Value-added Services and E-commerce Platform Competitiveness: A Game Theoretic Approach

Abstract

Purpose – In response to the intense competition in the platform economy, e-commerce platforms are actively introducing value-added services to maintain their competitiveness. However, how effective these value-added services are in fulfilling this purpose remains unclear. This paper explores how value-added services can enhance e-commerce platform competitiveness, measured by both user scale and reputation, considering the effect of network externalities.

Design/methodology/approach – A bilateral e-commerce platform with potential high-quality sellers and low-quality sellers on one side and potential buyers on the other side was chosen as research setting. Game theory models are constructed to simultaneously consider the behaviors of all actors (including sellers, buyers and the platform).

Findings – On the one hand, to increase the seller scale, basic services play a substituting role in determining the effect of value-added services. On the other hand, to increase the buyer scale and improve platform reputation, basic services play a fundamental role in determining the effect of value-added services. Furthermore, the higher the loss rate of the product value, the bigger the room for providing value-added services. With increasing loss rate of the product value, participating buyers who are attracted by value-added services are the fastest growing indicators; this indicates that the most significant effect of value-added services is its increase in the buyer scale.

Theoretical implications – (1) While previous studies on how to enhance platform competitiveness only considered scale or reputation separately, this paper applies a new perspective of platform competitiveness, namely the improvement of both the seller scale/buyer scale and platform reputation. (2) According to the characteristics of bilateral platforms, game theory models are constructed to explore how value-added services can enhance platform competitiveness considering both positive and negative network externalities. (3) The existing literature studies basic services and value-added services in a fragmented state; this paper contributes to research on value-added services by considering the mutual effect between basic and value-added services.

Managerial implications – Basic services determine the lower limit of platform competitiveness, while value-added services set the upper limit. The results of this paper can instruct different types of platforms to enhance their competitiveness in different ways.

Keywords E-commerce platforms, Platform competitiveness, Value-added services, Network externalities

Paper type Research paper

1. Introduction

Because of the intense competition in the platform economy, e-commerce platforms are actively expanding their provision of free services to sellers, which is critical to maintain transactions in a transparent online market (Cennamo, 2021). For example, ***Jingdong.com*** and ***eBay.com*** provide match and information release services to sellers. As these basic services are free for all sellers, access to the platform is made extremely easy; this potentially attracts not only high-quality sellers (H-type sellers), but also low-quality sellers (L-type sellers). Note that H-type sellers mainly sell high-quality products, which are reliable and durable, perform well, and conform to standards; Low-type sellers sell low-quality products, which mimic certain characteristics of high-quality products, but use fewer materials at lower quality. In this case, although the seller scale of the platform may increase, Low-type sellers can affect buyers' shopping experience and stickiness and damage the reputation of the platform; this is unfavorable for the long-term development of the platform.

To increase the stickiness of buyers as well as competitiveness, e-commerce platforms have started to introduce more value-added services (Liu and Wang, 2020). Value-added services refer to a series of customized services with the goal to meet the personalized needs of sellers by charging value-added fees (Zhang *et al.*, 2021). For example, the certification service of ***Amazon*** and big data and store decoration services of ***T-mall.com*** are particularly helpful for the marketing strategies of sellers. While these additional value-added services can attract more high-quality sellers and improve the platform reputation, the higher cost associated with using them can also deter entry and growth of the platform (Zhang *et al.*, 2021). Therefore, it has become a strategic task for e-commerce platforms to appropriately balance the provision of free basic services and additional value-added services while maintaining their reputation and growth.

Compared with the traditional market, an e-commerce platform is a bilateral market which has network externalities, i.e., the effect between sellers' and buyers' participation choices is mutual (Chen *et al.*, 2016). Understanding how value-added services can improve the reputation of e-commerce platforms reputation and expand the scale through the lens of network externalities is essential (Zhang *et al.*, 2021). Existing literature has shown that positive network externalities can improve the shopping experience for buyers, and increase both the user base of the platform and its reputation (Zhang *et al.*, 2021). However, network externalities tend to be negative when too many L-type sellers are dominating the platform because of information asymmetry (Dou *et al.*, 2018). This situation will lead to buyer dissatisfaction and damage the reputation of the platform. Therefore, negative network externalities further complicate the effect of value-added services in platform operations. Based on this discussion, the aim of this paper is to explore how both positive and negative network externalities affect the role of value-added services in increasing both scale and reputation of the platform. This is achieved by addressing the following research question:

What is the effect of value-added services of e-commerce platforms on platform scale and reputation and how can it be enhanced?

To address this research question, a bilateral e-commerce platform with potential H-type sellers and L-type sellers on one side and buyers on the other side (Rochet *et al.*, 2006) is chosen as research context. Because of the ability of the applied game-theoretic method to consider the behavior of multiple actors simultaneously (including sellers, buyers and the platform), game theoretic models are constructed. These are used to analyze how value-added services can balance both the scale and reputation of e-commerce platforms with both positive and negative network externalities as well as the presence of basic services. The results suggest that value-added services can enhance the competitiveness of e-commerce platforms; moreover, basic services play different roles in determining how value-added services can enlarge both the seller scale and buyer scale, as well as improve platform reputation.

The remainder of this paper is structured as follows: A review of the related literature is presented in Section 2, and the model is described in Section 3. In Section 4, the equilibrium of a platform with basic services is analyzed as benchmark; then, a platform with value-added services is explored. Section 5 presents an equilibrium comparison of optimal outcomes. In Section 6, numerical analysis is presented to explain certain analytical results and gain additional insight. Section 7 presents both theoretical and managerial implications. In Section 8, conclusions and limitations are presented.

2 Literature review

2.1 Competitiveness of e-commerce platforms

As the most important form of industrial organization in today's new economic era, competition among e-commerce platforms has received extensive attention from both scholars and practitioners (Sedera *et al.*, 2016). The mainstream literature on platform competition argues that the competitiveness of e-commerce platform relies on the rapid expansion of users (including both sellers and buyers). Therefore, most e-commerce platforms adopt a “get-big-fast” strategy, aiming to rapidly acquire and grow their user base by providing more products and services (Cennamo, 2013). The platform with the largest user base will ‘tip the market’ in its favor because of network externalities (Cennamo, 2021).

With increasingly fierce competition among e-commerce platforms in recent years, scholars have started to focus on platform reputation as a means to enhance their competitiveness (Hesse *et al.*, 2022). Platform reputation refers to buyers’ evaluation of the products and trading experience of the e-commerce platform, highlighting the critical role of H-type sellers (Teubner *et al.*, 2020; Zhang *et al.*, 2022). According to evidence in the e-commerce environment, platform reputation has a significant positive impact on the participation and stickiness of users (Su *et al.*, 2016). On the one hand, the good reputation of a platform can "lock in" buyers, and this locking effect can generate sufficient flow of resources to attract additional sellers. On the other hand, platforms with good reputation can provide a ‘reputation guarantee’ for sellers, and this halo effect can influence buyers’ perception of sellers (Teubner *et al.*, 2020; Zhang *et al.*, 2022). In summary, reputation has become a core component of platform competitiveness (Kokkodis and Ipeirotis, 2016), and platforms need to make efforts to secure their user scale and manage their reputation (Cennamo, 2021; Dimoka *et al.*, 2012).

Existing research on platform competitiveness has mainly focused on the role of either the user scale or platform reputation (Schwanholz and Leipold, 2020; Blackburn *et al.*, 2022; Pizzi *et al.*, 2022). However, because of information asymmetry, low-quality products can participate in the platform, which may increase the user scale but damage buyer satisfaction and thereby also platform reputation (Liu and Wang, 2020). When this vicious circle continues, the competitiveness of the platform will be lost because of a lack of operation efficiency (Kuo-Kuang and Chi-Hua, 2008). Therefore, scale and reputation are mutually influencing factors that collectively affect platform competitiveness and should be managed strategically.

2.2 E-commerce platform services

Research has shown that platform services can help e-commerce platforms improve their efficiency by influencing the choices of platform participants (Abrate and Viglia, 2019; Luca and Zervas, 2016). Platform services mainly include basic services and value-added services (Zhang *et al.*, 2021; Liu and Wang, 2020; Dou *et al.*, 2016). Basic services refer to platform architecture services used to generate the trading space, where defined interaction rules ensure that interactions or transactions between participants can be successfully realized (Cennamo, 2021). How basic services affect platform participants has been extensively studied (Cennamo, 2021; Wang *et al.*, 2019; Gawer, 2014). For instance, Wang *et al.* (2019) took third-party ride-sharing platforms as an example to examine how matching service capabilities affect the utility of user access to platforms.

With intensifying competition among e-commerce platforms, value-added services are increasingly introduced by platforms to pursue further development. Value-added services refer to a series of customized services with the goal to meet the personalized needs of participants (Liu *et al.*, 2019). One stream of the literature focused on the improvement of the value-added capability of platforms (Zhang *et al.*, 2021; Liu and Wang, 2020; Chi *et al.*, 2020; Liu *et al.*, 2019; Boudreau and Jeppesen, 2015). For instance, Zhang *et al.* (2021) examined bilateral value-added services and pricing strategies of a third-party platform for manufacturing by considering positive network externalities. Chi *et al.* (2020) proposed a research model to explain sustainable consumption behaviors in an accommodation sharing platform by improving value-added signals. Boudreau and Jeppesen (2015) suggested that digital platforms increase trading opportunities for H-type sellers by setting high standards for value-added services; this also implies that platforms set entry barriers for potential quality sellers. Another stream of the literature focused on the pricing of value-added services (Basu *et al.*, 2019; Hong *et al.*, 2017; Kung and Zhong, 2017). For example, by studying authentication services and related pricing decisions, Basu *et al.* (2019) found that authentication services affect users' utility. Hong *et al.* (2017) explored the service and pricing strategies of third-party platforms by considering the incentives for consumer entry from value-added services such as accurate identification.

In summary, previous studies mainly focused on exploring how to invest and price value-added services in the accommodation sharing platforms, the industrial Internet, and mobility fields (Xie *et al.*, 2020; Chen *et al.*, 2020; Chi *et al.*, 2020; Basu *et al.*, 2019; Dou *et al.*, 2016; Boudreau and Jeppesen, 2015). However, little is known on how the scale and the reputation of e-commerce platforms can be fulfilled simultaneously by providing value-added services. Existing studies have two important limitations. First, they disregarded the relationship between basic services and value-added services. Specifically, the provision of free basic services is the basic function of e-commerce platforms, which affects the participation strategies of both sellers and buyers. Only when sellers are attracted to the platform by its basic services will they consider whether to purchase value-added services. This mutual effect between basic and value-added services cannot be ignored. Second, theoretical model prior studies have constructed to explore the effect of value-added services on platform competitiveness only considered positive network externalities. However, as both H-type and Low-type sellers can be potentially attracted to the platform because of information asymmetry and enjoy the value-added services provided by the platform, both positive and negative network externalities (defined as the mutual effect between sellers' and buyers' participation choices) are likely to exist and co-influence the effect of value-added services. While H-type sellers will generate positive network externalities and improve the user scale, Low-type sellers tend to generate negative network externalities which undermine user experience and platform reputation (Zhang *et al.*, 2021). Therefore, this study explores how value-added services can improve both the scale and reputation of e-commerce platforms. To this end, game theoretical models are constructed considering basic services and both positive and negative network externalities.

3 Model description

To assess the effect of value-added services on seller scale, buyer scale, and platform reputation, potential sellers are divided into H-type sellers and L-type sellers (Gomes *et al.*, 2013). Specifically, H-type sellers sell high-quality products, which are reliable and durable, perform well, and conform to standards; Low-type sellers sell low-quality products, which mimic certain characteristics of high-quality products, but use less materials and ingredients with lower quality. Therefore, the model assumes that there is a bilateral e-commerce platform P that has two groups of sellers and one group of buyers on both sides (Song *et al.*, 2021).

In general, e-commerce platforms gain their revenue by charging a commission rate τ from participating sellers for each sale. On the one hand, each e-commerce platform provides free basic services to participating sellers to ensure smooth transactions and increase market transparency; examples of such free basic services are product information release services and delivery services (Chen *et al.*, 2016). Because e-commerce platforms have various business objectives and profitability levels, they provide such basic services at different qualities (Zhang *et al.*, 2021). For example, ***JD.com*** has greater control and flexibility in logistics delivery than ***Taobao.com***, which can provide faster and more reliable delivery services. It is assumed that the quality of basic services is α, which reflects a probability of facilitating the transaction between a buyer and a seller. That is, the range of basic capacity is $(0,1)$, which also implies that sellers will gain profit from basic services under the probability α. On the other hand, to further promote online transactions and increase the stickiness of buyers, certain e-commerce platforms provide various personalized value-added services. For these services, sellers are charged an additional fee, namely the value-added fee q. Examples for these value-added services include certification services and recommendation services, which can attract more H-type sellers and improve the reputation of the platform. Similarly, as e-commerce platforms have various business objectives and profitability levels, they provide such value-added services at different qualities (Zhang *et al.*, 2021). For example, ***JD.com*** offers JD+ data services, ***Taobao.com*** provides Cost Per Click services. These platforms provide various value-added services, resulting in differences in the quality of value-added services. It is assumed that the quality of value-added services is called value-added capability β, which can increase the demand of H-type sellers. Because value-added services mainly provide personalized services to help H-type sellers to become more easily recognized by buyers, the effect of value-added services varies for different seller types: H-type sellers gain more profit from value-added services at probability β based on basic services; L-type sellers gain more profit from value-added services at probability $1-\beta$ based on basic services (Basu *et al.*, 2019).

Different types of sellers gain different profits when selling their products: the profit of an H-type seller is b, the profit of an L-type seller is $b+\Delta b$, where Δb denotes the additional profit of an L-type seller obtained by selling low-quality products. To exclude trivial cases, it is assumed that $1>2b+\Delta b$, as otherwise, the number of participating L-type sellers is greater than 1, which is not meaningful. In this paper, while the product price is not considered, the value of the seller's profit is defined as the product price minus the product cost. Considering the heterogeneity of each type of sellers wanting to participate in the platform, each type of seller has different fixed costs when conducting a transaction (including personnel costs, equipment costs, and maintenance costs but excluding product costs). Consequently, c_H is the random variable of H-type sellers' fixed costs for selling products through the platform; c_L is the random variable of L-type sellers' fixed costs for selling products through the platform; c_H and c_L are uniformly distributed over [0,1].

Regarding buyers who wants to participate in the platform, because of their heterogeneity, they face opportunity costs for participating in the platform (Jullien, 2005). μ is the random variable of buyers' opportunity cost, μ which is uniformly distributed over [0,1]. Because products sold by each type of seller have different values in a vertically differentiated market, the value of a product a buyer purchases from an H-type seller is v and the value of a product a buyer purchases from an L-type seller is λv. Note that $\lambda\left(0>\lambda>\underline{\lambda}\right)$ is the loss rate of the product value. To exclude trivial cases, this rate should not be too small (e.g., $\lambda>\underline{\lambda}=-\frac{\Delta b}{b+\Delta b}$); otherwise, the buyer will either never participate in the platform or the difference between H-type and L-type sellers will be too small to represent all typical cases.

Using this framework illustrated in **Fig.1**, U_H and U_L are denoted as the revenue of an H-type seller and the revenue of an L-type seller, respectively, S is the expected surplus of a buyer and π is the revenue of the platform. When the revenue of an H-type seller and that of an L-type seller satisfies $U_H>0$ and $U_L>0$, respectively, prospective sellers decide to participate in the platform. Similarly, when the expected surplus of a buyer satisfies $S>0$, prospective buyers will participate in the platform. Specifically, to exclude conditions under which the problem is less interesting, $U_H\leq 1$, $U_L\leq 1$, and $S\leq 1$. For example, if $S>1$, all buyers will participate in the platform, and the mass of participating buyers is simply 1. Note that these variables are all endogenous and their values are different under different conditions.

Furthermore, the scale of sellers (seller scale) m is equal to the sum of the number of participating H-type sellers m_H and the number of participating L-type sellers m_L, i.e., $m=m_H+m_L$; the scale of buyers (buyer scale) is determined by the number of participating buyers n. Specifically, the probability that a seller (or buyer) encounters a buyer (or seller) on the platform is based on network externalities. In general, with increasing number of participating sellers (or buyers) in the platform, the probability that a buyer's (or seller's) target seller (or buyer) is on the platform also increases (Roth, 1989). The probability for a buyer to encounter sellers on the platform is equal to the number of participating sellers m; the probability for a seller to encounter buyers on the platform is equal to the number of participating buyers n. This assumption simplifies mathematical expressions while capturing the essential idea that a buyer's (or seller's) target seller (or buyer) is more likely to be on the platform if more sellers (or buyers) participate in the platform. This assumption has often been used in the existing literature (Jullien 2006; Chen *et al.*, 2016). Furthermore, because reputation depends on the type of seller, platform reputation is defined as $\delta = \frac{m_H}{m}$. Note that platform reputation is an outcome variable that is determined by the proportion of different types of participating sellers. This, in turn, is influenced by and different from the capability of basic services and the capability of value-add services. The definitions of all notations are provided in **Table 1**.

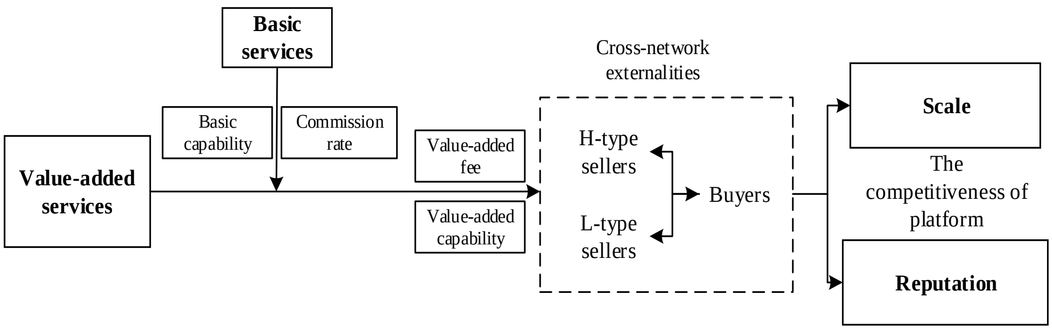


Figure 1. Framework for this paper

Table 1. Summary of notations

Notation	Definition
τ	Commission rate for each sale
q	Value-added fee for sellers who purchase value-added services
α	Basic capability
β	Value-added capability

b	Profit of an H-type seller
Δb	Additional profit of an L-type seller
c_H	Fixed cost of an H-type seller
c_L	Fixed cost of an L-type seller
μ	Opportunity cost of a buyer
v	Value of a product sold by an H-type seller
λ	Loss rate of the product value
m	Seller scale
m_H	Number of participating H-type sellers
m_L	Number of participating L-type sellers
n	Buyer scale (number of participating buyers)
δ	Platform reputation
U_H	Revenue of an H-type seller
U_L	Revenue of an L-type seller
S	Expected surplus of a buyer
π	Revenue of the platform

3.1 Model for a platform with only basic services (benchmark)

This benchmark scenario, considers a platform that only provides basic services. To achieve a threefold win-win for the platform, each type of seller, buyers and the platform's revenue functions are constructed as follows:

First, the probability that a seller encounters a buyer is n, which is normalized according to network externalities. Then, an H-type seller who participates in the platform will gain profit b at probability α, but the seller must pay a transaction fee $\alpha\tau b$ and fixed cost c_H. Similarly, an L-type seller who participates in the platform will gain a profit $(b+\Delta b)$ at probability α, but it must pay a transaction fee $\alpha(b+\Delta b)\tau$ and a fixed cost c_L.

Second, the probability for a buyer to encounter a seller is m. After their encounter, the probability that a buyer purchases from an H-type seller is δ; the value a buyer gains from the H-type seller is v, which generates positive network externalities. The probability that a buyer purchases from an L-type seller is $(1-\delta)$; the value a buyer gains from the L-type seller is λv, which generates negative network externalities.

Third, the demand for basic services is n and all incomes of the platform are generated by charging a commission from each type of seller.

The value functions for an H-type seller, an L-type seller, a buyer and the platform are shown in Equations (1), (2), (3), and (4), respectively:

$$U_H{}^o = n\left[\alpha b(1-\tau)-c_H\right] \tag{1}$$

$$U_L{}^o = n\left[\alpha(b+\Delta b)(1-\tau)-c_L\right] \tag{2}$$

$$S_o = m\left[\delta+\lambda(1-\delta)\right]v-\mu \tag{3}$$

$$\pi_o = \left[\alpha b+\alpha(b+\Delta b)\right]n\tau \tag{4}$$

3.2 Model of a platform with value-added services

This scenario considers that a platform provides both basic and value-added services. To achieve a threefold win-win for the platform, each type of seller, buyers and the platform's revenue functions are constructed as follows.

First, the probability that a seller to encounter a buyer is n, which is normalized according to network externalities. Then, an H-type seller who participates in the platform will gain profit b at probability α. The participating H-type seller can gain an additional profit $(1-\alpha)b$ and pay value-added fee q at probability β. Therefore, the participating H-type seller must pay a commission $\left[\alpha+(1-\alpha)\beta\right]b\tau$, value-added fee βq, and fixed cost c_H. Similarly, an L-type seller who participates in the platform will gain profit $(b+\Delta b)$ at probability α. The participating L-type seller can also gain an additional profit $(1-\alpha)(b+\Delta b)$ and pay a value-added fee q at probability $(1-\beta)$. Therefore, the participating L-type seller must pay commission $\left[\alpha+(1-\alpha)(1-\beta)\right](b+\Delta b)\tau$, a value-added fee $(1-\beta)q$, and fixed cost c_L.

Second, the probability for a buyer encountering a seller is m. After their encounter, the probability that a buyer purchases from an H-type seller is δ; the value a buyer gains from the H-type seller is v, which generates positive network externalities. The probability that a buyer purchases from an L-type seller is $(1-\delta)$; the value a buyer gains from an L-type seller is λv, which generates negative network externalities.

Third, the demand for basic services is n and the demand for value-added services is n. All incomes of the platform are generated by charging both basic fees and value-added fees from each type of seller.

The value functions for an H-type seller, an L-type seller, a buyer and the platform are calculated according to Equations (5), (6), (7), and (8), respectively:

$$U_H{}^a = n\left[\left(\alpha+\beta-\alpha\beta\right)b(1-\tau)-\beta q-c_H\right] \tag{5}$$

$$U_L{}^a = n\left[\left(1-\beta+\alpha\beta\right)\left(b+\Delta b\right)(1-\tau)-(1-\beta)q-c_L\right] \tag{6}$$

$$S_a = m\left[\delta+\lambda\left(1-\delta\right)\right]v-\mu \tag{7}$$

$$\pi_a = \left[\left(\alpha+\beta-\alpha\beta\right)b+\left(1-\beta+\alpha\beta\right)\left(b+\Delta b\right)\right]n\tau+nq \tag{8}$$

4 Equilibrium

In this section, the optimal commission rate is calculated first as it determines all other equilibrium outcomes of a platform providing only basic services. Next, the optimal value-added fee is calculated as it determines all other equilibrium outcomes of a platform providing value-added services.

4.1 Equilibrium of a platform with only basic services

First, according to the monotonicity principle, the seller scale is determined by the choices of sellers, i.e., sellers whose fixed costs remain below a certain threshold will participate in the platform (Chen *et al.*, 2016). The fixed costs to marginalize an H-type seller and an L-type seller are c_{Hmax} and c_{Lmax}, respectively. Because the fixed costs of both types of sellers are uniformly distributed over $[0,1]$, the number of participating H-type sellers can be calculated as $c_{Hmax} = m_H{}^o = \alpha b(1-\tau)$, and the number of participating L-type sellers can be calculated as $c_{Lmax} = m_L{}^o = \alpha\left(b+\Delta b\right)(1-\tau)$. Therefore, it can be derived that the seller scale is $m_o = \alpha\left(2b+\Delta b\right)(1-\tau)$ and the platform reputation is $\delta_o = \dfrac{b}{2b+\Delta b}$.

Similarly, the opportunity cost to marginalize a buyer is defined as $\mu_{\max}$. Because the opportunity cost of buyers is uniformly distributed over $[0,1]$, the number of participating buyers is $\mu_{\max} = n_o = \left[\alpha b+\lambda\alpha\left(b+\Delta b\right)\right](1-\tau)v$, i.e., the buyer scale is $n_o = \left[\alpha b+\lambda\alpha\left(b+\Delta b\right)\right](1-\tau)v$. Finally, the revenue of a platform with basic services is $\pi_o = \left[b+\lambda\left(b+\Delta b\right)\right]\left[b+\left(b+\Delta b\right)\right](1-\tau)\tau\alpha^2 v$.

Next, the optimal commission rate can be obtained with Lemma 1.

Lemma 1. *The platform will charge the optimal commission rate* $\tau^* = \frac{1}{2}$ *to encourage all sellers to participate.*

Lemma 1 illustrates that the platform can charge the optimal commission rate τ^* to encourage all sellers to participate. Note that in this scenario, the optimal commission rate τ^* is determined. In the remainder of this paper, the value of the optimal commission rate is always $\tau^* = \frac{1}{2}$, which is assumed to be determined variable. Note that in this paper, the commission rate is endogenous, but it is also influenced by other external factors (e.g., market institution and governmental regulation) which are difficult to capture. Therefore, other factors that may influence the change of the commission rate are not considered.

The optimal seller scale, the optimal buyer scale and the optimal platform reputation for a platform with only basic services are calculated as shown in **Table 2**.

Table 2 Equilibrium outcomes of a platform with only basic services

Notation	Optimal expressions
m_o	$\frac{(A+B)}{2}$
n_o	$\frac{v\left(A+\lambda B\right)}{2}$
δ_o	$\frac{A}{A+B}$

(*Note that the values of A and B are detailed in the Appendix.)

4.2 Equilibrium of a platform with value-added services

As in the description of Section 4.1 and according to the monotonicity principle, the numbers of participating H-type sellers and L-type sellers are calculated as $m_H{}^a = \left(\alpha+\beta-\alpha\beta\right)b(1-\tau)-\beta q$ and $m_L{}^a = \left(1-\beta+\alpha\beta\right)\left(b+\Delta b\right)(1-\tau)-(1-\beta)q$, respectively. Therefore, the seller scale is $m_a = \left[\left(1+\alpha\right)b+\left(1-\beta+\alpha\beta\right)\Delta b\right](1-\tau)-q$ and the platform reputation is $\delta_a = \frac{\left(\alpha+\beta-\alpha\beta\right)b(1-\tau)-\beta q}{\left[\left(1+\alpha\right)b+\left(1-\beta+\alpha\beta\right)\Delta b\right](1-\tau)-q}$.

Similarly, the buyer scale is

$n_a = \{[(\alpha+\beta-\alpha\beta)b+\lambda(1-\beta+\alpha\beta)(b+\Delta b)](1-\tau)-[\beta+\lambda(1-\beta)]q\}v$, and the platform revenue with value-added services is $\pi_a = \left\{\begin{bmatrix}(\alpha+\beta-\alpha\beta)b-[\beta+\lambda(1-\beta)]q \\ +\lambda(1-\beta+\alpha\beta)(b+\Delta b)\end{bmatrix}(1-\tau)\right\}\left\{\begin{bmatrix}(1-\beta+\alpha\beta)(b+\Delta b) \\ +(\alpha+\beta-\alpha\beta)b\end{bmatrix}\tau+q\right\}v$.

According to the revenue of the platform with value-added services, the optimal value-added fee can be obtained.

Proposition 1. *When the platform provides value-added services, the optimal value-added fee is* $q^* = \frac{D(1-C)+E(\lambda-C)}{4C}$.

Firstly, Proposition 1 characterizes the endogenous optimal value-added fee q^* to encourage all sellers to purchase value-added services. Secondly, as shown in Table 3, based on the optimal value-added fee, the optimal seller scale, the optimal buyer scale and the optimal platform reputation are calculated for a platform that provides value-added services.

Table 3 Equilibrium outcomes of a platform with value-added services

Notation	Equilibrium outcomes
m_a^*	$\frac{D(3C-1)+E(3C-\lambda)}{4C}$
n_a^*	$\frac{D(1+C)+E(\lambda+C)}{4}$
δ_a^*	$\frac{CD(1+\beta)+\beta^2(1-\lambda)E}{D(3C-1)+E(3C-\lambda)}$

(*Note the values of C, D and E are detailed in the Appendix.)

5 Equilibrium comparison

Based on both equilibria (i.e., that of a platform with only basic services and that of a platform with value-added services), the conditions under which a platform with value-added services can increase its seller scale and buyer scale are obtained in subsection 5.1 and 5.2, respectively. The platform reputations under both conditions are also compared, which is presented in Subsection 5.3.

5.1 The scale of sellers

A comparison of the optimal seller scale of a platform with only basic services and the optimal seller scale of a platform with value-added services is presented in Tables 2 and 3. The comparison yields the following proposition.

Proposition 2. *When* $\alpha > \alpha(\beta)_m$*, a platform with only basic services has a larger seller scale than a platform with value-added services; when* $\alpha < \alpha(\beta)_m$*, a platform with value-added services has a larger seller scale than a platform with only basic services. The cutoff curve of the seller scale is defined as*

$$\alpha(\beta)_m = \begin{cases} 0 & \text{if} \quad \beta \in \left[0, \underline{\beta}_m\right] \\ \dfrac{a_1\beta^2 + d_1\beta + f_1}{d_2\beta + f_2} & \text{if} \quad \beta \in \left[\underline{\beta}_m, \overline{\beta}_m\right] \\ 1 & \text{if} \quad \beta \in \left[\overline{\beta}_m, 1\right] \end{cases} \tag{9}$$

where m *stands for the scale of sellers.*

(*Note that the values of a_1, d_1, d_2, f_1, and f_2 are detailed in the Appendix.)

This finding indicates that when the value-added capability is low, the seller scale of a platform with only basic services is always larger than the seller scale of a platform with value-added services. The reason for this result is that the low value-added capability cannot provide sufficient personalized services to benefit sellers, i.e., the benefit sellers can gain from providing value-added services is lower than the price they must pay for them, which will incentivize more sellers to transfer to other platform competitor. Therefore, the number of sellers attracted by value-added services is limited. That is, the increase in participating sellers induced by value-added services is lower than the increase in participating sellers induced by basic services.

When the value-added capability is relatively high, the basic capability plays a substituting role in determining the effect of value-added services on increasing the seller scale. If the basic capability is high, a platform with only basic services attracts more sellers than a platform with value-added services; otherwise, a platform with value-added services attracts more sellers. The underlying logic is explained as follows: In a platform with only basic services, the increase in participating sellers induced by an improvement of basic capability increases continuously; i.e., the higher the basic capability, the more the number of participating sellers will increase. In a platform with value-added services, basic services play a substituting role in the increase in participating sellers. The reason is that the lower the basic capability, the lower the increase in participating sellers induced by basic services. Under this condition, there is a large number of potential sellers who will be attracted by value-added services. As a result, the higher the basic capability, the lower the increase in participating sellers induced by value-added services. This difference explains the existence of the cutoff: Once the basic capability drops below a certain threshold, a platform with value-added services has more sellers than a platform with only basic services.

When the value-added capability far exceeds a certain threshold, the seller scale of a platform with value-added services is always larger than the seller scale of a platform with only basic services. The reason is that the value-added capability is sufficiently high to provide personalized services to attract additional sellers, which leads to sellers being more attracted by value-added services than by basic services. That is, the increase in participating sellers induced by value-added services is always higher than the increase in participating sellers induced by basic services.

5.2 The scale of buyers

A comparison of the optimal buyer scale of a platform with only basic services and the optimal buyer scale of a platform with value-added services shown in Table 2 and Table 3 obtains the following proposition.

Proposition 3. *When $\alpha < \alpha(\beta)_n$, a platform with only basic services has a larger buyer scale than a platform with value-added services; when $\alpha > \alpha(\beta)_n$, a platform with value-added services has a larger buyer scale than a platform with only basic services. The cutoff curve of the buyer scale is defined as*

$$\alpha(\beta)_n = \begin{cases} \dfrac{a_2\beta^2 + d_3\beta + f_3}{a_2\beta^2 + d_4\beta + f_4} & if \quad \beta \in [0, \beta_n] \\ 0 & if \quad \beta \in [\beta_n, 1] \end{cases} \tag{10}$$

where n stands for the scale of buyers.

(*Note that the values of a_2, d_3, d_4, f_3, and f_4 are detailed in the Appendix.)

This finding indicates that when the value-added capability remains below a certain threshold, the basic capability plays a fundamental role in determining the effect value-added services have on increasing the buyer scale. If the basic capability is high, a platform with value-added services attracts more buyers than a platform with only basic services; otherwise, a platform with only basic services attracts more sellers. The underlying logic is explained as follows: In a platform with only basic services, although the number of participating sellers increases with increasing basic capability, the increase in participating buyers induced by the improvement of basic services is only marginal; i.e., the higher the basic capability, the lower the increase in participating buyers. The reason is that a high basic capability attracts a large number of sellers, especially L-type sellers, which will strengthen the effect of negative network externalities compared with the effect of positive network externalities. Under this condition, the basic capability induces a lower increase in participating buyers. In a platform with value-added services, basic services play a fundamental role in the buyer scale; i.e., the higher the basic capability, the higher the increase in participating buyers who are attracted by value-added services. The reason is that a high basic capability will attract more sellers, especial L-type sellers who will bring negative network externalities. Under this situation, the high value-added capability weakens the effect of negative network externalities but strengthens the effect of positive network externalities. As a result, the higher the basic capability, the higher the increase in participating buyers who are attracted by value-added services. This difference explains the existence of the cutoff: Once the basic capability increases beyond a certain threshold, a platform with value-added services has more buyers than a platform with basic services only.

When the value-added capability is relatively high, the buyer scale of a platform with only basic services is always lower than the buyer scale of a platform with value-added services. The reason is that because of negative network externalities, a platform with only basic services only attracts a limited number of buyers. As the high value-added capability can yield higher positive network externalities, a platform with value-added services can always provide more benefit for buyers than a platform with only basic services. That is, the increase in participating buyers obtained from the increase in H-type sellers who purchased value-added services is larger than the decrease in participating buyers obtained from the increase in L-type sellers who purchased value-added services. As a result, the increase in participating buyers obtained from value-added services is always higher than the increase in participating sellers obtained from basic services.

5.3 Platform reputation

The optimal reputations of a platform with only basic services and that of a platform with value-added services are compared in Table 2 and Table 3. The following proposition are derived:

Proposition 4. *When* $\alpha < \alpha(\beta)_r$, *a platform with only basic services has a better* *platform reputation than a platform with value-added services; when* $\alpha > \alpha(\beta)_r$, *a platform with value-added services has a better platform reputation than a platform with only basic services. The cutoff curve of the platform reputation is defined as*

$$\alpha(\beta)_r = \begin{cases} 1 & \text{if} \quad \beta \in [0, \beta_r] \\ \dfrac{i_1\beta^3 + a_3\beta^2 + d_5\beta + f_5}{i_1\beta^3 + a_4\beta^2 + d_6\beta + f_6} & \text{if} \quad \beta \in [\beta_r, 1] \end{cases} \tag{11}$$

where r *stands for the reputation of the platform.*

(*Note that the values of i_1, a_3, a_4, d_5, d_6, f_5, and f_6 are detailed in the Appendix.)

This finding indicates that when the value-added capability is low, the reputation of a platform with only basic services is always higher than the reputation of a platform with value-added services. The reason is that, the attraction of the low value-added capability is stronger for L-type sellers than for H-type sellers. As a result, the reputation of a platform with value-added services is always lower than the reputation of a platform with only basic services.

When the value-added capability is relatively high, the basic capability plays a fundamental role in determining the effect value-added services have on improving the platform reputation. If the basic capability is low, a platform with only basic services has a higher platform reputation than a platform with value-added services; otherwise, a platform with value-added services has a higher platform reputation. The underlying logic is explained as follows: In a platform with only basic services, with increasing basic capability, the platform provides more benefit to L-type sellers than to H-type sellers; i.e., the higher the basic capability, the higher the number of participating L-type sellers, which decrease the platform reputation. In a platform with value-added services, basic services play a fundamental role in improving the platform reputation. The reason is that the higher the basic capability, the more L-type sellers are participating in the platform. Under this condition, the value-added capability is sufficiently high to provide personalized services to attract more H-type sellers, which leads to H-type sellers being more attracted by value-added services than L-type sellers; i.e., value-added services can lead to a large increase in participating H-type sellers. As a result, the higher the basic capability, the higher the platform reputation obtained from value-added services. This difference explains the existence of the cutoff: Once the basic capability decreases below a certain threshold, a platform with value-added services has a higher platform reputation than a platform with only basic services.

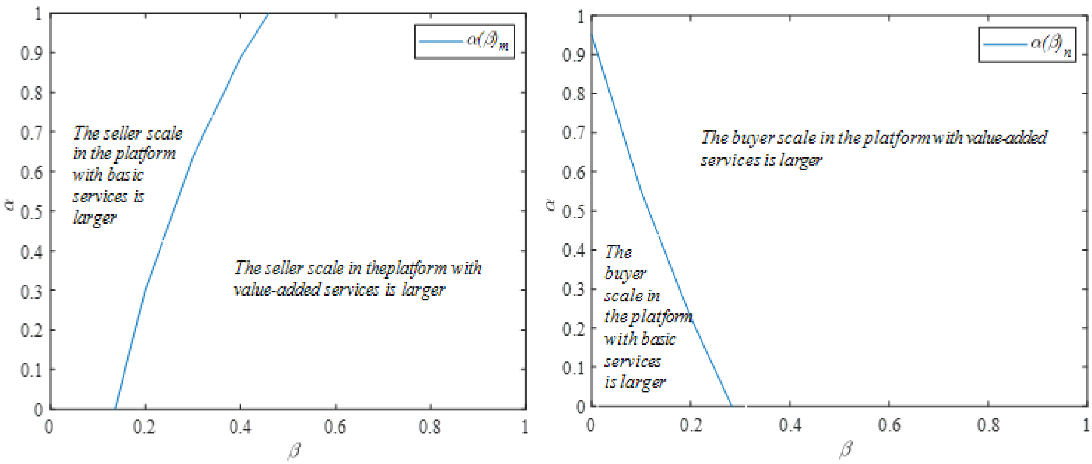
6 Numerical analysis

Because the variables involved in this game theoretical model are difficult to collect in reality, this paper assumes the numerical design and value selection of variables according to Chen *et al.* (2016), Basu *et al.* (2019), and Zhang *et al.* (2021). Based on variable settings in the assumptions and variable boundary obtained in the propositions, appropriate variables $b = 0.3$, $\Delta b = 0.2$, $\lambda = -0.2$ and $v = 1$ are chosen to intuitively explain part of the analytical results and gain more insight.

In Subsection 6.1, an equilibrium comparison of seller scale, buyer scale, and platform reputation is presented. In Subsection 6.2, the effect of a platform with value-added services is illustrated under different values.

6.1 Equilibrium comparison analysis

To identify the results of equilibrium comparison, firstly, a comparison of the seller scale is shown in Figure (a) and a comparison of the buyer scale is shown in Figure (b).



(a) Equilibrium comparison of the seller scale (b) Equilibrium comparison of the buyer scale

Figure 2. Equilibrium comparison of the seller scale and the buyer scale

The lines in Fig. 2(a) verify the results of Proposition 2: A platform with only basic services that has a large seller scale is shown in the left top part of Fig. 2(a); a platform with value-added services that has a large seller scale is shown in the rest part of Fig. 2(a). In addition, the lines in Fig. 2(b) verifies the results of Proposition 3: A platform with only basic services that has a larger buyer scale is shown in the left bottom part of Fig. 2(b); a platform with value-added services that has a larger buyer scale is shown in the rest part of Fig. 2(b).

Secondly, the equilibrium comparison result of the platform reputation is illustrated in Figure 3.

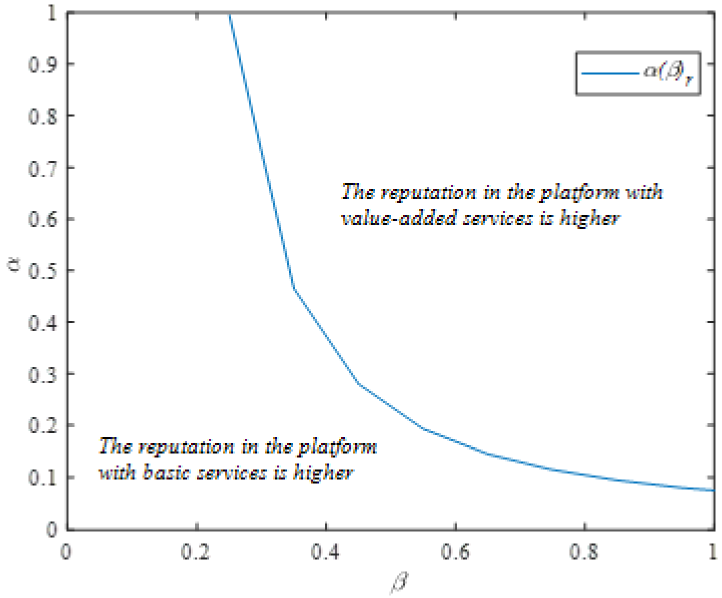
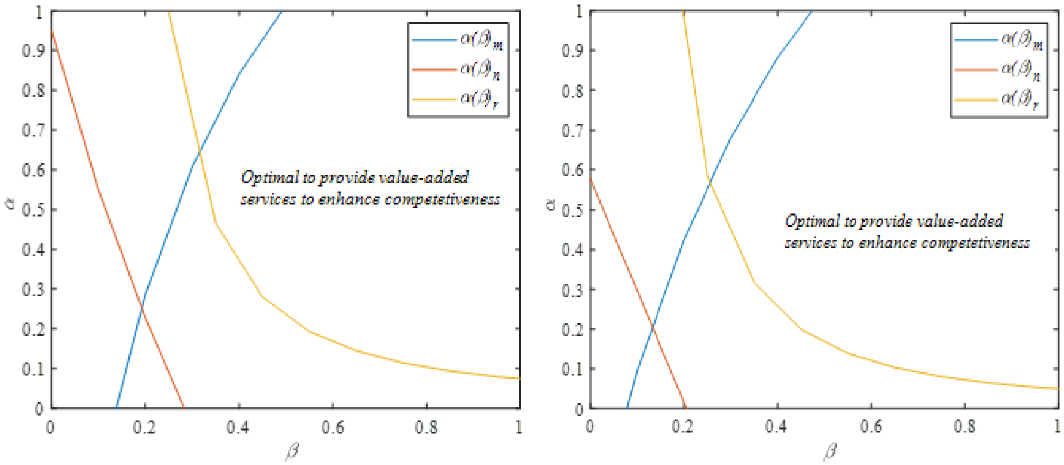


Figure 3. Equilibrium comparison of platform reputation

The lines in Fig. 3 verifies the results of Proposition 4: A platform with only basic services that has a higher platform reputation is shown in the left part of Fig. 3; a platform with value-added services that has a higher platform reputation is shown in the top right part of Fig.3.

6.2 Effect of value-added services

This subsection examines how other factors (e.g., the loss rate of the product) influence the effect of value-added services. First, at a loss rate of the produce value of $\lambda = -0.2$, according to Subsection 5.4.1, all illustrations are shown in Fig. 4(a). Then, the loss rate of the product value $\lambda = -0.1$ is chosen to plot Fig. 4(b) to explore how the loss rate of the product value affects the effect of value-added services.



(a) $\lambda = -0.2$ (b) $\lambda = -0.1$

Figure 4. Effect of value-added services influenced by the loss rate of the product value

Fig. 4 illustrates the effect of value-added services influenced by the loss rate of the product value. Specifically, the effect of value-added services (where the scale is increased and the reputation is improved by the provision of value-added services) is shown in the top right part of Fig. 4.

Furthermore, a comparison of the effect of value-added services shown in Fig. 4(a) with the effect shown in Fig. 4(b) is conducted to explore how the effect of value-added services is influenced by the loss rate of the product value. As expected, with decreasing loss rate of the product value, the room for value-added services is broadened. This means that when the value of the product sold by an L-type seller is relatively low (i.e., the product value loss rate is high), value-added services are needed more. In other words, value-added services are necessary to safeguard both the scale and the reputation of the platform. Especially, with increasing loss rate of the product value, the participating buyers who are attracted by value-added services are the fastest growing indicator. This result verifies the strongest effect of value-added services in enhancing the buyer scale.

7 Discussions

7.1 Theoretical implications

This study contributes to the existing literature in three important ways: First, a new perspective of platform competitiveness is proposed that incorporates both the seller/buyer scale and the reputation of the platform. In contrast to previous studies that only considered either scale or reputation to enhance competitiveness

(Schwanholz and Leipold, 2020; Blackburn *et al.*, 2022; Pizzi *et al.*, 2022), this paper assumes that information asymmetry can cause both H-type sellers and Low-type sellers to participate in the platform (Liu and Wang, 2020). Such a scale growth is not sustainable as it undermines user experience, platform reputation, and platform competitiveness in the long run (Kuo-Kuang and Chi-Hua, 2008). Therefore, this study examines platform competitiveness holistically, combining both scale and reputation.

Second, based on the characteristics of bilateral platforms, game theoretical models are expanded by considering both positive and negative network externalities. Existing studies have explored the effect of value-added services for platforms focusing mainly on positive network externalities. However, because of information asymmetry, both H-type sellers and Low-type sellers will participate in the platform and use both basic and value-added services. As the interactions between different types of platform users simultaneously generate positive and negative network externalities, how value-added services affect platform competitiveness becomes less clear and requires a deeper examination (Zhang *et al*., 2021). This paper contributes to this body of literature by considering both positive and negative network externalities using an approach informed by game theory.

Third, the findings of this study offer valuable insights into value-added services of platforms by considering the role of basic services. Existing studies on basic and value-added services are still in a fragmented state (Cennamo, 2021; Wang *et al.*, 2019; Gawer, 2014), and this paper is among the first attempts to examine both types of services holistically. Theoretically, providing free basic services is the basic function of e-commerce platforms, and this affects sellers' and buyer' participation choices. The results show that basic services play a substituting role in determining the effect of value-added services at the seller scale; they also play a fundamental role in determining the effect of value-added services on both buyer scale and platform reputation. Therefore, the findings contribute to research on value-added services by considering the effect of basic services.

7.2 Managerial implications

In addition to these theoretical contributions, this study also provides managerial implications tailored to e-commerce platforms under different situations. According to the obtained research results, basic services take on two different roles in determining how value-added services can enhance the competitiveness of e-commerce platforms.

That is, basic services determine the lower limit of platform competitiveness, while value-added services set the upper limit. The results can instruct different types of e-commerce platforms on how to enhance their competitiveness in different ways.

First, newly established e-commerce platforms with a small scale and low reputation, the short-term priority is to survive by growing their user base (including sellers and buyers). Informed by the findings of this paper, which highlight the crucial role of basic services, platforms are advised to identify target sellers, and provide basic services based on their needs. For example, platforms should provide sellers with a transparent trading space and establish clear transaction rules (such as enrich the means of promotion and build both flow distribution mechanisms, and quality assurance mechanisms). Smooth transactions between sellers and buyers can further strengthen positive externalities to ensure a positive buyer experience and provide room for value-added services.

Second, e-commerce platforms with a large user scale but low platform reputation, such as ***Pinduoduo.com*** and ***Taobao.com*** in China, should prioritize improving their reputation by optimizing the quality effect of network externality. According to the findings of this study, the provision of value-added services can strengthen positive network externalities. Therefore, platforms should focus on how to further increase the exposure of high-quality sellers to buyers by providing more accurate signaling mechanisms, more reliable certification services, and more comprehensive consumer protection mechanisms.

Third, e-commerce platforms with a small user scale and a good platform reputation, such as ***VIPS*** and ***POIZON*** in China, should expand through growing their product portfolio. As such platforms typically focus on a specific market segment, they tend to have limited offerings, which caps their growth. ***VIPS*** mainly focuses on providing online sales of branded discount goods, and ***POIZON*** provides clothes and goods that are currently trendy. For such platforms, it is important to enrich product categories through certain basic services, such as appropriate rewarding and motivating mechanisms for sellers to expand their offerings and provide more inclusive search and match services.

Fourth, e-commerce platforms with a large user scale and good reputation, such as ***T-mall.com*** in China and ***Amazon.com*** globally, it is crucial to maintain their market dominance position and continue to grow steadily. However, with intensifying competition in the platform economy, these successful platforms need to be more innovative to maintain their competitive edge, and the development of value-added services is one of the most important ways to achieve this. Examples for innovations are advanced algorithms that provide more accurate flow distribution mechanisms and deep mining that can inform diverse demand of buyers to sellers.

Overall, platforms in different situations can extract different insights from this paper to enhance their competitiveness.

8 Conclusion and limitations

8.1 Conclusion

With the growth of the platform economy, e-commerce platforms increasingly become indispensable shopping channels for most consumers. However, information asymmetry has led to the rapid expansion of e-commerce platforms that are consistently flooded with low-quality products (Liu and Wang, 2020). This development reduces platform reputations, thus limiting their competitiveness (Kuo-Kuang and Chi-Hua, 2008). Against this backdrop, most e-commerce platforms and researchers have identified value-added services as an useful tool for enhancing competitiveness (including the scale and the platform reputation). However, according to previous literature, little is known about how the scale and the platform reputation can be improved using value-added services considering both positive and negative network externalities.

To fill this gap in the literature, this paper examines the effect of value-added services considering network externalities; valuable results and insights are obtained. Firstly, this paper identifies how value-added services can enhance the competitiveness of e-commerce platforms. Two different roles of basic services in determining how value-added services can enlarge the seller scale, buyer scale and platform reputation are obtained. On the one hand, the higher the basic capability, the lower the increase in participating sellers obtained from value-added services. This logic indicates that basic services play a substituting role in determining the effect of value-added services on enlarging the seller scale. On the other hand, the higher the basic capability, the higher the increase in participating buyers who are attracted by value-added services and the higher the platform reputation obtained from value-added services. These logics indicate that basic services play a fundamental role in determining the effect of value-added services on increasing the buyer scale and improving the platform reputation.

Secondly, to further understand the effect of value-added services, how other factors (e.g., the loss rate of the product) influence the effect of value-added services is also explored. According to the results of this exploration, the higher the loss rate of the product value, the bigger the room for providing value-added services. This means that value-added services are more needed when the value of the product sold by a low-quality seller is relatively low. Furthermore, with increasing loss rate of the product value, participating buyers who are attracted by value-added services are the fastest growing indicators. This result indicates that the most significant effect of value-added services is the enhancement of the buyer scale.

8.2 Limitations and future research

This study also has certain limitations, which provide avenues for future research. First, although internal factors of e-commerce platforms (e.g., network externalities or value-added fees) greatly influence the competitiveness enhancing effect of value-added services of these platforms, the authors acknowledge that it may also be shaped by external factors, such as market competition (Fan *et al.*, 2022). This acknowledgment suggests fruitful opportunities to consider the effect of market competition on the impact of value-added services on enhancing the competitiveness of e-commerce platforms. Second, because sellers are providers of products on the platform which directly influence the benefit of both buyers and the platform, how the effect of value-added services for sellers enhances the competitiveness of e-commerce platforms can be examined. Because of the network externalities, the value-added services provided by a platform to sellers not only affect the participating choice of other sellers directly, but also indirectly affect the participating choice of buyers (Sui *et al.*, 2022). Based on this reasoning, how to provide differentiated value-added services to sellers and buyers, with the goal to enhance the competitiveness of e-commerce platforms is worth exploring further.

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Appendix A

A.1. Proof of Lemma 1

Proof. To simplify the calculation, $A=\alpha b$ and $B=\alpha(b+\Delta b)$ are denoted. Then, $\pi_o=(A+B)(A+\lambda B)(\tau-\tau^2)v$ is derived. On this basis, the first-order derivative is $\frac{d\pi_o}{d\tau}=\left(A+\lambda B\right)(A+B)(1-2\tau)v$. Therefore, π_o is positive over $\left(0,\frac{1}{2}\right)$ and negative over $\left(\frac{1}{2},1\right)$. The optimal basic fee is $\tau^*=\frac{1}{2}$.

A.2. Proof of Proposition 1

Proof. To simplify the calculation, $C=\beta+\lambda(1-\beta)$, $D=(\alpha+\beta-\alpha\beta)b$ and $E=\left(1-\beta+\alpha\beta\right)(b+\Delta b)$ are denoted. Then, it is derived that $\pi_a=\left[\left(D+E\right)(1-\tau)-q\right]\left[\left(D+\lambda E\right)(1-\tau)-Cq\right]\tau v+\left[\left(D+\lambda E\right)(1-\tau)-Cq\right]vq$. On this basis, the first-order derivative is $\frac{d\pi_a}{dq}=\left[2Cq-C\left(D+E\right)(1-\tau)-\left(D+\lambda E\right)(1-\tau)+\right]\tau v+\left[\left(D+\lambda E\right)(1-\tau)-2Cq\right]v$. Therefore, π_a is positive over $\left(0,q^*\right)$ and negative over $\left(q^*,1\right)$, where $q^*=\frac{\left(D+\lambda E\right)\left(1-\tau\right)^2-\left(D+E\right)C\left(1-\tau\right)\tau}{6C}$. Because the optimal basic fee $\tau^*=\frac{1}{2}$ has already been determined, it is obtained that $q^*=\frac{D\left(2-C\right)+E\left(2\lambda-C\right)}{6C}$.

A.3. Proof of Proposition 2

Proof. According to the equilibrium comparison of the seller scale shown in Table 2, it is derived that $m_a{}^*-m_o{}^*=\frac{a_1\beta^2+d_1\beta+f_1}{d_2\beta+f_2}-\alpha$ where $a_1=(3\lambda-1)\Delta b$, $d_1=\left(3-6\lambda\right)\Delta b+(2-3\lambda)b$, $f_1=2\left(\Delta b+b\right)\lambda$, $d_2=(2-4\lambda)\Delta b-2\lambda b$ and $f_2=\left(1+\lambda\right)b+2\lambda\Delta b$. Note that $\underline{\beta}_m$ and $\overline{\beta}_m$ are determined by $\frac{a_1\beta^2+d_1\beta+f_1}{d_2\beta+f_2}$. It is assumed that $\alpha(\beta)_m=\frac{a_1\beta^2+d_1\beta+f_1}{d_2\beta+f_2}$. Because it is already assumed that $\alpha\in(0,1)$ and $\beta\in(0,1)$, it is obtained that if $\beta\in\left[0,\underline{\beta}_m\right]$, $\alpha(\beta)_m=0$; if $\beta\in\left[\underline{\beta}_m,\overline{\beta}_m\right]$, $\alpha(\beta)_m=\frac{a_1\beta^2+d_1\beta+f_1}{d_2\beta+f_2}$; if $\beta\in\left[\overline{\beta}_m,1\right]$, $\alpha(\beta)_m=1$. As a result, when $\alpha>\alpha(\beta)_m$, $m_a{}^*<m_o{}^*$; when $\alpha<\alpha(\beta)_m$, $m_a{}^*>m_o{}^*$.

A.4. Proof of Proposition 3

Proof. According to the equilibrium comparison of the buyer scale shown in Table 2, it is derived that $n_a^* - n_o^* = \alpha - \frac{a_2\beta^2 + d_3\beta + f_3}{a_2\beta^2 + d_4\beta + f_4}$ where $a_2 = (1-\lambda)\Delta b$, $d_3 = 2(1-\lambda)b + (3\lambda - 1)\Delta b$, $f_3 = 2\lambda(b - \Delta b)$, $d_4 = 2\lambda\Delta b$ and $f_4 = -(1+\lambda)b$. Note that β_n is determined by $\frac{a_2\beta^2 + d_3\beta + f_3}{a_2\beta^2 + d_4\beta + f_4}$. It is assumed that $\alpha(\beta)_n = \frac{a_2\beta^2 + d_3\beta + f_3}{a_2\beta^2 + d_4\beta + f_4}$.

Because it is already assumed that $\alpha \in (0,1)$ and $\beta \in (0,1)$, it is obtained if $\beta \in [0, \beta_n]$, $\alpha(\beta)_n = \frac{a_2\beta^2 + d_3\beta + f_3}{a_2\beta^2 + d_4\beta + f_4}$; if $\beta \in [\beta_n, 1]$, $\alpha(\beta)_n = 0$. As a result, when $\alpha > \alpha(\beta)_n$, $n_a^* > n_o^*$; when $\alpha < \alpha(\beta)_n$, $n_a^* < n_o^*$.

A.5. Proof of Proposition 4

Proof. According to the equilibrium comparison of platform reputation shown in Table 2, it is derived that $\delta_a^* - \delta_o^* = \frac{j_1\beta^3 + a_3\beta^2 + d_5\beta + f_5}{j_1\beta^3 + a_4\beta^2 + d_6\beta + f_6} - \alpha$ where $j_1 = (\lambda - 1)(2b + \Delta b)\Delta b$, $a_3 = (4 - 2\lambda)b^2 + (1 - 6\lambda)b\Delta b + (1-\lambda)\Delta b^2$, $d_5 = (4\lambda - 2)b^2 + (6\lambda - 3)b\Delta b$, $f_5 = -2\lambda b(b + \Delta b)$, $a_4 = (8 - 6\lambda)b^2 + (3 - 2\lambda)b\Delta b$, $d_6 = 4\lambda b^2 + (3\lambda - 1)b\Delta b$ and $f_6 = (\lambda - 1)b^2 - \lambda b\Delta b$. Note that $\underline{\beta}_r$ and $\overline{\beta}_r$ are determined by $\frac{j_1\beta^3 + a_3\beta^2 + d_5\beta + f_5}{j_1\beta^3 + a_4\beta^2 + d_6\beta + f_6}$.

It is assumed that $\alpha(\beta)_r = \frac{j_1\beta^3 + a_3\beta^2 + d_5\beta + f_5}{j_1\beta^3 + a_4\beta^2 + d_6\beta + f_6}$.

Because it is already assumed that $\alpha \in (0,1)$ and $\beta \in (0,1)$, it is obtained that if $\beta \in [0, \underline{\beta}_r]$, $\alpha(\beta)_r = 0$; if $\beta \in [\underline{\beta}_r, \overline{\beta}_r]$, $\alpha(\beta)_r = \frac{j_1\beta^3 + a_3\beta^2 + d_5\beta + f_5}{j_1\beta^3 + a_4\beta^2 + d_6\beta + f_6}$; if $\beta \in [\overline{\beta}_r, 1]$, $\alpha(\beta)_r = 1$.

As a result, when $\alpha > \alpha(\beta)_r$, $\delta_a^* < \delta_o^*$; when $\alpha < \alpha(\beta)_r$, $\delta_a^* > \delta_o^*$.

References

Abrate, G. and Viglia, G. (2019), "*Personal or product reputation? Optimizing revenues in the sharing economy*", Journal of Travel Research, Vol. 58 Nos 1, pp. 136-148.

Armstrong, M. (2006), "Competition in two-sided markets", Rand Journal of Economics, Vol. 37, pp. 668–691.

Basu, A., Bhaskaran, S. and Mukherjee, R. (2019), "*An analysis of search and authentication strategies for online matching platforms*", Management Science, Vol. 65 Nos 5, pp. 2412-2431.

Boudreau, K. J. and Jeppesen, L. B. (2015), "*Unpaid crowd complementors: the platform network* *effect mirage*", Strategic Management Journal, Vol. 36 Nos 12, pp. 1761-1777.

Blackburn, O., Ritala, P. and Keranen, J. (2022), "*Digital Platforms for the Circular Economy: Exploring Meta-Organizational Orchestration Mechanisms*", Organization & Environment, Online.

Cennamo, C. (2021), "*Competing in digital markets: A platform-based perspective*", Academy of Management Perspectives, Vol. 35 Nos 2, pp. 265-291.

Chen, Y. J., Dai, T., Korpeoglu, C. G. (2020), "*Innovative online platforms: Research Opportunities*", M&SOM-Manufacturing & Service Operations Management, Vol. 22 Nos 3, pp. 429-643.

Chen, J.Q., Fan, M., Li, M.Z. (2016), *"Advertising versus brokerage model for online trading platforms"*, MIS Quarterly, Vol. 40 Nos 3, pp. 575-596.

Cennamo, C. and Santalo, J. (2013), *"Platform competition: Strategic trade-offs in platform markets"*, Strategic Management Journal, Vol. 34, pp. 1331-1350.

Dimoka A, Hong Y, Pavlou P. (2012), *"On product uncertainty in online markets: theory and evidence"*, MIS Quarterly, Vol. 36 Nos 2, pp. 395-426.

Dou, G.W., Lin, X.D., Xu, X.P. (2018), *"Value-added services investment strategy of a two-sided platform with the negative intra-group network externality"*, Kybernetes, Vol. 47 Nos 5, pp. 937-956.

Dou, G., He, P., and Xu, X. (2016), "*One-side value-added service investment and pricing strategies for a two-sided platform*", International Journal of Production Research, Vol. 54 Nos 13, pp. 3808-3821.

Fan, X.J., Wang, S.S. (2022), "*Equilibrium strategies of value-added service investment with two competitive platforms*", Operations Research and Management Sciences, Vol. 31 Nos 7, pp. 200-206.

Gawer, A. (2014), "*Bridging differing perspectives on technological platforms: Toward an integrative framework*", Research Policy, Vol. 43 Nos 7, pp. 1239-1249.

Gomes, R., Pavan, A. (2013), *"Cross-subsidization and matching design"*, Working Paper.

Hesse, M., Teubner, T. and Adam, M.T.P. (2022), *"In stars we trust - a note on reputation portability between digital platforms"*, Business & Information Systems Engineering, Vol. 64, pp. 349-358.

Hong, H., Xu, D., Wang, G. A. and Fan, W. (2017), *"Understanding the determinants of online review helpfulness: a meta-analytic investigation"*, Decision Support Systems, Vol. 102, pp.1-11.

Jullien, B. (2005), *"Two-sided markets and electronic intermediaries"*, CESifo Ecnomic Studies, Vol. 51 Nos 23, pp. 233-260.

Kung, L. C. and Zhong, G. Y. (2017), "*The optimal pricing strategy for two-sided platform delivery in the sharing economy*", Transportation Research Part E: Logistics and Transportation Review, Vol. 101, pp. 1-12.

Kokkodis M., Ipeirotis P.G. (2016), *"Reputation transferability in online labor markets"*, Management Science, Vol. 62, pp. 1687–1706.

Kuo-Kuang, C. and Chi-Hua, L. (2008), "*A study of the effect of risk-reduction strategies on purchase intentions in online shopping*", International Journal of Electronic Business Management, Vol. 6 Nos 4, pp. 213-226.

Luca, M, and Zervas, G. (2016), "*Fake it till you make it: Reputation, competition, and Yelp review fraud*", Management Science, Vol. 62 Nos 12, pp. 3412-3427.

Liu, H. X. and Wang, X. X. (2020), "*Research on the Influence of Platform Service Quality on the Competition Result of Bilateral Platform*", Operations Research and Management Science, Vol. 29 Nos 11, pp. 232-239.

Liu, W., Yan, X., Wei, W. and Xie, D. (2019), *"Pricing decisions for service platform with provider's threshold participating quantity, value-added service and matching ability"*, Transportation Research Part E: Logistics and Transportation Review, Vol. 122, pp. 410-432.

Pan, X.J. (2022), *"Value-added service pricing model based on industrial internet platform"*, Chinese Journal of Management Science, Vol. 30 Nos 11, pp. 239-249.

Rochet, J.C., Tirole, J. (2006), *"Two-sided markets: a progress report"*, Rand Journal of Economics, Vol. 37 Nos 3, pp. 645-667.

Song, W., Chen J.Q., Li, W.L. (2021), *"Spillover effect of consumer awareness on third parties' selling strategies and retailers' platform openness"*, Information System Research, Vol. 32 Nos 1, pp.172-193.

Sui, R.H., Zhang, X.M., Dan, B., Li, M.L., Liu, M.L. (2022), *"Bilateral user introduction and value-added service strategies for the third-party platform with cross-network effects"*, Chinese Journal of Management Science, pp. 1-14.

Schwanholz, J. and Leipold, S. (2020), "*Sharing for a circular economy? An analysis of digital sharing platforms' principles and business models*", Journal of Cleaner Production, Vol. 269, pp. 122327.

Sedera, D., Lokuge, S., Grover, V., Sarker, S. and Sarker, S. (2016), *"Innovating with enterprise systems and digital platforms: A contingent resource-based theory view"*, Information & Management, Vol. 53 Nos 3, pp. 366–379.

Su L., Swanson S.R. and Chinchanachokchai S. (2016), *"Reputation and Intentions: The Role of Satisfaction, Identification, and Commitment"*, Journal of Business Research, Vol. 69 Nos 9, pp. 3261-3269.

Teubner, T., Adam, M.T.P. and Hawlitschek, F. (2020), *"Unlocking Online Reputation"*, Business & Information Systems Engineering, Vol. 62, pp. 501–513.

Wang, Y. Y., Yu, Z. Q. and Jin, M. Z. (2019), "*E-commerce supply chains under capital constraints*", Electronic Commerce Research and Applications, Vol. 35, pp. 100851.

Xie, K., Kwok, L., Chen, C.C. and Wu, J. (2020), "*To share or to access? Travelers' choice on the types of accommodation-sharing services*", Journal of Hospitality and Tourism Management, Vol. 42, pp. 77-87.

Zhang, X., Sui, R., Dan, B. and Guan, Z. (2021), "*Bilateral value-added services and pricing strategies of the third-party platform considering the cross-network externality*", Computers & Industrial Engineering, Vol. 155, pp. 107196.

Zhang, Q.L., Wang, X.H. (2022), *"A study on the transfer mechanism from e-commerce platform reputation to seller reputation: analysis based on extended theory of transfer of learning"*, Journal of management world, Nos 12, pp. 143-158.