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Research Article

Decision-Making of Electronic Commerce Supply Chain considering EW Service

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With the rapid development of the network economy, it is a marketing strategy to provide an extended warranty (EW) service. Considering the differences in the EW service providers and dominant enterprises, this paper proposes four kinds of decision-making models and aims to study decisions of the electronic commerce supply chain, including EW price, sales price, and service level of e-platform. Through comparative analysis and numerical analysis, this research shows that, among four decision-making models, the highest system profit can be achieved when the seller provides the EW service and the e-platform dominates the system. For electronic commerce supply chain enterprises, whether to dominate the system or to provide EW service, it is conducive to the increase of profits. When the e-platform provides the EW service, the conclusion is that who dominates the system is the one who gets more profit. However, when the seller provides the EW service, the conclusion is that who dominates the system is the one who gets less profit. When the EW service is offered by the dominating enterprise, service levels of the e-platform are lower.

1. Introduction

With the development of the network economy, the electronic commerce supply chain (ECSC) has been greatly promoted and advanced. The ECSC focuses on core enterprises, integrates upstream and downstream resources, makes full use of the network technology, and ultimately achieves all-win results for supply chain participants [1, 2]. Besides, the ECSC not only improves the competitiveness of products but also solves problems in online shopping, such as excessive fakes, low transportation services, and slow after-sales processing. In the ECSC, sellers sell products with the aid of the e-commerce platform (e-platform) and consumers cannot physically contact products before receiving them. Therefore, many e-platforms and sellers have introduced an extended warranty (EW) service to alleviate consumer concerns, for example, *Home Security Service* of GOME (http://help.gome.com.cn/question/5588.html), *Sunshine Package* for electrical appliances of SUNNING (http://issm.snisc.cn/articleDetail_A10632.htm), *Jingdong Service Steward* of JD (http://fuwu.jd.com/service.html), *Haier extended warranty service* of Haier (http://www.ehaier.com/article.php?a=fixed&alias=warranty, and *Apple Care Protection Plan* of Apple (https://www.apple.com/legal/sales-support/applecare/countrylist.html).

The EW service is a kind of insurance, similar to a contract that consumers can purchase to obtain opportunities for product repair after the time limit specified in the *three guarantees*. It is an optional contract that is offered by a retailer, a manufacturer, or an outsourcing service provider. The EW service provides customers with the opportunity to repair products at a low cost after the warranty period ends, which can effectively expand the product market and open up a new profit source. Many consumers would purchase EW service for home appliances, electronics, and automobiles. Statistics show that the penetration rate of EW service in the United States has reached 35% and that of electronic products has exceeded 85% (the report is available at http://www.315online.com/survey/331921.html). As consumers' awareness of EW service has increased, market demand has gradually opened up, and EW service is a market with great potential.

EW service not only increases consumers' trust in products and brands but also contributes to profits for companies that provide EW service [3]. Currently, there are four main operation modes for EW service (the report is available at https://36kr.com/coop/toutiao/5059989.html): the retailer mode, where retail enterprises provide professional marketing for EW service; the manufacturer mode, which has technical advantages and high service quality; the third-party mode, which is professional but usually relies on retailers to sell; insurance company mode, with a high ability to bear and transfer risks, but rarely studied. With the development of the Internet economy, the ECSC has gradually developed and improved. The e-platforms have replaced the retail stores in the traditional supply chain and can independently sell EW service, especially large e-platforms, such as Tmall and Amazon. Therefore, two modes of EW service provided by the seller or the e-platform are studied in this research.

EW service is conducive to product sales [4, 5], and each node company in the supply chain is willing to provide EW service. In general, leading companies in the supply chain have greater power when making decisions. Therefore, the power structure of the supply chain has a certain impact on the EW service decision. In the network economy environment, the characteristics of online sales, especially the asymmetry of product information, lead to a deeper influence of the power structure on the EW strategy [6, 7]. Moreover, the ECSC is very different from the traditional supply chain, which causes the existing conclusions of traditional supply chains not applicable to the ECSC. The main differences between ECSCs and traditional supply chains are as follows.

Firstly, in the ECSC, e-platforms replace retail stores for product sales, but their operations are different from traditional retail stores. Manufacturers wholesale products to retail stores in traditional supply chains. Among them, the manufacturer decides the product's wholesale price and the retail store decides the retail price. However, in the ECSC, the seller directly sells products to consumers with the aid of the e-platform, which is a direct-sale model [8]. Therefore, the seller directly decides the retail price and the wholesale price to distribute profits is not involved. Also, the commission is an intermediate variable in the profit distribution between e-platforms and sellers to ensure e-platforms to provide sales services. Moreover, the commission rate is a specific percentage of the sales amount of the seller. This rate is set by the e-platform when the seller enters and is not determined based on the retail price of the product [9].

Secondly, the profit modes of sellers and e-platforms are different. The traditional retailer's unit product revenue depends on wholesale price and retail price, which depends on upstream sellers and downstream consumers. However, unit product revenue of the e-platform depends only on upstream sellers. Therefore, in the ECSC model, the revenue of e-platform comes from the commission income and it does not involve direct unit product costs.

Finally, ECSCs and traditional supply chains are affected by different factors. In traditional supply chains, price is a major factor in sales. However, in the ECSC, the market demand for products is greatly affected by the sales service of the e-platform, including advertising promotion, return and exchange policies, and logistics services [10, 11].

At present, more and more ECSCs consisting of sellers and e-platforms are being formed and developed. In the ECSC, providing EW to alleviate consumers' concerns about product quality has become a popular sales strategy. Who is better to provide EW service? How does the power structure of ECSC affect EW? Existing research has not addressed these issues. Considering research gaps, four decision models are constructed and analyzed taking into account the differences in the power structure and EW providers in the ECSC.

This paper aims to address the following problems: what are the optimal decisions of the ECSC system when considering the EW service and the sales service of the e-platform; what is the influence of power structure and different EW service providers on the optimal decisions; what is the comparative relationship of optimal decisions in different decision models; how do enterprises provide the EW service, and whether should they provide the EW service when they dominate ECSC? With these problems in mind, the conclusions intend to provide the managerial insights for the operation of enterprises in the ECSC.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 provides the model illustration and assumptions. Section 4 presents model analysis of EW being provided by the seller or the e-platform. The decisions of the four models are compared and analyzed in Section 5. Section 6 consists of the numerical analysis. Section 7 presents the conclusion.

2. Literature Review

EW service has been recognized and developed rapidly in the economic market, which has also been discussed in many kinds of literature. These studies include the following three streams.

The first stream focuses on the pricing and cost of EW in supply chains. Considering the cost of EW, Chen et al. [12] analyzed how different pricing strategies affect supply chain decisions and profits. Bouguerra et al. [13] studied the maximum payment for consumers and the minimum price for manufacturers to sell EW service. Given EW costs, Shahanaghi et al. [14] designed an EW mechanism and proposed the best operation strategy. Wu and Longhurst [15] and Jung et al. [16] analyzed the cost of EW from the perspective of consumers. Considering the dynamic change of the company's long-term EW price with the learning ability of consumers, Lei et al. [17] explored the impact of EW pricing on corporate earnings. Chen et al. [18] proposed the optimal production cycle and product pricing strategy considering the EW period. Bian et al. [19] compared traditional EW and old-to-new EW and explored the optimal sales price for different EW modes. Based on the hypothesis of bounded rational, Zhao et al. [20] analyzed the impact of vertical competition and fair concerns on the pricing of EW.

The second stream focuses on the provider of EW in supply chains. In a two-tier duopoly supply chain system with EW provided by the retailer, Ma et al. [21] explored the decision of EW periods under supply chain competition. Also, considering that EW is provided by retailers, Zhang et al. [22] investigated the impact of EW costs on retailers' decisions. Li et al. [23] explored the impact of EW providers on decisions in the supply chain. From the perspective of the manufacturer, Su and Wang [24] and Huang et al. [25] presented a preventive maintenance strategy to reduce the cost of EW. Ashayeri et al. [26] proposed a nonconvex mixed-integer programming model and designed a closed-loop distribution network with EW provided by outsourcers.

The third stream focuses on the operation strategy of EW in the supply chain. Heese [27] constructed a supply chain for two manufacturers and one retailer who provided EW and studied the optimal EW strategy for manufacturers and the retailer. Su and Shen [28] considered three repair options for failed components and proposed the best-EW policies. Qin et al. [29] proposed a three-tier online sales supply chain model and analyzed the impact of EW periods on manufacturers' profits and EW value. Mai et al. [30] explored the impact of the way that retailers transfer revenue from manufacturers to EW prices through three methods. In a dual-channel supply chain, He et al. [31] explored the impact of customer channel preferences on EW strategies. Based on consumers' purchasing decision behavior, Zhu et al. [32] studied and coordinated the EW decision model for the closed-loop supply chain with the Stackelberg game. Zheng et al. [5] considered the carbon tax and the trade-in subsidy policy and explored the impact of the trade-in policy on the EW operation model.

Most of the abovementioned research focuses on the context of traditional supply chains and did not consider the development of the Internet economy, nor have they explored the impact of e-platforms on the operation of supply chains and the impact of system channel power structure on EW. Considering the differences in the channel power structure and EW service provider, pricing decisions and service decisions are studied in this research. The differences between this study and the existing literature are shown in Table 1.

The main contributions of this article are as follows:

(1) Considering the differences between the ECSC and the traditional supply chain, four ECSC models are constructed. Then, EW decisions and sales strategies are analyzed. Most of the existing literature focuses on traditional supply chains and rarely considers the impact of the network economy on the supply chain.

(2) Taking the differences of EW providers and dominant enterprises into consideration, this paper explores the impact of supply chain dominance on EW, proposes the optimal EW provider and EW mode, and provides management insights for corporates in the ECSC.

(3) Incorporating the service level of e-platform into the ECSC decision models, this paper explores EW decisions and pricing decisions under different EW models. The research results can guide supply chain participants to set EW price and product price to maximize ECSC profit.

3. Model Illustration and Assumptions

This paper researches an ECSC system that consists of a single seller (called her) and a single e-platform (called him), as shown in Figure 1. In this ECSC, it is assumed that the seller can release the sales information of her products with the aid of e-platform. Meanwhile, to increase sales and improve the service level, both the seller and e-platform can implement a sales strategy of providing EW.

In this ECSC, there are two types of fees paid by the seller when entering the third-party e-platform:

(1) The fixed fee, such as technical fee and deposit, can ensure that the e-platform provides basic services; that is, e-platform allocates an online store (website) to the seller and empowers her to release sales information.

(2) The variable fee, such as commission, changes according to the sales. Currently, many e-platforms, including Tmall (tmall.com) and JD (jd.com), charge commission based on sales revenue. Likewise, e-platform can provide various supplementary services based on the amount of commission, such as advertising (quantity, position, and slot of advertisements), the service of a quick return and exchange for goods, the propagation of online stores, and the sales preservation service (operations agent, payment and customer service, warehouse and logistics service). For instance, Tmall will provide different sales services according to the different commissions paid by the seller, especially for advertising efforts.

The notations used in the models are summarized in Table 2.

In this ECSC system, the dominant modes of the supply chain can be divided into two types: one is the decision-making process dominated by the seller; the other is dominated by the e-platform. In these two dominant modes, both the seller and e-platform individually provide EW service. Thus, the supply chain system has four different decision-making models, as shown in Figure 2.

The following four decision-making models are considered: the seller provides EW service and dominates the ECSC such as Apple that provides EW service for iPhones; the seller provides EW service but does not dominate the ECSC, such as the sellers of mobile phones on JD.com; the e-platform provides EW service and dominates the ECSC, such as GOME; it not only dominates system but also provides EW service; the platform provides EW service but

Table 1: Literature comparison of this study and the existing studies.

References	Pricing strategy	Sales service is involved	EW provider	Dominant enterprise	EW period is considered	Coordination contract	Managerial insights are discussed	EW cost is involved
Li et al. [23]	Y	N	Retailer/ manufacturer	Manufacturer	Y	N	Y	Y
Chiang et al. [8]	N	N	Seller	—	Y	N	N	Y
Afsahi and Shafiee [33]	Y	N	Manufacturer	—	Y	N	N	Y
Bian et al. [34]	Y	N	Two retailers	Manufacturer	Y	N	N	Y
Bian et al. [19]	Y	N	Retailer/ manufacturer	—	N	N	N	Y
Bouguerra et al. [13]	N	N	Manufacturer	—	Y	N	N	Y
Su and Shen [28]	N	N	Manufacturer	—	Y	N	N	Y
Ma et al. [21]	Y	N	Retailers	Manufacturers	Y	Y	N	Y
Huang et al. [25]	N	N	Manufacturer	—	Y	N	N	Y
He et al. [31]	Y	N	Retailer/ manufacturer	Manufacturer	N	N	N	Y
Zhao et al. [20]	Y	N	Retailer/ manufacturer	Retailer	N	N	N	N
Mai et al. [30]	Y	N	Manufacturer	Manufacturer	N	Y	N	Y
This study	Y	Y	Seller/e-platform	Seller/e-platform	N	N	Y	Y

Y = Yes; N = No; — = not consider power structure.

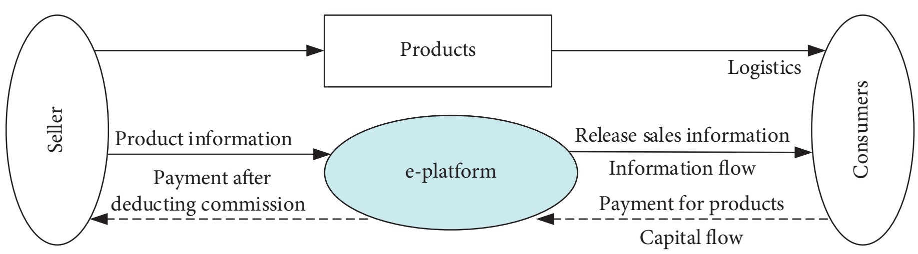

Figure 1: A framework of the ECSC.

does not dominate the ECSC, such as cooperation between powerful mobile phone sellers and JD.com.

4. Model Formulation and Equilibrium Solution

4.1. EW Provided by the Seller. In this case, the profit function of the seller who provides EW service is

$$\pi_r = (p - \rho p)q + (p_o - c_o)q_o - f. \tag{1}$$

The e-platform's profit function is

$$\pi_e = \rho p q - \frac{s^2}{2} + f. \tag{2}$$

The total profit function of the ECSC is

$$\pi = \pi_r + \pi_e. \tag{3}$$

The following sections focus on the decision-making processes of two modes: dominated by the seller or the e-platform. When the seller provides the EW service, there are the following two cases: if the ECSC is dominated by the seller, the seller first determines the sales price and the EW price and then the e-platform determines the service level, and if the ECSC is dominated by the e-platform, the e-platform first determines the service level and then the seller determines the sales price and the EW price.

4.1.1. Decision Model with Dominant Seller. In the ECSC, if the strength of the seller is stronger than the e-platform, the seller can dominate the ECSC and become the leader (first-mover in the game). In practice, according to the cooperation mode of Chinese retail magnate, RT-mart, and her cooperator, Feiniu (www.feiniu.com), a model with the dominant seller can be established: RT-mart sells her

Table 2: Description of notations.

Notations	Description
p	The sales price of the seller
f	The fixed fee paid by the seller for the technical service provided by the e-platform in the selling period
ρ	The commission rate, $0<\rho<1$. ρpq is the total commission charged by e-platform
s	The service level provided by the e-platform for selling products. According to Wang and Li [35] and Pokharel and Liang [36], this paper assumes that the sales service cost function satisfies $C(s) = ks^2/2$, where $k(k>0)$ is the service cost coefficient
c_o	The unit cost of providing EW service in the warranty period
p_o	EW price
q	Market demand for products is greatly affected by sales price and service level. Based on the study of Wu [37] and Otrodi et al. [38], this paper assumes that the demand function (the form of market demand function with the sales price in existing studies includes power function [39, 40], inverse demand function [41], and linear demand function [38]. In this paper, we use the linear demand function which can reflect that demand decreases with sales price and increases with service level [22, 23]) is $q = \alpha - \beta p + \gamma s$, in which, $\alpha(\alpha>0)$ refers to the market saturation, $\beta(\beta>0)$ is the sales price elasticity, and $\gamma(\gamma>0)$ represents the service level elasticity. The larger the value in β and γ, the more the demand is affected. $0<\gamma\leq\beta<\alpha$ implies that consumers are more sensitive to price than service
q_o	Market demand for EW: this demand only emerges from consumers who purchased products. Thus, the highest demand for EW is equal to the highest demand for products without sales service. Meanwhile, the product sales price is also the main factor affecting EW demand (the price elasticity coefficient is the same in both product demand function and EW demand function). Referring to Klaussner and Hendrickson [42], this paper assumes that the EW period is an exogenous constant and the EW demand function is $q_o = \alpha - \beta p - \lambda p_o$. λ is the elasticity coefficient of EW price. The larger the value in λ, the more the demand for EW service is affected. Without the loss of feasibility, $\lambda<\beta<2\lambda$ is required, which restricts that there is no big gap between consumers' sensitivity coefficients to the product price and the EW price
Remarks	To simplify the calculations, this study assumes $\beta = 1$ and $k = 1$. The sales function can be simplified as $q = \alpha - p + \gamma s$, and the EW service demand and the cost function of the e-platform are $q_o = \alpha - p - \lambda p_o$ and $C(s) = s^2/2$, respectively. Meanwhile, it is assumed that $0<\gamma\leq 1<\alpha$, which indicates that consumers are more sensitive to price than service

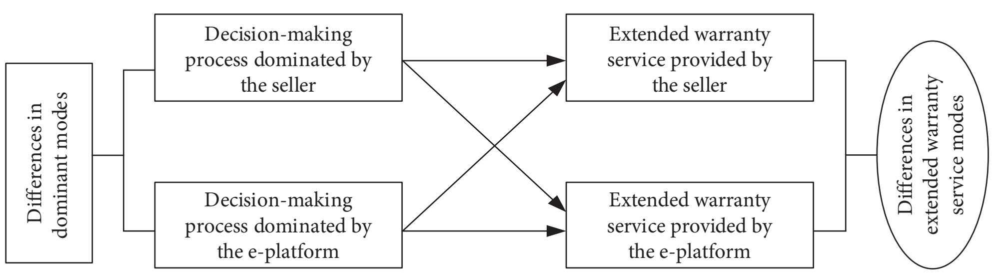

Figure 2: Four decision-making models in the ECSC.

products with the aid of e-platform, Feiniu, forming an ECSC system with the dominant seller and the following e-platform. In this two-echelon Stackelberg game model, the dominant seller first decides the sales price p and the EW price p_o; then, the following e-platform decides the service level s. Both enterprises make decisions individually to maximize their profits. Optimal decisions can be derived by the backward induction method.

There is $\partial^2\pi_e/\partial s^2 = -1 < 0$ according to equation (2); the optimal solution of π_e exists and the response function of service level can be derived as

$$s = \rho\gamma p. \tag{4}$$

Substitute equation (4) into equation (1) and take the second-order derivative of the seller's profit function with respect to the sales price and the EW price; Hessian matrix $H = \begin{bmatrix} \partial^2\pi_r/\partial p^2 & \partial^2\pi_r/\partial p\partial p_o \\ \partial^2\pi_r/\partial p_o\partial p & \partial^2\pi_r/\partial p_o^2 \end{bmatrix} = \begin{bmatrix} -2(1-\rho)(1-\rho\gamma^2) & -1 \\ -1 & -2\lambda \end{bmatrix}$. When $2(1-\rho)(1-\rho\gamma^2)>0$ and $4\lambda(1-\rho)(1-\rho\gamma^2)-1>0$, the optimal solution of $\pi_r(p,p_o)$ exists. The sales price and EW price can be solved by $\partial\pi_r/\partial p = 0$ and $\partial\pi_r/\partial p_o = 0$:

$$\begin{aligned} p^{rR} &= \frac{[2\lambda(1-\rho)-1]\alpha + \lambda c_o}{4\lambda(1-\rho)(1-\rho\gamma^2)-1}, \\ p_o^{rR} &= \frac{\alpha + 2c_0}{2\lambda} - \frac{[2\lambda(1-\rho)-1]\alpha + \lambda c_o}{2\lambda[4\lambda(1-\rho)(1-\rho\gamma^2)-1]}. \end{aligned} \tag{5}$$

When equation (5) is substituted into equation (4), the optimal service level of the e-platform can be obtained. Overall, when the seller dominates the ECSC and provides the EW service, optimal pricing and service strategies are derived as follows:

The optimal product sales price is

$$p^{rR} = \frac{\alpha[2\lambda(1-\rho)-1]+\lambda c_o}{4\lambda(1-\rho)(1-\rho\gamma^2)-1}. \quad (6)$$

The optimal EW price is

$$p_o^{rR} = \frac{\alpha+\lambda c_0}{2\lambda} - \frac{\alpha[2\lambda(1-\rho)-1]+\lambda c_o}{2\lambda[4\lambda(1-\rho)(1-\rho\gamma^2)-1]}. \quad (7)$$

The optimal service level of e-platform is

$$s^{rR} = \frac{\rho\gamma\{\alpha[2\lambda(1-\rho)-1]+\lambda c_o\}}{4\lambda(1-\rho)(1-\rho\gamma^2)-1}. \quad (8)$$

The optimal profit of the seller is

$$\pi_r^{rR} = \frac{\alpha^2(1-\rho)[\lambda(1-\rho)-\rho\gamma^2]}{4\lambda(1-\rho)(1-\rho\gamma^2)-1} + \frac{\lambda^2 c_o^2\alpha^2(1-\rho)(1-\rho\gamma^2)}{4\lambda(1-\rho)(1-\rho\gamma^2)-1} - \frac{\alpha\lambda c_o(1-\rho)(1-2\rho\gamma^2)}{4\lambda(1-\rho)(1-\rho\gamma^2)-1} - f. \quad (9)$$

The optimal profit of e-platform is

$$\pi_e^{rR} = \frac{\rho[\alpha-2\alpha\lambda(1-\rho)-\lambda c_o]}{2[4\lambda(1-\rho)(1-\rho\gamma^2)-1]^2} \cdot \left\{\alpha\left[\rho\gamma^2-2\lambda(1-\rho)\left(2-3\rho\gamma^2\right)\right]+\lambda c_o\left(2-\rho\gamma^2\right)\right\}+f. \quad (10)$$

The optimal profit of the ECSC is

$$\pi^{rR} = \pi_r^{rR} + \pi_e^{rR}. \quad (11)$$

4.1.2. Decision Model with Dominant e-Platform. In the ECSC, if the strength of e-platform is stronger than the seller, the e-platform can dominate the supply chain. This section takes Tmall as a practical case, and a model with a dominant e-platform can be established. Tmall, as a powerful platform enterprise, has the initiative to choose cooperators, including small and medium-sized sellers, thus can dominate the whole supply chain. Therefore, in this two-echelon Stackelberg game model, the dominant e-platform first decides service level s; then, the following seller decides sales price p and EW price p_o. The optimal decisions can be derived by the backward induction method.

Based on equation (1), $\partial^2\pi_r/\partial p^2 = -2(1-\rho) < 0$, $\partial^2\pi_r/\partial p_o^2 = -2\lambda$, and $\partial^2\pi_r/\partial p\partial p_o = \partial^2\pi_r/\partial p_o\partial p = -1$. When $4\lambda(1-\rho)-1>0$, the optimal solution of $\pi_r(p,p_o)$ exists. According to $\partial\pi_r/\partial p = 0$ and $\partial\pi_r/\partial p_o = 0$, the response functions of the sales price and the EW price are as follows:

$$p = \frac{\alpha-\lambda c_o-2\lambda[(1-\rho)(\alpha+\gamma s)]}{1-4\lambda(1-\rho)}, \; p_o = \frac{c_o+(1-\rho)(\gamma s-\alpha-2\lambda c_o)}{1-4\lambda(1-\rho)}. \quad (12)$$

Substituting equation (12) into equation (2), $\partial^2\pi_e/\partial s^2 = -4\lambda(1-\rho)(2-\rho\gamma^2)\,[2\lambda(1-\rho)-1]+1/[4\lambda(1-\rho)-1]^2$; when $4\lambda(1-\rho)(2-\rho\gamma^2)[2\lambda(1-\rho)-1]+1>0$, the optimal solution of $\pi_e(s)$ exists. Solving $\partial\pi_e/\partial s=0$,

$$s^{rE} = \rho\gamma\cdot\frac{\alpha\{1+4\lambda[2\lambda(1-\rho)-1](1-\rho)\}-\lambda c_o}{N}. \quad (13)$$

When equation (13) is substituted into equation (12), the optimal sales price and the EW price can be obtained.

The optimal product sales price is

$$p^{rE} = \frac{2\lambda(1-\rho)}{Q}\cdot\frac{M}{N} - \frac{\alpha-\lambda c_o}{Q}. \quad (14)$$

The optimal EW price is

$$p_o^{rE} = \frac{(1-\rho)}{Q}\cdot\frac{\alpha Q^2(1-\rho\gamma^2)+\rho\gamma^2\lambda c_o}{N} - \frac{c_o[1-2\lambda(1-\rho)]}{Q}. \quad (15)$$

The optimal service level of e-platform is

$$s^{rE} = \rho\gamma\cdot\frac{\alpha\{1+4\lambda[2\lambda(1-\rho)-1](1-\rho)\}-\lambda c_o}{N}. \quad (16)$$

The optimal profit of seller is

$$\pi_r^{rE} = \frac{(1-\rho)}{Q}\left[2\lambda(1-\rho)\cdot\frac{M}{N}-(\alpha-\lambda c_o)\right]\left[\frac{2\lambda(1-\rho)-1}{Q}\cdot\frac{M}{N}+\frac{\alpha-\lambda c_o}{Q}\right] + \frac{(1-\rho)^2}{Q^2}\left[\frac{\alpha Q^2(1-\rho\gamma^2)-\rho\gamma^2\lambda c_o}{N}-2\lambda c_o\right]\cdot\left[2(\alpha-\lambda c_o)-\lambda\cdot\frac{M}{N}\right]-f. \quad (17)$$

The optimal profit of e-platform is

$$\pi_e^{rE} = \frac{\rho\alpha^2\{4\lambda(1-\rho)[2\lambda(1-\rho)-1]+\rho\gamma^2\}+\lambda\rho c_o\{2\alpha(1-\rho\gamma^2)-\lambda c_o(2-\rho\gamma^2)\}}{2N}+f. \quad (18)$$

The optimal profit of ECSC is $\pi = \pi_r^{rE} + \pi_e^{rE}$, in which $Q = 4\lambda(1-\rho)-1$, $N = 4\lambda[2\lambda(1-\rho)-1](1-\rho)(2-\rho\gamma^2)+1$, and

$$M = \alpha\left\{1+\rho\gamma^2+8\lambda[2\lambda(1-\rho)-1](1-\rho)\right\}-\rho\gamma^2\lambda c_o. \quad (19)$$

4.2. EW Provided by e-Platform. In order to obtain more profits, the e-platform should consider providing EW. For example, many e-platforms, such as JD (jd.com), GOME (gome.com.cn), and Suning (suning.com), would provide EW service for consumers. In this case, the profit function of the seller is

$$\pi_r = (p - \rho p)q - f. \tag{20}$$

The e-platform's profit function is

$$\pi_e = \rho p q + (p_o - c_o)q_o - \frac{s^2}{2} + f. \tag{21}$$

The total profit function of the ECSC is

$$\pi = \pi_r + \pi_e. \tag{22}$$

Similarly, there are two dominant modes: the ECSC dominated by the seller or the ECSC dominated by the e-platform. When the e-platform provides the EW service, there are the following two cases: if the ECSC is dominated by the e-platform, the e-platform first determines the service level and the EW price and then the seller determines the sales price, and if the ECSC is dominated by the seller, the seller first determines the sales price and then the e-platform determines the service level and the EW price.

4.2.1. Decision Model with Dominant Seller. When the seller dominates the ECSC and the e-platform provides the EW service, the seller first decides the sales price p and then the e-platform decides the service level s and the EW price p_o, forming a two-echelon Stackelberg game model.

From equation (21), $\partial^2\pi_e/\partial s^2 = -k < 0$, $\partial^2\pi_e/\partial p_o^2 = -2\lambda < 0$, and $\partial^2\pi_e/\partial p_o\partial s = \partial^2\pi_e/\partial s\,\partial p_o = 0$, where π_e is a strictly concave function of p_o and s. According to $\partial\pi_e/\partial p_o = 0$ and $\partial\pi_e/\partial s = 0$, we obtain

$$p_o = \frac{\alpha - p + \lambda c_o}{2\lambda}, s = \frac{\rho\gamma p}{k}. \tag{23}$$

Substituting equation (23) into equation (20), $\partial^2\pi_r/\partial p^2 = -2(1-\rho)(1-\rho\gamma^2) < 0$; the optimal solution of $\pi_r(p)$ exists. Solving $\partial\pi_r/\partial p = 0$, we obtain

$$p^{eR} = \frac{\alpha}{2(1-\rho\gamma^2)}. \tag{24}$$

Substituting equation (24) into equation (23), the optimal EW price and service level can be obtained.

The optimal product sales price is

$$p^{eR} = \frac{\alpha}{2(1-\rho\gamma^2)}. \tag{25}$$

The optimal EW price is

$$p_o^{eR} = \frac{\alpha + \lambda c_o}{2\lambda} - \frac{\alpha}{4\lambda(1-\rho\gamma^2)}. \tag{26}$$

The optimal service level of e-platform is

$$s^{eR} = \frac{\rho\gamma\alpha}{2(1-\rho\gamma^2)}. \tag{27}$$

The optimal profit of the seller is

$$\pi_r^{eR} = \frac{\alpha^2(1-\rho)}{4(1-\rho\gamma^2)} - f. \tag{28}$$

The optimal profit of e-platform is

$$\pi_e^{eR} = \frac{\alpha^2\rho}{4(1-\rho\gamma^2)} + \frac{1}{16\lambda}\left[\frac{\alpha(1-2\rho\gamma^2)}{1-\rho\gamma^2} - 2\lambda c_o\right]^2 - \frac{\alpha^2\rho^2\gamma^2}{8(1-\rho\gamma^2)^2} + f. \tag{29}$$

The optimal profit of the ECSC is

$$\pi^{eR} = \pi_r^{eR} + \pi_e^{eR}. \tag{30}$$

4.2.2. Decision Model with Dominant e-Platform. When the e-platform dominates the ECSC and provides the EW service, the service level s and the EW price p_o are given first and then the seller decides the sales price p, forming a two-echelon Stackelberg game model.

According to equation (20), $\partial^2\pi_r/\partial p^2 = -2(1-\rho) < 0$; through $\partial\pi_r/\partial p = 0$, we obtain

$$p = \frac{(\alpha + \gamma s)}{2}. \tag{31}$$

Substituting equation (31) into equation (21), $\partial^2\pi_e/\partial s^2 = \rho\gamma^2/2 - 1 < 0$, $\partial^2\pi_e/\partial p_o^2 = -2\lambda$, and $\partial^2\pi_e/\partial p_o\partial s = \partial^2\pi_e/\partial s\,\partial p_o = -\gamma/2$; when $8\lambda - \gamma^2(1+4\lambda\rho) > 0$, the optimal solution of $\pi_e(p_o, s)$ exists. According to $\partial\pi_e/\partial p_o = 0$ and $\partial\pi_e/\partial s = 0$, we obtain

$$p_o^{eE} = \frac{2\alpha(1-\rho\gamma^2) + c_o[4\lambda - \gamma^2(1+2\lambda\rho)]}{8\lambda - \gamma^2(1+4\lambda\rho)}, s^{eE} = \frac{\gamma[2\lambda c_o - \alpha(1-4\lambda\rho)]}{8\lambda - \gamma^2(1+4\lambda\rho)}. \tag{32}$$

Substituting equation (32) into equation (31), the optimal sales price can be obtained.

The optimal product sales price is

$$p^{eE} = \frac{4\alpha\lambda - \alpha\gamma^2 + \lambda\gamma^2 c_o}{8\lambda - \gamma^2(1+4\lambda\rho)}. \tag{33}$$

The optimal EW price is

$$p_o^{eE} = \frac{2\alpha(1-\rho\gamma^2) + c_o[4\lambda - \gamma^2(1+2\lambda\rho)]}{8\lambda - \gamma^2(1+4\lambda\rho)}. \tag{34}$$

The optimal service level of e-platform is

$$s^{eE} = \frac{\gamma[2\lambda c_o - \alpha(1-4\lambda\rho)]}{8\lambda - \gamma^2(1+4\lambda\rho)}. \tag{35}$$

The optimal profit of the seller is

$$\pi_r^{eE} = (1-\rho)\left\{\frac{\alpha(4\lambda-\gamma^2) + \lambda\gamma^2 c_o}{[8\lambda - \gamma^2(1+4\lambda\rho)]}\right\}^2 - f. \tag{36}$$

The optimal profit of e-platform is

$$\pi_e^{eE} = \frac{\alpha^2(1+4\lambda\rho-2\rho\gamma^2) - 4\lambda c_o\alpha(1-\rho\gamma^2)}{2[8\lambda - \gamma^2(1+4\lambda\rho)]} + f. \tag{37}$$

The optimal profit of the ECSC is

$$\pi^{eE} = \pi_r^{eE} + \pi_e^{eE}. \quad (38)$$

5. Analysis of Optimal Decisions

The following propositions can be obtained by comparing and analyzing the optimal decisions of the four decision-making models.

Proposition 1

(1) *Sales prices in different models: $p^{eR} > p^{eE} > p^{rE} > p^{rR}$; EW prices in different models: $p_o^{rR} > p_o^{rE} > p_o^{eE} > p_o^{eR}$*

The proof is given in Appendix A.

Because products and the EW service are the sources of profits for enterprises, there may be competition between the sales price and the EW price. Proposition 1 compares the sales price of products and the EW price under different models to find out how channel power structure and the EW service enterprise affect the sales price and the EW price. According to Proposition 1,

(1) The comparison of product sales prices is contrary to the EW prices because the demand for EW is negatively related to the sales price. When the sales price reaches the highest, enterprises would reduce the EW price for maintaining market demand for the EW service. In these four models, when the dominant seller provides the EW service, the sales price reaches the lowest but the EW price reaches the highest; when the following e-platform provides the EW service, the sales price is the highest but the EW price is the lowest. This is because when the seller dominates the supply chain and provides the EW service simultaneously, the seller would like to stimulate product market demand through setting a lower sales price. However, the dominant seller decides a higher sales price when the following e-platform provides the EW service, and the e-platform has to set a lower EW price to maintain market demand for the EW service which is negatively related to the sales price.

(2) Compared with the case that the seller provides the EW service, it is indicated that the sales price is higher and the EW price is lower when the e-platform becomes the provider of EW service. This is because all the profit generated from the EW service is possessed by the e-platform when it provides the EW service, the seller can only gain profit from product sales by setting a higher sales price. However, a higher sales price means that the demand for EW service may decrease, forcing the e-platform to reduce the EW price to maintain demand for the EW service. For instance, JD, a Chinese online e-platform, has been providing the EW service for electrical appliances and digital products, and the sales prices of these products are relatively higher in JD than other e-platforms, such as GOME and Suning (like the insurance for broken phone screens at https://www.jd.com/pinpai/982-9639.html).

Proposition 2. *p^{rE}, p^{rR}, p_o^{eE}, and p_o^{eR} have a negative correlation with ρ, but p^{eR}, p^{eE}, p_o^{rR}, and p_o^{rE} have a positive correlation with ρ.*

The proof is given in Appendix B.

Proposition 2 analyzes how the sales price of products and the EW price change with the commission rate of the e-platform. The commission rate is set by the platform and affects price adjustments and profit distribution between the seller and the platform, which is of significance for enterprises.

When the seller provides the EW service, the sales price decreases but the EW price increases with the commission rate. However, in the case of the e-platform providing the EW service, the results are the opposite: the sales price increases but the EW price decreases with the commission rate. This is because the seller who provides the EW service can gain profit by reducing her sales price and increasing the EW price concurrently even if the commission rate gets higher. Such behavior is more acceptable for consumers than increasing the sales price directly, thus helping the seller to implicitly occupy the consumer surplus. For example, Haier, a Chinese firm who produces and sells electric appliances, has been focusing on dynamically adjusting the sales price and the EW price to keep profitable. In 2011, in order to cope with the pressure of high operating costs, Haier increased the EW price while reducing the product sales price (http://news.sina.com.cn/c/2011-06-28/090322718682.shtml). However, when EW is provided by the e-platform, sellers can only gain profit from selling products and set a higher sales price with the increase in the commission rate. As for the e-platform, the provider of EW service has to reduce the EW price for the market demand for EW.

Proposition 3. *The service level of the e-platform in different models: $s^{rE} > s^{eR} > s^{rR} > s^{eE}$.*

The proof is given in Appendix C.

Proposition 3 compares the service level of the e-platform under four operation models to study the influence of channel power structure and EW service enterprise on the service level. According to Proposition 3,

(1) When the following seller provides EW in an ECSC with the dominant e-platform, the service level of e-platform reaches the highest. This is because the dominant e-platform only gains profit from selling products, the higher service level is determined to attract more consumers and increase market demand for products.

(2) When the dominant e-platform provides the EW service, the service level of e-platform reaches the lowest. The EW service is a source of the e-platform's profit, which makes e-platform pay more attention to the EW service market but neglect the product market to a certain extent. Hence, the service level for product sales would decrease. On the other hand, when the seller dominates the supply chain, the dominant seller can compel the following e-platform to increase the service level to promote product sales.

(3) If the ECSC is dominated by the seller, the service level will be higher with the e-platform providing EW than the seller providing EW. In this case, it is extremely difficult for the e-platform to increase his profit by raising the service level, which forces the e-platform to make more efforts to improve the EW service. Therefore, in this situation, the service level will be higher with the e-platform providing the EW service than the seller providing the EW service.

In conclusion, if the ECSC is dominated by the e-platform, it is beneficial for the e-platform to increase the service level for product sales when the seller provides the EW service. Otherwise, if the seller dominates the ECSC, it is conducive for the e-platform to improve service level when the e-platform is the EW provider. In brief, the service level of product sales is always lower when the dominant enterprise in the supply chain provides the EW service compared with the following enterprise providing the EW service. This indicates that the service level can be higher as long as the dominant party and the provider of EW service are different.

6. Numerical Analysis

This section analyzes the performance of various models through numerical examples and investigates the variations in optimal decisions and profits. Suning, a Chinese online e-platform, is used to carry out the numerical analysis. Based on the laptop sales of Suning, this paper assumes that $\alpha = 1000$, $\gamma = 0.3$, $\lambda = 0.7$, $c_o = 50$, and $f = 1500$. Then, this section discusses the impact of the commission rate $\rho \in [0.03, 0.1]$ on decisions and profits. The results of the four decision-making structures are indicated in Figures 3–8.

It can be seen from Figures 3 and 4 that when the e-platform provides the EW service, the sales price increases but the EW price decreases with the commission rate and when the seller provides the EW service, the sales price decreases but the EW price increases over the commission rate. Moreover, the sales price (EW price) reaches the highest (lowest) with the e-platform providing EW than the seller providing EW. According to Figure 5, the service level of the e-platform increases with the commission rate and the service level reaches the highest with the seller providing EW and the e-platform dominating the ECSC. The service level becomes the lowest in the ECSC with the dominant e-platform which also provides the EW service. This conclusion is consistent with Proposition 3.

Proposition 4 is derived from Figures 6 and 7.

Proposition 4. *Comparing the different decision-making models, there are* $\pi_r^{rE} > \pi_r^{rR} > \pi_r^{eR} > \pi_r^{eE}$ *and* $\pi_e^{eE} > \pi_e^{eR} > \pi_e^{rR} > \pi_e^{rE}$.

As a service product, the EW service contributes to enterprise profits, so Proposition 4 compares the profits of the seller and the e-platform under the four models to analyze the influence of channel power structure and EW service enterprise on profits. According to Proposition 4,

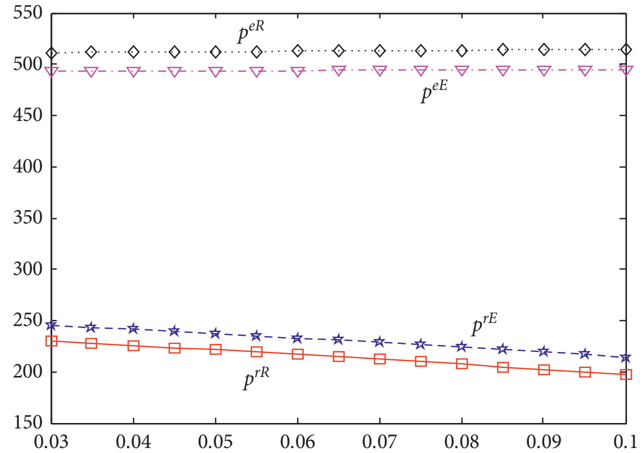

Figure 3: Optimal sales price over ρ.

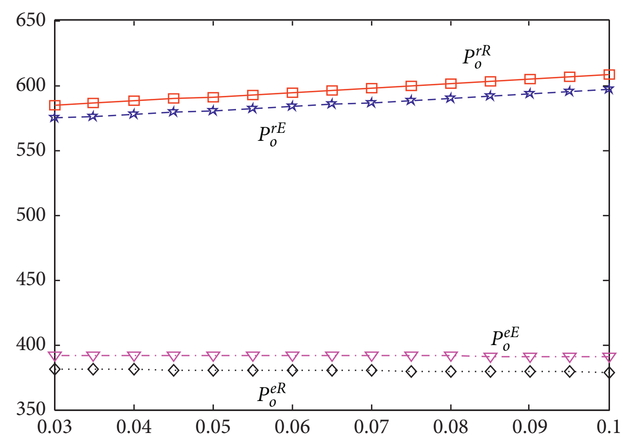

Figure 4: Optimal EW price over ρ.

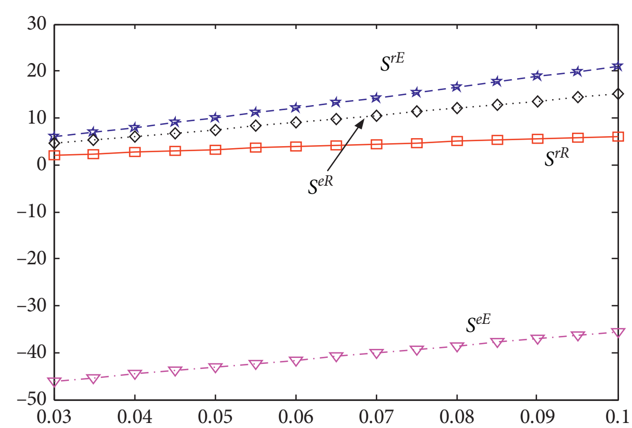

Figure 5: Optimal service level over ρ.

(1) Both the seller and e-platform can obtain more profits when providing EW, which is why all supply chain members are keen on providing EW.

(2) According to the comparison of four decision-making models, the comparison of the seller's profits has the

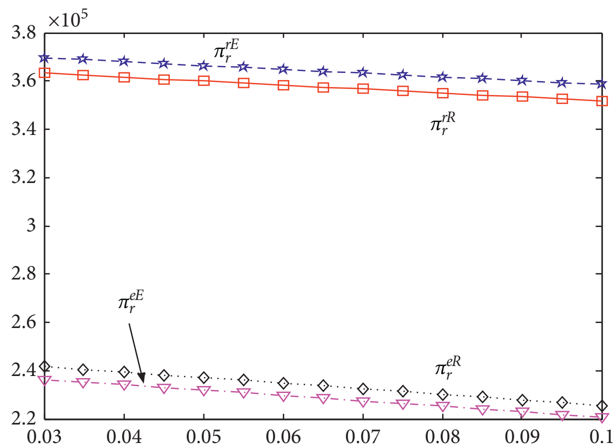

Figure 6: Optimal profit of the seller over ρ.

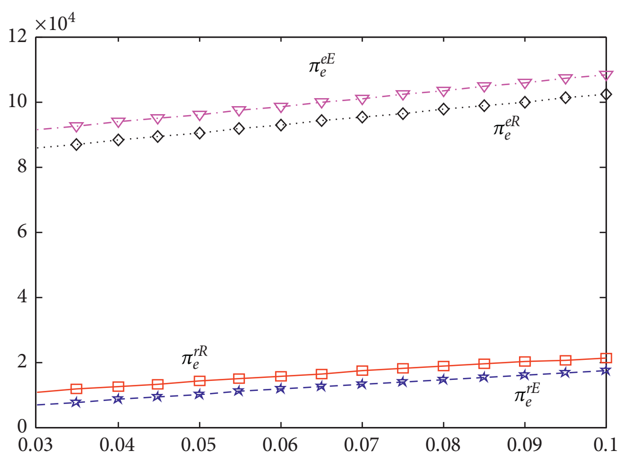

Figure 7: Optimal profit of e-platform over ρ.

contrary order with the e-platform's profits. The seller's profit is the highest when the seller provides EW in a supply chain with a dominant e-platform, but the e-platform's profit is the lowest in this model. Likewise, the e-platform's profit is the highest when the e-platform provides the EW service and dominates the supply chain at the same time, but the seller's profit is the lowest. Therefore, when e-platform provides EW in an ECSC, it is profitable for supply chain members to obtain the dominant power. However, the result is the opposite when the seller provides EW, the dominant enterprise will get less profit.

Overall, for the supply chain enterprises, it is conducive to increasing profit to dominate the supply chain or provide EW.

Proposition 5 can be obtained from Figure 8.

Proposition 5. *Comparing different decision-making models, there is* $\pi^{rE} > \pi^{rR} > \pi^{eR} > \pi^{eE}$.

Proposition 5 compares the profits of the ECSC system under four decision-making models to show which decision-making model can achieve the highest system profit. Propositions 4 and 5 indicate that comparison results of system profit are consistent with the results of the seller's profit. In these four decision models, the system profit reaches the highest when the seller provides the EW service and the e-platform dominates the supply chain. In this case, the sales service level also reaches the highest, and both the sales price and the EW price are relatively lower, which can improve the product demand and demand for the EW service. This is the reason why the system profit is the highest in the condition where the seller provides the EW service and the e-platform dominates the supply chain. Therefore, in practice, Suning, as a dominant e-platform enterprise in the electric appliance supply chain, leaves the EW service to sellers, such as Philips, Changhong, TCL, LG, and Samsung.

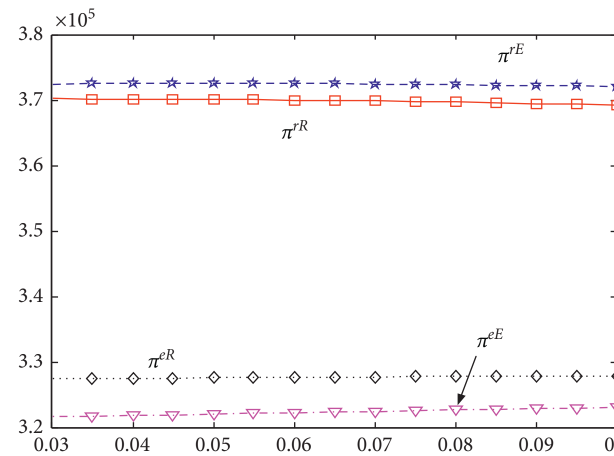

Figure 8: Optimal system profit over ρ.

7. Discussion

7.1. Main Findings. With the rapid development of the network economy, the ECSC has been greatly promoted and advanced. In order to expand the e-commerce sales market and product diversity, a great number of enterprises in the ECSC begin to focus on EW business. Therefore, this paper builds an ECSC model with a single seller and a single e-platform and studies the pricing and EW strategies. Furthermore, this study considers the differences of providers and dominators and then constructs four decision-making models: when the seller provides EW, there are two models with the dominant seller or dominant e-platform; likewise, there are also two models when e-platform provides EW. Ultimately, this paper obtains the optimal solutions in various models and further analyzes them with numerical examples. The results show the following.

According to the comparison of four decision-making models, the total profit reaches the highest when the seller provides EW and e-platform dominates the supply chain. Meanwhile, in this case, the sales service level reaches the highest, but both the sales price and the EW price are relatively lower. For the supply chain members, dominating the supply chain or providing EW is conducive to improving profit. Therefore, when e-platform provides EW in an ECSC, it is profitable for supply chain members to obtain the dominant power. However, the result is the opposite when the seller provides EW; it is not beneficial to obtain the dominant power.

Moreover, this paper finds that when e-platform dominates the supply chain system, it is beneficial for e-platform increasing product service level when the seller provides EW. However, when the seller dominates the whole system, it is constructive for e-platform to increase the product service level when the e-platform is the EW provider. The service level for product sales is always lower when the dominant enterprise provides EW. Besides, this study points out that the sales price is relatively higher but the EW price goes lower with the e-platform providing EW rather than the seller providing EW.

7.2. Managerial Implications. Some managerial suggestions can be derived from conclusions as follows.

By the comparative analysis of sales price and EW price, it can be known that the minimum sales price and the minimum EW price cannot be in the same decision model. The seller and the e-platform should recognize this and set a sales price and an EW price rationally.

Regardless of the seller or the e-platform providing the EW service, the provider can obtain higher profit, which indicates that the EW service can be a profit source for enterprises. Therefore, the sellers and the e-platform should actively provide the EW service to increase profits.

The findings show that when the e-platform provides the EW service, the conclusion is that who dominates the system is the one who gets more profit; and when the seller provides the EW service, the conclusion is that who dominates the system is the one who gets less profit. Therefore, when leading the supply chain, the e-platform should provide the EW service; however, when the seller dominates the system, it is wise not to provide the EW service.

In the ECSC, if the product market demand tends to be increased through service level, the dominant enterprise and the enterprise that provides the EW service might just as well not be the same because the service level is higher in this operating model.

7.3. Limitation and Future Research. This paper only considers an ECSC system which is composed of a single seller and a single e-platform. In reality, there are also other operation modes, such as multisellers on single platform and multisellers on multiplatforms, which are the future research directions we should focus on. Besides, we also need to pay attention to the other key factor, the warranty period, which can significantly influence the decision-making process.

Appendix

A. Proof of Proposition 1

Proof

$$p^{eR} - p^{eE} = \gamma^2 \cdot \frac{\alpha\left(1 + 4\lambda\rho - 2\rho\gamma^2\right) - 2\lambda c_o\left(1 - \rho\gamma^2\right)}{2\left(1 - \rho\gamma^2\right)\left[8\lambda - \gamma^2\left(1 + 4\lambda\rho\right)\right]} > 0, \quad \text{(A.1)}$$

$$p^{rE} - p^{rR} = \frac{2\alpha\lambda\rho\gamma^2\left(1 - \rho\right)\left\{4\lambda\left(1 - \rho\right)\left[2 - 2\lambda\left(1 - \rho\right) - \rho\gamma^2\right] - 1\right\} - \lambda c_o\left(1 - \rho\right)\left[4\lambda\left(1 - \rho\right)\left(2 - \rho\gamma^2\right) - 1\right]}{\left[4\lambda\left(1 - \rho\right)\left(1 - \rho\gamma^2\right) - 1\right]\left\{4\lambda\left[2\lambda\left(1 - \rho\right) - 1\right]\left(1 - \rho\right)\left(2 - \rho\gamma^2\right) + 1\right\}} > 0, \quad \text{(A.2)}$$

$$p_o^{eE} - p_o^{eR} = \frac{\alpha\left\{4\lambda\left(2\lambda - 1\right) + \gamma^2\left(1 - \lambda\right)\left(1 + 4\lambda\rho\right) - \rho\gamma^4\right\} - \lambda\gamma^2 c_o\left(1 - \rho\gamma^2\right)}{2\lambda\left(2 - \rho\gamma^2\right)\left[8\lambda - \gamma^2\left(1 + 4\lambda\rho\right)\right]} > 0. \quad \text{(A.3)}$$

The same can be proved, $p^{eE} - p^{rE} > 0$, $p_o^{rR} - p_o^{rE} > 0$, and $p_o^{rE} - p_o^{eE} > 0$; therefore, $p^{eR} > p^{eE} > p^{rE} > p^{rR}$ and $p_o^{rR} > p_o^{rE} > p_o^{eE} > p_o^{eR}$. □

B. Proof of Proposition 2

Proof

$$\frac{\partial p^{eR}}{\partial \rho} = \frac{\alpha\gamma^2}{2\left(1 - \rho\gamma^2\right)^2} > 0,$$

$$\frac{\partial p_o^{eR}}{\partial \rho} = -\frac{\alpha\gamma^2}{2\left(1 - \rho\gamma^2\right)^2} < 0,$$

$$\frac{\partial p^{eE}}{\partial \rho} = 4\lambda\gamma^2 \cdot \frac{\alpha\left(4\lambda - \gamma^2\right) + \lambda c_o\gamma^2}{\left[8\lambda - \gamma^2\left(1 + 4\lambda\rho\right)\right]^2} > 0,$$

(B.1)

$$\frac{\partial p_o^{eE}}{\partial \rho} = \frac{-2\alpha\gamma^2(4\lambda-\gamma^2) - 2\lambda c_o\gamma^4}{\left[8\lambda - \gamma^2(1+4\lambda\rho)\right]^2} < 0,$$
$$\frac{\partial p^{rR}}{\partial \rho} = 2\lambda\frac{\alpha\left\{-1+\gamma^2\left[4\rho+4\lambda(1-\rho)^2-2\right]\right\} + 2\lambda c_o\left[1+\gamma^2(1-2\rho)\right]}{\left[4\lambda(1-\rho)(1-\rho\gamma^2)-1\right]^2} < 0, \tag{B.2}$$

$$\frac{\partial p_o^{rR}}{\partial \rho} = \frac{\alpha\left\{1+\gamma^2\left[2-4\rho-4\lambda(1-\rho)^2\right]\right\} - 2\lambda c_o\left[1+\gamma^2(1-2\rho)\right]}{\left[4\lambda(1-\rho)(1-\rho\gamma^2)-1\right]^2} > 0. \tag{B.3}$$

Similarly, $\partial p^{rE}/\partial\rho < 0$ and $\partial p_o^{rE}/\partial\rho > 0$. □

C. Proof of Proposition 3

Proof

$$s^{eR} - s^{rR} = \rho\gamma\cdot\frac{\alpha(1-2\rho\gamma^2) - 2\lambda c_o(1-\rho\gamma^2)}{2(1-\rho\gamma^2)\left[4\lambda(1-\rho)(1-\rho\gamma^2)-1\right]} > 0, \tag{C.1}$$

$$s^{rE} - s^{eR} = \alpha\rho\gamma\cdot\frac{1-2\gamma^2\{1+2\lambda\rho(1-\rho)[2\lambda(1-\rho)-1]\}}{2(1-\rho\gamma^2)\{4\lambda[2\lambda(1-\rho)-1](1-\rho)(2-\rho\gamma^2)+1\}} + \frac{2\lambda c_o}{2\{4\lambda[2\lambda(1-\rho)-1](1-\rho)(2-\rho\gamma^2)+1\}} > 0. \tag{C.2}$$

Similarly, $s^{rR} - s^{eE} > 0$; therefore, $s^{rE} > s^{eR} > s^{rR} > s^{eE}$. □

Data Availability

The data used to support the findings of this study are included within the article.

Additional Points

Suning's (suning.com) sales case is referenced in this paper, but we did not use Suning's real sales data for numerical analysis. Just refer to Suning's sales and warranty extensions and make theoretical assumptions about the parameters involved in the numerical analysis so as to give simulation graphics analysis.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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