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Selling models for platforms under service-sensitive demand☆

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ABSTRACT

Choosing an appropriate selling model for online retailing is a crucial problem faced by many e-commerce platforms and manufacturers. We examined three popular selling models on e-commerce platforms—the reselling model, the agency selling model, and the advertising service model—and examined the impact of product features, service efficiency, and interfirm power relationships on the choice of selling models. The problem was analyzed as a two-stage bargaining problem between a platform and a manufacturer under service-sensitive demand. We show that the choice of selling models is influenced by the interfirm power relationship, firms' service efficiencies, and demand sensitivities. Specifically, when the manufacturer dominates the bargaining game, it is always beneficial to choose the agency selling model, except when the manufacturer has lower service efficiency than the platform and customer demand is extremely sensitive to service. In contrast, when the platform has the dominant bargaining power, it should always opt for the reselling model if it has better service efficiency than the manufacturer. As the price and service sensitivities of customer demand increase, their influences in determining the optimal selling model increase. The advertising service model becomes a viable option only when the manufacturer has superior service efficiency but less bargaining power than the platform and when there is low price sensitivity but high service sensitivity. In addition, we considered a two-part tariff selling model that includes a fixed membership fee and a unit transaction rate, and different direct sales costs for the platform under the three selling models.

1. Introduction

1.1. A motivational case

Over the past decade, there has been significant growth in online retailing, a trend that the recent COVID-19 pandemic has accelerated. Global retail e-commerce sales reached a staggering US$4.9 trillion worldwide in 2021 and are expected to continue to grow in the future.[1] Consumers in the United States (US) spent $870.78 billion online in 2021, a 14.0% increase over the previous year, according to the US Department of Commerce.[2] Total online retail sales in China amounted to just over $2 trillion in 2021, which represents 52.1% of all retail e-commerce sales worldwide.[3] Online retail platforms contributed substantially to this growth. For instance, Amazon reached an all-time high of 56.7% of US online retail sales in 2021.[4] In China, the leading e-commerce platforms, such as Taobao and Tmall, both owned by Alibaba Group Holding Ltd., and JD.com account for more than 60% of the e-commerce market.[5]

Different selling models have been adopted by major e-commerce platforms, as shown in Table 1 [37]. The three most popular selling models are the reselling model, the agency selling model, and the advertising service model. For instance, Ama-

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Table 1
Selling models for major e-commerce platforms.

E-commerce Platforms	Selling models
Amazon	Reselling/Agency selling
eBay	Agency selling
AliExpress	Agency selling
Taobao	Advertising service
JD.com	Reselling/Agency selling
Mercado libre	Agency selling
Shopee	Agency selling /Advertising service
Tmall	Agency selling
Wish	Advertising service
Lazada	Reselling/Agency selling

zon and JD.com use both reselling and agency selling models, while Taobao uses an advertising service model. In the reselling model, e-commerce platforms buy products from manufacturers and sell them to consumers, which is similar to traditional brick-and-mortar retailing. In the agency selling model, manufacturers sell products directly to consumers on e-commerce platforms and pay the platforms a transaction fee for each unit of product sold [1]. In the advertising service model, manufacturers can utilize basic platform services for free but pay for advertising services to expand their exposure [5]. For platforms, an important decision is whether to sell a range of product categories using the reselling model or charge manufacturers for service fees using either the agency selling model or the advertising service model. For manufacturers, the strategic choice is whether to engage in wholesale operation with platforms under the reselling model or sell directly to consumers on the platforms under either the agency selling model or the advertising service model.

We examined the three selling models systematically under service-sensitive demand. While price is usually considered the most important factor affecting demand, service-related factors such as convenience, delivery, and product returns have become more critical in attracting consumers who buy online [16]. For example, free two-day delivery service for Amazon Prime customers has played a crucial role in Amazon's success. High-quality customer service has become a strategic weapon for JD.com to compete with other leading e-commerce platforms such as Taobao and Pinduoduo in the Chinese market. We also consider interfirm power relationships between platforms and manufacturers [31,34]. Although firms of different sizes, from leading international brands to small family businesses, sell on e-commerce platforms, most vendors are less powerful than platforms. It is therefore valuable to understand the role of power relationships when selecting a selling model.

1.2. Research questions and main findings

Our modeling framework considered the setting of a manufacturer selling a product on a platform through one of the three selling models. Depending on the contractual agreements between the manufacturer and the platform, the two firms negotiate the wholesale price (the reselling model), unit transaction rate (the agency selling model), or advertising fee (the advertising service model). We sought to understand how firms' strategic choice of different selling models is affected by price and service demand sensitivities and interfirm power relationships. We also extended our analysis to a two-part tariff model that incorporates both the advertising service fee and the unit transaction rate.

The following three research questions were investigated:

- Given service-sensitive demand, when should the reselling model, agency selling model, or advertising service model be used?
- How does bargaining power in contractual negotiations between platforms and manufacturers affect the choice of the selling models?
- How do the product price and service sensitivities affect the choice of a selling model?

To address these research questions, we first determined the equilibrium solution for each selling model. Then, we compared the reselling and agency selling models with respect to retail prices, service levels, and firms' individual and collective profits. We conducted a similar comparison between the reselling and advertising service models. The choice of a selling model was then explored by evaluating the platform's profit and the total channel profit among the three selling models. This evaluation systematically examined the impacts of price, service demand sensitivities, the interfirm power relationship, and the efficiency of firms' service provision on the selection of a selling model. We also extend the analysis to a similar comparison between the reselling model and a two-part tariff model with a fixed membership fee and a unit transaction rate.

We show in this paper that firms' bargaining power is crucial in the choice of a selling model. In particular, when the manufacturer's negotiating power is greater than that of the platform, it is almost always beneficial for the manufacturer to choose the agency selling model; the exception is when the service demand sensitivity is high and the manufacturer has lower service efficiency than the platform. In contrast, when the manufacturer has less negotiating power than the platform, the platform should always opt for the reselling model if its service efficiency is greater than that of the manufacturer. The price and service sensitivities of customer demand become more influential than bargaining power in the choice of a selling model as demand sensitivities increase. For instance, regardless of the interfirm power relationship, the agency selling model always performs the best when both the price and service sensitivities are high and the manufacturer has superior service efficiency; conversely, the reselling model is the preferred selling model when customers are extremely service-sensitive and the platform has superior service efficiency. In contrast to the exiting literature [30] that the agency selling model leads to better financial performance because of an elimination of double marginalization, our results reveal the effects of several other factors including firms' service efficiencies, the demand sensitivity to service, and the interfirm power relationship on the performance of alternative selling models. Interestingly, the advertising service model only becomes a viable option when the manufacturer has superior service efficiency but less bargaining power than the platform and when there is low price sensitivity but high service sensitivity.

1.3. Research background

Our results highlight the importance of firms' service efficiency and the service sensitivity of demand on the choice of selling models. These results stand in contrast to those of studies that have focused on modeling the price sensitivity of demand while ignoring service considerations. In the existing literature, the studies most similar to ours are those of Abhishek et al. [1], Chen et al. [5], Tian et al. [36], Guo et al. [17], He et al. [23], Wang et al. [39], and Mantin et al. [31]. Abhishek et al. [1] considered channel competition and structure in their examination of agency selling and reselling models. Chen et al. [5] compared two e-commerce platform revenue models: brokerage and advertising service. Tian et al. [36] presented a strategic analysis of emerging e-commerce models (agency selling, reselling, and hybrid models). Guo et al. [17] studied the bundling strategy for an online platform under the agency selling background. He et al. [23] explored the opti-

mal modes for local brick-and-mortar retail stores that adopt the online-to-offline strategy (platform mode, self-building mode, and mixed mode). Wang et al. [39] studied three alliance strategies between a manufacturer, a retailer, and the platform. They found the retailer and platform are likely to form alliances only if agency fees are relatively low. Mantin et al. [31] examined the impact of retailers' introduction of a third-party marketplace on the retailer–manufacturer bargaining game. In all of these studies, consumer demand was assumed to be price sensitive. However, the impact of service on demand was not explicitly modeled. Our study complements the existing literature on platform selling models that only considers consumer price sensitivity by assessing the influence of the service sensitivity of customer demand on platforms' decisions in selecting selling models.

It is well established that demand for online retailing is affected by service [16,18,27,42]. The influence of service on demand can differ substantially among product categories. It can be argued that service is more important for some categories than others. For example, service is probably more important for major appliances (such as TVs and refrigerators) than for books and DVDs. We observe different selling models for different product categories in practice. It is much more common for platforms to adopt the reselling model for staple products, while major appliances are often sold under the agency selling model. Achieving superior service efficiency through continuous investment in fulfillment and the logistics infrastructure enables platform giants such as Amazon and JD.com to expand their reselling product categories and grow their market share [15,38]. Somewhat surprisingly, bargaining power is not as important as one might expect. This is welcome news for manufacturers who are wary of selling through platforms that are perceived to be too powerful. Despite their market dominance, major platforms such as JD.com and Amazon use different selling models for different products. Our analysis provides one plausible explanation for the observed plurality of selling model choices.

There is a growing body of literature in marketing and operations management covering various aspects of online retailing. We do not attempt a comprehensive literature review here but rather highlight our contributions by discussing two closely related research streams: (1) the selling models of online platforms and (2) retail competition and bargaining within a channel.

The first stream involves studies on the different selling models of online platforms. Many scholars have performed comparative analyses of selling models. Jiang et al. [25] took the Amazon platform as an example to illustrate the benefits of platform sales, demonstrating that platforms can understand the demand for long-tailed products sold by third-party sellers and can then carefully select successful products to sell directly. Johnson [26] showed that the agency selling model is preferred to the reselling model when the difference among manufacturers is greater than that among platforms; otherwise, the reselling model is preferred. Hagiu and Wright [19,20] discussed how to choose between the reselling model and the agency selling model by outlining the possible equilibrium conditions. Hagiu and Wright [21] argued that the option between the agency selling model and the reselling model depends on whether supply chain members have relevant information to optimize the marketing activities for a given product. Chen et al. [5] illustrated the effects of two revenue models (brokerage and advertising service) on a platform's income, purchasers' payoffs, sellers' payoffs, and social welfare. Lu [30] evaluated the reselling model and the agency selling model under the bilateral duopoly framework and showed that the two models led to different financial benefits for manufacturers and retailers, whereas consumers can benefit from the agency selling model with lower retail prices because of the elimination of double marginalization. Chen et al. [7] compared the effects of agency selling and reselling models on product promotion. The aforementioned studies have presented pairwise comparisons of the three selling models, whereas we have systematically examined all three in a common framework, with an emphasis on service-sensitive demand.

Our study is also relevant to the growing literature on vertical channel structure and bargaining power. Taking the Amazon platform as an example, Ryan et al. [33] studied competition and coordination in online marketplaces and discussed the retailers' and Amazon's optimal decisions under three different sales strategies. Abhishek et al. [1] suggested that e-tailers should adopt the agency selling model if the e-channel has a negative cross-effect on the demand of the offline channel, and conversely, they should adopt the reselling model if there is a positive cross-effect from the e-channel on the demand of the offline channel. Ha et al. [18] derived equilibrium conditions for three channel structures (agency channel, reselling channel, and dual channel) and analyzed the retail platform's channel selection strategy. Recent work in channels has assessed the impact of power relationships between channel members on their decisions and performance [9–11]]. Several studies [24,31,34] have incorporated negotiation power into the bargaining game to examine its effect on channel decisions. Using a stylized bargaining game model between a retailer and a manufacturer, Mantin et al. [31] showed that third-party marketplaces hurt the manufacturer and benefit the retailer by altering outside options. Shen et al. [34] considered bargaining power in an investigation of a manufacturer's channel strategy for engaging with an online platform and traditional reselling. He et al. [24] considered a bargaining model between a supplier and two downstream retailers and found that the supplier's preference for retail channel structure was influenced by retailers' bargain power, product substitutability, and channel competition.

Unlike these studies, our study considered service-sensitive demand and explored the effects of service efficiency and interfirm power relationships on the choice of selling models.

The specific differences between the proposed model and the previous constructed models are summarized in Table 2. While the studies closest to ours are those of Abhishek et al. [1], Chen et al. [5], and Mantin et al. [31], our work differs from the aforementioned papers as follow. First, we systematically compare three platform selling models as well as a two-part tariff model that combines the agency selling and advertising service models; and examine the effects of product features, service efficiency, and interfirm power relationships on firms' optimal choice of selling models with the consideration of service-sensitive demand. Second, through the systematic examination, we identify the influential factors in determining the optimal selling model for the channel members individually and collectively. Furthermore, we highlight the decision regions in which further coordination is required to achieve a win-win outcome for both the platform and manufacturer. Insights derived from our analysis are critical for manufacturers and platforms making important strategic and operational decisions on platform selling.

The remainder of the paper is structured as follows. Section 2 presents the three selling models—the reselling model, the agency selling model, and the advertising service model—and the corresponding equilibria. The equilibrium results of the reselling model are compared to those of the agency selling model and the advertising service model in Sections 3 and 4. In Section 5, we examine the selling model selection mainly from the perspective of the platform and the manufacturer. In Section 6, we extend the analysis to the mixed model with a two-part tariff, the case of the platform with higher service efficiency, and the platform's different direct sales costs under the three selling models. Finally, we discuss the key findings and avenues for future research in Section 7. All technical proofs are provided in the appendix.

Table 2
Comparison between the proposed model and previous research.

Papers	Demand function	Firms' service efficiency	Bargaining process	Who determines the selling format?	Selling format
Abhishek et al. [1]	Price sensitive	No	No	E-tailers	Reselling and agency selling
Chen et al. [5]	Price sensitive	No	No	Platform	Brokerage model and advertising service model
Tian et al. [36]	Price sensitive	No	No	Online intermediary	Pure reseller mode, Pure marketplace mode, hybrid mode
Ding et al. [16]	Price and service time sensitive	No	No	/	Traditional brick-and-mortar retailing
Ha et al. [18]	Price and service sensitive	Yes	No	The manufacturer and platform jointly decide	Agency channel, reselling channel, and dual channel
Mantin et al. [31]	Price sensitive	No	Yes	Retailer	Third-part marketplace,
Shen et al. [34]	Price sensitive	No	Yes	Manufacturer	Agency selling and traditional retailing
He et al. [24]	Price sensitive	No	Yes	/	Traditional brick-and-mortar retailing
This Paper	Price and service sensitive	Yes	Yes	The manufacturer or platform with dominant bargaining power	Reselling, agency selling, advertising service, and mixed-fee model

2. Models and equilibrium analysis

This section presents three selling models—the reselling model, the agency selling model, and the advertising service model—and derives the corresponding equilibria.

2.1. Model setup

Our study considers a manufacturer who sells a product on an e-commerce platform (hereinafter referred to as "the platform") through three alternative selling models: (i) the reselling model, (ii) the agency selling model, and (iii) the advertising service model.

- Under the reselling model, the platform and the manufacturer enter into a reselling agreement via a wholesale contract. The platform first buys the product from the manufacturer at a wholesale price and then determines the retail price. The reselling model is akin to the model commonly adopted in traditional brick-and-mortar retailing.
- Under the agency selling model, the platform and the manufacturer enter into an agency agreement. The manufacturer determines the retail price and sells its products directly to consumers on the platform. Under this arrangement, the platform charges the manufacturer a transaction fee for each unit sold ([8,21,29,41]).
- Under the advertising service model, the manufacturer can utilize the basic platform services, such as listing and selling, for free; however, it pays a fee to the platform to participate in advertising or promotion services provided by the platform to increase its exposure to potential customers ([5,22,36]).

The strategic and operational decisions of both the platform and the manufacturer are illustrated in the framework shown in Fig. 1. At the strategic level, the manufacturer and the platform can select one of the three selling models. More specifically, we consider that the selling model is determined by the firm with the dominant bargaining power. That is, when the manufacturer has the dominant bargaining power, the selling model is determined by the manufacturer's profit maximization. In contrast, when the platform has the dominant bargaining power, the selling model is determined by the platform's profit maximization.

At the operational level, the two firms need to negotiate the relevant contractual arrangement (wholesale price, unit transaction fee, or advertising service fee) for each selling model and then set the service level and retail price accordingly. We present relevant notation in Table 3.

We assume that the firm managing the selling operation bears the service cost. That is, the platform incurs this cost in the reselling model, and the manufacturer incurs this cost in the agency selling and advertising service models. Both firms aim to maximize their own profits. To avoid triviality and focus on more relevant scenarios, we make the following assumptions:

Table 3
Notation.

Notation	Description
m	Unit production cost for the manufacturer
c	Unit direct sales cost for the platform
w	Unit wholesale price
p	Unit retail price
$q(\cdot)$	Consumer demand
K	Advertising service fee paid by the manufacturer
λ	Unit transaction fee paid by the manufacturer
M	Fixed membership fee paid by the manufacturer in a two-part tariff selling model
θ	Bargaining power of the manufacturer, $0 < \theta < 1$
$1-\theta$	Bargaining power of the platform
v	Service level of the manufacturer or the platform
μ_m	Coefficient of the manufacturer's service cost
μ_p	Coefficient of the platform's service cost
$\Delta\mu$	Difference between the service cost coefficients of the manufacturer and the platform, $\Delta\mu = \mu_p - \mu_m$
$C(v)$	Service cost of the product for service level v
$\pi_m(\cdot)$	Manufacturer's profit
$\pi_p(\cdot)$	Platform's profit
$\pi_t(\cdot)$	Supply chain's total profit; $\pi_t(\cdot) = \pi_m(\cdot) + \pi_p(\cdot)$
CS	Consumer surplus, $CS = \int_p^{\frac{\alpha+\gamma v}{\beta}} (\alpha - \beta x + \gamma v)dx$
SW	Social welfare, $SW = \pi_t(\cdot) + CS$

(1) $p > w + c$, $p > m + \lambda$ and $w > m$. This assumption, which is necessary for both the platform and the manufacturer to have positive marginal profits, can be made without loss of generality.
(2) Given retail price p and service level v, the consumer demand is given by $q(p, v) = \alpha - \beta p + \gamma v$. Here, α represents the potential market size, and $\beta > 0$ and $\gamma > 0$ represent the price and service sensitivities of demand, respectively. That is, we assume the demand is linearly additive and deterministic. This demand function form is often adopted in the marketing and operations management literature to model price and service-sensitive demand [2,6,18,28]. In addition, the linear form allows us to maintain analytical tractability. Since our modeling framework captures strategic decisions concerning the choice of selling models, we chose to ignore demand uncertainty in our analysis, which is typical in the relevant literature.

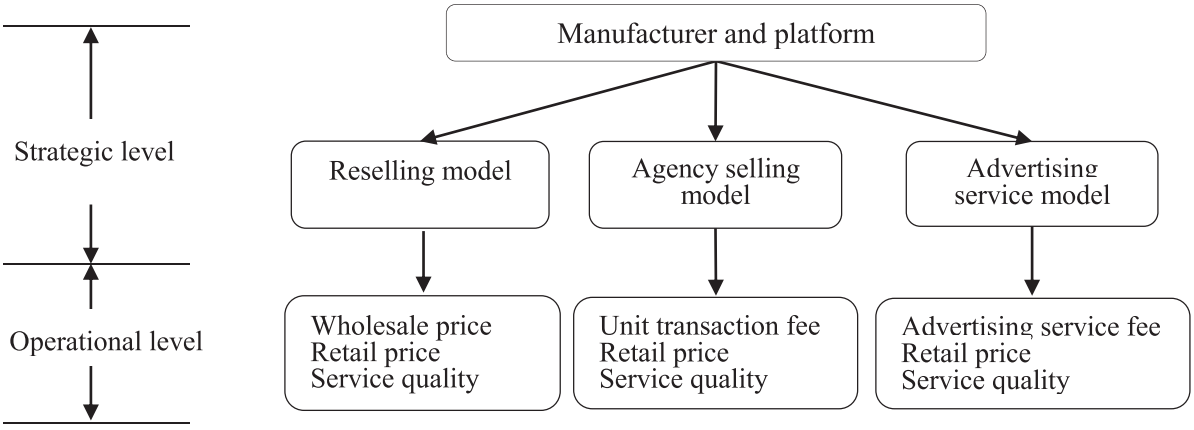


Fig. 1. The modeling framework.

(3) The service cost of the product is $C(v) = \frac{1}{2}\mu_i v^2$, where $i = m, p$ [13,22,35]. The quadratic form of this model suggests diminishing returns on expenditures, and the coefficients μ_m and μ_p differentiate between the manufacturer and the platform vis-á-vis their relative cost-effectiveness in operational deployment of service. While the main analysis is based on the assumption that $\mu_m < \mu_p$, which means that the manufacturer has a higher service efficiency than the platform, an extended analysis was carried out for the case of the platform having a higher service efficiency than the manufacturer.

(4) $0 < \gamma < \min(\sqrt{2\beta\mu_p}, \sqrt{2\beta\mu_m})$. This is a technical assumption that ensures that the Hessian matrix is negatively definite. Intuitively, this condition means that the service sensitivity of demand is not "too large" relative to firms' service costs and the price sensitivity of demand.

2.2. Reselling model

Under the reselling model, the decision-making process of the platform and the manufacturer is as follows. In the first stage, the platform and the manufacturer bargain with each other to agree on the wholesale price (w). In the second stage, the platform determines the retail price (p) and the service level (v). For given values of (w, p, v), the manufacturer's profit $\pi_m(w, p, v)$ is given by

$$\pi_m(w, p, v) = wq(p, v) - mq(p, v). \tag{1}$$

The first and second terms on the right-hand side of Eq. (1) represent the wholesale revenue and production cost, respectively. Similarly, the platform's profit $\pi_p(w, p, v)$ is

$$\pi_p(w, p, v) = pq(p, v) - wq(p, v) - cq(p, v) - \frac{1}{2}\mu_p v^2. \tag{2}$$

The first and second terms on the right-hand side of Eq. (2) are the revenue and wholesale cost, respectively. The third and fourth terms are the direct sales cost and service cost, respectively. Note that the platform bears the service cost, since it sells directly to consumers.

The model can be solved via backward induction, starting with the second-stage problem, in which, given the wholesale price (w) negotiated in the first stage, the platform solves the following profit maximization problem:

$$\max_{p,v} \pi_p(w, p, v).$$

The equilibrium solution to the problem above is denoted by $(p(w), v(w))$. In the first stage, a bargaining process occurs between the platform and the manufacturer to determine the wholesale price, which can be stated as follows:

$$\max_{w} \ \Phi(w) = \max_{w} \left[\pi_m(w, p(w), v(w))^{\theta} \pi_p(w, p(w), v(w))^{(1-\theta)}\right]. \tag{3}$$

This kind of bargaining process has been commonly used in the operations management literature (e.g. [12,32]). The parameter θ represents the manufacturer's bargaining power, and $1 - \theta$ represents the platform's bargaining power.

2.3. Agency selling model

In the agency selling model, the decision-making process of the platform and the manufacturer can be similarly divided into two stages. In the first stage, the two firms negotiate the unit transaction fee λ. In the second stage, the manufacturer decides on the retail price p and the service level v simultaneously. For given values of (λ, p, v), the manufacturer's profit $\pi_m(\lambda, p, v)$ is

$$\pi_m(\lambda, p, v) = pq(p, v) - mq(p, v) - \lambda q(p, v) - \frac{1}{2}\mu_m v^2. \tag{4}$$

The first, second, and third terms on the right-hand side represent the manufacturer's sales revenue, the production cost, the transaction fee paid to the platform, and the manufacturer's service cost, respectively. Similarly, the platform's profit $\pi_p(\lambda, p, v)$ is

$$\pi_p(\lambda, p, v) = \lambda q(p, v) - cq(p, v). \tag{5}$$

The first term on the right-hand side represents the transaction fee received from the manufacturer, and the second term represents the direct sales cost of the platform.

In the second stage, given the unit transaction fee λ negotiated in the first stage, the manufacturer solves the following profit maximization problem:

$$\max_{p,v} \pi_m(\lambda, p, v).$$

The equilibrium solution is denoted by $(p(\lambda), v(\lambda))$. In the first stage, a bargaining process occurs between the two parties to determine the unit transaction fee as follows:

$$\max_{\lambda} \Phi(\lambda) = \max_{\lambda} \left[\pi_m(\lambda, p(\lambda), v(\lambda))^{\theta} \pi_p(\lambda, p(\lambda), v(\lambda))^{(1-\theta)}\right]. \tag{6}$$

Table 4
Equilibrium solutions of the three selling models.

Models	Reselling model ($i = w$)	Agency selling model ($i = \lambda$)	Advertising service model ($i = k$)
v^i	$\frac{\gamma(2-\theta)[\alpha-\beta(c+m)]}{2(2\beta\mu_p-\gamma^2)}$	$\frac{\gamma(1+\theta)[\alpha-\beta(c+m)]}{2(2\beta\mu_m-\gamma^2)}$	$\frac{(\alpha-m\beta)\gamma}{2\beta\mu_m-\gamma^2}$
w^*	$m+\frac{[\alpha-\beta(c+m)]\theta}{2\beta}$	/	/
λ^*	/	$\frac{[\alpha-\beta(c+m)](1-\theta)}{2\beta}+c$	/
K^*	/	/	$\frac{(\alpha-m\beta)[\alpha(1-\theta)+\beta(-m+m\theta+2c\theta)]\mu_m}{2(2\beta\mu_m-\gamma^2)}$
p^i	$\frac{\beta(c+m)(2-\theta)(\beta\mu_p-\gamma^2)+\alpha[\beta\mu_p(2+\theta)-\gamma^2\theta]}{2\beta(2\beta\mu_p-\gamma^2)}$	$\frac{\beta(c+m)(1+\theta)(\beta\mu_m-\gamma^2)+\alpha[\beta(3-\theta)\mu_m-\gamma^2(1-\theta)]}{2\beta(2\beta\mu_m-\gamma^2)}$	$\frac{\alpha\mu_m+\beta m\mu_m-m\gamma^2}{2\beta\mu_m-\gamma^2}$
q^i	$\frac{\beta\mu_p(2-\theta)[\alpha-\beta(c+m)]}{2(2\beta\mu_p-\gamma^2)}$	$\frac{\beta\mu_m(1+\theta)[\alpha-\beta(c+m)]}{2(2\beta\mu_m-\gamma^2)}$	$\frac{\beta\mu_m(\alpha-m\beta)}{2\beta\mu_m-\gamma^2}$

2.4. Advertising service model

In the advertising service model, the decision-making process is similar to that in the agency selling mode. However, in the first stage, the platform and the manufacturer negotiate to determine the advertising service fee K rather than the unit transaction fee. Then, the manufacturer determines the retail price p and the service level v simultaneously. For given values of (K, p, v), the manufacturer's profit $\pi_m(K, p, v)$ is

$$\pi_m(K, p, v) = pq(p, v) - mq(p, v) - K - \frac{1}{2}\mu_m v^2. \tag{7}$$

The terms on the right-hand side of the equation represent the manufacturer's sales revenue, the production cost, the advertising service fee, and the manufacturer's service cost. Similarly, the platform's profit $\pi_p(K, p, v)$ is

$$\pi_p(K, p, v) = K - cq(p, v). \tag{8}$$

The two terms on the right-hand side represent the revenue from the advertising service and the direct sales cost of the platform, respectively.

In the second stage, given the advertising service fee K negotiated in the first stage, the manufacturer solves the following profit maximization problem:

$$\max_{p,v} \pi_m(K, p, v).$$

The equilibrium solution is denoted by $(p(K), v(K))$. In the first stage, a bargaining process occurs to determine the advertising service fee as follows:

$$\max_K \Phi(K) = \max_K \left[\pi_m(K, p(K), v(K))^{\theta} \pi_p(K, p(K), v(K))^{(1-\theta)}\right]. \tag{9}$$

2.5. Equilibrium analysis

We derive the equilibrium outcome under the reselling, agency selling, and advertising service models. The two-stage games are solved by backward induction. Based on their respective profit functions, the equilibrium solutions for the three selling models are shown in Table 4. The derivations of these equilibrium solutions are provided in the appendix. For equilibrium quantities that appear in more than one model, we use superscripts to differentiate them, with $i \in \{w, \lambda, k\}$ denoting reselling, agency selling, and advertising service, respectively.

3. Comparison between agency selling and reselling models

This section compares the equilibrium solutions for the agency selling and reselling models. Through the comparison, we analyze the effects of firms' relative service efficiencies, the service and price sensitivities of demand, and bargaining power on the choice of the two selling models. We also discuss the economic rationale and managerial implications of the comparison results.

We start with a comparison of the equilibrium service levels and retail prices, summarized in Lemma 1.

Lemma 1.

(1) *If* $\Delta\mu < \frac{\mu_p}{2}$, $0 < \gamma < \gamma_c$, *and* $0 < \theta < \theta_1$, *then* $v^\lambda < v^w$; *otherwise,* $v^\lambda \geq v^w$.
(2) *If* $0 < \gamma < \gamma_i$ *and* $\theta_2 < \theta < 1$; *or* $\Delta\mu < \frac{\mu_p}{9}$, $\gamma_e < \gamma < \gamma_f$ *and* $0 < \theta < \theta_2$, *then* $p^\lambda < p^w$; *otherwise,* $p^\lambda \geq p^w$.[6]

According to Lemma 1, the two firms' service efficiencies, indicated by the coefficients of their service costs, strongly influence the equilibrium service levels and retail prices. Note that a higher service efficiency corresponds to a lower coefficient of service cost. This lemma shows that when the platform's service efficiency is less than that of the manufacturer, the difference in service level between the two selling models varies with the price and service sensitivities of demand and the manufacturer's bargaining power. Specifically, when the manufacturer's service efficiency is twice that of the platform, the equilibrium service level according to the agency selling model is lower than that according to the reselling model if the service sensitivity of demand and the manufacturer's bargain power are lower than the critical thresholds ($0 < \gamma < \gamma_c$, $0 < \theta < \theta_1$). Otherwise, the equilibrium service level according to the agency selling model is always higher than that according to the reselling model. This result is due to the fact that when the manufacturer's bargain power is low ($0 < \theta < \theta_1$), the manufacturer may pay higher unit transaction fee to the platform under the agency selling model. So when consumers are less sensitive to service ($0 < \gamma < \gamma_c$), the manufacturer will lower the service level to reduce the service cost and thus maximize profit.

Similarly, as the results in Lemma 1 show, retail prices are also influenced by the price and service sensitivities of demand and the interfirm power relationship. Specifically, only when the service sensitivity is low and the manufacturer has superior power ($0 < \gamma < \gamma_i$, $\theta_2 < \theta < 1$) does the agency selling model lead to a lower retail price than the reselling model, which benefits the consumer. This stands contrast to the findings of Lu [30] that the agency selling model leads to lower retail prices because of the elimination of double marginalization. While incentive distortion in a supply chain certainly plays an important role, as shown by Lu [30], our results demonstrate the importance of several other factors such as firms' service efficiencies, the demand sensitivity to service, and the interfirm power relationship in the contract negotiation of wholesale price (in the reselling model) and unit transaction rate (in the agency model).

[6] $\gamma_c = \sqrt{2\beta(\mu_p - 2\Delta\mu)}$, $\gamma_{e,f} = \sqrt{\frac{3\beta(\mu_p-\Delta\mu)\mp\beta\sqrt{(\mu_p-\Delta\mu)(\mu_p-9\Delta\mu)}}{2}}$, $\gamma_i = \sqrt{\frac{3\beta\mu_p-\sqrt{\beta^2\mu_p(\mu_p+8\Delta\mu)}}{2}}$, $\theta_1 = \frac{\gamma^2-2\beta\mu_p+4\beta\Delta\mu}{2(\gamma^2-2\beta\mu_p+\beta\Delta\mu)}$ and $\theta_2 = \frac{\gamma^4-3\beta\gamma^2(\mu_p-\Delta\mu)+2\beta^2\mu_p(\mu_p-\Delta\mu)}{2\gamma^4+4\beta^2\mu_p(\mu_p-\Delta\mu)-5\beta\gamma^2(2\mu_p-\Delta\mu)}$.

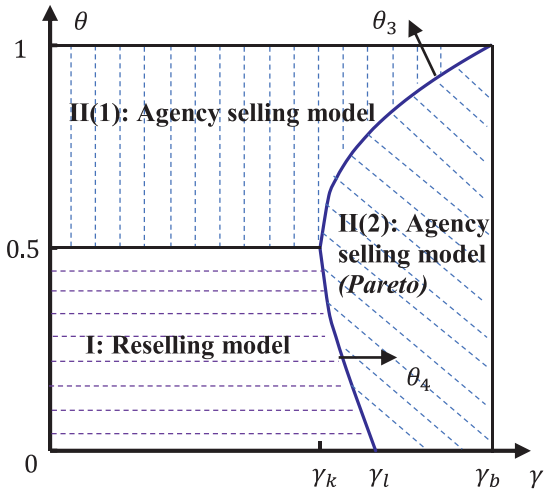


Fig. 2. Profit comparison between the reselling and agency selling models.

Next, we explore the economic performance of the platform and the manufacturer under the reselling and agency selling models.

Proposition 1. *If* $\frac{1}{2} < \theta < 1$*; or* $\gamma_k < \gamma < \gamma_l$ *and* $\theta_4 < \theta < \frac{1}{2}$*; or* $\gamma_l < \gamma < \gamma_b$ *and* $0 < \theta < \frac{1}{2}$*, then the agency selling model is the better selling model; otherwise, the reselling model is the better selling model.*[7]

The results described by this proposition are further illustrated in Fig. 2. Note that the selling model is determined by the firm with the dominant bargaining power. That is, in the region of $0.5 < \theta < 1$, the manufacturer has the dominant bargaining power, so the selling model is determined by the manufacturer's profit maximization. In contrast, in the region of $0 < \theta < 0.5$, the platform has the dominant bargaining power, so the selling model is determined by the platform's profit maximization. Region I corresponds to the conditions under which the platform's profit for the reselling model is greater than that for the agency selling model. Region II(1) corresponds to the conditions under which the agency selling model performs better than the reselling model for the manufacturer. In Region II(1), the manufacturer will experience a profit increase, but the platform will be worse off financially. Interestingly, in Region II(2), both the manufacturer and the platform earn more under the agency selling model, leading to *Pareto improvement*. In this case, the agency selling model will be embraced by both parties. Because when consumers have a high level of service sensitivity ($\gamma_l < \gamma < \gamma_b$), the manufacturer and the platform try to improve the service level. However, the platform's service efficiency is lower than that of the manufacturer, so the platform prefers the agency selling model to avoid high service costs. This finding provides a plausible explanation for why some leading electronic appliance manufacturers with reputable service records (e.g., Haier in China) often have a strong presence on electronic platforms opting to sell directly to customers via the agency selling model, and in contrast, smaller manufacturers often choose the reselling model when selling through leading e-commerce platforms.

The critical thresholds (i.e., γ_l, θ_3, θ_4) that determine the different regions in Fig. 2 are influenced by the price sensitivity of demand (β). The Pareto improvement region of the agency selling model shrinks as β increases: when consumers are more sensitive to price, even though the profit for the manufacturer can still increase under the agency selling model, the platform's profit decreases compared to that under the reselling model. The platform is more likely to prefer the reselling model over the agency selling model when consumers become more sensitive to price since θ_4 increases in β.

Finally, we examine the effects of the two selling models on social welfare, which are calculated based on the economic performance of the whole channel profit and consumer surplus. We then obtain the following corollary.

Corollary 1. $SW^{\lambda} > SW^{w}$.

This corollary indicates that in the region within which the agency selling model produces better economic performance, the social welfare under the agency model is greater than that under the reselling model. This is because the increase in whole channel profit under the agency selling model is larger than the decrease in consumer surplus. Thus, the agency selling model can achieve a win–win between society and firms.

4. Comparison of the advertising service and reselling models

In this section, we describe a comparison of the equilibrium solutions for the advertising service model and the reselling model, which we conducted to evaluate the effects of firms' relative service efficiencies, service and price sensitivities, and bargaining power on firms' price and service decisions, as well as their strategic choice between the advertising service and reselling models.

A comparison of the equilibrium service levels and retail prices leads to the following lemma.

Lemma 2.

(1) $v^k > v^w$.

(2) *(i) If* $\Delta\mu > \frac{\mu_p}{2}$, $\gamma_m < \gamma < \gamma_b$ *and* $0 < \theta < \min\{\theta_8, 1\}$*; or* $\Delta\mu < \frac{\mu_p}{2}$, $\gamma_m < \gamma < \gamma_d$ *and* $0 < \theta < \min\{\theta_8, 1\}$*; or* $\Delta\mu < \frac{\mu_p}{2}$ *and* $\gamma_d < \gamma < \gamma_b$*, then* $p^k > p^w$*. (ii) Otherwise,* $p^k \le p^w$.[8]

According to Lemma 2, when the platform has lower service efficiency than the manufacturer, the service level under the advertising service model is always higher than that under the reselling model. As the manufacturer is responsible for the service and retail price decisions in the advertising service model, it can fully utilize its greater efficiency in service provision to establish an improved service level.

The difference in the equilibrium retail prices between the two models is determined by the difference in the two firms' coefficients of service cost, the manufacturer's negotiation power, and the corresponding critical thresholds ($\frac{\mu_p}{2}$, γ_m, γ_b, γ_d and θ_8). When the difference in the two firms' service efficiency is smaller than the critical threshold ($\Delta\mu < \frac{\mu_p}{2}$) and the service sensitivity of the customer demand is large ($\gamma_d < \gamma < \gamma_b$), the reselling model can drive down the retail price, which is beneficial to consumers. Otherwise, the difference in the equilibrium retail prices between the two models is determined by the manufacturer's negotiation power and the corresponding critical thresholds (θ_8).

Next, we examine the economic performance of the platform and the manufacturer under the reselling and advertising service models.

[7] $\gamma_b = \sqrt{2\beta\mu_m}$, $\gamma_k = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p+2\Delta\mu}}$, $\gamma_l = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p+\Delta\mu}}$ and $\theta_{3,4} = \frac{-2\gamma^2\mu_p+4\beta\mu_p(\mu_p-\Delta\mu)\pm\sqrt{2}\sqrt{(\mu_p-\Delta\mu)(\gamma^2-2\beta\mu_p)[\gamma^2(-2\Delta\mu-\mu_p)+2\beta\mu_p(\mu_p-\Delta\mu)]}}{6\beta\mu_p(\mu_p-\Delta\mu)-\gamma^2(3\mu_p-2\Delta\mu)}$.

[8] $\gamma_d = \sqrt{\beta\mu_p}$, $\gamma_m = \sqrt{\frac{-[-\alpha\Delta\mu+\beta(m\Delta\mu+2c\Delta\mu-3c\mu_p)]-\sqrt{\Delta_1}}{2c}}$ and $\theta_8 = \frac{2\beta[-(\alpha-m\beta)\gamma^2\Delta\mu-c(\gamma^2-\beta\mu_p)[2\beta(\mu_p-\Delta\mu)-\gamma^2]]}{[\alpha-(c+m)\beta](\gamma^2-\beta\mu_p)[2\beta(\mu_p-\Delta\mu)-\gamma^2]}$. Where $\Delta_1 = [\alpha-(m+2c)\beta]^2\Delta\mu^2 + 2c\beta(3\alpha-3m\beta-2c\beta)\Delta\mu\mu_p + c^2\beta^2\mu_p^2$.

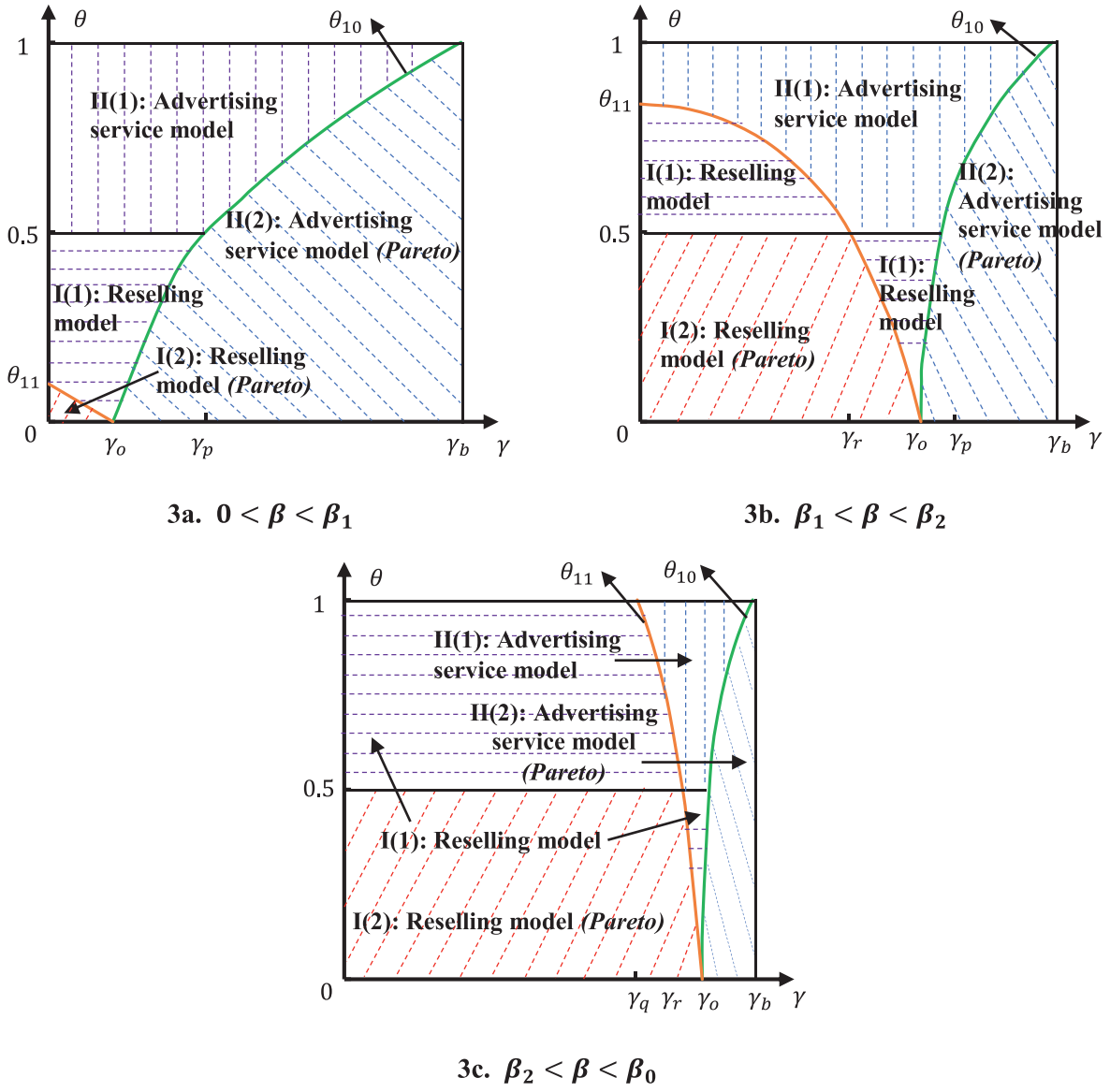


Fig. 3. Profit comparison between the reselling and advertising models.

Proposition 2.

(1) *If* $\gamma_o < \gamma < \gamma_b$ *and* $0 < \theta < \min\{\theta_{10}, \frac{1}{2}\}$; *or* $0 < \beta < \beta_1$, $\frac{1}{2} < \theta < 1$; *or* $\beta_1 < \beta < \beta_2$, $0 < \gamma < \gamma_r$ *and* $\theta_{11} < \theta < 1$; *or* $\beta_1 < \beta < \beta_2$, $\gamma_r < \gamma < \gamma_b$ *and* $\frac{1}{2} < \theta < 1$; *or* $\beta_2 < \beta < \beta_0$, $\gamma_q < \gamma < \gamma_r$ *and* $\theta_{11} < \theta < 1$; *or* $\beta_2 < \beta < \beta_0$, $\gamma_r < \gamma < \gamma_b$ *and* $\frac{1}{2} < \theta < 1$, *then the advertising service model produces better financial performance.*

(2) *Otherwise, the reselling model performs better financially.*[9]

The outcomes of Proposition 2 are illustrated in Fig. 3. The choice between the advertising service model and the reselling model is divided into three scenarios according to the price sensitivity of demand (β). Specifically, when the price sensitivity is low ($0 < \beta < \beta_1$), the advertising service model generates greater profit for the manufacturer if the manufacturer has superior negotiation power ($\frac{1}{2} < \theta < 1$), as shown by Region II(1). Interestingly, the advertising service model is also beneficial to the platform if the service sensitivity increases ($\gamma > \gamma_o$) and the manufacturer's bargaining power decreases ($\theta < \theta_{10}$), achieving a Pareto improvement, as shown by Region II(2). Intuitively, since the manufacturer is responsible for making retail and service decisions under the advertising service model, it can take advantage of its service efficiency to generate more profit, while the platform also increases profits by avoiding high service costs. In contrast, when the platform has the superior bargaining power ($0 < \theta < \frac{1}{2}$), the advertising service model may still be the better choice for the platform and the manufacturer than the reselling model if the manufacturer's power is lower than the threshold ($\theta < \min\{\theta_{10}, \frac{1}{2}\}$) as the service sensitivity increases. Otherwise, the reselling model leads to more profits for both the platform and the manufacturer if service sensitivity and the manufacturer's power are lower than the thresholds ($\gamma < \gamma_o, \theta < \theta_{11}$), which indicates that the reselling model achieves a *Pareto improvement*, corresponding to Region I(2). This is due to

[9] $\beta_0 = \frac{\alpha}{m+2c}$, $\beta_1 = \frac{\alpha}{3c+m}$, $\beta_2 = \frac{(m+c-\sqrt{2}c)\alpha}{m^2+2cm-c^2}$, $\gamma_o = \sqrt{\frac{2c^2\beta^3\mu_p(\mu_p-\Delta\mu)}{(\alpha-m\beta)[\alpha-(2c+m)\beta]\Delta\mu+c^2\beta^2\mu_p}}$, $\gamma_q = \sqrt{\frac{2\beta\mu_p[\alpha^2-2(c+m)\alpha\beta+(m^2+2cm-c^2)\beta^2](\mu_p-\Delta\mu)}{\alpha^2(\mu_p-2\Delta\mu)-2(c+m)\alpha\beta(\mu_p-2\Delta\mu)+\beta^2[-c^2\mu_p+m^2(\mu_p-2\Delta\mu)+2cm(\mu_p-2\Delta\mu)]}}$, $\gamma_r = \sqrt{\frac{2\beta\mu_p[\alpha+(c-m)\beta][\alpha-(m+3c)\beta](\mu_p-\Delta\mu)}{-4(\alpha-m\beta)[\alpha-(m+2c)\beta]\Delta\mu+[\alpha+(c-m)\beta][\alpha-(m+3c)\beta]\mu_p}}$, $\theta_{10} = \frac{-4(\alpha-m\beta)[\alpha-(2c+m)\beta]\gamma^2\Delta\mu+4c^2\beta^2(-2\beta\Delta\mu-\gamma^2)\mu_p+8c^2\beta^3\mu_p^2+\sqrt{\Delta}}{2[\alpha-(c+m)\beta]^2\mu_p[2\beta(\mu_p-\Delta\mu)-\gamma^2]}$ and $\theta_{11} = \frac{-2(\alpha-m\beta)[\alpha-(m+2c)\beta]\gamma^2\Delta\mu-2c^2\beta^2(2\beta\Delta\mu+\gamma^2)\mu_p+4c^2\beta^3\mu_p^2}{[\alpha-(m+c)\beta]^2[2\beta(\mu_p-\Delta\mu)-\gamma^2]\mu_p}$. Where $\Delta = 16(\alpha-m\beta)[\alpha-(m+2c)\beta](\mu_p-\Delta\mu)(\gamma^2-2\beta\mu_p)\{-(\alpha-m\beta)[\alpha-(m+2c)\beta]\gamma^2\Delta\mu+c^2\beta^2(-2\beta\Delta\mu-\gamma^2)\mu_p+2c^2\beta^3\mu_p^2\}$.

the fact that when service sensitivity is low, the platform is willing to bear certain service costs to gain pricing power. Consequently, the platform's revenue from selling products is greater than the incurred costs, and the manufacturer's profit from wholesale is higher than the profit from its own sales, so the reselling model is embraced by both parties in this case. This finding applies to scenarios with different price sensitivities, although the corresponding critical thresholds (*e.g.*, γ_o, θ_{10}, θ_{11}) vary. In general, the critical threshold for the service sensitivity of demand (γ_o) moves rightward in Fig. 3b and 3c when the price sensitivity of demand (β) increases.

We next examine the effects of the reselling and advertising service models on social welfare and derive Corollary 2.

Corollary 2. $SW^k > SW^w$.

This corollary indicates that when the advertising service model produces better economic performance than the reselling model, the social welfare achieved under the advertising service model is greater than that achieved under the reselling model. As with the agency selling model, the improved social welfare under the advertising service model is due to the increased whole channel profit under the advertising service model being larger than the decrease in consumer surplus. Thus, the advertising service model can achieve win–win outcomes for society and firms.

5. Selection of optimal selling models

In this section, we explore the selection of a selling model from among the three models discussed in the previous sections. The firm with greater market power chooses the selling model to maximize its financial benefit. Therefore, we discuss the choice of a selling model based on a profit comparison of the platform and the manufacturer.

Proposition 3.

(1) *When* $0 < \beta < \beta_1$, *if* $\frac{1}{2} < \theta < 1$, *then the agency selling model is preferred; if* $\gamma_o < \gamma < \gamma_p$ *and* $0 < \theta < \theta_{10}$; *or* $\gamma_p < \gamma < \gamma_b$ *and* $0 < \theta < \frac{1}{2}$, *then the advertising service model is preferred; otherwise, the reselling model is preferred.*

(2) *When* $\beta_1 < \beta < \beta_2$, *if* $\frac{1}{2} < \theta < 1$; *or* $\gamma_k < \gamma < \gamma_s$ *and* $\theta_4 < \theta < \frac{1}{2}$; *or* $\gamma_s < \gamma < \gamma_b$ *and* $\theta_{13} < \theta < \frac{1}{2}$, *then the agency selling model is preferred; if* $\gamma_o < \gamma < \gamma_s$ *and* $0 < \theta < \theta_{10}$; *or* $\gamma_s < \gamma < \gamma_b$ *and* $0 < \theta < \theta_{13}$, *then the advertising service model is preferred; otherwise, the reselling model is preferred.*

(3) *When* $\beta_2 < \beta < \beta_0$, *if* $\frac{1}{2} < \theta < 1$; *or* $\gamma_k < \gamma < \gamma_l$ *and* $\theta_4 < \theta < \frac{1}{2}$; *or* $\gamma_l < \gamma < \gamma_b$ *and* $0 < \theta < \frac{1}{2}$, *then the agency selling model is preferred; otherwise, the reselling model is preferred.*[10]

Proposition 3 indicates that the selection of the optimal selling model depends on the price and service sensitivities (β, γ), the bargaining power of the manufacturer (θ), and the relationships of these values to the corresponding critical thresholds. To elaborate further, we stipulate the conditions of the optimal choice among the three selling models in Fig. 4.

From Proposition 3, we find that the agency selling model becomes the choice that yields the best result for the manufacturer when the manufacturer has superior market power ($\frac{1}{2} < \theta < 1$), regardless of the price and service sensitivity of demand (i.e., β, γ). If the platform holds more bargaining power than the manufacturer ($0 < \theta < \frac{1}{2}$), the choice of selling model varies depending on the price and service sensitivities (β, γ), the bargaining power of the manufacturer (θ), and their relationships with the corresponding thresholds.

When the price sensitivity is low ($0 < \beta < \beta_1$), the platform profits more under the reselling model than under the other selling models if the platform has more bargaining power and the service sensitivity is low, as shown by Region I of Fig. 4a. This is because when service sensitivity is low, the platform is willing to bear certain service costs to gain pricing power, so the platform prefers the reselling model. As the service sensitivity increases to within a certain range ($\gamma_o < \gamma < \gamma_p$), the advertising service model performs better for the platform if the manufacturer's negotiating power is lower than the threshold (θ_{10}). As the service sensitivity increases further ($\gamma > \gamma_p$), the advertising service model yields more profits to the platform than the other two selling models if the platform still has greater bargaining power than the manufacturer.

When the price sensitivity increases to within a certain range ($\beta_1 < \beta < \beta_2$), the reselling model performs the best for the platform if the service sensitivity is below a certain threshold ($\gamma < \gamma_k$), regardless of the manufacturer's negotiating power. When the service sensitivity increases to within a certain range ($\gamma_k < \gamma < \gamma_s$), the interfirm power relationship determines the optimal choice among the three selling models. When the manufacturer's bargaining power is greater than a critical threshold ($\theta > \theta_4$), the agency selling model generates the most profit for the platform (Region II in Fig. 4b). When the manufacturer's bargaining power is below the critical threshold ($\theta < \theta_{10}$), the advertising service model becomes the preferred choice (Region III in Fig. 4b). Furthermore, when the service sensitivity increases beyond a critical threshold ($\gamma > \gamma_s$), the agency selling model is the preferred option for the platform when the manufacturer's bargaining power is greater than a threshold ($\theta_{13} < \theta < \frac{1}{2}$); conversely, the advertising service model becomes the preferred choice when the platform's bargaining power is below this threshold ($\theta < \theta_{13}$). This is because the interfirm power relationship has an impact on the unit transaction rate (under the agency selling model) and the advertising service fee (under the advertising service model). Consequently, it influences the financial outcomes of the three selling models by changing decisions on the retail price and service level made by the manufacturer and the platform.

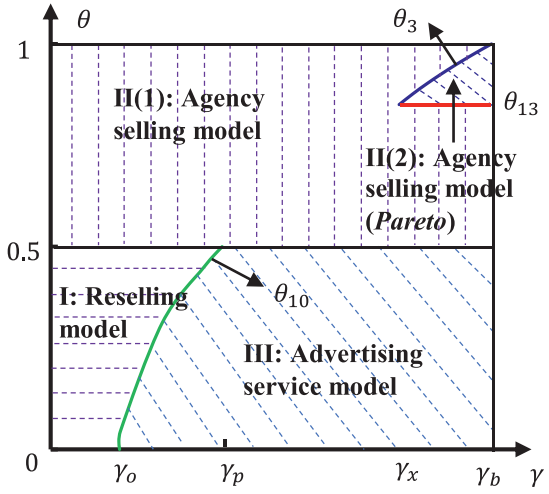
Furthermore, when the degree of price sensitivity exceeds a critical threshold ($\beta > \beta_2$), the preferred choice is either the reselling model or the agency selling model, as shown in Fig. 4c. This is mainly because the advertising fee is less influential than the unit transaction rate or the wholesale price in setting the optimal retail price. Therefore, the advertising service model is outperformed by the agency selling and reselling models when customer demand is highly sensitive to the retail price. This finding is consistent with industry practice on platforms. For example, major appliances, the sale of which is sensitive to both price and service, are often sold under the agency selling model or the reselling model by prominent manufacturers.

6. Extended models

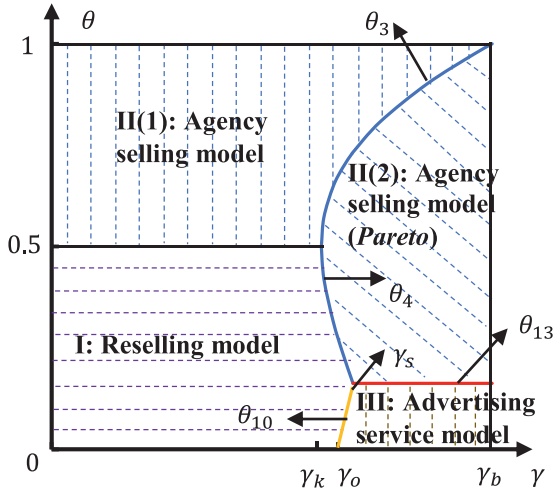
6.1. Mixed model with a two-part tariff

In this section, we consider a two-part tariff model, called the mixed model, in which the manufacturer's payment to the platform consists of a one-off fixed membership fee (M) and a transaction fee for each unit sold (λ).

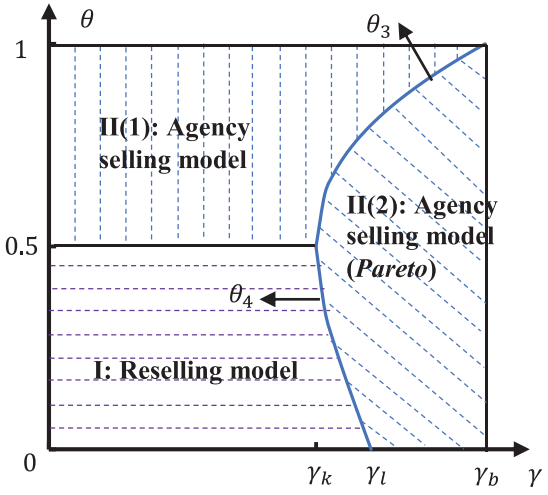
[10] $\gamma_s = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)[\alpha^4-4(c+m)\alpha^3\beta+2(c^2+6cm+3m^2)\alpha^2\beta^2+4(c+m)(c^2-2cm-m^2)\alpha\beta^3+(9c^4-4c^3m+2c^2m^2+4cm^3+m^4)\beta^4]}{2c^2\beta^2(\alpha-m\beta)^2(4\Delta\mu+\mu_p)+9c^4\beta^4\mu_p+(\alpha-m\beta)^4\mu_p+4c\beta(-\alpha+m\beta)^3\mu_p+4c^3\beta^3(\alpha-m\beta)(\mu_p-4\Delta\mu)}}$,
$\gamma_p = \sqrt{\frac{2\beta\mu_p[\alpha^2-2(c+m)\alpha\beta+(9c^2+2cm+m^2)\beta^2](\mu_p-\Delta\mu)}{[\alpha^2-2(c+m)\alpha\beta+(9c^2+2cm+m^2)\beta^2]\mu_p+8(\alpha-m\beta)[\alpha-(2c+m)\beta]\Delta\mu}}$ and $\theta_{13} = \frac{\alpha^2-2(c+m)\alpha\beta-(c^2-2cm-m^2)\beta^2}{[\alpha-(c+m)\beta]^2}$.



4a. $0 < \beta < \beta_1$



4b. $\beta_1 < \beta < \beta_2$



4c. $\beta_2 < \beta < \beta_0$

Fig. 4. Parameter values dictating choice among selling models.

In the mixed model, the manufacturer's profit $\pi_m(M, \lambda, p, v)$ is

$$\pi_m(M, \lambda, p, v) = pq(p, v) - mq(p, v) - M - \lambda q(p, v) - \frac{1}{2}\mu_m v^2. \tag{10}$$

The terms on the right-hand side represent the manufacturer's sales revenue, the production cost, the membership fee and the transaction fee paid to the platform, and the manufacturer's service cost.

The platform's profit $\pi_p(M, \lambda)$ includes revenue from the membership fee and the unit transaction fee received from the vendor minus the sales cost of the platform as follows:

$$\pi_p(M, \lambda) = M + \lambda q(p, v) - cq(p, v). \tag{11}$$

The decision-making process is similar to the selling models discussed in previous section. In the first stage, the platform and the manufacturer negotiate to determine the membership fee (M) and the unit transaction fee (λ) simultaneously. Then, the manufacturer determines the retail price (p) and the service level (v). Therefore, in the mixed model, the decision-making process can be briefly described as follows, where we first consider the second stage problem. In the second stage, given the fixed membership fee M and the unit transaction fee λ negotiated in the first stage, the manufacturer solves the following profit maximization problem:

$$\max_{p,v} \pi_m(M, \lambda, p, v).$$

Denote the equilibrium solution $(p(M, \lambda), v(M, \lambda))$. In the first stage, there is a bargaining process between the two parties to determine the membership fee and unit transaction fee simultane-

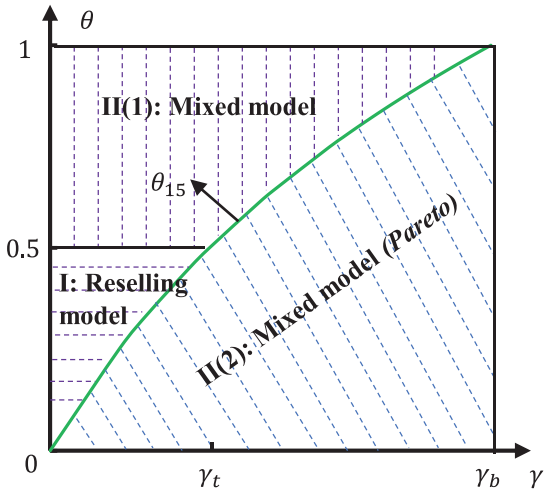


Fig. 5. Profit comparison between the reselling and mixed models.

ously, shown as follows:

$$\max_{M,\lambda} \Phi(M,\lambda) = \max_{M,\lambda} \left[\pi_m(M,\lambda,p(M,\lambda),v(M,\lambda))^{\theta} \pi_p(M,\lambda,p(M,\lambda),v(M,\lambda))^{(1-\theta)} \right]. \quad (12)$$

The equilibrium solution $(p^M, q^M, v^M, K^*, \lambda^*)$ for the mixed model is characterized in the following lemma.

Lemma 3. *For the mixed model, there exists a unique equilibrium membership fee* $M^* = \frac{[\alpha-(c+m)\beta]^2(1-\theta)\mu_m}{2(2\beta\mu_m-\gamma^2)}$, *unit transaction rate* $\lambda^* = c$, *retail service level* $v^M = \frac{\gamma(\alpha-c\beta-m\beta)}{2\beta\mu_m-\gamma^2}$, *retail price* $p^M = \frac{(\alpha+c\beta+\beta m)\mu_m-\gamma^2(c+m)}{2\beta\mu_m-\gamma^2}$, *and ordering quantity* $q^M = \frac{\beta[\alpha-(c+m)\beta]\mu_m}{2\beta\mu_m-\gamma^2}$.

Since mathematically the agency selling model and the advertising service are special cases of the mixed model, we now compare the equilibrium solutions of the mixed model to those of the reselling model.

Lemma 4.

(1) $v^M > v^w$.
(2) *If* $0 < \gamma < \gamma_i$ *and* $\theta_{14} < \theta < 1$, *then* $p^M < p^w$; *otherwise,* $p^M \geq p^w$.[11]

Lemma 4 shows the relationship between the service level and the optimal retail prices in the reselling and mixed models. Specifically, the service level in the mixed model is always higher than that in the reselling model. The retail price in the mixed model is lower than that in the reselling model if there is a low degree of service sensitivity and the manufacturer's bargaining power exceeds a threshold ($\gamma < \gamma_i$ and $\theta > \theta_{14}$). Otherwise, the mixed model leads to higher retail price than that in the reselling model.

Now, we examine the economic performance of the platform and the manufacturer under the reselling and mixed models. The following proposition is obtained.

Proposition 4. *If* $\frac{1}{2} < \theta < 1$; *or* $0 < \gamma < \gamma_t$ *and* $0 < \theta < \theta_{15}$; *or* $\gamma_t < \gamma < \gamma_b$ *and* $0 < \theta < \frac{1}{2}$, *then the mixed model is the better strategy; otherwise, the reselling model is the better strategy.*[12]

Proposition 4 specifies the decision region for firms to choose the mixed model or the reselling model, and the outcomes are illustrated in Fig. 5. Region I indicates that compared with the mixed model, the reselling performs better for the platform while performs worse for the manufacturer when the manufacturer's bargaining power is greater than the critical threshold ($\theta_{15} < \theta < 0.5$) and the service sensitivity is low ($0 < \gamma < \gamma_t$). Region II corresponds to the conditions under which the mixed model performs better that the reselling model. Specifically, in Region II(1), the platform will suffer a loss of profit, but the manufacturer will obtain a gain of profit. In Region II(2), both the manufacturer and the platform earn more under the mixed model, leading to *Pareto improvement*. Consequently, the mixed model will be embraced by both parties.

Now, we compare the social welfare between the reselling and mixed models and derive Corollary 3.

Corollary 3. $SW^M > SW^w$.

This corollary indicates that when the mixed model produces better economic performance than the reselling model, the social welfare under the mixed model is greater than that under the reselling model. This is because the increase in whole channel profit under the mixed model is larger than the decrease in consumer surplus. Thus, the mixed model can achieve a win–win outcome for the society and firms.

6.2. The case of the platform with higher service efficiency

In the previous sections, we assumed that the manufacturer had a higher service efficiency than the platform, that is, $\mu_m < \mu_p$. In practice, online platforms such as Amazon and JD.com can have greater service efficiency than manufacturers because of the economy of scale and their continuous investment in distribution and fulfillment capability [22]. To verify the research findings, we extend the analysis to the scenario in which $\mu_m \geq \mu_p$.

First, we explore the choice of optimal selling models by comparing the profits of the platform and the manufacturer under the three different selling models. Proposition 5 is derived as follows.

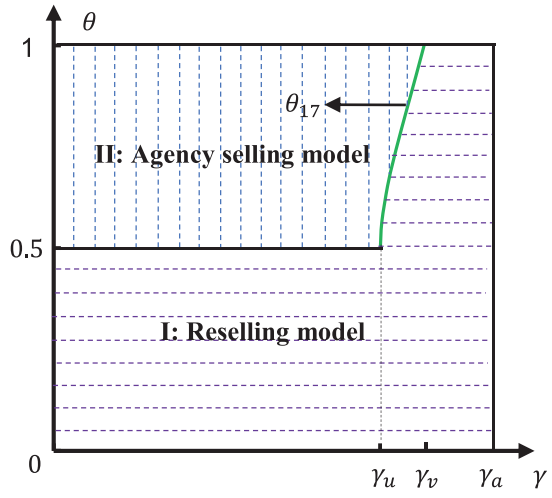
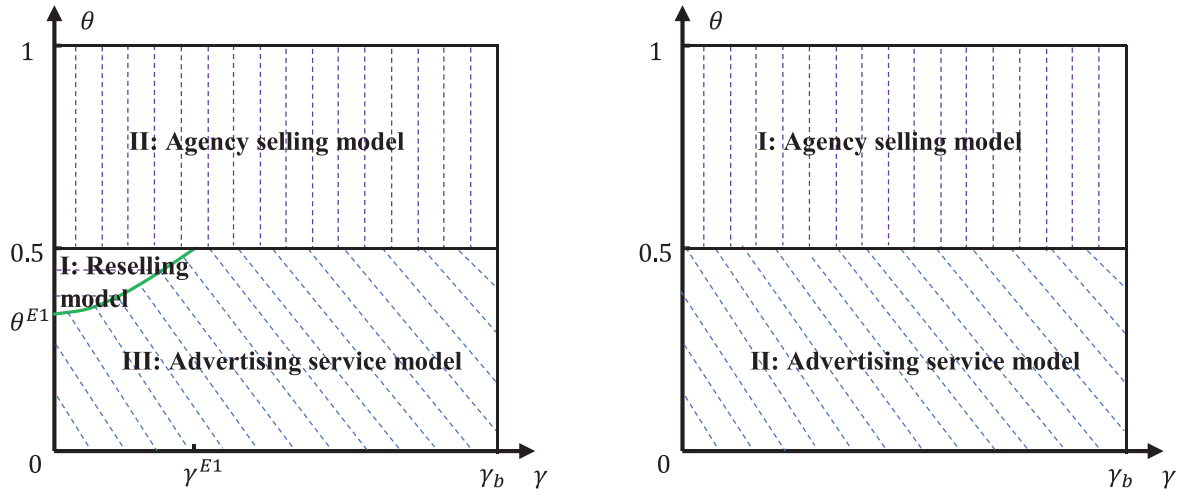


Fig. 6. Choice of the selling models.

[11] Where $\theta_{14} = \frac{2\beta\gamma^2\Delta\mu}{(\beta\mu_p-\gamma^2)[2\beta(\mu_p-\Delta\mu)-\gamma^2]}$.

[12] Where $\gamma_t = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p+8\Delta\mu}}$ and $\theta_{15} = \frac{2\gamma^2\Delta\mu}{\gamma^2\Delta\mu+\sqrt{\gamma^2\Delta\mu(\mu_p-\Delta\mu)(2\beta\mu_p-\gamma^2)}}$.



7a $0 < \beta < \beta^{E1}$ 7b $\beta^{E1} < \beta < \frac{\alpha}{c+m}$

Fig. 7. Selection of optimal selling models.

Proposition 5. *If $0 < \gamma < \gamma_u$ and $\frac{1}{2} < \theta < 1$, or $\gamma_u < \gamma < \gamma_v$ and $\theta_{17} < \theta < 1$, then the agency selling model performs better financially; otherwise, the reselling model is the preferred option.*[13]

From this proposition, we find that when the platform's service efficiency is not lower than the manufacturer's service efficiency ($\mu_m \geq \mu_p$), the advertising service model is not a viable option. The preferred choice is either the reselling model or the agency selling model, as shown in Fig. 6. When the platform has strong bargaining power ($0 < \theta < \frac{1}{2}$), the reselling model is the preferred choice regardless of the price and service sensitivities. This is because the platform can take full advantage of its superior service efficiency and bargaining power to maximize its profit in the reselling model. This finding explains the market phenomenon that platform giants like Amazon and JD.com can continuously expand their reselling businesses from big item appliances to groceries with their super-efficient logistics and delivery service [3,38]. When the platform's bargaining power decreases, the service sensitivity plays a critical role in the choice of the selling model. If the service sensitivity is lower ($0 < \gamma < \gamma_u$), the agency selling model is the preferred option over the reselling model.

Next, we explore the effect of the agency selling model on social welfare and obtain Corollary 4.

Corollary 4. *If $0 < \gamma < \gamma_w$, $\theta_5 < \theta < 1$, then $SW^{\lambda} > SW^{w}$; otherwise, $SW^{\lambda} < SW^{w}$.*[14]

This corollary indicates that superior economic performance under either the reselling model or the agency model does not guarantee an improvement in social welfare. In fact, the positive impact on social welfare is further determined by the service sensitivity and the manufacturer's bargaining power, unlike under previous corollaries. Specifically, when the service sensitivity is less than the critical threshold ($0 < \gamma < \gamma_w$) and the manufacturer's bargaining power exceeds the critical threshold ($\theta_5 < \theta < 1$), social welfare under the agency selling model is higher than that under the reselling model.

6.3. Different direct sales costs for the platform under the three selling models

In previous sections, we consider that the direct sales costs for the platform under the three selling models are identical. However, the platform sells the product under the reselling model, the manufacturer sells the product directly under the agency selling model and the advertising service model. Therefore, in this section, we extend the analysis to different direct sales costs for the platform under the three selling models. For simplicity, we assume that the direct sales cost for the platform in the reselling model is c and that the direct sales costs for the platform in the agency selling model and the advertising service model are both zero.

Corollary 5. *If $0 < \beta < \beta^{E1}$ and $0 < \theta < \min\{\theta^{E1}, \frac{1}{2}\}$; or $\beta^{E1} < \beta < \frac{\alpha}{c+m}$ and $0 < \theta < \frac{1}{2}$, then the advertising service model is the preferred model; if $\frac{1}{2} < \theta < 1$, then the agency selling model is the preferred model; otherwise, the reselling model is the preferred model.*[15]

This corollary presents the selection of optimal selling models when the platform has different direct sales costs under the three selling models. Similar to the scenario where the platform has identical direct sales costs under the three selling models, the manufacturer always prefers the agency selling model. However, the platform's selection of the selling model recedes into two options: the advertising service model and the reselling model. The specific selling model depends on the price and service sensitivities of demand (β, γ). When the price sensitivity of demand is high, rather than pricing the product, the platform charges the fixed advertising service fees. Otherwise, when the price and service sensitivities of demand are low, the platform prefers the reselling model. Because the platform can decrease the service level in the reselling model to control the service cost incurred by the

[13] $\gamma_u = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p-3\Delta\mu}}$, $\gamma_v = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p-2\Delta\mu}}$ and $\theta_{17} = \frac{\gamma^2(-\Delta\mu-\mu_p)+2\beta\mu_p(\mu_p-\Delta\mu)+\sqrt{2}\sqrt{-\mu_p[\gamma^2-2\beta(\mu_p-\Delta\mu)][-2\beta\mu_p(\mu_p-\Delta\mu)+\gamma^2(\mu_p-3\Delta\mu)]}}{6\beta\mu_p(\mu_p-\Delta\mu)-\gamma^2(3\mu_p-\Delta\mu)}$.

[14] $\gamma_w = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)}{\mu_p-4\Delta\mu}}$ and $\theta_5 = \frac{2\beta\mu_p(\mu_p-\Delta\mu)+\gamma^2(\Delta\mu-\mu_p) - \sqrt{2\beta\gamma^2(\Delta\mu-2\mu_p)(\mu_p-\Delta\mu)\mu_p+4\beta^2(\mu_p-\Delta\mu)^2\mu_p^2+\gamma^4(4\Delta\mu^2-\Delta\mu\mu_p+\mu_p^2)}}{\gamma^2\Delta\mu}$.

[15] $\beta^{E1} = \frac{\alpha[(9-6\sqrt{2})c+m]}{9c^2+18cm+m^2}$, $\gamma^{E1} = \sqrt{\frac{2\beta\mu_p(\mu_p-\Delta\mu)[\alpha^2-2(9c+m)\alpha\beta+(9c^2+18cm+m^2)\beta^2]}{8\Delta\mu(\alpha-m\beta)^2+\mu_p[\alpha^2-2(9c+m)\alpha\beta+(9c^2+18cm+m^2)\beta^2]}}$ and $\theta^{E1} = \frac{2}{[\alpha-(c+m)\beta]^2(2\beta\mu_m-\gamma^2)\mu_p}\{c\beta\mu_p[2\alpha-(c+2m)\beta][\gamma^2-2\beta(\mu_p-\Delta\mu)]-(\alpha-m\beta)^2\gamma^2\Delta\mu+\sqrt{f}\}$, where $f = (\alpha-m\beta)^2(\mu_p-\Delta\mu)(2\beta\mu_p-\gamma^2)\{(\alpha-m\beta)^2\gamma^2\Delta\mu-c\beta\mu_p[\gamma^2-2\beta(\mu_p-\Delta\mu)][2\alpha-(c+2m)\beta]\}$.

low service efficiency. Notably, there is no one selling model that is best for both the manufacturer and the platform, which means there is no Pareto improvement region for three selling models.

7. Conclusions

This paper examines practical problems faced by many e-commerce platforms and product manufacturers. Should platforms provide retailing services themselves? If so, which product categories should they sell? If not, what kind of selling model should they choose? Should manufacturers sell to consumers directly on the platforms? If so, should they choose the agency selling model or the advertising service model? To answer these questions, we consider three widely used selling models: the reselling model, the agency selling model, and the advertising service model. Through an equilibrium analysis, we systematically examine how different selling models affect the financial performance of platforms and manufacturers and social welfare. Our results help clarify the effects of key product features (such as price and service sensitivities), firms' service efficiency, and bargaining power on the choice of selling models.

Our research findings contribute to crucial managerial insights that would allow e-commerce platforms and manufacturers to make informed strategic and operational decisions to enhance their competitive advantages. A combination of important factors influences the choice of a selling model. Interfirm bargaining power plays a pivotal role in choosing among the three different selling models, especially when demand's price or service sensitivity is low. In these scenarios, the agency selling model delivers better financial performance when the manufacturer has dominant bargaining power, and in contrast, the reselling model generates more profits when the platform dominates the bargaining game. This finding applies regardless of whether the manufacturer or the platform has superior service efficiency. The influences of customer demand's price and service sensitivities on the choice of a selling model increase as customers become increasingly sensitive to price and service. For instance, the agency selling model produces the best financial and social performance when both the price and service sensitivities are high and the manufacturer has superior service efficiency, and the reselling model generates great financial benefits when consumers are more service-sensitive and the platform is more efficient in service provision. Interestingly, the advertising service model only performs better than the other two selling models when the manufacturer has superior service efficiency but less bargaining power than the platform and customer demand is less sensitive to price but more sensitive to service. Since customer demand's price and service sensitivities vary across different product categories, different selling models may be appropriate for different products. Our findings highlight the strategic importance of platforms investing in service (such as logistics and warehousing) and incorporating demand characteristics (especially service sensitivity) in the choice of selling models. As manufacturers are often in weak bargaining positions in contractual negotiations with e-commerce platforms, it is critical for manufacturers to enhance their bargaining power to thrive on e-commerce platforms through the agency selling model.

This study also has some limitations that point to several attractive future research directions. First, this paper studies an online retail channel that consists of a platform and a manufacturer; it does not consider competition among multiple manufacturers on one platform or among multiple platforms using different selling models. Channel competition has been discussed extensively in the operations and marketing literature [4,14,36]. The products and services offered by competing manufacturers and platforms will certainly have an impact on firms' strategic and operational decisions. Therefore, one future research direction would be to study competition among multiple platforms and manufacturers. Second, in the advertising service model, advertising is considered to be a revenue stream for the platform and an additional cost for the manufacturer. However, the analysis here does not consider the fact that advertising can increase the exposure of a manufacturer's products and consequently may result in higher demand [5]. Therefore, our analysis of the advertising service model can be viewed as a conservative baseline. It may be interesting to examine the scenario in which the advertising service fee is dependent with the retail price or the total demand under the advertising service model is not equal to but rather higher than that under the reselling or agency selling models. In the agency selling model, the unit commission rate related to the retail price is also popular. It is a promising future extension to examine the effects of both types of transaction fees in the similar research context of this paper. Furthermore, this study employs a linear, additive, and deterministic demand function. Although this form of demand function has commonly been used in relevant studies [1,31,40], it takes a specific functional form and ignores demand uncertainty. More general demand functions that incorporate demand uncertainty may influence firms' decisions on selling models. Finally, many platforms, such as Amazon and JD.com, offer fulfillment and logistics services to manufacturers. Under these service arrangements, manufacturers decide on the retail prices, but the platform is responsible for the logistics operation, including warehousing and delivery. Incorporating such services (e.g., logistics services) into our modeling framework might reveal new insights.

Declaration of Competing Interest

None.

Data Availability

No data was used for the research described in the article.

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Supplementary materials

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