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Strategic analysis of manufacturer encroachment in dual-channel supply chains with platform service

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A B S T R A C T

This paper considers a dual-channel supply chain with two members, comprising a manufacturer and an online platform. We mainly investigate the influence of various key system variables on manufacturer encroachment strategy and all members' optimal decisions through Stackelberg game models. Our findings show that, regardless of the size of each parameter, the encroachment strategy is always optimal to the manufacturer; the manufacturer may be motivated to choose the direct selling channel and the platform may opt for the agency selling channel due to a high commission rate. Moreover, when the inter-channel substitution rate is high, the encroachment strategy has a diminishing positive effect on the manufacturer and an increasing negative effect on the platform so that the platform may temporarily benefit from the manufacturer encroachment; in cases where the inter-channel substitution rate is not high, the encroachment strategy always yields advantages for the manufacturer while causing disadvantages for the platform. In addition, if the elasticity coefficient is large, both the manufacturer and the platform are inclined to the reselling channel, that is, if the platform service cost is high, it is advisable for the platform to reduce its investment of service to avoid negative effect.

1. Introduction

Over the past decade, there has been a continuous increase in the scale of online shopping users due to the continuous improvement of network infrastructure and the increasing penetration of smart devices. This trend has led to the swift advancement of e-commerce, serving as a new driving force to economic development. Moreover, the global pandemic of COVID-19 epidemic has led to a rapid shift from global offline consumption patterns to online consumption patterns. Nowadays, online shopping has become a common way of consumption. According to the data published on the official website of National Bureau of Statistics, the national online retail sales in 2021 amounted to 130,884 billion yuan, reflecting a growth rate of 14.1% year-on-year, and the online retail sales of physical commodities reached a total of 10,084.2 billion yuan with 17.8%, 8.3%, and 12.5% growth in food, wear, and self-use goods respectively. In the first half of 2022, the online retail market also maintained its growth trend with its sales reaching RMB 6.3 trillion, up 3.1% year-on-year. Manufacturers focus on the thriving e-commerce market to build their core competencies by establishing their own direct selling channels (such as official APPs, websites, etc.) or offline stores. With the promotion of effective consumption policies, the e-tailing market has steadily rebounded to help the consumer market to continue to recover.

Some manufacturers invest in establishing direct selling channels along with traditional channels. Such a sales strategy is referred to manufacturer encroachment, which may take various forms such as catalog sales, establishment of factory outlet stores, and utilization of online stores (Arya et al., 2007; Ha et al., 2016). In such circumstance, the direct selling channel competes with the original channel for consumption (Ha et al., 2016; Hotkar & Gilbert, 2021). Practical examples include

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electronics manufacturers (such as Apple, Huawei, SONY, Dell, Haier, Xiaomi), clothing manufacturers (such as Nike, Adidas, Anta, Li-Ning), cosmetics manufacturers (such as Lancôme, Estee Lauder), and others (such as Starbucks, IKEA, Boxmaster). Specifically, Dell is one of the earliest to establish an encroachment channel, Haier employs a strategy that involves the utilization of both offline direct stores and online brand stores as channels for product sales. Xiaomi, on the other hand, employs a multi-faceted strategy by selling its products through various online platforms such as JD.com and Taobao, as well as through its official website and offline store "Xiaomi Home" (He et al., 2022). However, manufacturer encroachment has a significant impact on both retail and online channels, as the direct selling channel can differentiate the original market demand and may lead to channel conflicts, weaken partnerships, and reduce downstream retailers' profits (Zhang et al., 2021). Conversely, from a positive perspective, the direct selling channel may lead manufacturers to lower wholesale prices to avoid excessively reducing demand from other channels. The wholesale price effect arises when retailers possess advantages in terms of demand or cost compared to manufacturers (Zhang et al., 2020). Therefore, manufacturer encroachment has become an important channel sales choice and is worth to study.

The development of online payment technology has contributed to the thriving growth of online platforms, many of which have invested heavily in service operations in online channels to meet their customers' lifestyles. Platform service refers to the multiple types of demand growth services offered by online platforms, which can be reflected in storage, logistics, payment, pre-sales and post-sales consultation, return services, technical assistance, and assembly services (Yan & Pei, 2009; Zhang et al., 2021). For example, JD.com launched several innovative services during China's 2020 Double Eleven shopping festival, such as trade-in and warranty exchange, to meet consumers' needs for convenient shopping. JD Local Life also provides consumers with various life services including electricity purchases, gasoline, cell phone recharge, restaurant vouchers, etc. To ensure consumers to always enjoy the benefits of worry-free ordering, during China's 618 shopping festival in 2021, more than 90% of the hot commodities provided price guarantee services. Moreover, JD.com and Realme jointly launched a half-year broken screen guarantee, film rights, a year extended warranty, and other innovative services to protect consumers' purchasing experience[1]. In November 2022, JD.com's one-stop service platform (i.e., JD.com service+) launched laundry time visualization, bicycle door-to-door installation, home appliance de-bacterization wash, all-inclusive save heart installation, and other services to upgrade ordinary laundry services. In addition to optimize timeliness and process, JD.com Service+ also launched high-end laundry services, using exclusive dust bag packaging to deliver clothes and meet consumers' diversified laundry needs[2]. High level of platform service may encourage consumers to buy and enhance their purchase satisfaction while effectively protecting them from pre-sales and post-sales problems.

The purpose of this paper is to explore the impact of different market factors on the encroachment strategy employed by manufacturers in relation to the service on online platforms. Specifically, our primary objective is to investigate the questions undermentioned:

- How does the implementation of manufacturer encroachment strategy affect the optimal decisions and profits of all members within the supply chain?
- How does the manufacturer encroachment strategy affect the strategic choices made by the manufacturer and the platform?
- How do system factors such as commission rate, inter-channel substitution rate, and unit service cost elasticity coefficient influence the strategic choices of the manufacturer and the platform?

The subsequent sections of the paper are structured as follows. Section 2 offers a thorough examination of the pertinent literature. Section 3 provides a comprehensive overview of both models. Section 4 analyzes the optimal decisions to get some managerial implications. Section 5 then proceeds to numerical experiments that explore the effect of various market factors on manufacturer encroachment strategy and optimal decisions for all supply chain members. Section 6 concludes the article by summarizing our results and suggesting potential avenues for future research. All proof is given in the appendix.

2. Literature review

This study holds significant relevance to three primary areas, namely, manufacturer encroachment, sales mode in supply chain, and platform's service level strategy.

2.1 Manufacturer encroachment

The existing literature extensively examines manufacturer encroachment and primarily focuses on the impact of manufacturer encroachment strategy on downstream enterprises. In particular, Chiang et al. (2003) conducted a study in which they developed a price-setting game, and they highlighted the potential benefits for manufacturers in combining both direct and indirect channels. According to Arya et al. (2007), although manufacturer encroachment reduces retailers' market shares, reduced wholesale price might ensure demand in the retail channel and hence is beneficial to retailers, that is, there exists the potential for manufacturers and retailers to achieve a mutually beneficial outcome. Tsay & Agrawal (2009) constructed a model to capture the key properties of manufacturer encroachment and investigated the ways to adjust supply chain structure.

[1] https://zhuanlan.zhihu.com/p/374099058
[2] https://www.163.com/dy/article/HMUMAT1P051188EC.html

Yoo & Lee (2011) comparatively analyzed how supply chain members and consumer surplus influenced by different channel structures. Balasubramanian & Ponnachiyur Maruthasalam (2021) declared that the coexistence of manufacturer encroachment and store brands may result in mutually beneficial outcome for manufacturers, retailers, consumers, and thereby create a win-win-win situation. He et al. (2022) looked into the effects of manufacturer encroachment on the service supply chain of an e-commerce platform. They found the platform's comprehensive logistics integration strategy had significant benefits for the entire supply chain and all participants. Shi et al. (2023) studied manufacturer encroachment in supply chain by endogenizing manufacturers' choices between integrated and the decentralized structures. Their findings revealed that the positive effects of manufacturer encroachment on retailers persist under the decentralized structure. Wang et al. (2023) explored an interaction mechanism between contract manufacturer encroachment and platform's private brand, and they discovered that channel encroachment may hinder platform's brand introduction.

With extensive research on the impact of manufacturer encroachment, some scholars aim to explore the constraints of manufacturer encroachment by redirecting the focus towards the influence of diverse market factors on decision-making. For example, Lal (1990) suggested that national firms can adopt price promotion strategy to protect their market share from encroachment by third-party firms. Lu & Liu (2015) found that the constraints affecting manufacturer encroachment are related to the relative effectiveness of the network channel and, when such effectiveness falls below a certain threshold, manufacturers are unwilling to adopt encroachment strategy because it may reduce total profits. Ha et al. (2016) studied manufacturer encroachment strategy, considering the endogeneity of product quality and the heterogeneity of customers' preferences for product quality. Their findings indicate that when manufacturers have sufficient flexibility for adjusting product quality, the manufacturer encroachment strategy always disadvantages retailers, while manufacturers favor through online direct selling channel to sell quality products when they sell heterogeneous products through two channels. Zhang et al. (2020) considered advertising information in manufacturer encroachment problem by aiming to the effect of advertising input on the manufacturer's encroachment strategy and showed that, when manufacturers and retailers invest in advertising, the encroachment decision can lead to mutually beneficial outcome for them, regardless of whether they cooperate or not. Hamamura and Zennyo (2021) examined a dynamic interplay between manufacturer's encroachment decision and retailer's investment decision. Their findings suggested that, when retailer's cost-reduction technology demonstrates significant efficiency, manufacturer encroachment may be strategically confined. Meanwhile, Chang et al. (2023) assessed the effects of various scenarios on manufacturer encroachment and retailer' investment strategies by analyzing three investment alternatives. Elahi et al. (2023) offered strategic perspectives on potential information-sharing strategies within cooperative supply chains, elucidating that encroachment occurs more prevalent when supplier's capacity level is held as private information.

In addition, there are some studies on symmetric or asymmetric information. Specifically, Huang et al. (2018) discussed whether retailers are willing to disclose their private demand information in situations involving encroachment and non-encroachment. In contrast to the previous view that retailers should keep their private information to maintain their information advantage, they showed that, under the potential risk of manufacturer encroachment, the act of sharing demand information might deter such encroachment and consequently reduce the competition among downstream channels. Li et al. (2021) delved into the impact of consumer environmental consciousness and the substitutability of products on supply chain parties. They considered centralized versus decentralized encroachment and concluded that the latter is more favorable for manufacturers. Additionally, heightened green awareness and increased product substitutability are also advantageous for manufacturers. Ha et al. (2022) constructed a game-theoretic framework to explore supply chain members' decisions through online retail platforms. Their results showed a noteworthy interdependence between encroachment strategies and information-sharing. Ponnachiyur Maruthasalam & Balasubramanian (2023) revealed favorable conditions for manufacturer to encroach under retailer duopoly and showed that asymmetric retail competition may lead to manufacturer encroachment.

Different from the above works that examined the impact induced by manufacturer encroachment, its constraints, and conflicts that exists among online and traditional offline channels, this paper centers on how manufacturer encroachment affects platform and other chain members' performance. That is to say, this paper delves into manufacturer's encroachment strategy within the dual-channel framework of online platforms.

2.2 Sales mode in supply chain

E-commerce has prompted research on online platforms' sales modes in supply chain. In particular, in a study conducted by Yan et al. (2018), researchers aimed to examine the potential benefits and conditions for introducing an agency selling channel alongside the traditional reselling channel. Their findings suggested that manufacturers show a greater inclined towards adopting the agency selling channel, while platforms are less inclined to do so as spillover effects increase. Based on the above findings, Yan et al. (2019) continued to introduce sale efficiency and demand information considerations into the study of issues related to agency selling channel. Johnson (2020) conducted a comprehensive analysis of dynamic competition among platforms, taking into consideration the presence of consumer lock-in. The findings indicated that, in comparison to the wholesale model, the agency model may impose additional social costs. Zennyo (2020) discussed contract selection of suppliers on a monopoly platform and found that, when product substitutability is low (high), platform provides low (high) royalties to induce suppliers to adopt agency (wholesale) contracts. He et al. (2021) developed an analytical framework aiming to explore the offline entry by retailers as well as the establishment of self-service stores in the context of competition among platform self-service stores. They specifically investigated the ship-from-store mechanism and its impact on retailers' and platforms' pricing decisions, taking into account the consumer heterogeneity. Xu & Choi (2021) studied a supply chain that involves manufacturers utilize online and offline channels to sell their products, while platforms adopt an agency reselling mode. They aimed to discover the conditions under which platforms and manufacturers benefit, as well as the optimal sales mode, by considering cross-channel effects. Similarly, Xu et al. (2022) conducted research on a supply chain that the same structure and considered cross-channel effects, with the difference that they also considered the environmental awareness of consumers by exploring how to operate both reselling and agency modes and how to choose between them.

Several works consider strategic selection among different business modes for platforms through different key factors. For example, Hagiu & Wright (2015) gave some conditions for two sale modes of suppliers on online platforms in two-sided markets and they also investigated the choices between the marketplace and reselling mode for platforms. Subsequently, Abhishek et al. (2016) examined the impact of different spillover effects on retailers' platform business mode choices. Their results indicated that retailers prefer the agency mode when there are negative spillover effects on traditional channels and conversely, they prefer the reselling mode when there are great incentives. Kwark et al. (2017) took third-party information into consideration to conduct research on sales modes and demonstrated that, when the accuracy of third-party information is high (low), retailers prefer to adopt wholesale (platform) mode to benefit from third-party information. Tian et al. (2018) investigated the channel selection process on online platforms in such a context of multiple upstream suppliers and gave selection conditions for different channel modes of online platform and supplier such as reselling, agency, and hybrid modes. The study discovered that the interplay between sales cost and competition intensity among upstream suppliers moderates the optimal choice of the platform. Ha et al. (2021) studied the decision-making process involved in the selection of channels on platforms and investigated channel preference and equilibrium channel structure by considering the equilibrium solution under three different channel modes. Lyu et al. (2023) studied four strategies concerning green express packaging recycling and sales modes and they found that the MR scenario predominantly emerges as the most favorable for the platform.

Inspired by the above research, this study investigates the market factors influencing manufacturers' decisions and platforms' decisions, analyzes the conditions under which manufacturers should encroach, and further gets some management insights for manufacturers and platforms.

2.3 Platform's service level strategy

The competition among enterprises is also reflected in products' pre-sales and after-sales service levels. More and more consumers are concerned about product service level beyond price, thereby making product service a significant factor in the markets. In this respect, Parasuraman et al. (1988) found that service level can increase consumers' perceptions of product value. Mohr & Bitner (1995) yielded a noteworthy finding that the perception of employee effort exerts a robust positive influence on transaction satisfaction. Mentzer et al. (2001) suggested that a powerful source for firms to create differentiated competition for diverse products is high-quality logistics service. In the research conducted by Taylor (2002), it was showed that, when demand is affected by retailer sales effort, properly designed target rebate and returns contract may achieve coordinated and win-win results. Zhang et al. (2019) studied a supply chain that primarily led by retailers, they discovered that investing in retail service can serve as a means for retailers to resist manufacturer encroachment and enable all sides in supply chain to achieve Pareto improvement. Moon & Armstrong (2020) examined the influence brought by service quality acts on customers' perceived risk and trust towards the retailer, as well as its influence on customer satisfaction and revisit intention. Wang et al. (2022) implemented a study in order to explore some effects of manufacturer encroachment on private demand information-sharing when manufacturers competing in price and product service effort and showed that, under the influence of the cost-of-service effort and the level of competition in service effort, manufacturers transmit demand information to retailers by distorting wholesale prices upward or downward.

Certain scholars direct their focus towards the factors influencing service efforts. For instance, Li et al. (2014) carried out an investigation on a supply chain consisting of a manufacturer and a retailer. In their model, the retailer offers product and its after-sales service. Retailers have the option to either establish their service capacity at a cost before determining the service demand, or to outsource the service without cost once the demand is known. Their findings highlighted how such service decisions can affect the profit strategies of both the supply chain members. In another study, Roy et al. (2015) analyzed the benefits of integrating promotional with after-sales service efforts to boost demand, proposing buy-back contracts as a coordination mechanism. Cao & He (2016) investigated the impact of platform commissions on supplier service levels and their results showed that increasing the intensity of channel competition motivates e-commerce platforms to improve their own channel services while reducing those of competing channels. Zhou et al. (2018) explored the pricing and service strategies of two supply chain members under the influence of free ridership, considering both differential and non-differential pricing. Ali et al. (2018) demonstrated that service level investment decisions are considerably impacted by demand disruptions in retail market. In a research conducted by Li et al. (2019), the scholars examined the effects of different service strategies as well as the showroom effect on pricing and service effort, including no-service, ex-ante service, and ex-post service. Ranjan & Jha (2019) constructed three distinct models by positing that channel demand is affected by product green quality level and sales effort level, and their study uncovered that products display high-quality green level within collaboration models.

Some scholars also put their attention to the impact brought by service strategies. For instance, Liu et al. (2019) proposed a platform model aimed at maximizing profits, which takes into account the influence of price decisions on the threshold number of suppliers' participation, value-added services, matching capabilities, and their conclusions indicated that value-added services always benefit platforms, regardless of their capital and basic needs. In the model proposed by Heydari et al. (2022), government provided subsidies to manufacturers who produced green products, while retailers have the ability to implement green sales effort to incentivize customers to purchase green goods. Empirical findings indicated that produce green products yields favorable outcomes for manufacturers and it engenders unfavorable consequences for retailers. Wang and Chaolu (2022) considered the interaction between offline service strategy employed by manufacturers and online sales modes adopted by platforms, they constructed four different models and found that the implementation of service effort strategy, which includes the phenomenon of showrooming, can significantly impact the selection of sales mode by the platform. In a study conducted by Liu et al. (2022), a comprehensive examination was carried out on a dual-channel supply chain, demonstrating that increased service effort is advantageous for the entire chain. Moreover, Wang et al. (2023) studied within an e-commerce supply chain, primarily aimed to investigate the feasibility and efficacy of employing logistics service sharing as a means to foster the establishment of a carbon emission pooling mechanism.

Noting that most literature primarily concentrates on pricing, sales mode selection, and service strategies of retailers' offline channels, the objective of this study is to shift the focus towards the strategic selection of services in various online channels and investigate the interactions among the members of the supply chain.

3. Platform formulation

Consider a supply chain that includes a manufacturer and a platform. The manufacturer has the option to sell homogeneous alternative products either through the platform's agency selling channel or reselling channel, while the platform provides certain services for consumers. In addition to platform agency selling or reselling channels, the manufacturer has the option to establish a direct selling channel through encroachment as well, which allow him to directly sell products to consumers. The structure of the supply chain can be seen in Fig. 1.

In the case depicted in Fig. 1 (a), there is a dual-channel sales mode that includes both 'platform agency' and 'platform resale' without manufacturer encroachment. In the agency selling channel, the manufacturer determines the market launch volume q_A and pays to the platform with a commission rate $\alpha \in [0, 0.3]$, which refers to the tariff of various categories of JD Open platform in 2023[3]. In the reselling channel, the product sold by the manufacturer to the platform at a wholesale price w, while the platform is responsible for determining the market launch q_R in the reselling channel. In both channels, the platform provides a certain level s of service to consumers. In the case depicted in Fig. 1 (b), the manufacturer has a direct selling channel through encroachment and hence there are three channels that can sell products to consumers.

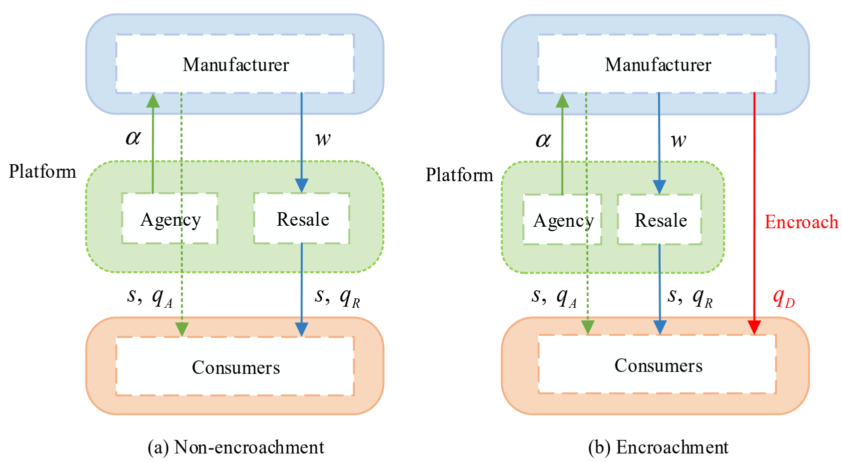

Fig. 1. Modelling framework

We make the assumption that the platform's service cost is given by the quadratic expression $ks^2/2$, which has been a common cost expression in prior research (Ha et al., 2021; Tsay & Agrawal, 2000; Wang et al., 2022), which implies that the cost borne by the platform increases as the level of service increases. Here, k denotes the service input unit cost coefficient and the magnitude of k represents the level of the platform's marginal cost that increase the unit service level, which specifically refers to the fund required to increase the unit service level of product warehousing service, logistics service, payment service, customer service, after-sales service, and return service, etc. High k indicates low efficiency because the platform costs more for the same service level. Without loss of generality, we make the widely adopted assumption that the production cost generated by the manufacturer and the selling cost brought by the platform are both equal to zero (Ha et al.,

[3] https://rule.jd.com/rule/ruleDetail.action?ruleId=950583665543483392&btype=8

2022; Li et al., 2019; Wang & Chaolu, 2022).

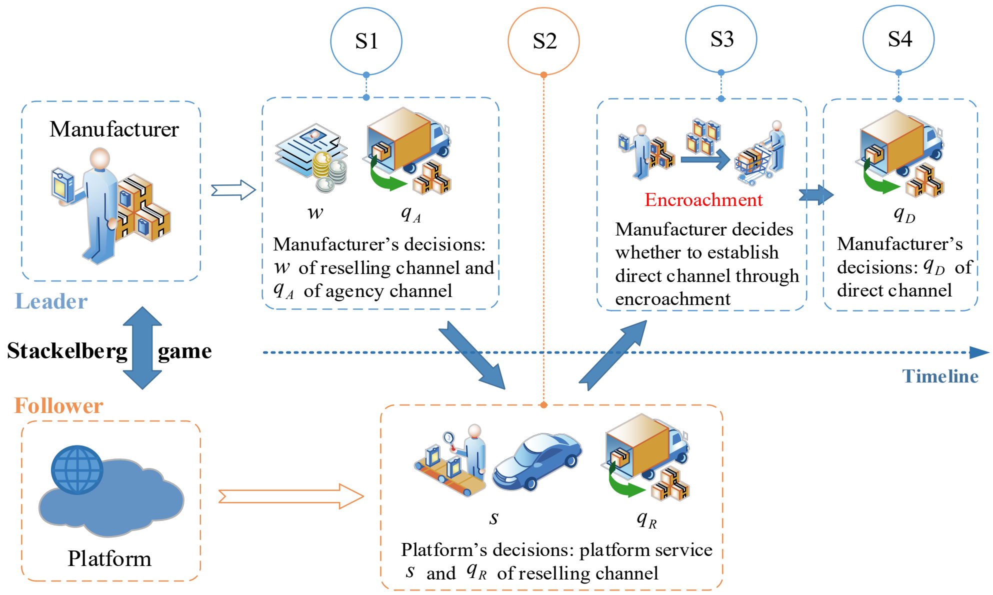

Fig. 2. The timeline of the game

The figure presented in Fig. 2 shows the timeline of the game. At Stage 1, the manufacturer makes decisions of the wholesale price provided to the platform, as well as the market launch volume to be launched in the reselling channel considering the commission rate. At Stage 2, the platform determines the market launch volume in the reselling channel by considering the wholesale price and service level. Stage 3 involves the manufacturer's decision regarding whether to establish a direct selling channel through encroachment or not. If encroachment occurs at Stage 3, the manufacturer sets the market launch volume for the direct selling channel at Stage 4.

4. Model settings

In this section, we examine the influence of different variables on the encroachment strategy employed by manufacturers. To represent equilibrium outcomes in both non-encroachment and encroachment situations, we utilize the subscripts '-E' and 'E' respectively.

4.1 Non-encroachment situation

In this situation, the manufacturer engages in selling products through two distinct channels on the platform, the agency selling channel and the reselling channel. Due to the competitive relationship between two channels, we make the assumption that the inverse demand function in the agency selling channel is $p_A = 1 - q_A - \beta q_R + s$ and the inverse demand function in the reselling channel is $p_R = 1 - q_R - \beta q_A + s$, where $\beta \in [0,1]$ denotes the inter-channel substitution rate between above two channels. To help the manufacturer make optimal decision, we construct the following Stackelberg game model P^{-E} for the non-encroachment situation:

$$\max_{w,\, q_A} \quad \pi_m = w q_R + (1-\alpha)(1 - q_A - \beta q_R + s) q_A \qquad (1)$$
$$\text{s.t.} \quad w \geq 0, \; q_A \geq 0,$$

$$\max_{s,\, q_R} \quad \pi_f = \alpha(1 - q_A - \beta q_R + s) q_A + (1 - q_R - \beta q_A + s - w) q_R - \frac{1}{2} k s^2 \qquad (2)$$
$$\text{s.t.} \quad s \geq 0, \; q_R \geq 0,$$

where the manufacturer's profit comes from two distinct channels: the agency selling channel and the reselling channel, while the platform's profit encompasses the portion of profit obtained from the agency selling channel, the sales revenue generated by the reselling channel, and the cost associated with providing platform services. We utilize the backward induction method to resolve the bilevel program. Specifically, we initially solve (2) to get the optimal service level and the optimal market launch volume in the reselling channel, both of which are decided by the platform. Subsequently, we solve (1) to gain the manufacturer's optimal wholesale price within the reselling channel and the manufacturer's optimal market launch volume within the agency channel are derived. The results and findings of this analysis are outlined in the following proposition.

Proposition 1 *In the non-encroachment situation, when* $k > 1$, *the optimal decisions and the optimal profits of the manufacturer and the platform are*

$$w^{-E} = \frac{k(1-\alpha)(2\alpha\beta(1-2k)+2k(2-\beta^2)+3\beta-4)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}, \quad q_A^{-E} = \frac{k(2k-1)(1-2\alpha)+2k^2(1-\beta)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2},$$

$$s^{-E} = \frac{2k((1+2\alpha)(1-\alpha)-\beta)+(2\alpha-1)^2}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}, \quad q_R^{-E} = \frac{k(1-\alpha)((1-2\alpha)+2k(1-\beta))}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2},$$

$$\pi_m^{-E} = \frac{k^2(1-\alpha)(3-2\alpha-2\beta)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}, \quad \pi_f^{-E} = \frac{M_1}{2(4(2k-1)(1-\alpha)(\alpha-k)+(2k\beta-1)^2)^2},$$

where the notation M_1 is given in Table 1 of Appendix.

Refer to the appendix for proof of the proposition mentioned above. From Proposition 1, it can be indicated that in case where the manufacturer does not encroach, a higher service cost elasticity coefficient leads to a diminished incentive for the platform to exert service effort and the platform poses a small threat to the manufacturer. It should be noted that, the manufacturer and platform must consider two aspects when determining the wholesale price and market launch volume in practice, the one is to follow the service cost elasticity characteristics, another is to adjust according to actual business activities.

Proposition 2. *In Model P^{-E}, the sensitivity analysis results for the optimal decisions are as follows:*

(1) $\frac{\partial w^{-E}}{\partial \alpha} < 0, \frac{\partial q_A^{-E}}{\partial \alpha} > 0, \frac{\partial q_R^{-E}}{\partial \alpha} < 0, \frac{\partial \pi_m^{-E}}{\partial \alpha} < 0, \frac{\partial \pi_f^{-E}}{\partial \alpha} > 0$;

(2) $\frac{\partial w^{-E}}{\partial \beta} > 0, \frac{\partial q_A^{-E}}{\partial \beta} < 0, \frac{\partial q_R^{-E}}{\partial \beta} < 0, \frac{\partial \pi_m^{-E}}{\partial \beta} < 0, \frac{\partial \pi_f^{-E}}{\partial \beta} < 0$;

(3) $\frac{\partial w^{-E}}{\partial k} > 0, \frac{\partial q_A^{-E}}{\partial k} < 0, \frac{\partial q_R^{-E}}{\partial k} < 0, \frac{\partial \pi_m^{-E}}{\partial k} < 0, \frac{\partial \pi_f^{-E}}{\partial k} < 0$.

Proposition 2 demonstrates that, as the commission rate increases, the manufacturer increases the launch volume of products that sell through agency selling channel to achieve profitability goal, simultaneously he sets low wholesale price and reduce the launch volume of products that sell through reselling channel to balance production. This strategy ultimately results in a reduction in the manufacturer's profit and a growth in the platform's profit. Moreover, as the inter-channel substitution rate or the service cost elasticity coefficient increases, the manufacturer's profit decreases, it becomes necessary for the manufacturer to set a higher wholesale price. Because the manufacturer needs to compensate for the loss caused by intensified competition among different channels by increasing wholesale price. Realistically, channel competition may lead to low market launch volumes for all members and harm both parties' profits. It is necessary to continuously improve management and operational capabilities, formulate effective marketing strategies, and adapt to market changes. Therefore, an appropriate competition level is more conducive for the members of the supply chain to achieve mutually benefits outcomes.

4.2 Encroachment situation

When the manufacturer decides to establish a direct selling channel through encroachment, they have three sales modes to choose, specifically, the platform agency mode, the platform resale mode, and the direct sales mode. The manufacturer needs to decide the market launch volume q_D in the direct selling channel. The inverse demand functions of the manufacturer's encroachment in the agency selling channel, the reselling channel, and the direct selling channel are respectively,

$$p_A = 1 - q_A - \beta q_R - \gamma q_D + s,$$

$$p_R = 1 - q_R - \beta q_A - \gamma q_D + s,$$

$$p_D = 1 - q_D - \beta q_A - \gamma q_R,$$

where β and γ represent the inter-channel substitution rates between any two channels. In the situation of manufacturer encroachment, the direct selling channel captures a part of the market, which further affects the market launches of the agency selling channel and the reselling channel. In this case, it constitutes a Stackelberg game, where the manufacturer assumes the role of the leader and the platform assumes the role of the follower. Both make decisions by maximizing their own profits. Thus, a bilevel programming model P^E for the manufacturer encroachment situation can be given as

$$\max_{w, q_A, q_D} \quad \pi_m = wq_R + (1-\alpha)(1-q_A-\beta q_R-\gamma q_D+s)q_A + (1-q_D-\beta q_R-\gamma q_A)q_D$$
$$\text{s.t.} \quad w \ge 0, \ q_A \ge 0, \ q_D \ge 0, \tag{3}$$

$$\max_{s, q_R} \quad \pi_f = \alpha(1-q_A-\beta q_R-\gamma q_D+s)q_A + (1-q_R-\beta q_A-\gamma q_D+s-w)q_R - \frac{1}{2}ks^2$$
$$\text{s.t.} \quad s \ge 0, \ q_R \ge 0, \tag{4}$$

where the manufacturer's profit is derived from three channels, while the profit of platform encompasses agency selling channel's profit share, reselling channel's sales profit, and platform service cost. The backward induction method is employed to address the aforementioned model, which leads to the following proposition.

Proposition 3 *In the encroachment situation, when* $\alpha \in [0, \min\{0.3, \alpha_1\}]$, $\gamma \in [0, \gamma_1)$ *and* $k > \max\{1, \frac{a_2}{a_1}\}$, *the optimal decisions and the optimal profits of manufacturer and platform are*

$$w^E = \frac{M_4 + M_3(2\alpha - 2k\alpha\beta - 1) + M_2(\beta - \gamma)}{2M_4}, \quad q_A^E = \frac{kM_3}{M_4}, \quad s^E = \frac{M_4 - M_3(2\alpha - 4k\alpha + 2k\beta - 1) - M_2(\beta + \gamma)}{2M_4(2k-1)},$$

$$q_R^E = \frac{kM_4 + kM_3(1 - 2k\beta) - kM_2(\beta + \gamma)}{2M_4(2k-1)}, \quad q_D^E = \frac{M_2}{M_4}, \quad \pi_m^E = \frac{M_5}{4M_4^2(2k-1)}, \quad \pi_f^E = \frac{M_6}{8M_4^2(2k-1)},$$

where $\alpha_1 = \frac{5\beta^2 + 2\beta\gamma + \gamma^2 - 8}{(\beta+\gamma)^2 - 8}$, $\gamma_1 = \frac{2\beta(\beta - (1-\alpha)(1-\beta))}{2\alpha(\alpha+\beta) + 9(1-\alpha) - 4\beta}$ *and the notations* M_2, M_3, M_4, M_5, M_6, a_1, a_2 *are given in Table 1 of Appendix.*

Refer to the appendix for proof of the proposition mentioned above. A rational decision-making process is to sort through the variables, then find the criteria for the decision and define a boundary and solution objective for this decision. Proposition 3 suggests that, in order for the platform and manufacturer to make optimal decisions under the encroachment situation, the commission rate must be lower than the firm's expected threshold (i.e., $\alpha \in [0, \min\{0.3, \alpha_1\}]$), the channel substitution rate must be below a certain threshold (i.e., $\gamma \in [0, \gamma_1)$), and the service cost elasticity coefficient must exceed a specific threshold (i.e., $k > \max\{1, \frac{a_2}{a_1}\}$), only when these conditions are satisfied can the platform and manufacturer be guaranteed to make optimal decisions. When α is too high, the manufacturer will suffer from high commission rate, which prompts them to offset profits through encroachment, further exacerbating market competition, a high inter-channel substitution rate (i.e., $\gamma > \gamma_1$) can also increase competition between channels. Furthermore, when k is too low (i.e., $k < 1$), excessive service effort exerted by the platform can easily lead to an imbalanced structure in the supply chain, thereby causing adverse impact for the supply chain members. Therefore, appropriate values of key factors can ensure that the optimal solutions can be obtained in the encroachment situation.

Proposition 4. *In Model* P^{E}, *the sensitivity analysis results for the optimal decisions are as follows:*

(1) $\frac{\partial w^E}{\partial \alpha} > 0, \frac{\partial q_A^E}{\partial \alpha} > 0, \frac{\partial q_R^E}{\partial \alpha} < 0, \frac{\partial q_D^E}{\partial \alpha} > 0, \frac{\partial \pi_m^E}{\partial \alpha} < 0, \frac{\partial \pi_f^E}{\partial \alpha} > 0$;

(2) $\frac{\partial w^E}{\partial \beta} > 0, \frac{\partial q_A^E}{\partial \beta} < 0, \frac{\partial q_R^E}{\partial \beta} < 0, \frac{\partial q_D^E}{\partial \beta} > 0, \frac{\partial \pi_m^E}{\partial \beta} < 0, \frac{\partial \pi_f^E}{\partial \beta} < 0$;

(3) $\frac{\partial w^E}{\partial k} > 0, \frac{\partial q_A^E}{\partial k} < 0, \frac{\partial q_R^E}{\partial k} < 0, \frac{\partial q_D^E}{\partial k} > 0, \frac{\partial \pi_m^E}{\partial k} < 0, \frac{\partial \pi_f^E}{\partial k} < 0$.

Proposition 4 indicates the truth that an increase in the commission rate, inter-channel substitution rate or service cost elasticity coefficient results in a rise in both the wholesale price of manufacturer in the reselling channel and the market launch volume of direct selling channel. This can be attributed to the manufacturer's need to offset the losses incurred from the elevated commission rate and intensified inter-channel competition by raising the wholesale price. It is undoubtedly that a higher commission rate can generate great profit for the platform, while an excessive commission rate can also result in elevated wholesale prices. Therefore, in reality, it is advisable for the platform to set an appropriate commission rate rather than set excessively high rate, so as to mitigate the negative impact associated with high wholesale prices. Moreover, as the commission rate increases, it is recommended to set the agency's selling channel's launch volume a higher level and the reselling channel's launch volume a lower level. Given that a higher commission rate would clearly benefit the platform, the platform may maximize its profits by shifting its focus and resources towards the agency selling channel, while concurrently reducing the reselling channel's launch volume. Besides, as the inter-channel substitution rate or the service cost elasticity coefficient increases, it is advisable for the agency selling channel and the online reselling channel to have lower market launch volumes. This is because the direct selling channel, in comparison to the agency selling and reselling channels, involve intermediaries, eliminates intermediate links, effectively reduces sales costs, and improves sales efficiency. Therefore, in cases where the inter-channel substitution rate is high, the manufacturer's encroachment strategy leads to channel competition, causing a shift in market launch volume from the agency selling and reselling channels to the direct selling channel, hence the encroachment strategy becomes a more favorable choice for the manufacturer. Like Proposition 2, the manufacturer and platform experience a decline in profits on account of intensified competition among channels, simultaneously manufacturer encroachment makes the situation of channel competition more intense. So, both the manufacturer and the platform should learn to operate some marketing strategies to alleviate channel conflicts and losses caused by competition and steer the competition in their own direction.

5. Numerical analysis

By utilizing parametric approach, this section examines the influence of some key variables, including the commission rate α , the inter-channel substitution rate β , as well as the service cost elasticity coefficient k , on supply chain members so as to give some management insights based on numerical experiments.

5.1 Impact of commission rate

In this subsection, we analyze the impact of the commission rate of the platform on the optimal decisions and profits of the members within the supply chain. In order to ensure the values of parameter α are reasonable, we investigated the practical commission rates on multiple e-commerce platforms including Amazon[4], JD.com[5], Walmart[6], eBay[7], OZON[8] and Vip.com[9]. The corresponding values of commission rates adopted by different platforms are listed in Fig. 3. Based on the empirical sample data in Fig. 3, we performed pertinent numerical analyses utilizing parametric methodology and confine the parameter $\alpha \in [0, 0.3]$, while different values of α can be seen as the commission rates paid by diverse product categories. That is, different values of α represent varying commission rates paid by different manufacturers who produce different types of products. In our experiments, we set $k = 3,\ \beta = 0.3,\ \gamma = 0.3$.

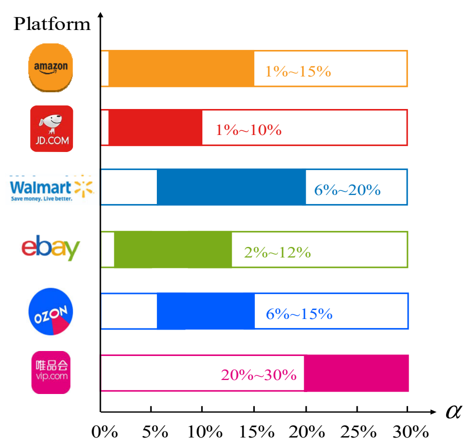

Fig. 3. Platform commission rate

Recall that previous studies primarily concentrated on exploring the influence of commission rates on channel structure and channel selection, with little attention paid to the effects on decision-making and profitability of supply chain members. These effects hold important practical implications in determining wholesale prices, market launch volume scale, and profitability, which are key considerations for supply chain members. In contrast with existing works, we investigated how the commission rates affect the decision-making and profitability of supply chain members. The numerical results are shown in Figs. 4-7.

[4] http://kaidian.amazon.cn/services/cb/pricing.html
[5] https://rule.jd.com/rule/ruleDetail.action?ruleID=3863
[6] https://www.163.com/dy/article/HLQQ3R0I0518IELI.html
[7] https://www.kuajingyan.com/article/14140
[8] https://www.cifnews.com/article/128900
[9] https://www.sohu.com/a/60917291_116672

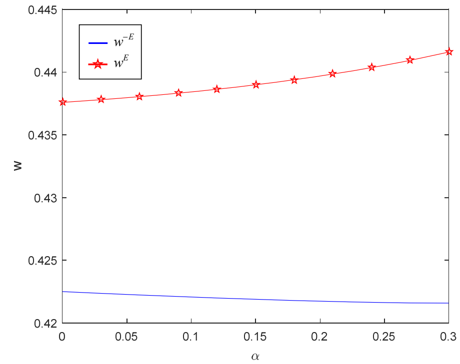

Fig. 4. Changes of wholesale prices with α

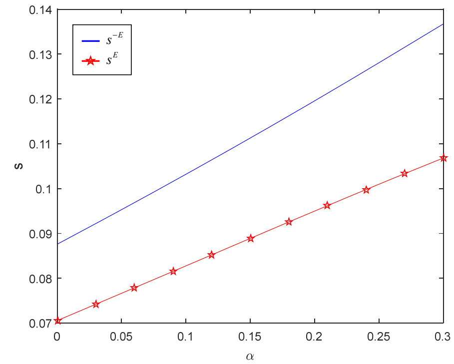

Fig. 5. Impacts of α on service levels

Fig. 4 shows that the wholesale price set by the manufacturer is always higher in the encroachment situation compared to the non-encroachment situation. As the commission rate increases, the wholesale price experiences a decline in the non-encroachment situation, while undergoes an increase in the encroachment situation. This implies the manufacturer who refrains from implementing the encroachment strategy is able to decrease the wholesale price in response to an increase in the commission rate. Meanwhile, the manufacturer is motivated to incentive platform of providing high service level and facilitates the shifting of sales towards the reselling channel. Furthermore, when manufacturer encroachment occurs, the wholesale price set by manufacturer in the reselling channel increases, as a result of an increase in commission rate erodes the revenue of manufacturer in the agency selling channel, consequently high wholesale price in the reselling channel can compensate the manufacturer. No matter the commission rate, in the encroachment situation, the service level imposed by the platform is always lower compared to the non-encroachment situation, as shown in Fig. 5 where the curves show an upward trend. This phenomenon can be attributed to that manufacturer encroachment leads to the establishment of the direct selling channel which captures part of the market. With the increase of commission rates, the platform has more motivation to pay for service efforts and improve service levels. Moreover, the degree of service imposed by the platform in the non-encroachment situation rises faster in comparison with the encroachment situation so that the platform-imposed service strategy may be more effective when the manufacturer does not encroach.

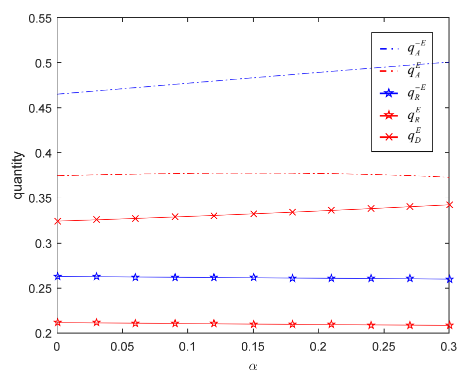

Fig. 6. Changes of q with α

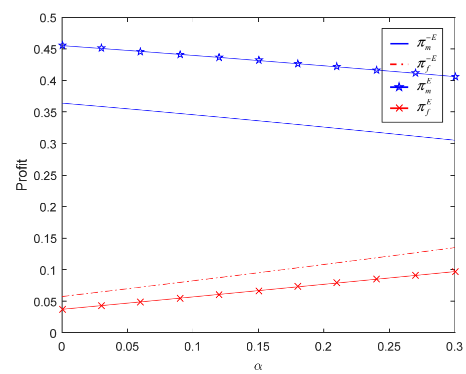

Fig. 7. Changes of optimal profits with α

The change in market launch volume with commission rate is illustrated in Fig. 6. Under the encroachment situation, the agency selling channel's market launch volume set by manufacturer is lower contrasted with the non-encroachment situation, as manufacturer encroachment divides up part of the market and thereby reduces the platform's market share within two original channels. Furthermore, with an increase of the commission rate, there is a tendency for the agency selling channel's market launch volume to increase and, in particular, it tends to increase first and then decrease when the manufacturer encroaches. This means that increasing the commission rate may provide an incentive for the platform to favor the agency selling channel, resulting in more market share for the highly profitable agency selling channel. Consequently, agencies selling the channel's market launch volume will increase. Under the encroachment situation, both the reselling channel's market launch volume set by the platform and the agency selling channel's market launch volume set by the manufacturer are lower compared to the non-encroachment situation, while an increase of the commission rate may result in a decrease in the reselling channel's market launch volume of platform. Meanwhile, the manufacturer tends to increase its direct selling channel's market launch volume, which means that, when manufacturer encroachment occurs, there will be an added direct selling channel that capture the market and splits the original market to grab some consumers to maximize its revenue. Moreover, in the non-encroachment situation, the agency selling channel's market launch volume set by the manufacturer is higher compared to the reselling channel's market launch volume set by the platform. In the encroachment situation, the manufacturer's market launch volume in the agency selling channel is higher compared to in the direct selling channel, and higher compared to the platform's market launch in the reselling channel. Consequently, no matter whether the manufacturer adopts an encroachment strategy, the manufacturer may capture a large market share and deliver more products to the market.

As illustrated in Fig. 7, the manufacturer's profit curve exhibits a declining pattern, while the platform's profit curve shows an upward trend. This means that, the profit of manufacturer decreases in both encroachment and non-encroachment situations under the increasing of the commission rate, particularly, the profit in the encroachment situation decreases slightly faster than the non-encroachment situation. In cases where the commission rate increases, the profit of platform in the non-encroachment situation increases more quickly than the encroachment situation. Moreover, the profit of manufacturer is always higher in contrast to the profit of platform in both non-encroachment and encroachment situations, which indicates that the manufacturer always dominates the market, irrespective of whether the manufacturer adopts encroachment strategy. From the profitable perspective, in the encroachment situation, the manufacturer consistently possesses higher profit while the platform holds lower profit, when in comparison with the non-encroachment situation. That is, manufacturer encroachment may benefit manufacturers and be detrimental to platforms. The best way for platforms may be to capture the market and attract more consumers by improving their service levels so as to increase their profitability.

5.2 Impact of inter-channel substitution rate

In this subsection, we investigate how the inter-channel substitution rate β affects supply chain members' optimal profits through numerical experiments. To characterize the differences in substitutability among different channels, we studied three different scenarios γ (i.e., $\gamma = 0.2$, $\gamma = 0.5$, $\gamma = 0.8$) and the default values for the other parameters were set to be $k = 3$, $\alpha = 0.1$. Note that previous research primarily concentrated on examining the influence of inter-channel substitution rate on channel structure. In our numerical experiments, we examined the effects of different channel substitution rates on the profits of manufacturers and platforms. The numerical results are shown in Figs. 8-10.

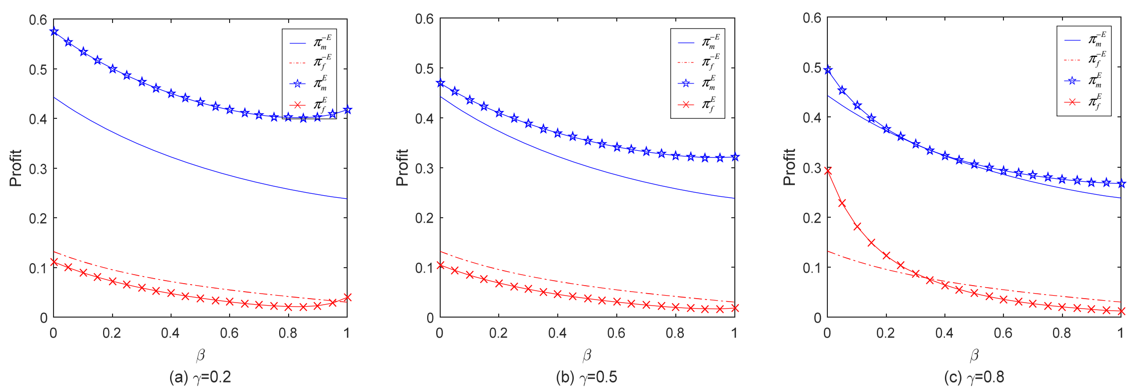

Fig. 8. Changes of optimal profits with β

It can be seen in Fig. 8 that in the encroachment situation, the profit of the manufacturer is consistently greater contrasted to the non-encroachment situation. The size of γ exerts an influence on the profit of the manufacturer only under the encroachment situation, while under the non-encroachment situation, it does not create any impact on the profit of the manufacturer. Combining the three scenarios in Fig. 8, our survey reveals that, in most cases, the profit of the platform is greater in the non-encroachment situation compared to the encroachment situation, specifically, manufacturer encroachment is not conducive to platform's revenue. In Fig. 8 (c), when $\beta < 0.3318$, the platform has better profitability in the encroachment situation in contrast to the non-encroachment situation, which indicates that manufacturer encroachment is beneficial to the platform and hence there is a win-win situation when $\beta < 0.3318$. If $\beta > 0.3318$, the platform is more profitable in the non-encroachment situation, indicating that manufacturer encroachment has a negative impact on the platform. The best way for the platform to deal with manufacturer encroachment is to improve its service level to capture a larger market share and increase its consumer base. Moreover, in both non-encroachment and encroachment situations, the manufacturer and the platform experience a decline in profits as the inter-channel substitutability increases. This implies that, regardless of manufacturer encroachment, the manufacturers always dominate the market and, the level of inter-channel substitutability has a negative impact on the competitive advantage of the manufacturer and the platform, with higher substitutability resulting in a weaker advantage. Regardless of the size of γ, the difference between the profits of manufacturer in both non-encroachment and encroachment situations is always positive, suggesting that the manufacturer consistently gains advantages from manufacturer encroachment. The difference between the platform's profits in both non-encroachment and encroachment situations is always negative when $\gamma = 0.5$, which means that the platform suffers from manufacturer encroachment, and, only when substitutability among channels is distinct, the platform is profitable. In Fig. 9, when $\beta < 0.3318$, the difference between the platform's profits in both non-encroachment and encroachment situations is positive, which indicates that the platform is more favorable with manufacturer encroachment and, on the opposite, when $\beta > 0.3318$, the difference between the platform's profits in both non-encroachment and encroachment situations is negative, which indicates that the platform is better off without manufacturer encroachment. From Fig. 9, it can be concluded that, for $\gamma = 0.2$ or $\gamma = 0.5$, the profit differential between the manufacturer and the platform in both non-encroachment and encroachment situations increases as there is an increase in γ. In particular, when $\gamma = 0.8$, the manufacturer's profit differential exhibits a trend of decreasing and then increasing, while the platform's profit differential exhibits a trend of decreasing as there is an increase in β. This reveals that the negative effect on the platform brought by manufacturer encroachment increases as the inter-channel substitution rate increases.

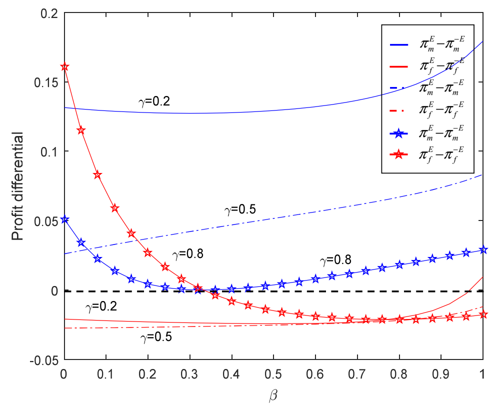

Fig. 9. Changes of optimal profits differential with β

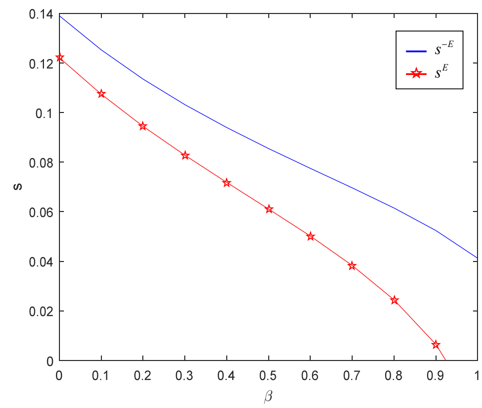

Fig. 10. Impacts of β on service level

Similarly, regardless of the size of γ, in the encroachment situation, the service level imposed by the platform is consistently lower compared to the non-encroachment situation. According to Fig. 10, as the inter-channel substitutability β increases, the service level platform-imposed decreases, more slowly in the non-encroachment situation but more rapidly in the encroachment situation. The strategy of platform-imposed service level is more effective when the manufacturer does not encroach, increasing channel substitutability mitigates conflict among channels, and the platform can slow down the service imposed to avoid the over-imposing negative effect.

5.3 Impact of service cost elasticity coefficient

In light of the diversification of consumption patterns, consumers need not only physical products to satisfy their needs, but also intangible services to bring a virtuous experience of purchase. In previous studies, only theoretical relationship between service level and sales volume has been analyzed qualitatively and little literature focus on service cost elasticity coefficient, which has important practical significance for determining service level and optimizing business objectives under seller's preset goals. In this subsection, we focus on how the service cost elasticity coefficient affects the optimal decision-making and profitability of supply chain members. In our experiments, the size of the parameter k was set to be in $[1,2]$, which can reflect the size of the platform input service cost. With the aim of describing the influence of the service cost elasticity coefficient, we set the values of β to be 0.2, 0.5, 0.8, to represent three scenarios of low, medium, and high inter-channel substitution rates, respectively. Other relevant parameters were taken as $\alpha = 0.1, \gamma = 0.3$. The numerical findings are presented in Fig. 11.

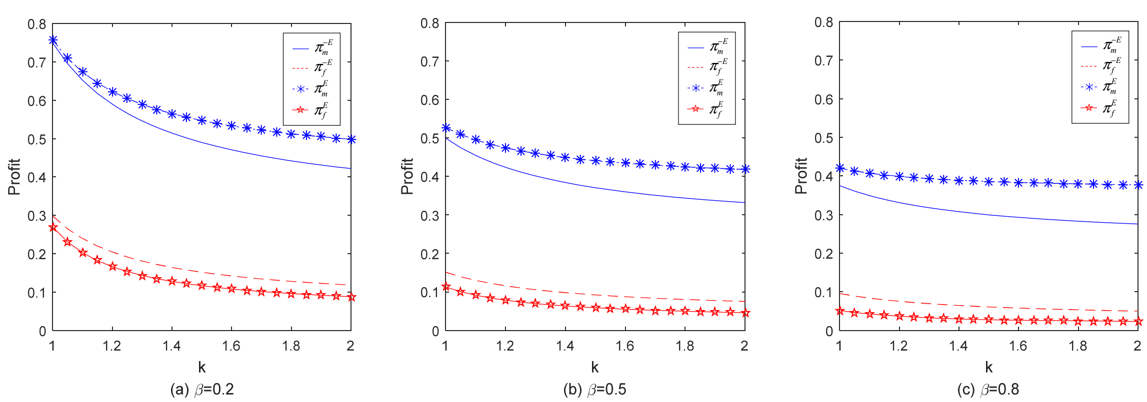

Fig. 11. Changes of optimal profits with k

Fig. 11 shows that, regardless of the service cost elasticity coefficient, in the encroachment situation, the manufacturer consistently achieves higher profits in comparison with the non-encroachment situation. Conversely, in the encroachment situation, the platform invariably gains lower profits in comparison with the non-encroachment situation. This shows that manufacturer encroachment favors the manufacturer to generate revenue. As a result of encroachment, the manufacturer may seek to generate additional revenue by implementing a direct selling channel. In cases where the inter-channel substitution rate and service cost elasticity coefficient are both low, the platform may increase its service to broaden its market and win more consumers to get high profits. However, at the condition there is a high inter-channel substitution rate as well as the unit service input cost increases, the platform's effort to capture market by increasing its service may be hindered by costs and channel competition and therefore cannot achieve desired results. In cases where there is an increasing service cost elasticity coefficient, indicating a rise of the service input cost, the profit of manufacturer decreases in both non-encroachment and encroachment situations. Especially, this decrease is slightly faster in the non-encroachment situation compared to the encroachment situation, consequently, results in an increase in the profit differential for manufacturers as the service cost rises. The platform's profit decreases in both non-encroachment and encroachment situations, but its profit differential increases. This may be due to that, the platform's profit in the non-encroachment situation increases more quickly compared to the encroachment situation as the service cost increases. That is to say, increasing the services cost may force the platform to raise its commission rate in order to attain higher profits. However, the positive effect of commission rate on the platform does not offset the negative effect of the service cost, similarly, the advantageous impact brought by manufacturer encroachment does not counterbalance the adverse impact brought by the commission rate increase. In addition, in both non-encroachment and encroachment situations, the manufacturer always achieves higher profits than the platform, which indicates that the manufacturer invariably holds a dominate position in the market, irrespective of whether the manufacturer encroaches. Simultaneously, neither the magnitude of platform service cost nor the level of substitution rate among channels can offset the utility of manufacturer encroachment. In particular, in cases where the inter-channel substitution rate increases, both the manufacturer and the platform experience a decline in profitability, as well as a decreasing profit differential between them. This may be because high inter-channel substitution rate reduces channel difference and slows down the dynamic competition among manufacturers and platforms.

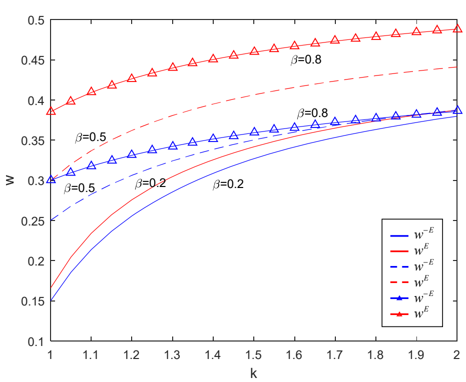

Fig. 12. Changes of w with k

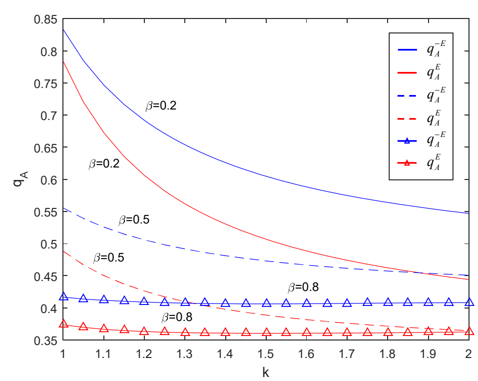

Fig. 13. Changes of q_A with k

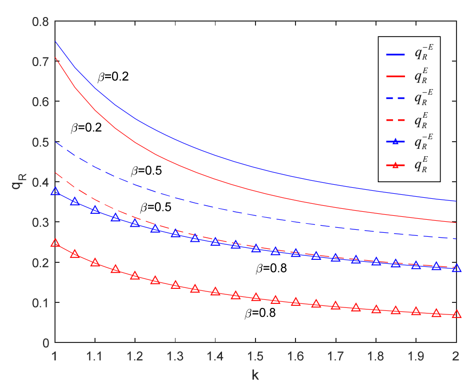

Fig. 14. Changes of q_R with k

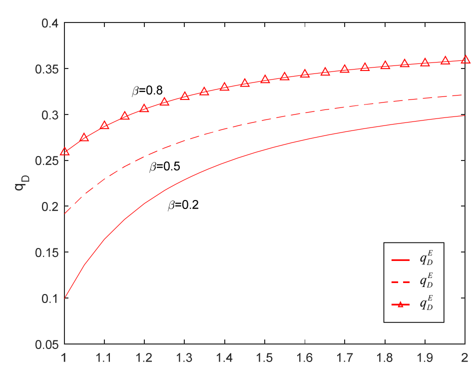

Fig. 15. Changes of q_D with k

Changes in product price and market launch volume are mainly influenced by supply, demand, and cost. Previous studies mainly focus on the relationship between service cost elasticity coefficient and retail price, with little literature on their impact on wholesale price and market launch volume. In our experiments, we investigated how the service cost elasticity coefficient affects the decisions of supply chain members by considering three different inter-channel substitution rate scenarios. The numerical results are shown in Figs. 12-15. In the encroachment situation, the manufacturer's wholesale price is not always higher compared to the non-encroachment situation. Specifically, in the encroachment situation, the manufacturer's wholesale price is invariably higher in comparison with the non-encroachment situation in the case of $\beta = 0.8$, which indicates that high inter-channel substitution rate may identify early channel shock from encroachment. This phenomenon is consistent with the fact that the more substitutable a channel, the more the consumers choose beneficial and convenient channel. Fig. 12 also shows that the wholesale price under low inter-channel substitution is lower than high inter-channel substitution. Similarly, the wholesale price differential between non-encroachment and encroachment situations under low inter-channel substitution is lower than high inter-channel substitution and increases as the service cost elasticity coefficient increases in both non-encroachment and encroachment situations. This implies that the greater the substitutability among channels, the greater the shock from manufacturer encroachment. This also enhances its competitive advantage by decreasing the wholesale price, irrespective of whether the manufacturer encroaches. Furthermore, in cases where there is an increase in the platform service cost, the platform may capture high margins from the reseller channel by increasing commission rate, while the manufacturer may obtain compensation by raising the wholesale price charged to the reselling channel.

From Figs. 13 and 14 we can observe that the agency selling channel's market launch volume decided by the manufacturer is lower under the encroachment situation compared to the non-encroachment situation, while the platform's market launch volume in the reselling channel under the encroachment situation is lower than the non-encroachment situation. In both non-encroachment and encroachment situations, regardless of the service cost elasticity coefficient, the market launch volumes in the agency selling and reselling channels at low inter-channel substitution rate are consistently higher than high inter-channel substitution rate. This implies that there is a negative relationship between inter-channel substitution and the utility of manufacturer encroachment. Moreover, under non-encroachment and encroachment situations, the market launch volumes both in the agency selling and reselling channels decrease in cases where the service cost elasticity coefficient increases. Therefore, when the platform input service cost increases, the platform has the potential to get high profit by increasing its commission rate, conversely, the manufacturer may reduce agency selling and reselling channels' launch volume to mitigate its loss. Unlike the agency selling and reselling channels, the market launch in the direct selling channel is positively influenced by increasing service cost elasticity coefficient, additionally, a higher inter-channel substitution rate leads to a higher market launch volume in direct selling channel.

Combining the results in Figs. 12-15, it is evident that in cases the platform's cost of input services increases and the manufacturer does not encroach, the manufacturer will maximize profitability by increasing the wholesale price. Consequently, the platform is unable to appeal to consumers by increasing service with the increasing of service cost, resulting in a decline in the market launch volumes for both reselling and agency selling channels. When the manufacturer adopts the encroachment strategy, it can get more revenue by not only increasing the wholesale price but also by increasing direct selling channel's market launch volume. Similarly, the platform is unable to attract consumers by increasing service level and the additional direct selling channel from manufacturer encroachment exacerbates the platform's loss, as shown in Fig. 11.

6. Conclusion

We investigated the interactive effects of manufacturer encroachment on market launch volume decision and profits of supply chain members by considering platform's service level. Specifically, we developed two Stackelberg game models and derived their corresponding equilibrium solutions in the case of manufacturer encroachment and non-encroachment, respectively. Based on numerical experiments, we obtained some interesting results: Firstly, when the manufacturer encroaches, it will increase the wholesale price and the agency selling channel's market launch volume, while the platform will reduce the market launch volume and service level in the reselling channel; besides, manufacturer encroachment tends to favor the manufacturer, but most of time it has detrimental effects on the platform. Secondly, in cases where the manufacturer does not encroach, it prefers reselling channel to compensate for profit losses by increasing wholesale prices, while the platform prefers agency selling channel as high commission rate may bring high profit; when the manufacturer encroaches, the manufacturer consistently favors direct selling channel while the platform typically prefers agency selling channel. Finally, the optimal strategy for the manufacturer is always to encroach and the manufacturer always dominates the market; in cases where the commission rate is high, the manufacturer will shift its focus to non-middleman direct selling channel thereby maximizing profitability, while the platform tilt towards agency selling channel and has more motivation to leverage service effort to improve service level so as to attract consumers to compensate for profit loss; in cases where the inter-channel substitution rate is high, manufacturer encroachment may temporarily benefit the platform thereby achieve mutually beneficial outcome and, however, in most cases, manufacturer encroachment always benefits the manufacturer but is detrimental to the platform; in cases where there is a high service cost elasticity coefficient, the manufacturer might decide to raise the wholesale price in order to obtain profit compensation from reselling channel, however, the platform's ability of enhancing service level to seize the market will be hindered by cost and channel competition, which cannot achieve expected effect so that the platform should appropriately apply service and ask the manufacturer for high commission rate to obtain compensation. Moreover, appropriate commission rates, reasonable service costs, and avoidance of vicious competition among different channels are necessary, which may promote efficient collaboration among members of supply chain and attain mutually beneficial outcome.

In the above discussion, it is posited that the products under consideration are homogeneous and perfectly substitutable. However, this substitutability is usually an important influencing factor and hence the level of substitutability among products is worth investigating. Moreover, the manufacturer and platform's costs are negligible in this study, but the costs may also influence supply chain members' decisions. In addition, this paper merely examines vertical competition between a single manufacturer and a single platform. As a potential for future work, it is necessary to investigate horizontal competition among multiple manufacturers and multiple platforms. Another future work is to study information-sharing behavior among manufacturers and platforms.

Declarations

The authors declare that they do not possess any identifiable conflicting financial interests or personal affiliations that may have potentially influenced the findings presented in this paper.

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Appendix

Table 1
Related notations in propositions

Notation	Definition
M_1	$k(8k^3(4\alpha^3+(\beta+1)(5\beta-7)\alpha^2+(\beta(\beta-3)(2\beta-1)+\beta+2)\alpha+(\beta-1)^2)$ $-4k^2(12\alpha^3(\alpha-1)+(4(\beta+4)(\beta-1)+3)\alpha^2+14(1-\beta)\alpha+\beta^2-1)$ $+2k(2\alpha-1)(\alpha((\alpha-1)(14\alpha-3)-2)+2\beta(3\alpha-1)+1)-(2\alpha-1)^4)$
M_2	$k(2k\beta(\beta+\gamma)+4k\gamma(\alpha-2)+\gamma(3-2\alpha)-\beta)(2k(2-\beta)-2\alpha(2k-1)-1)$ $+(4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2)(2(2k-1)-k(\beta+\gamma))$
M_3	$(2k(2-\beta)-2\alpha(2k-1)-1)(4(2k-1)-k(\beta+\gamma)^2)$ $+(2k\beta(\beta+\gamma)+4k\gamma(\alpha-2)+\gamma(3-2\alpha)-\beta)(2(2k-1)-k(\beta+\gamma))$
M_4	$(4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2)(4(2k-1)-k(\beta+\gamma)^2)$ $-k(2k\beta(\beta+\gamma)+4k\gamma(\alpha-2)+\gamma(3-2\alpha)-\beta)^2$
M_5	${M_2}^2(k(\beta+\gamma)^2-8k+4)+k{M_3}^2(4\alpha^2(1-2k)+4k\alpha(1+2k)+4k\beta(k\beta-1)-8k^2+4k+1)$ $+k{M_4}^2+2kM_2M_3(2k\beta(\beta+\gamma)+2\alpha\gamma(2k-1)+\gamma(3-8k)-\beta)+2M_2M_4(2(2k-1)-k(\beta+\gamma))$ $-2kM_3M_4(2k(\beta-2)+2\alpha(2k-1)+1)$
M_6	$k{M_2}^2(\beta+\gamma)^2+k{M_3}^2(4k\beta(k\beta-1)-4\alpha(2k-1)(2k-\alpha)+1)+k{M_4}^2$ $+2kM_2M_3((2k\beta-1)(\beta+\gamma)-4\alpha\gamma(2k-1))-2kM_2M_4(\beta+\gamma)+2kM_3M_4(4\alpha(2k-1)+1-2k\beta)$
a_1	$\gamma^2(2\alpha(\alpha+\beta)+9(1-\alpha)-4\beta)+2\beta\gamma((1-\alpha)(1-\beta)-\beta)$
a_2	$-(2\gamma^2(1-\alpha)+\alpha\beta^2+\alpha^2(8-\beta)+(2\alpha-1)^2)$
a_3	$\beta^2(5-\alpha)-8(1-\alpha)$
a_4	$4(\alpha-\beta+1)-\beta\gamma(3\alpha-2\alpha^2-2)$
a_5	$(1-k)(2\alpha-1)^2$
b_1	$2k\beta(\beta+\gamma)+4k\gamma(\alpha-2)+\gamma(3-2\alpha)-\beta$
b_2	$2k(2-\beta)-2\alpha(2k-1)-1$
b_3	$4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2$
b_4	$4(2k-1)-k(\beta+\gamma)^2$
b_5	$2(2k-1)-k(\beta+\gamma)$

c_1	$4((\beta+\gamma)^2-8)(2\alpha+\beta^2-2)-(2\beta(\beta+\gamma)+4\gamma(\alpha-2))^2$
c_2	$((\beta+\gamma)^2-8)(4\beta+4(2\alpha+1)(\alpha-1))-16\beta^2-2(\beta+\gamma(2\alpha-3))(2\beta(\beta+\gamma)+4\gamma(\alpha-2))-32(\alpha-1)$
c_3	$((\beta+\gamma)^2-8)(4\alpha(\alpha-1)+1)-16\beta-16(2\alpha+1)(\alpha-1)-(\beta+\gamma(2\alpha-3))^2$
c_4	$16\alpha(1-\alpha)-4$

Proof of Proposition 1: Let $k>1$. The Hessian matrix of the lower-level objective function π_f is

$$\nabla^2\pi_f(s,q_R)=\begin{bmatrix}-k & 1\\ 1 & -2\end{bmatrix},$$

which is obviously a negative definite. Thereby, the platform's profit function π_f is concave in (s,q_R). Given that all the constraints are linear, the model P_f^{-E} is a convex optimization problem. By solving the first-order conditions

$$\frac{\partial\pi_f}{\partial s}=\alpha q_A+q_R-ks=0,\qquad \frac{\partial\pi_f}{\partial q_R}=1+s-w-\alpha\beta q_A-\beta q_A-2q_R=0,$$

we get

$$s^{-E}=\frac{1-w+(2\alpha-\beta(1+\alpha))q_A}{2k-1},\qquad q_R^{-E}=\frac{k-kw+(\alpha-k\beta(1+\alpha))q_A}{2k-1}. \tag{A.1}$$

In order to ensure the constraints $s^{-E}\geq 0$ and $q_R^{-E}\geq 0$, it requires $w\leq 1+(\frac{\alpha}{k}-\beta(1+\alpha))q_A$.

By substituting (A.1) into (1), the model P_m^{-E} becomes

$$\max_{w,\,q_A}\quad \pi_m=\frac{(1-\alpha)((2\alpha+1)(1-\beta)-2k+k\beta^2(1+\alpha))q_A{}^2-(1-2\alpha+2k\alpha\beta)wq_A+k(2-\beta)(1-\alpha)q_A-kw^2+kw}{2k-1}$$

$$\text{s.t.}\quad 0\leq w\leq 1+(\frac{\alpha}{k}-\beta(1+\alpha))q_A,\ \ q_A\geq 0.$$

Since

$$\frac{\partial\pi_m}{\partial w}=\frac{k+(2\alpha-2k\alpha\beta-1)q_A-2kw}{2k-1},\qquad \frac{\partial\pi_m}{\partial q_A}=\frac{k(2-\beta)(1-\alpha)+(2\alpha-2k\alpha\beta-1)w+F_1q_A}{2k-1}, \tag{A.2}$$

the Hessian matrix of the profit function π_m is

$$\nabla^2\pi_m^{-E}=\frac{1}{2k-1}\begin{bmatrix}-2k & 2\alpha-2k\alpha\beta-1\\ 2\alpha-2k\alpha\beta-1 & X_1\end{bmatrix},$$

where $X_1=(2\beta^2(1-\alpha^2)-4(1-\alpha))k+2(2\alpha+1)(1-\alpha)(1-\beta)$. Since $k>1$, we have $\frac{\partial^2\pi_m}{\partial w^2}=\frac{-2k}{2k-1}<0$ and so the above Hessian matrix is negative definite if $-2kX_1-(2\alpha-2k\alpha\beta-1)^2>0$, which is equivalent to

$$4k^2(2-2\alpha-\beta^2)+k(4\alpha^2+4\beta-5)+k(2\alpha-1)^2-(2\alpha-1)^2>0.$$

To ensure this condition, we divide it into two inequalities

$$4k^2(2-2\alpha-\beta^2)+k(4\alpha^2+4\beta-5)>0 \text{ and } (k-1)(2\alpha-1)^2>0.$$

Since $\alpha\in[0,0.3]$ and $k>1$ by the assumption, the above inequalities hold. Then, the platform's profit function π_m is jointly concave in (w,q_A). Given that all the constraints are linear, the model P_m^{-E} is a convex optimization problem. Solving the equations (A.2) yields

$$w^{-E}=\frac{k(1-\alpha)(2\alpha\beta(1-2k)+2k(2-\beta^2)+3\beta-4)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2},\qquad q_A^{-E}=\frac{k(2k-1)(1-2\alpha)+2k^2(1-\beta)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}. \tag{A.3}$$

We next show that the constraints $0 \le w^{-E} \le 1+(\frac{\alpha}{k}-\beta(1+\alpha))q_A^{-E}$ and $q_A^{-E} \ge 0$ are satisfied.

(i) According to the domain of parameters, the function $g_1(\beta)=4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2>0$ if and only if $\beta_1<\beta<\beta_2$, where

$$\beta_1=\frac{1-2\sqrt{(2k-1)(1-\alpha)(k-\alpha)}}{2k}, \quad \beta_2=\frac{1+2\sqrt{(2k-1)(1-\alpha)(k-\alpha)}}{2k}.$$

Since $\alpha\in[0,0.3]$ and $k>1$, $1-2k+2\sqrt{(2k-1)(1-\alpha)(k-\alpha)}>0$ always holds and hence

$$\beta_2-1=\frac{1-2k+2\sqrt{(2k-1)(1-\alpha)(k-\alpha)}}{2k}>0.$$

Therefore, we always have $\beta_1<0\le\beta\le1<\beta_2$ and hence $4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2>0$. This means that $q_A^{-E}\ge 0$.

(ii) To prove $0 \le w^{-E} \le 1+(\frac{\alpha}{k}-\beta(1+\alpha))q_A^{-E}$, we can simplify it to show

$$\begin{cases}2\alpha\beta(1-2k)+2k(2-\beta^2)+3\beta-4\ge 0,\\(2k-1)(1-\alpha)(2\alpha-2k(1-\beta)-1)\le 0.\end{cases}$$

Firstly, we have $2\alpha\beta(1-2k)+2k(2-\beta^2)+3\beta-4\ge 0$ if $\alpha\le\frac{2k(2-\beta^2)-4+3\beta}{2\beta(2k-1)}$. Since $\alpha\in[0,0.3]$ and $k>1$, we get

$$\frac{2k(2-\beta^2)-4+3\beta}{2\beta(2k-1)}-0.3=\frac{k(10-3\beta-5\beta^2)+9\beta-10}{2\beta(2k-1)}>0.$$

This means that we always have $2\alpha\beta(1-2k)+2k(2-\beta^2)+3\beta-4>0$. Secondly, we have $(2k-1)(1-\alpha)(2\alpha-2k(1-\beta)-1)\le 0$ if $k\ge\frac{2\alpha-1}{2(1-\beta)}$, which is always true due to $\alpha\in[0,0.3]$ and $k>1$.

Based on the above analysis, the constraints are both satisfied and hence w^{-E}, q_A^{-E} are optimal solutions to the model P_m^{-E}.

Substituting (A.3) into (A.1), we have

$$s^{-E}=\frac{2k((1+2\alpha)(1-\alpha)-\beta)+(2\alpha-1)^2}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}, \qquad q_R^{-E}=\frac{k(1-\alpha)((1-2\alpha)+2k(1-\beta))}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}. \tag{A.4}$$

Substituting (A.3) and (A.4) to (1) and (2), we get

$$\pi_m^{-E}=\frac{k^2(1-\alpha)(3-2\alpha-2\beta)}{4(2k-1)(1-\alpha)(k-\alpha)-(2k\beta-1)^2}, \qquad \pi_f^{-E}=\frac{M_1}{2(4(2k-1)(1-\alpha)(\alpha-k)+(2k\beta-1)^2)^2},$$

where M_1 is defined in Table 1. This completes the proof.

Proof of Proposition 3: Let $k>1$. The Hessian matrix of the profit function π_f is

$$\nabla^2\pi_f=\begin{bmatrix}-k & 1\\ 1 & -2\end{bmatrix},$$

which is negative definite. Hence, the platform's profit function π_f is jointly concave in (s,q_R). Given that all the constraints are linear, the model P_f^E is a convex optimization problem. By solving the first-order conditions

$$\frac{\partial\pi_f}{\partial s}=\alpha q_A+q_R-ks=0, \qquad \frac{\partial\pi_f}{\partial q_R}=1+s-w-\alpha\beta q_A-\beta q_A-2q_R-\gamma q_D=0,$$

we get

$$s^E=\frac{1-w+(2\alpha-\beta(1+\alpha))q_A-\gamma q_D}{2k-1}, \qquad q_R^E=\frac{k-kw-k\gamma q_D+(\alpha-k\beta(1+\alpha))q_A}{2k-1}. \tag{A.5}$$

Substituting (A.5) into (3) and taking the constraints into consideration, we can convert the model P_m^E into $P_m^{E'}$

$$\max_{w,q_A,q_D} \quad \pi_m = \frac{1}{2k-1}((1-\alpha)((2\alpha+1)(1-\beta)+k\beta^2(1+\alpha)-2k)q_A{}^2+(k\beta\gamma-2k+1)q_D{}^2-kw^2$$
$$-(1-\alpha)(k\beta-2k)q_A+(2k-k\beta-1)q_D+kw+(2\alpha-2k\alpha\beta-1)wq_A+(k\beta-k\gamma)wq_D$$
$$+(\gamma-\alpha\beta+k(2\gamma(\alpha-2)+\beta\gamma(1-\alpha)+\beta^2(1+\alpha)))q_Aq_D)$$
$$\text{s.t.} \quad 0\le w\le 1-\gamma q_D+(\frac{\alpha}{k}-\beta(1+\alpha))q_A,\ q_A\ge 0,\ q_D\ge 0.$$

The first-order conditions of the objective function π_m with respect to $\{w, q_A, q_D\}$ are

$$\frac{\partial\pi_m}{\partial w}=\frac{k+(2\alpha-2k\alpha\beta-1)q_A-2kw+k(\beta-\gamma)q_D}{2k-1},$$
$$\frac{\partial\pi_m}{\partial q_A}=\frac{k(2-\beta)(1-\alpha)+(2\alpha-2k\alpha\beta-1)w+X_1q_A+X_2q_D}{2k-1}, \qquad \text{(A.6)}$$
$$\frac{\partial\pi_m}{\partial q_D}=\frac{2k-k\beta-1+k(\beta-\gamma)w+X_2q_A+2(1-2k+k\beta\gamma)q_D}{2k-1}.$$

Then, the Hessian matrix of the profit function of π_m is

$$\nabla^2\pi_m^E=\frac{1}{2k-1}\begin{bmatrix} -2k & 2\alpha-2k\alpha\beta-1 & k\beta-k\gamma \\ 2\alpha-2k\alpha\beta-1 & X_1 & X_2 \\ k\beta-k\gamma & X_2 & 2-4k+2k\beta\gamma \end{bmatrix},$$

where $X_2=k\beta(\beta(1+\alpha)+\gamma(1-\alpha))-2k\gamma(2-\alpha)-\alpha\beta+\gamma$. It is easy to see that the above Hessian matrix is negative definite if

$$\begin{cases} \dfrac{-2k}{2k-1}<0, \qquad \dfrac{-2kX_1-(2\alpha-2k\alpha\beta-1)^2}{(2k-1)^2}>0, \\ (-2k((2-4k+2k\beta\gamma)X_1-X_2{}^2)-(2\alpha-2k\alpha\beta-1)((2\alpha-2k\alpha\beta-1)(2-4k+2k\beta\gamma)-(k\beta-k\gamma)X_2) \\ +(k\beta-k\gamma)((2\alpha-2k\alpha\beta-1)X_2-(k\beta-k\gamma)X_1))/(2k-1)^3<0. \end{cases}$$

Since $k>1$, we can easily get the first two inequalities from the proof of Proposition 1. We next show the last inequality, which is equivalent to

$$k^2(\gamma^2(2\alpha(\alpha+\beta)+9(1-\alpha)-4\beta)+2\beta\gamma((1-\alpha)(1-\beta)-\beta)+\beta^2(5-\alpha)-8(1-\alpha))$$
$$+k(2\gamma^2(1-\alpha)+\beta\gamma(3\alpha-2\alpha^2-2)+\alpha\beta^2+\alpha^2(8-\beta)-4(\alpha-\beta+1))+(2\alpha-1)^2<0.$$

In fact, by letting $Z_1(k)=(a_1+a_3)k^2-(a_2+a_4)k+a_5$, where a_1, a_2, a_3, a_4, a_5 are defined in Table 1, we have $a_1<0$, $a_2<0$, $a_3<0$, $a_4>0$ and $a_5<0$ from the assumptions $\alpha\in[0,0.3]$, $\beta\in[0,1]$, $\gamma\in[0,\gamma_1)$ immediately, where $\gamma_1=\dfrac{2\beta(\beta-(1-\alpha)(1-\beta))}{2\alpha(\alpha+\beta)+9(1-\alpha)-4\beta}$. This implies $Z_1(k)<0$ when $k>\dfrac{a_2}{a_1}>0$.

Thus, the platform's profit function π_m is jointly concave in (w,q_A,q_D) when $\gamma\in[0,\gamma_1)$ and $k>\max\{1,\dfrac{a_2}{a_1}\}$. Then, solving the equations (A.6) yields

$$w^E=\frac{M_4+M_3(2\alpha-2k\alpha\beta-1)+M_2(\beta-\gamma)}{2M_4}, \qquad q_A^E=\frac{kM_3}{M_4}, \qquad q_D^E=\frac{M_2}{M_4}, \qquad \text{(A.7)}$$

where M_2, M_3, M_4 are defined in Table 1. In order to ensure the constraints

$$0\le w^E\le 1-\gamma q_D^E+(\frac{\alpha}{k}-\beta(1+\alpha))q_A^E, \qquad q_A^E\ge 0,$$

it requires

$$M_2=kb_1b_2+b_3b_4\ge 0, \qquad M_3=b_1b_5+b_2b_4\ge 0,$$
$$M_4=k^2(c_1k-c_2)+c_3k-c_4\ge 0,$$
$$Z_2(\gamma,\alpha)=M_4+M_3(2\alpha-2k\alpha\beta-1)+M_2(\beta-\gamma)\ge 0,$$
$$Z_3(\gamma,\alpha)=M_4+M_3(1-2k\beta)-M_2(\beta+\gamma)\ge 0,$$

where $b_1,b_2,b_3,b_4,b_5,c_1,c_2,c_3,c_4$ are defined in Table 1.

(i) When $\alpha \in [0, 0.3]$, $\beta \in [0,1]$, $\gamma \in [0, \gamma_1)$ and $k > \max\{1, \frac{a_2}{a_1}\}$, we have $b_1 > 0, b_2 > 0, b_3 > 0, b_4 > 0, b_5 > 0$, which implies $M_2, M_3 > 0$.

(ii) When $\alpha \in [0, \min\{0.3, \alpha_1\}]$, $\beta \in [0,1]$, $\gamma \in [0, \gamma_1)$ and $k > \max\{1, \frac{a_2}{a_1}\}$, we have $c_1 > 0$, $c_2 < 0$, $c_3 > 0$, $c_4 > 0$, where $\alpha_1 = \frac{5\beta^2 + 2\beta\gamma + \gamma^2 - 8}{(\beta+\gamma)^2 - 8}$. This implies $M_4 > 0$.

(iii) Since $\frac{\partial Z_2}{\partial \alpha} < 0$, $Z_2(\gamma, \alpha)$ is decreasing in α and hence $Z_2(\gamma, \alpha) \geq Z_2(\gamma, 0.3)$. Since $\frac{\partial Z_2(\gamma, 0.3)}{\partial \gamma} < 0$, $Z_2(\gamma, 0.3)$ is decreasing in γ. By substituting $\alpha = 0.3$ and $\gamma = \gamma_1$ into $Z_2(\gamma, \alpha)$, it is easy to get $Z_2(\gamma_1, 0.3) > 0$ and hence $Z_2(\gamma, \alpha) > 0$. Similarly, we can show that $Z_3(\gamma, \alpha)$ is decreasing in α, γ and then $Z_3(\gamma, \alpha) \geq Z_2(\gamma, 0.3) \geq Z_3(\gamma_1, 0.3) > 0$.

Based on the above analysis, w^E and q_A^E are optimal solutions to the model $\mathrm{P}_m^{\mathrm{E}}$. Substituting (A.7) into (A.5), we have

$$s^E = \frac{M_4 - M_3(2\alpha - 4k\alpha + 2k\beta - 1) - M_2(\beta+\gamma)}{2M_4(2k-1)}, \qquad q_R^E = \frac{kM_4 + kM_3(1 - 2k\beta) - kM_2(\beta+\gamma)}{2M_4(2k-1)}. \tag{A.8}$$

Substituting (A.7)-(A.8) to (3)-(4), we get

$$\pi_m^E = \frac{M_5}{4{M_4}^2(2k-1)}, \qquad \pi_f^E = \frac{M_6}{8{M_4}^2(2k-1)},$$

where M_5, M_6 are defined in Table 1. This completes the proof.