform.

By Equation (12), Hessian matrix $\mathrm{H} = \begin{bmatrix} \frac{\partial^2 \pi}{\partial p^2} & \frac{\partial^2 \pi}{\partial p \partial s} \\ \frac{\partial^2 \pi}{\partial s \partial p} & \frac{\partial^2 \pi}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -2\beta & \gamma \\ \gamma & -k \end{bmatrix}$. Since $-2\beta < 0$ and $2k\beta - \gamma^2 > 0$, the Hessian matrix is negative definite, so the optimal solution of $\pi(p, s)$ exists.

According to $\partial \pi_l / \partial p_l = 0$, logistics services price's response function is:

$$p_l = \frac{\alpha - p\beta + s\gamma + v\delta}{2\delta} \tag{14}$$

Substituting Equation (14) into Equation (12), Equation (15) can be obtained by solving $\frac{\partial \pi}{\partial p} = 0$ and $\frac{\partial \pi}{\partial s} = 0$.

$$p^{C*} = \frac{2k\alpha + 2ck\beta - c\gamma^2 - 2kv\delta}{4k\beta - \gamma^2},\ s^{C*} = \frac{\gamma(\alpha - c\beta - v\delta)}{4k\beta - \gamma^2} \tag{15}$$

Substituting Equation (15) into Equation (14), The optimal logistics services price can be obtained. Equilibrium solutions for the centralized decision are shown in Table 3.

Comparing the optimal decisions under different models, Conclusion 1 and Conclusion 2 can be derived.

Conclusion 1. (1) $s^{C*} > s^{F*} > s^{D*}$, $p_l^{C*} > p_l^{F*} > p_l^{D*}$;
(2) When $2\delta(1-\rho)\theta_1 + \beta\theta_2 < \Delta$, $p^{C*} > p^{F*} > p^{D*}$. *When* $\Delta < 2\delta(1-\rho)\theta_1 + \beta\theta_2 < 2\delta(1-\rho)$, $p^{F*} > p^{C*} > p^{D*}$, *where* $\Delta = \frac{\delta\{4k\gamma^2[(\alpha - v\delta)(1-\rho)^2 + c\beta(-1+2\rho+\rho^2)] - 16ck^2\beta^2\rho + c\gamma^4\rho(1-2\rho)\}}{\gamma^2\{c\gamma^2\rho + 2k[(\alpha - v\delta)(1-\rho) - c\beta(1+\rho)]\}}$.

See Appendix D for proof.

Under the centralized model, close cooperation between e-platform and manufacturer can maintain the SP-service level and the logistics services price at relatively high levels, which can increase market demand and profit of the TPLSP. Moreover, the sales price is lowest under decentralized model where members are perfectly rational, and the comparison of sales price in the other two decision models depends on the degree of the e-platform's altruistic preference. When the e-platform is less altruistic ($2\delta(1-\rho)\theta_1 + \beta\theta_2 < \Delta$), the highest the sales price is achieved under centralized decision-making. When the degree of altruistic preference is large ($\Delta < 2\delta(1-\rho)\theta_1 + \beta\theta_2 < 2\delta(1-\rho)$), the sales price is highest under decentralized decision-making with the e-platform's altruistic preferences. This finding differs from the "lowest selling price under centralized decision-making" conclusion of offline or dual-channel supply chains [13,14,56]. In ESC models, the sales price under centralized decision-making is consistently higher than that under decentralized decision-making where members are perfectly rational. This is because the price is no longer the only consideration for consumers when they purchase products. Coupled with the uncertainty and complexity of the online shopping process, consumers are increasingly expecting e-platforms to provide better sales and after-sales service and are willing to pay more for it.

Conclusion 2. $\pi_m^{F*} > \pi_m^{D*}$, $\pi_e^{D*} > \pi_e^{F*}$, $\pi_l^{C*} > \pi_l^{F*} > \pi_l^{D*}$, $\pi^{C*} > \pi^{F*} > \pi^{D*}$.

The proof is similar to Conclusion 1.

Conclusion 2 further validates Proposition 4 and shows that centralized decision-making model can maximize system profits. However, centralized decision-making can only be achieved through the coordination mechanism.

5. Coordination Mechanism

5.1. Design of Coordination Mechanism

In this section, a coordination mechanism of "altruistic preference joint fixed-cost" is proposed to coordinate ESC. Since the TPLSP is an outsourcing company, it is not involved in ESC decisions other than logistics services pricing. Therefore, the e-platform and manufacturer are regarded as coordinating players in the contract. The idea of a coordination mechanism is that, first, e-platform adopts altruistic preference behavior to improve SP-service levels and reduce commissions, which can increase product sales and boost the manufacturer's profits. Second, to compensate e-platform for the profit loss due to the altruistic preferences, the manufacturer pays a fixed fee to e-platform.

In the "altruistic preference joint fixed-cost" coordination mechanism, assuming the e-platform has an altruistic preference of $\overline{\theta}_1$ for the manufacturer and $\overline{\theta}_2$ for TPLSP, the fixed fee paid by the manufacturer is f, and the commission charged by the e-platform is $\overline{\rho}$.

The manufacturer's profit is:

$$\overline{\pi}_m = (p - \overline{\rho} p - c)q - f \tag{16}$$

The e-platform's profit is:

$$\overline{\pi}_e = \overline{\rho} pq - \frac{ks^2}{2} + f \tag{17}$$

The TPLSP's profit is:

$$\overline{\pi_l} = (p_l - v)q \tag{18}$$

The e-platform's utility function is:

$$\overline{U}_e = \overline{\pi}_e + \overline{\theta}_1 \overline{\pi}_m + \overline{\theta}_2 \overline{\pi_l} \tag{19}$$

At this point, e-platform makes the decision to maximize her utility, while manufacturer and TPLSP aim to maximize their profits. Equilibrium solutions after coordination are as follows (resolution procedures similar to those in Section 4.1).

The optimal SP-service level is:

$$\overline{s}^{F*} = \frac{\gamma\left\{\left[\beta\overline{\theta}_2 + 2\delta\left(\overline{\theta}_1 + \rho - \overline{\theta}_1\rho\right)\right](\alpha - v\delta)(1-\rho) - c\beta\left[\beta\overline{\theta}_2 + 2\delta\overline{\theta}_1(1-\rho)\right]\right\}}{(1-\rho)\left\{8k\beta\delta - \gamma^2\left[2\delta\left(\overline{\theta}_1 + \rho - \overline{\theta}_1\rho\right) + \beta\overline{\theta}_2\right]\right\}} \tag{20}$$

The optimal sales price is:

$$\overline{p}^{F*} = \frac{4k\delta[(\alpha - v\delta)(1-\rho) + c\beta] - c\gamma^2\left[\beta\overline{\theta}_2 + \delta\left(2\overline{\theta}_1 - 2\overline{\theta}_1\rho + \rho\right)\right]}{(1-\rho)\left\{8k\beta\delta - \gamma^2\left[2\delta\left(\overline{\theta}_1 + \rho - \overline{\theta}_1\rho\right) + \beta\overline{\theta}_2\right]\right\}} \tag{21}$$

The optimal logistics services price is:

$$\overline{p}_l^{F*} = v + \frac{c\beta\gamma^2\rho + 4k\beta((\alpha - v\delta)(1-\rho) - c\beta)}{2(1-\rho)\left\{8k\beta\delta - \gamma^2\left[2\delta\left(\overline{\theta}_1 + \rho - \overline{\theta}_1\rho\right) + \beta\overline{\theta}_2\right]\right\}} \tag{22}$$

To ensure that coordination can be achieved, it is necessary that $\begin{cases} \overline{s}^{F*} \equiv s^{C*} \\ \overline{p}^{F*} \equiv p^{C*} \\ \overline{p}_l^{F*} \equiv p_l^{C*} \end{cases}$ holds, and the solution yields $\begin{cases} \overline{\theta}_1 = \frac{2\delta-\beta\overline{\theta}_2}{2\delta} \\ \overline{\rho} = 0 \end{cases}$. Therefore, the following conclusion can be drawn.

Conclusion 3. *Under the "altruistic preference joint fixed-cost" contract, when* $(\overline{\theta}_1, \overline{\theta}_2, \overline{\rho})$ *satisfies* $\begin{cases} \overline{\theta}_1 = \frac{2\delta-\beta\overline{\theta}_2}{2\delta} \\ \overline{\rho} = 0 \end{cases}$, *the coordination of ESC can be achieved.*

Conclusion 3 shows that after coordination, the sum of the altruistic preference coefficients of the e-platform for manufacturer and TPLSP is a fixed value. Meanwhile, the values of the two altruistic preference coefficients $(\overline{\theta}_1, \overline{\theta}_2)$ satisfies $2\delta\overline{\theta}_1 + \beta\overline{\theta}_2 = 2\delta$, which guarantees that the e-platform does not lose profits to a large extent. In addition, the coordinated e-platform does not charge commissions and relies solely on charging a fixed fee to make a profit.

To ensure the effective implementation of the coordination mechanism, the following is an analysis of the feasible conditions.

(1) When ESC members are perfectly rational, ESC members accept the contract on the condition that their own profits after coordination are not lower than before, that is, $\begin{cases} \overline{\pi}_l^* \geq \pi_l^{D*} \\ \overline{\pi}_m^* \geq \pi_m^{D*} \\ \overline{\pi}_e^* \geq \pi_e^{D*} \end{cases}$ needs to be satisfied. The feasible interval for f is derived as $\left[\frac{k\gamma^2(\alpha-c\beta-v\delta)^2}{2(4k\beta-\gamma^2)^2} + \pi_e^{D*}, \frac{2k^2\beta(\alpha-c\beta-v\delta)^2}{(4k\beta-\gamma^2)^2} - \pi_m^{D*}\right]$.

(2) When the e-platform has the altruistic preference, ESC members accept coordination on the condition that the manufacturer's and TPLSP's own profits after coordination are not lower than before coordination, and the utility of e-platform after coordination is not lower than before coordination. that is, $\begin{cases} \overline{\pi}_l^* \geq \pi_l^{F*} \\ \overline{\pi}_m^* \geq \pi_m^{F*} \\ \overline{\pi}_e^* \geq \pi_e^{F*} \\ \overline{U}_e^* \geq U_e^{F*} \end{cases}$ needs to be satisfied. The feasible interval for f is derived as $\left[\frac{k\gamma^2(\alpha-c\beta-v\delta)^2}{2(4k\beta-\gamma^2)^2} + \pi_e^{F*}, \frac{2k^2\beta(\alpha-c\beta-v\delta)^2}{(4k\beta-\gamma^2)^2} - \pi_m^{F*}\right]$.

In summary, the feasible range of the coordination mechanism is $[f_{min}, f_{max}]$, where $f_{min} = \frac{k\gamma^2(\alpha-c\beta-v\delta)^2}{2(4k\beta-\gamma^2)^2} + \pi_e^{D*}$ and $f_{max} = \frac{2k^2\beta(\alpha-c\beta-v\delta)^2}{(4k\beta-\gamma^2)^2} - \pi_m^{F*}$. The feasible range of this contract is further investigated in numerical analysis.

5.2. Discussion of Coordination Mechanism

In the previous subsection, we designed the "altruistic preference joint fixed-cost" contract. Through this contract, the sales price, logistics service price and SP-services level under centralized decision are realized and the highest ESC system profit is achieved. Meanwhile, the contract also gives a solution on how to allocate the ESC profit to ensure that all three parties' profit can be increased by the contract.

There are three key points to be noted in the implementation of the "altruistic preference joint fixed-cost" contract.

Firstly, the contract shifts the revenue of the e-platform from gaining the commission to charging a fixed fee to the manufacturer. There is a precedent for this in the e-commerce marketplace, as China's Pinduoduo (www.pinduoduo.com) does not charge commissions and annual fees. As of the end of September 2020, Pinduoduo's one-year sales reached CNY 1457.6 billion. According to the current industry rules, the commission is about 3–5%, which means that Pinduoduo saves CNY 43.7 billion to CNY 72.9 billion a year for merchants. This will attract a large number of merchants and can lower the price of products in the platform, thus expanding the influence of Pinduoduo. However, it also results in Pinduoduo's profits being much lower than those of similar-sized e-platforms. Therefore, the contract introduces the fixed cost fee that redistributes the commission savings between the e-platform and the merchants.

Secondly, the range of the fixed fee charged by e-platforms should be noted. If the fixed fee charged is too high, manufacturers will not be able to profit from the implementation of the contract, which will lead to the loss of merchants. If the fixed fee charged is too low, e-platforms will have no incentive to shift their revenue model, which will make it difficult to enforce the contract. In the previous section, we gave a range of values for the fixed fee as $[\frac{k\gamma^2(\alpha-c\beta-v\delta)^2}{2(4k\beta-\gamma^2)^2}+\pi_e^{F*}, \frac{2k^2\beta(\alpha-c\beta-v\delta)^2}{(4k\beta-\gamma^2)^2}-\pi_m^{F*}]$, which needs to be followed in the specific contract design process.

Finally, considering the altruistic preference behavior of e-commerce platforms, the range of altruistic preference coefficients needs to be noted. In the coordination mechanism, the two altruistic preference coefficients of the e-commerce platform need to satisfy $2\delta\overline{\theta}_1+\beta\overline{\theta}_2=2\delta$. This indicates that the altruistic preference behavior of the e-platform needs to consider the price preference of consumers. When consumers are more sensitive to sales price changes, the altruistic behavior of the e-commerce platform for TPLSP is more effective. Conversely, when consumers are more sensitive to logistics service prices, the altruistic behavior for the manufacturer exerts better results.

In addition, it should be clarified that the contract needs to be pushed by the e-platform that has a dominant position in ESC. The e-platform can first pilot in a certain area according to the "altruistic preference joint fixed-cost" contract, and then continuously supplement and improve the content of the contract to form a win-win situation in ESC step by step.

6. Numerical Analysis

6.1. Numerical Analysis of Comparison

To explore the impact of the altruistic preference coefficients of the e-commerce platform on the ESC decisions, numerical analysis is adopted as follows. Assuming $\alpha=200, \beta=4, \gamma=3, \delta=2, \rho=0.2, k=3, c=8, v=3$, the altruistic preference coefficient of the e-commerce platform for the manufacturer ranges from $\theta_1=[0,0.5]$ and that for the TPLSP ranges from $\theta_2=[0,0.5]$. The changes in the decision variables and profits with θ_1 and θ_2 are shown in Figures 3–5.

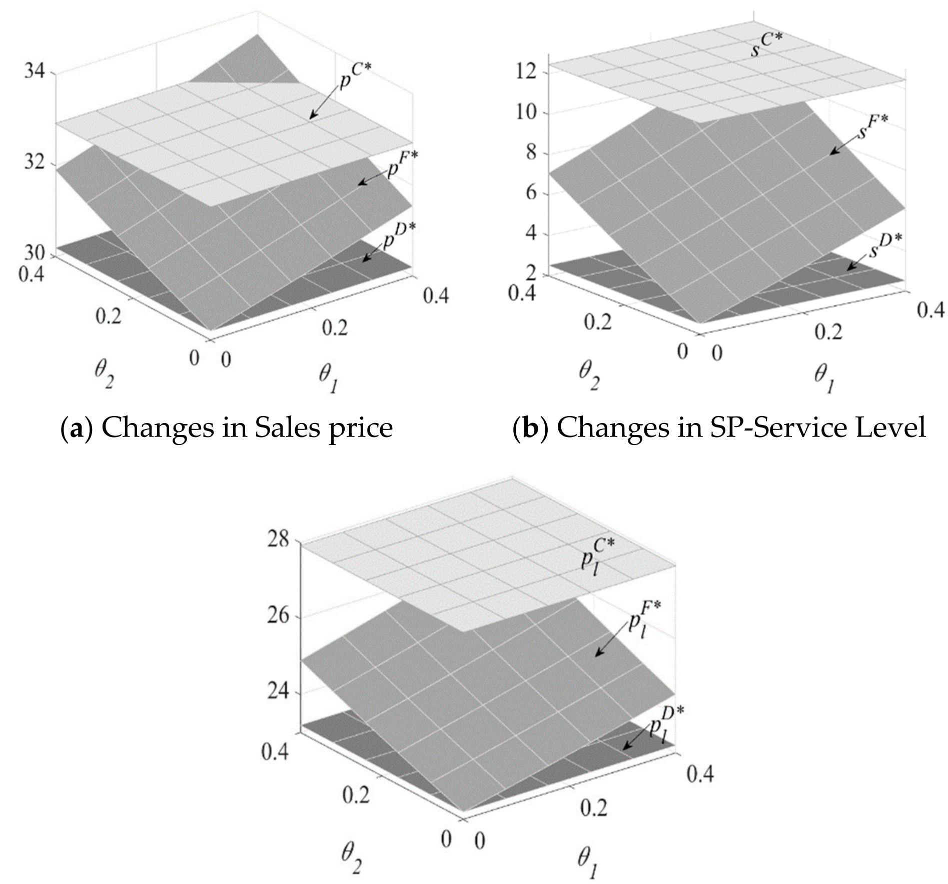
The following conclusions can be drawn from Figures 3–5.

(1) Whether the e-platform has an altruistic preference for the manufacturer or the TPLSP, it can be seen from Figure 3 that the sales price, logistics services price, and SP-service level increase. This indicates that e-platform altruistic preferences make manufacturer and TPLSP more profitable in providing the product or service. From Figure 4a, we find that the increase in sales price and logistics service price due to higher altruistic preferences does not negatively affect sales volume. By contrast, consumers will buy more products because of the increased level of SP-service. In addition, from Figure 4b, it can be determined that the altruistic preferences of e-platform positively affect the efficiency of the ESC.

(2) From Figure 5, it can be seen that the changes of the e-platform's profits with altruistic preferences are different from other variables and profits. On the one hand, the increase in altruistic preferences decreases profits of the e-platform, but helps improve decision variables, other decision-makers' profits, and ESC profits. On the other hand, with the improvement in altruistic preferences of the e-platform, decision variables or profits other than the e-platform's profits show a stable increasing trend, but the decline in e-platform's profits is obvious. Therefore, in reality, e-platforms tend to have a lower degree of altruistic preference as a means of ensuring that their interests are not harmed.

(3) From Figures 3–5, it can be seen that under the centralized model, SP-service level, logistics services price, market demand, profits of decision-makers and ESC all reach the highest, while the product's sales price under different models depends on the altruistic preference coefficients. The lowest sales price is in the decentralized model where members

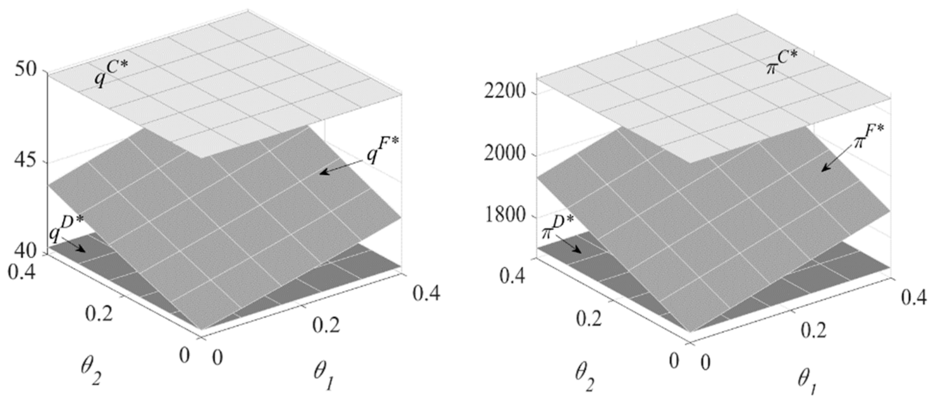
are perfectly rational. Also, when the altruistic preferences of the e-platform are all high, sales price in decentralized decision-making with altruistic preference is higher than that under centralized decision-making.



(**a**) Changes in Sales price (**b**) Changes in SP-Service Level

(**c**) Changes in Logistics Service Price

Figure 3. Changes in decision variables with θ_1 and θ_2.



(**a**) Changes in Market Demand (**b**) Changes in ESC Profit

Figure 4. Changes in market demand and ESC profit with θ_1 and θ_2.

(**a**) Changes in Third-Party Logistics Service Provider's Profit

(**b**) Changes in Manufacturer's Profit

(**c**) Changes in Platform's Profit

Figure 5. Changes in decision-maker's profits with θ_1 and θ_2.

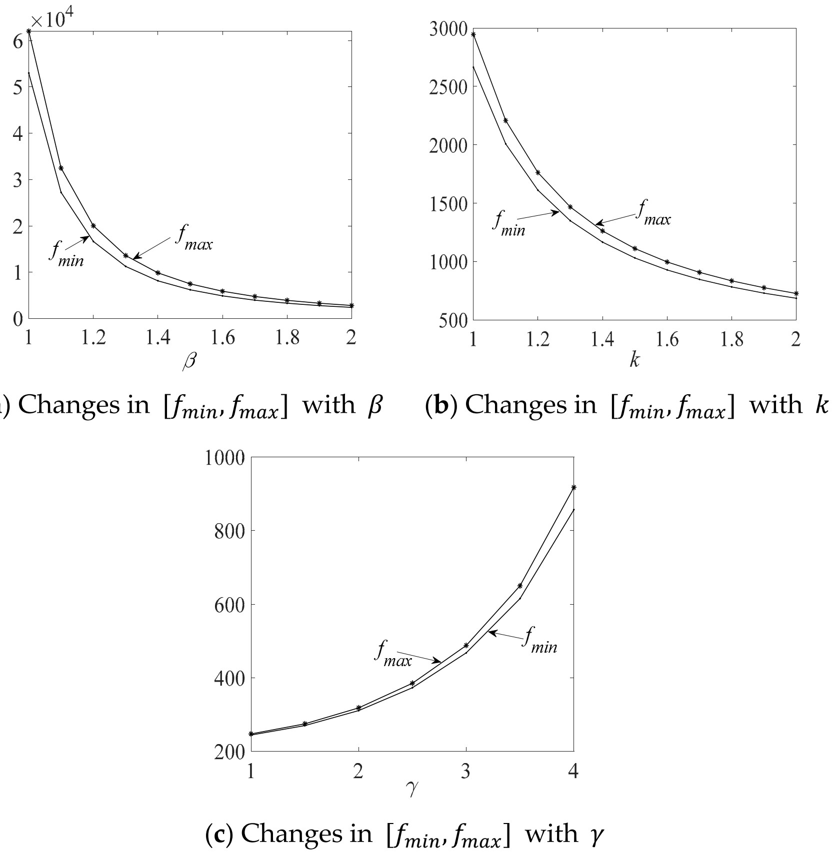
6.2. Numerical Analysis of Coordination Mechanism

Based on the above assumptions ($\alpha = 200$, $\beta = 4$, $\gamma = 3$, $\delta = 2$, $\rho = 0.2$, k = 3, c = 8, $v = 3$), it is further assumed that $\theta_1 = 0.2$ and $\theta_2 = 0.2$. In the decentralized model where ESC members are completely rational, there are $\pi_m^{D*} = 653$, $\pi_l^{D*} = 816$, and $\pi_e^{D*} = 234$. In decentralized decision-making with e-platform's altruistic preferences, there are $\pi_m^{F*} = 755$, $\pi_l^{F*} = 943$, and $\pi_e^{F*} = 211$. After coordination using the "altruistic preference joint fixed-cost" contract, there are $\overline{\pi}_m^* = 1242 - f$, $\overline{\pi}_e^* = 233 + f$, and $\overline{\pi}_l^* = 3075$, with a feasible range of $f \in [468, 487]$. First, let $\beta \in [1,2]$, $k \in [1,2]$, and $\gamma \in [1,4]$, the effects of β, k, γ on the fixed cost interval $[f_{min}, f_{max}]$ under the coordination mechanism are shown in Figure 6.

Figure 6 shows that effects of β and k on the feasible scope of this contract are opposite to that the effect of γ. An increase in β or k decreases the lower limit f_{min} and upper limit f_{max}, while the upper limit f_{max} decreases more, which narrows the feasible range $[f_{min}, f_{max}]$. An increase in γ raises the lower limit f_{min} and upper limit f_{max}, while the increase in the upper limit f_{max} is more significant, which enlarges the feasible range $[f_{min}, f_{max}]$.

Furthermore, based on the existing assumptions ($\alpha = 200$, $\beta = 4$, $\gamma = 3$, $\delta = 2$, $\rho = 0.2$, $k = 3$, $c = 8$, $v = 3$) and making $f = 480$, equilibrium solutions before and after coordination are shown in Table 4.

From Table 4: (1) the e-platform's altruistic preferences have a greater impact on the SP-service level. This is because the e-platform implements altruistic preferences by improving her SP-service level to increase sales, thus enabling the manufacturer and the TPLSP to gain more profits. Moreover, when e-platforms apply the same degree of altruistic preference to the TPLSP and the manufacturer, the increase in logistics services price is much greater than the increase in sales price. (2) The altruistic preferences of the e-platform reduce her own profit but improve profits of the manufacturer, TPLSP, and ESC. Moreover, the rise in profits for the manufacturer and TPLSP are more obvious than the decrease in the e-platform's profit. (3) The optimal decisions under the centralized model can be reached by the "altruistic preference joint fixed-cost" contract. The above findings illustrate the feasibility and validity of the contract, and also validate the content of Section 5.2.



(**a**) Changes in $[f_{min}, f_{max}]$ with β (**b**) Changes in $[f_{min}, f_{max}]$ with k

(**c**) Changes in $[f_{min}, f_{max}]$ with γ

Figure 6. Changes in $[f_{min}, f_{max}]$ with parameters.

Table 4. Parameter values and change rates before and after coordination.

Decision Variables	**Before Coordination**			**After Coordination**
	Decentralized Model		**Centralized Model**	
	ESC Members Are Completely Rational	**E-Platform Has Altruistic Preferences**		
Sales Price	30.2	31.7(4.96% ↑)	32.9(8.94% ↑)	32.9(8.94% ↑)
SP-Service Level	2.5	6.6(164.00% ↑)	12.5(400.00% ↑)	12.5(400.00% ↑)
Logistics Services Price	23.2	24.7(3.45% ↑)	27.9(20.26% ↑)	27.9(20.26% ↑)
Market Demand	40.4	43.4(7.43% ↑)	49.8(23.27% ↑)	49.8(23.27% ↑)
Manufacturer's Profit	653	755(15.62% ↑)	-	1722(163.71% ↑)
E-platform's Profit	234	211(9.83% ↓)	-	247(5.56% ↑)
TPLSP's Profit	816	943(15.56% ↑)	1242(52.21% ↑)	1242(52.21% ↑)
ESC's Profit	1703	1909(12.10% ↑)	2251(32.18% ↑)	2251(32.18% ↑)

Note: the percentage in the parentheses denotes the change rate, the up arrow denotes an increase and the down arrow denotes a decrease.

7. Conclusions

Recently, an increasing number of manufacturers have been selling their products with e-platforms and are outsourcing logistics services to TPLSPs. However, unlike traditional offline supply chains, e-platforms tend to dominate the ESC and often use their dominance to make decisions that are detrimental to TPLSPs and manufacturers. Therefore, conflicts in logistics outsourcing-based ESC are frequent and need to be mediated for long-term development. The paper constructs the ESC consisting of a manufacturer, a TPLSP, and an e-platform. Three ESC decision models are constructed, namely, the decentralized decision model where ESC members are completely rational, the decentralized decision model with an e-platform's altruistic preferences, and the centralized decision model under logistics outsourcing. Based on this, equilibrium solutions are derived, and the impacts of an e-platform's altruistic preferences on ESC are also explored. Moreover, the "altruistic preference joint fixed-cost" contract is proposed to coordinate the ESC. The results are as follows.

Firstly, ESC members' profits increase with improved consumer preference for the sales promotion service level, but decrease with increased consumer preference for logistics service price. Therefore, increasing ESC members' profits by influencing consumer preferences is a feasible approach.

Secondly, in an ESC, the e-platform as the dominant company has the lowest profit, while the comparison results of manufacturer's and TPLSP's profits are determined by the unit product commission rate. This shows that the conclusion of "whoever has more dominant power is more profitable" is not applicable to the ESC under logistics outsourcing.

Thirdly, the e-platform's altruistic preferences enhance the profits of subordinated companies and the ESC system, while harming their own profits. Moreover, the effect of the altruistic preferences of the e-platform on different subordinated companies depends on consumer preferences. When consumers have a higher desire for sales price, the altruistic preference behavior of TPLSPs is more effective; when consumers have a higher desire for logistics services price preferences, the altruistic behavior of the manufacturers produce better results.

Fourthly, logistics services price, SP-service level, and profits of each member and ESC are maximized under centralized decision-making. However, the sales price in centralized decision-making is not the lowest, but higher than that under a decentralized decision model where ESC members are completely rational, which differs from the findings of the offline or dual-channel supply chains [13,14].

Finally, the e-platform's altruistic preference coefficients are used as adjustment tools and the "altruistic preference joint fixed-cost" contract is designed. The study found that this contract can enable ESC coordination. Furthermore, the improvement in consumer preference for sales price and the increase in the sales promotion service cost coefficient narrow the feasible range of the contract, while the increase in consumer preference for the sales promotion service widens the feasibility range.

Therefore, this paper proposes the following management insights.

For TPLSPs, the growth of e-commerce has created a favorable demand environment and a greater challenge for their operations. On the one hand, TPLSPs can benefit from the altruistic preferences of e-platforms. At the same time, the degree of altruistic preference of e-platforms depends on the variability of TPLSPs' logistics services prices. That is, if TPLSPs will significantly increase the logistics services price after enjoying the altruistic behavior, then e-platforms will be more inclined to adopt altruistic preferences for manufacturers. Thus, TPLSPs should not increase their own profits by raising the logistics services price. On the contrary, TPLSPs should sign agreements with e-platforms and work closely with them to lower logistics service prices within an appropriate range. In this way, the e-platform can attract more price-sensitive consumers, which gives TPLSPs a larger order volume and profit margin. On the other hand, TPLSPs should be crisis aware. At present, e-platforms are developing their own logistics, and the advantages of outsourcing logistics are gradually becoming smaller. Therefore, TPLSPs should try to develop new business models or improve the quality of logistics and transportation, so as to improve their competitiveness and expand their channel power in ESCs.

For e-platforms, they should take the initiative to improve SP-service levels to maintain their competitiveness. Meanwhile, e-platforms need to implement altruistic preference behaviors to cement relationships with partner firms and mitigate ESC conflicts. In addition, e-platforms, as the dominant player in ESCs, should adopt the "altruistic preference joint fixed-cost" contract and use their own leading advantages to promote products.

For manufacturers, they need to improve their cooperation and exchange with e-platforms and provide feedback on the activities launched by e-platforms in a reasonable manner. Meanwhile, manufacturers need to cater to consumers' price preferences and cannot profit by raising prices or lowering quality. Manufacturers should take a systems perspective and establish deeper partnerships with e-platforms to boost their own profits by expanding the consumer market.

It is acknowledged that there are certain limitations to the study. For example, some idealistic assumptions in the model construction process are made. In future research, the case where TPLSPs form alliances with e-platforms can be investigated. In addition, decisions and coordination of ESC participants will also be examined where there is competition between self-built and outsourced logistics on e-platforms.

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Appendix A. Proof of Proposition 1.

Proof. $\frac{\partial p^{D*}}{\partial \gamma} = \frac{4k\gamma\rho(\alpha-v\delta)}{(4k\beta-\gamma^2\rho)^2} > 0$, $\frac{\partial p_l^{D*}}{\partial \gamma} = \frac{2k\beta\gamma\rho(\alpha-v\delta)}{\delta(4k\beta-\gamma^2\rho)^2} > 0$, $\frac{\partial s^{D*}}{\partial \gamma} = \frac{\rho(4k\beta+\gamma^2\rho)(\alpha-v\delta)}{(4k\beta-\gamma^2\rho)^2} > 0$,
$\frac{\partial q^{D*}}{\partial \gamma} = \frac{2k\beta\gamma\rho(\alpha-v\delta)}{(4k\beta-\gamma^2\rho)^2} > 0$, $\frac{\partial \pi_m^{D*}}{\partial \gamma} = \frac{2k\beta\gamma\rho(\alpha-v\delta)\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}}{(4k\beta-\gamma^2\rho)^3} > 0$,
$\frac{\partial \pi_e^{D*}}{\partial \gamma} = \frac{k\gamma\rho^2(\alpha-v\delta)^2}{(4k\beta-\gamma^2\rho)^2} > 0$, $\frac{\partial \pi_l^{D*}}{\partial \gamma} = \frac{k\beta^2\gamma\rho(\alpha-v\delta)\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}}{\delta(1-\rho)(4k\beta-\gamma^2\rho)^3} > 0$.
Since, $\pi^{D*} = \pi_m^{D*} + \pi_e^{D*} + \pi_l^{D*}$, π^{D*} is positively related to γ. □

Appendix B. Proof of Proposition 3.

Proof. $\pi_l^{D*} - \pi_m^{D*} = \frac{\beta[\beta-2\delta(1-\rho)]\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}^2}{16\delta(1-\rho)^2(4k\beta-\gamma^2\rho)^2}$
When $\beta - 2\delta(1-\rho) > 0$, that is, $\rho > 1 - \frac{\beta}{2\delta}$, $\pi_l^{D*} > \pi_m^{D*}$,
When $\beta - 2\delta(1-\rho) < 0$, that is, $\rho < 1 - \frac{\beta}{2\delta}$, $\pi_m^{D*} > \pi_l^{D*}$,
The same can be proved, $\pi_m^{D*} - \pi_e^{D*} > 0$, $\pi_l^{D*} - \pi_e^{D*} > 0$. □

Appendix C. Proof of Proposition 5.

Proof. When $\beta > 2\delta(1-\rho)$, $\frac{\partial p^{F*}}{\partial \theta_2} - \frac{\partial p^{F*}}{\partial \theta_1} = \frac{\gamma^2\delta[\beta-2\delta(1-\rho)]\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}}{(1-\rho)\{8k\beta\delta-\gamma^2[\beta\theta_2+2\delta(\theta_1+\rho-\theta_1\rho)]\}^2} > 0$, that is, $\frac{\partial p^{F*}}{\partial \theta_1} < \frac{\partial p^{F*}}{\partial \theta_2}$.

Similarly, When $\beta > 2\delta(1-\rho)$, $\frac{\partial s^{F*}}{\partial\theta_1} < \frac{\partial s^{F*}}{\partial\theta_2}$, $\frac{\partial p_l^{F*}}{\partial\theta_1} < \frac{\partial p_l^{F*}}{\partial\theta_2}$, $\frac{\partial q^{F*}}{\partial\theta_1} < \frac{\partial q^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_m^{F*}}{\partial\theta_1} < \frac{\partial \pi_m^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_e^{F*}}{\partial\theta_1} < \frac{\partial \pi_e^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_l^{F*}}{\partial\theta_1} < \frac{\partial \pi_l^{F*}}{\partial\theta_2}$, $\frac{\partial \pi^{F*}}{\partial\theta_1} < \frac{\partial \pi^{F*}}{\partial\theta_2}$.

When $\beta < 2\delta(1-\rho)$, $\frac{\partial p^{F*}}{\partial\theta_1} > \frac{\partial p^{F*}}{\partial\theta_2}$, $\frac{\partial s^{F*}}{\partial\theta_1} > \frac{\partial s^{F*}}{\partial\theta_2}$, $\frac{\partial p_l^{F*}}{\partial\theta_1} > \frac{\partial p_l^{F*}}{\partial\theta_2}$, $\frac{\partial q^{F*}}{\partial\theta_1} > \frac{\partial q^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_m^{F*}}{\partial\theta_1} > \frac{\partial \pi_m^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_e^{F*}}{\partial\theta_1} > \frac{\partial \pi_e^{F*}}{\partial\theta_2}$, $\frac{\partial \pi_l^{F*}}{\partial\theta_1} > \frac{\partial \pi_l^{F*}}{\partial\theta_2}$, $\frac{\partial \pi^{F*}}{\partial\theta_1} > \frac{\partial \pi^{F*}}{\partial\theta_2}$. □

Appendix D. Proof of Conclusion 1.

Proof. $s^{C*} - s^{D*} = \frac{\beta\gamma\{4k[(\alpha-v\delta)(1-\rho)-c\beta]+c\gamma^2\rho\}}{(4k\beta-\gamma^2)(4k\beta-\gamma^2\rho)} > 0$,

$s^{C*} - s^{F*} = \frac{\beta\gamma\{c\gamma^2\rho+4k[(\alpha-v\delta)(1-\rho)-c\beta]\}[2\delta(1-\rho)(1-\theta_1)-\beta\theta_2]}{(4k\beta-\gamma^2)(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1-\rho\theta_1+\rho)+\beta\theta_2]\}} > 0.$

Therefore, $s^{C*} > s^{F*} > s^{D*}$.

The same can be proved, $p^{C*} > p^{D*}$, $p^{F*} > p^{D*}$, $p_l^{F*} > p_l^{D*} > p_l^{C*}$.

$p^{C*} - p^{F*} =$
$\frac{\delta\{4k\gamma^2[(\alpha-v\delta)(1-\rho)^2+c\beta(-1+2\rho+\rho^2)]-16ck^2\beta^2\rho+c\gamma^4\rho(1-2\rho)\}-\gamma^2\{c\gamma^2\rho+2k[(\alpha-v\delta)(1-\rho)-c\beta(1+\rho)]\}[2\delta(1-\rho)\theta_1+\beta\theta_2]}{(4k\beta-\gamma^2)(1-\rho)\{8k\beta\delta-\gamma^2[2\delta(\theta_1-\theta_1\rho+\rho)+\beta\theta_2]\}}$, Making
$\Delta = \frac{\delta\{4k\gamma^2[(\alpha-v\delta)(1-\rho)^2+c\beta(-1+2\rho+\rho^2)]-16ck^2\beta^2\rho+c\gamma^4\rho(1-2\rho)\}}{\gamma^2\{c\gamma^2\rho+2k[(\alpha-v\delta)(1-\rho)-c\beta(1+\rho)]\}}$ and taking $p^{C*} - p^{F*} > 0$, $2\delta(1-\rho)\theta_1 + \beta\theta_2 < \Delta$ can be derived.

For $p^{C*} - p^{F*} < 0$, $\Delta < 2\delta(1-\rho)\theta_1 + \beta\theta_2 < 2\delta(1-\rho)$ can be obtained. □

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