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PLATFORM INFORMATION SHARING DECISIONS CONSIDERING SUPPLIER DELIVERY SERVICES AND ENCROACHMENT STRATEGIES

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Abstract. The platform often has private information about uncertain demand and determines whether to share the information with the supplier. And the supplier's choice of delivery services and encroachment may depend on the platform's information sharing policy. This paper examines the two-dimensional information sharing strategies in a supply chain where the supplier provides delivery services. Based on the game theory model, we find that when the platform shares unfavorable information, the motivation for the supplier's encroachment decreases firstly. Encroachment does not reduce the level of delivery service from the supplier. Second, delivery services levels of supplier increase with channel substitution rate. Although platform sharing information lowers profits in a supply chain where the supplier provides delivery services, the platform can share information on behalf of delivery services improvement under certain conditions interestingly. Previous papers that ignore a supplier's decision on delivery services may have underestimated the scope for platform profitable information sharing. Third, the equilibrium profits of supply chain entities present non-monotonous with respect to encroachment cost. The platform often faces a tradeoff. Sharing information, on the one hand, enables the supplier to gain a better understanding of the impact on demand and encourages enhancements to delivery services, which is advantageous to the platform. However, sharing information allows the supplier to absorb the impact of demand information by making modifications to the wholesale price and delivery services, which benefits the supplier but hurts the platform. This makes the negative effects of double marginalization worse.

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1. Introduction

With the rapid growth of e-commerce field in recent years, we have seen the emergence of many sales formats. Most popular sales format is the supplier selling products through an e-commerce platform [2,10]. For example, we are familiar with eBay, Amazon, Alibaba and JD.com platforms. Even some suppliers and platforms appear new cooperation patterns, such as the platform is responsible for selling products, the supplier is responsible for delivery of products to consumers. For example, Sufresh sells some products online. It uses cold-chain logistics for transporting some products throughout upstream suppliers[1]. In addition, some suppliers tend to create

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[1] https://www.sdongpo.com/xueyuan/c-29306.html.

their own sales channels rather than just selling through a single channel. This behavior is defined as supplier encroachment. For example, both Huawei and Apple have established their own directly sales channels. P&G sells through both direct and retail channels in other markets such as in the United States and in India [17]. Supplier encroachment actions often generate additional revenue [22]. Supplier infiltration can occasionally be advantageous for supply chains [3].

In practice, there exists some uncertainty about market sales. The supply chain is frequently designed in an uncertain atmosphere [14, 25]. In 2023, Amazon and its sellers earned $700 billion in merchandise revenue. The GMV is more than doubled in four years. Yet it is only $335 billion in 2019[2]. We can see that market demand may high or low. A good economic environment tends to produce high market demand, while a poor economic environment sometimes results in low market demand. And there remains some volatility even with high(low) market demand [5]. For example, political factors as well as supply chain disruptions [19]. But the platform will have access to a lot of data information about the market demand because it is closer to the consumers [29]. And now the fast-developing Internet technologies also make this thinking can be easily realized. About 9% of Americans have purchased from TEMU in the past year, making it one of the most popular apps in the United States[3]. On June 18, 2023, new users with first purchase of JD increased by 30% YoY[4].

In an e-commerce supply chain, the platform has the right to decide whether to share demand data with the supplier. The platform faces a tradeoff. Sharing information, on the one hand, enables the supplier to gain a better understanding of the impact on demand and encourages enhancements to delivery services, which is advantageous to the platform. However, sharing information allows the supplier to absorb the impact of demand information by making modifications to the wholesale price and delivery services, which benefits the supplier but hurts the platform. This makes the negative effects of double marginalization worse. Similarly, suppliers at an information disadvantage have also taken actions (*e.g.*, encroachment, delivery service and pricing) to reverse this situation. Even if they come at some cost (*e.g.*, supplier's encroachment incurs a cost), suppliers will consider implementing them. Significantly, the platform's information-sharing decisions will directly interfere the supplier's decisions (*e.g.*, encroachment, as well as the quality of delivery services).

Motivated by the above, we innovatively portray two-dimensional market demand signal updating in the supply chain system of supplier delivery services. The market demand signal updating includes two parts respectively: the basic market size signal updating and the uncertain part signal updating. We combine both high and low demand performances and their uncertainty component. A salient feature of our topic is that the supplier's choice of delivery services and encroachment may depend on the platform's information sharing policy. Therefore, it is unclear if information sharing can successfully motivate the provider to exert effort in delivery services. In our research, we study the information sharing problem considering supplier delivery services and encroachment. We consider two scenarios in which platform can share or not share demand information. We attempt to interpret the following issues: how do information sharing strategies on the platform modify the service levels of suppliers when upstream delivery services are used in supply chain system? How do the supplier's encroaching actions and delivery services affect the platform's information sharing decisions? Can the supplier counterbalance its weakness in market demand information with the help of encroachment and delivery services? Based on our findings, we find the following important and interesting conclusions: (1) The platform's information sharing tactics have an impact on the degree of service delivery and encroachment motivation of the supplier. Because the information shared by the platform is negative, there is less incentive for the supplier to encroach. (2) Delivery services levels of supplier increase with channel substitution rate. Surprisingly in a supply chain where the supplier offers delivery services, it appears that information sharing of platform reduces profits. However, in certain situations, the platform might be obtainable sharing information to improve the customer's delivery services experience. (3) The equilibrium profits of supply chain entities present non-monotonous with respect to encroachment cost. Compared with [9], they did not find an effect of information sharing on upstream delivery services. Our findings differ from theirs. Previous papers that did not consider a supplier's decision on

[2]https://mp.weixin.qq.com/s/MgFLEbm_1JO52oLE2RoiyQ.

[3]https://baijiahao.baidu.com/s?id=1784324759937015562&wfr=spider&for=pc.

[4]https://www.163.com/dy/article/IP5AN2RQ05562BAQ.html.

delivery services may have underestimated the scope for platform profitable information sharing. However, the information sharing decision of [16] since it does not consider the threat of encroachment from suppliers. This may overestimate the likelihood of platform information sharing. Our research extends the literature on platform information sharing by considering supplier delivery services.

The structure of the paper is as follows. We review the relevant research in the following section, and in Section 3, we present the mathematical model. The best equilibrium solutions for the manufacturer's encroachment in the absence of information sharing are covered in Section 4. The best equilibrium results under information sharing are shown in Section 5. In Section 6, we next examine the effects of information sharing on delivery services and the requirements for sharing demand information. We conclude with some remarks in Section 7.

2. Literature review

Our paper is most related to the literature on three streams of literature. The first relevant stream of literature is about information sharing. Most studies focus on vertical *information sharing*. For example, Guan *et al.* [4] investigate information sharing under competing environment. They demonstrate how manufacturers can respond to demand by adjusting their wholesale prices and service levels through information sharing. But they didn't consider the impact of the encroachment. Information sharing is expanded upon by Mehrjerdi and Shafiee [18] to create a robust closed-loop supply chain. They discover that in order to build a more flexible supply chain, information sharing and a variety of sourcing techniques have been used. Huang *et al.* [11] studied retailer information sharing strategies in a closed-loop supply chain. The retailer has private information about market demand information. Our study considers the impact of suppliers providing delivery services. Yang *et al.* [27] incorporate demand uncertainty into the information sharing model. The findings indicate that e-retailers are only willing to share information if the manufacturer's after-sales service is highly efficient in terms of investment. Zha *et al.* [28] focus on platform information sharing. Zhao *et al.* [33] talk about information acquisition and sharing of an online platform based on Bertrand competition model. Zhang *et al.* [32] study the information sharing problem of online travel platform in a tourism supply chain where competition exists. Although the above studies considered the effect of competition, they did not think about the endogeneity of the encroachment decision. There are also some papers exploring horizontal information sharing. Ha *et al.* [6] examine audit information sharing problem. Each manufacturer decides whether to share supplier audit information. In contrast to their study, we concentrate on the sharing of research horizontal information. In addition, scholars explore horizontal and vertical information sharing. Jiang and Hao [13] investigate retailers who can exchange signals (horizontal information sharing) and have access to demand signals. In order to grant retailers access to their signals, suppliers may offer them differentiating payments (vertical information acquisition). Based on this, Wu *et al.* [24] consider the impact of blockchain in platform information sharing. We will find that the above studies of information sharing have not focused on supplier encroachment and the impact of delivery services. We focus on the impact of information sharing under encroachment threat on the equilibrium outcomes of the system.

The second relevant stream of literature is about supplier encroachment. Researchers Huang *et al.* [9] and Wang and Zhuo [23] examine how retailers come up with creative ways to share demand data with suppliers when they fear supplier encroachment. Based on Huang *et al.* [9], Ha *et al.* [5] and Zhang and Zhang [30] combine encroachment with channel structure issues. And Tang *et al.* [22] consider two encroachment formats (*e.g.*, agency encroachment and direct encroachment). They find that the e-tailer has no incentive to share information under no encroachment and direct encroachment. The mode of encroachment is not the focus of this paper. We explore more the changes in supplier pricing as well as delivery services under the threat of encroachment. Some scholars have also focused on the impact of encroachment on contract choice problems. Yang *et al.* [26] examine how revenue-sharing and wholesale price contracts prevent suppliers from encroaching with substandard substitutes. In a supply chain, Zhang *et al.* [31] examine the decisions made by a retailer to introduce their store brand and a manufacturer to encroach. We're just focusing on the system under the platform's wholesale price contract. This is different from the literature described above. Our study employs a framework that is comparable to Huang *et al* [9]. This paper, however, adopts a different stance and focuses on retailer information sharing tactics considering the potential for supplier delivery services and encroachment.

The third relevant stream of literature is about services in the supply chain. In their development of a service competition model, Hall and Porteus [7] take a look at a scenario where the firm's service delivery system is unable to provide adequate customer service. But they did not consider the impact of information sharing. He *et al.* [8] examine the supply chain of an e-commerce platform, which comprises a manufacturer, an e-commerce platform, and a potential third-party logistics service provider. Their goal is to investigate the effects of the encroachment and the logistical integration of the platform. In contrast to their study, we consider suppliers providing delivery services to platforms rather than third-party providing services. Guan *et al.* [4] investigate the benefits of information sharing and look at how it affects decisions about price and services. They did not include the impact of encroachment threats on information sharing outcomes. In order to analyze the best choices in a dual-channel supply chain, Chen *et al.* [1] present an analytical framework with a focus on retail service, manufacturer-direct service, and quality effort. Two strategies for providing warranty services are studied by Huang *et al.* [11]. They demonstrate that, in equilibrium, service costs, product reliability, and the intensity of competition do not lead to a nonmonotonic profit for either manufacturer. However, we find that competition (*i.e.*, encroachment) may lead to profit non-monotonicity of supplier. According to Li *et al.* [15], the retailer makes investments in offline service initiatives while also providing online coupons. They discover that a high price, service effort, and retailer profit are all correlated with a high service effort coefficient. Using an empirical approach, Paul *et al.* [20] show that service-reward mechanism may affect upstream ordering strategies. Most of the above studies have focused on exploring service levels. Although the impact of the competitive environment has also been considered, it does not endogenize competition.

The research mentioned above are primarily concerned with the effects of information sharing on equilibrium decisions. The supplier delivery service is not fully covered by these studies. As a result, we examine information exchange in this kind of supply chain and the effects it has on decisions about encroachment and delivery services. Furthermore, we provide a more thorough description of market demand, accounting for the underlying market's volatility and unpredictability. We explore the platform's information sharing strategy under the threat of supplier encroachment and the level of supplier delivery services.

3. Model

We take into consideration a supplier (he) who uses a retail platform (she) to sell goods to customers. The supplier might also be motivated to create a direct sales channel in order to sell the product, and this encroachment influences the conventional channel platform's behaviors. We assume that there exist both high and low market sizes a_i, *i.e.*, $i \in \{H, L\}$. For example, Amazon and its sellers earned \$700 billion in merchandise revenue in 2023. Yet it is only \$335 billion in 2019. In addition, product market demand is often associated with a certain uncertainty θ, which is assumed to obey a uniform distribution, *i.e.*, $\theta \sim U[0, 2d]$ [9]. In recent years, in order to improve the efficiency of supply chain delivery, some supply chains have realized the operation model where the platform is responsible for the sales segment and the supplier provides the delivery service [16]. We use s to denote the supplier delivery service. As a result, there is a certain delivery cost $s^2/2$ accordingly. Therefore, when the supplier does not encroach, the market demand function can be expressed as $q_R(p_R) = a_i + \theta + \gamma - p_R$, where γ is the sensitivity of the market demand to the delivery service. The larger γ is, the more consumers prefer efficient delivery services. On the contrary, consumers pay little attention to delivery services. And when the supplier encroaches, the market demand function can be expressed as $q_R(p_R, p_S) = a_i + \theta + \gamma - p_R + bp_S$ and $q_S(p_R, p_S) = a_i + \theta + \gamma - p_S + bp_R$, where b denotes the channel substitution rate. In order to fit with the real supply chain, we assume that supplier's encroachment incurs a certain cost I. For example, suppliers need to pay a certain amount of rent to open a direct store. This can be interpreted as an encroachment cost for the supplier. w denotes the wholesale price [21].

When the selling period approaches, the platform will be the first to observe accurate market demand information, which contains both a_i and θ components. The platform will possess certain informational advantages over

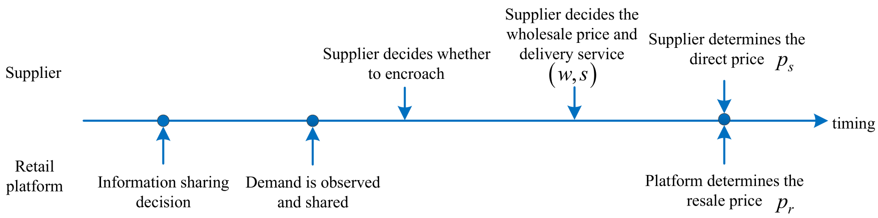


FIGURE 1. Game timing.

the upstream supplier, and it retains the autonomy to determine whether or not to provide information to the supplier. Assuming that the market size satisfies $Pr(a_H) = Pr(a_L) = 1/2$, and to simplify the computation, the following relationship $a_H > a_L = 1$ is satisfied. Considering that the market demand signal $Y \in \{h, l\}$ observed by the platform may have certain inaccuracy, we assume that $Pr(h|a_H) = Pr(l|a_L) = \rho$, where $\rho \in (1/2, 1]$. ρ can indicate the accuracy of the signal. This setup follows the study of Liu *et al.* [16]. By Bayesian updating, we can derive that the platform obtains accurate market size information as, $\hat{H} = E[a_i|h] = 1 + (H-1)\rho$ and $\hat{L} = E[a_i|l] = H - (H-1)\rho$. If the platform shares the private information with the supplier, the market size information of the supplier and the platform is updated as $a_H = \hat{H}$ and $a_L = \hat{L}$. Otherwise, the market size information is $a_i = \bar{a} = (H+1)/2$. We suppose that the market demand uncertainty is $E(\theta) = d$.

Game timing. We use backward induction to solve the problem based on game theory. Before seeing precise demand data, the platform makes a decision in the first stage regarding whether or not to exchange information with the supplier. The supplier can only possess the demand's expected value if the platform privately holds the accurate demand information. The precise demand information will also be available to the supplier if the platform shares it. As the selling season draws near, the platform gathers and analyzes demand data in private, sharing (retaining) it with the supplier in accordance with the first stage's information sharing plan. Following the acquisition (or non-acquisition) of demand data, the supplier decides whether to encroach and sets wholesale prices and service decisions (w, s). The supplier and platform establish a price competition in the last stage, wherein the supplier sets the price of the product p_R and the platform sets the price of the encroaching channel product p_S, respectively. The game timing is shown in Figure 1. We use the terms "NN", "NE", "SN" and "SE". They are used to denote the four scenarios of platform information not shared and supplier does not encroach, platform information not shared and supplier encroaches, platform information shared and supplier does not encroach, and platform information shared and supplier encroaches, respectively. In addition, "P" is used to indicate partial intrusion scenarios.

4. No information sharing

In this section, we first discuss the system equilibrium results under no encroachment and encroachment by the supplier when the platform has no information sharing. Then we endogenously analyze optimal delivery service and encroachment decisions of upstream supplier in presence of information opacity.

4.1. No encroachment

We first analyze the upstream supplier does not encroach. There is information asymmetry between the platform and the supplier. The information-advantaged side is the platform, and the information-disadvantaged side is the supplier. The circumstance in which the supplier does not encroach and the platform does not exchange information is indicated by the superscript "NN". The payoff function of the platform is provided by

$$\Pi_R^{\mathrm{NN}}(p_R) = (p_R - w)(a_i + \theta + \gamma_s - p_R), a_i \in \{\hat{H}, \hat{L}\}. \tag{1}$$

Our platform's optimal prices are functions of wholesale prices, as determined by the first-order conditions. The platform's optimal price is

$$p_R(w,s)=\frac{1}{2}(a_i+w+s\gamma+\theta). \tag{2}$$

Then since the supplier does not have access to accurate demand information, He is restricted to deciding based on expectations beliefs. So, the supplier's payoff function is provided by

$$\Pi_S^{\mathrm{NN}}(w,s)=E_{\{a_i,\theta\}}\left[w(a_i+\theta+\gamma s-p_R)-\frac{1}{2}s^2\right] \tag{3}$$

where $E(a_i)=\bar{a}=(H+1)/2$, $E(\theta)=d$. The optimal wholesale price, delivery service and resale price are

$$w^{\mathrm{NN}^*}=\frac{2(d+\bar{a})}{4-\gamma^2}=\frac{1+2d+H}{4-\gamma^2}, s^{\mathrm{NN}^*}=\frac{\gamma(d+\bar{a})}{4-\gamma^2}=\frac{(1+2d+H)\gamma}{8-2\gamma^2} \tag{4}$$

$$p_R^{\mathrm{NN}^*}=\frac{1}{2}\left(a_i+\theta+\frac{(1+2d+H)\gamma^2}{8-2\gamma^2}+\frac{1+2d+H}{4-\gamma^2}\right). \tag{5}$$

For the platform and supplier, the optimal expected payoffs are

$$\Pi_R^{\mathrm{NN}^*}=\frac{\begin{pmatrix}(3\hat{H}^2(\gamma^2-4)^2-12\hat{H}d(\gamma^2-4)+d^2(28-8\gamma^2+\gamma^4)+3(\gamma^2-2)\bar{a}(4d-2\hat{H}(\gamma^2-4)+(\gamma^2-2)\bar{a})\\+3\hat{L}^2(\gamma^2-4)^2-12\hat{L}d(\gamma^2-4)+d^2(28-8\gamma^2+\gamma^4)+3(\gamma^2-2)\bar{a}(4d-2\hat{L}(\gamma^2-4)+(\gamma^2-2)\bar{a}))\end{pmatrix}}{24(\gamma^2-4)^2} \tag{6}$$

$$\Pi_S^{\mathrm{NN}^*}=\frac{(1+2d+H)^2}{8(4-\gamma^2))}. \tag{7}$$

4.2. Encroachment

Next, we analyze the upstream supplier encroaches. The demand functions are $q_R(p_R,p_S)=a_i+\theta+\gamma-p_R+bp_S$ and $q_S(p_R,p_S)=a_i+\theta+\gamma-p_S+bp_R$. In contrast to Section 4.1, the supply chain model has a competitive consideration. The supplier incurs certain costs because of the encroachment. We employ "NE" to indicate the situation where the platform does not share information and the supplier encroaches. The payoff functions of platform and supplier are given by

$$\Pi_R^{\mathrm{NE}}(p_R)=(p_R-w)(a_i+\theta+\gamma-p_R+bp_S), a_i\in\{\hat{H},\hat{L}\} \tag{8}$$

$$\Pi_S^{\mathrm{NE}}(p_S,w,s)=E_{\{a_i,\theta\}}\left[p_S(a_i+\theta+\gamma-p_S+bp_R)+w(a_i+\theta+\gamma-p_R+bp_S)-\frac{1}{2}s^2\right]-I. \tag{9}$$

The product prices for the two channels can be obtained by associating equations (8) and (9).

$$p_R(w,s)=\frac{2a_i+bd+(2+b^2)w+(2+b)s\gamma+2\theta+b\bar{a}}{4-b^2} \tag{10}$$

$$p_S(w,s)=\frac{(2+b)d+3bw+(2+b)(s\gamma+\bar{a})}{4-b^2}. \tag{11}$$

The optimal wholesale price and delivery service are

$$\begin{cases}w^{\mathrm{NE}^*}=\frac{(8+b^3)(d+\bar{a})}{b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4)},\\ s^{\mathrm{NE}^*}=\frac{\gamma(12+4b+b^2+b^3)(d+\bar{a})}{b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4)}.\end{cases} \tag{12}$$

We simplify the formula expression by presenting χ_0, χ_1 and χ_2. The optimal expected payoffs of the platform and supplier are

$$\Pi_R^{\mathrm{NE}^*} = \frac{\begin{pmatrix} 2\begin{pmatrix} (3\hat{H}^2\chi_0^2 + d^2\chi_1 - 6\hat{H}(8-8b+2b^2-2b^3-b^4+b^5)d\chi_0 - \\ 6\chi_2((8b-8-2b^2+2b^3+b^4-b^5)d+\hat{H}\chi_0)\bar{a}+3\chi_2^2\bar{a}^2) \end{pmatrix} \\ +2\begin{pmatrix} (3\hat{L}^2\chi_0^2 + d^2\chi_1 - 6\hat{L}(8-8b+2b^2-2b^3-b^4+b^5)d\chi_0 - \\ 6\chi_2((8b-8-2b^2+2b^3+b^4-b^5)d+\hat{L}\chi_0)\bar{a}+3\chi_2^2\bar{a}^2 \end{pmatrix} \end{pmatrix}}{3(b^2-4)^2\chi_0^2} \tag{13}$$

$$\Pi_S^{\mathrm{NE}^*} = \frac{(2+b)(b-6-b^2)(d+\bar{a})^2}{2(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4)} - I \tag{14}$$

where $\chi_0 = b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4)$,
$\chi_2 = b^5 - 8 - b^4 + 12\gamma^2 + (b^2+b^3)\gamma^2 + 4b(2+\gamma^2)$,

$$\chi_1 = \begin{pmatrix} ((24b^7 - 9b^8 - 6b^9 + 3b^10 + 2b^5(32+\gamma^4) + 32b^3(\gamma^2+\gamma^4-10) \\ +b^6(4\gamma^2+\gamma^4-44) + 32b(8\gamma^2+3\gamma^4-28) + 8b^2(76+6\gamma^2+5\gamma^4)) \\ +16(28-24\gamma^2+9\gamma^4) + b^4(128+44\gamma^2+9\gamma^4)) \end{pmatrix}.$$

For analytical purposes, we define the function

$$\Psi(\theta, a_i) = \frac{(16+16b+b^2+3b^3)[(\theta+a_i)]^2}{\gamma^2-4)(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4)}. \tag{15}$$

Proposition 1 illustrates the best encroachment choice made by the supplier.

Proposition 1. *No information sharing, the supplier will encroach if* $I \leq \Psi(d, \bar{a})$. *Otherwise, the supplier will not encroach, where*

$$\Psi(d, \bar{a}) = \frac{(16+16b+b^2+3b^3)[(d+\bar{a})]^2}{\gamma^2-4)(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4)}.$$

$\Psi(d, \bar{a})$ *is strictly increasing in* γ *and* H.

Proposition 1 suggests that the supplier will want to earn higher profits through encroachment only if the cost of encroachment is less than a threshold (*i.e.*, $I \leq \Psi(d, \bar{a})$). In other words, the supplier is motivated to encroach when the positive effect of expanding market demand through encroachment is higher than the cost of encroachment incurred by the supplier. This result conforms to standard intuition. In this scenario, there is only one threshold between encroachment and no-encroachment for the supplier, regardless of whether the signal is high or low. This is because the platform does not share the accurate signal, and the supplier can only depend on the expectation of market size $\bar{a}$ and the expectation of uncertainty d. Furthermore, Figure 2 illustrates that the threshold increases with market size H. The incentive to encroach decreases as the market size increases. In addition, if demand is more dependent on how the delivery service responds γ, the supplier's encroachment threshold will be higher. This is because the supplier can improve the market demand only through enhancing the delivery service s^* without incurring more encroachment costs to achieve the same objective.

5. Information sharing

Based on above section, we explore the system equilibrium results under *no encroachment* and *encroachment* by the supplier in the case where the platform shares information. In this scenario, the supplier has the same demand information as the platform. Changes in the state of demand information have an impact on the equilibrium outcomes.

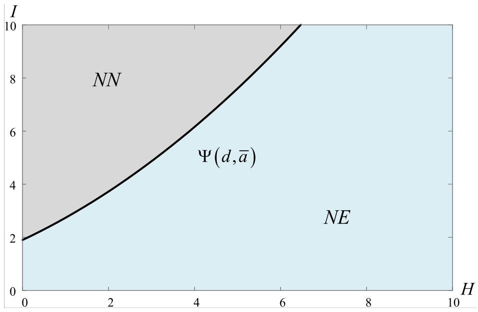


FIGURE 2. No information sharing-encroachment decisions.

5.1. No encroachment

Similar to Section 4.1, but with the difference that information about demand will be provided by the platform with upstream supplier. We employ "SN" to denote this case. The platform's payoff function is determined by

$$\Pi_R^{\mathrm{SN}}(p_R) = (p_R - w)(a_i + \theta + \gamma s - p_R), a_i \in \{\hat{H}, \hat{L}\}. \tag{16}$$

Considering the first-order requirements, we can derive the optimal resale price $p_R(w,s) = \frac{1}{2}(a_i + w + s\gamma + \theta)$. With the help of backward induction, replace $p_R(w,s)$ into the supplier profit formula.

$$\Pi_S^{\mathrm{SN}}(w,s) = w(a_i + \theta + \gamma - p_R) - \frac{1}{2}s^2. \tag{17}$$

The supplier maximizes his profits in the first stage of the game by selecting the best prices, anticipating the platform's response to the wholesale prices. Finally, we can obtain the equilibrium outcomes are

$$w^{\mathrm{SN}^*} = \frac{2(a_i+\theta)}{4-\gamma^2}, s^{\mathrm{SN}^*} = \frac{\gamma(a_i+\theta)}{4-\gamma^2}, p_R^{\mathrm{SN}^*} = \frac{3(a_i+\theta)}{4-\gamma^2}, a_i \in \{\hat{H}, \hat{L}\}. \tag{18}$$

The optimal expected payoffs of the platform and supplier are

$$\Pi_R^{\mathrm{SN}^*} = \frac{3\hat{H}2 + 6\hat{H}d + 4d^2}{6(\gamma^2-4)^2} + \frac{3\hat{L}^2 + 6\hat{L}d + 4d^2}{6(\gamma^2-4)^2} \tag{19}$$

$$\Pi_S^{\mathrm{SN}^*} = \frac{3\hat{H}2 + 6\hat{H}d + 4d^2}{2(24-6\gamma^2} + \frac{3\hat{L}^2 + 6\hat{L}d + 4d^2}{2(24-6\gamma^2)}. \tag{20}$$

5.2. Encroachment

Based on 4.2 and 5.1 sections, we employ "SE" to indicate the situation where the platform shares information and the supplier encroaches. Considering changes in competitive elements and the information shared by the platform, we construct this game model. The platform's and supplier's payoff functions are determined by

$$\Pi_R^{\mathrm{SE}}(p_R) = (p_R - w)(a_i + \theta + \gamma s - p_R + bp_S), a_i \in \{\hat{H}, \hat{L}\} \tag{21}$$

$$\Pi_S^{\mathrm{SE}}(p_S, w, s) = p_S(a_i + \theta + \gamma s - p_S + bp_R) + w(a_i + \theta + \gamma s - p_R + bp_S) - \frac{1}{2}s^2 - I. \tag{22}$$

We can obtain optimal prices, which are functions of wholesale prices, according to the first-order constraints.

$$p_R(w,s) = \frac{a_i(2+b) + (2+b^2)w + (2+b)(s\gamma+\theta)}{4-b^2}, p_S(w,s) = \frac{(a_i(2+b) + 2(s\gamma+\theta) + b(3w+s\gamma+\theta)}{4-b^2}. \tag{23}$$

At last, we can derive the equilibrium outcomes are

$$w^{\mathrm{SE}^*} = \frac{8+b^3)(a_i+\theta)}{b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4)}, a_i \in \{\hat{H},\hat{L}\} \tag{24}$$

$$s^{\mathrm{SE}^*} = \frac{\gamma(12+4b+b^2+b^3)(a_i+\theta)}{b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4)}, a_i \in \{\hat{H},\hat{L}\}. \tag{25}$$

The optimal expected payoffs of the platform and supplier are

$$\begin{aligned} \Pi_R^{\mathrm{SE}^*} &= \frac{2(2-2b+b^2-b^3)^2(3\hat{H}2+6\hat{H}d+4d^2)}{[3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))]^2} \\ &\quad + \frac{2(2-2b+b^2-b^3)^2(3\hat{L}^2+6\hat{L}d+4d^2)}{[3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))]^2} \end{aligned} \tag{26}$$

$$\begin{aligned} \Pi_S^{\mathrm{SE}^*} &= \frac{(12+4b+b^2+b^3)(3\hat{H}2+6\hat{H}d+4d^2)}{12(b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4))} \\ &\quad + \frac{(12+4b+b^2+b^3)(3\hat{L}^2+6\hat{L}d+4d^2)}{12(b^2(2-\gamma^2)-b^3(2+\gamma^2)-4b(4+\gamma^2)-4(3\gamma^2-4))} - I. \end{aligned} \tag{27}$$

The following describes the supplier's optimal encroachment choice under information sharing.

Proposition 2. *Information sharing,*

(a) *If $a_i = \hat{H}$, the supplier will definitely encroach when $I \le \Psi(0,\hat{H})$; the supplier will encroach when $\Psi(0,\hat{H}) < I \le \Psi(2d,\hat{H})$ and $\theta > \theta_1$; the supplier will not encroach when $I > \Psi(2d,\hat{H})$, where*

$$\theta_1 = \sqrt{\frac{(\gamma^2-4)(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)I}{(16+b(16+b+3b^2))}} - \hat{H};$$

(b) *If $a_i = \hat{L}$, the supplier will definitely encroach when $I \le \Psi(0,\hat{L})$; the supplier will encroach when $\Psi(0,\hat{L}) < I \le \Psi(2d,\hat{L})$ and $\theta > \theta_2$; the supplier will not encroach when $I > \Psi(2d,\hat{L})$, where*

$$\theta_2 = \sqrt{\frac{(\gamma^2-4)(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)I}{(16+b(16+b+3b^2))}} - \hat{L}.$$

Proposition 2 describes the encroachment strategy under platform's information sharing. Unsurprisingly, supplier encroachment strategies are more complex under the influence of information. When the platform shares information, encroachment strategy dose not only depend on the cost I, the magnitude of demand uncertainty θ, but also to the signaling level of market size $\hat{H}$ and $\hat{L}$. Compared to Proposition 1, encroachment not only takes into account the cost of encroachment, but also the value of the information disclosed by the platform. Especially when the cost of encroachment is moderate, the supplier cannot make an accurate judgment based on the cost of encroachment alone. Instead, the supplier will consider the magnitude of θ. Only when the platform releases positive signal (*i.e.*, $\theta > \theta_1$ and $\theta > \theta_2$), the supplier will be interested in channel expansion for higher margins. In Figure 3, when $\theta_2 > \theta_1$, it means that the platform's shared information is negative, which reduces the motivation for the supplier to intrude.

6. Information sharing strategies

In this section, we will discuss the first stage of the game timing. We will investigate the information sharing issues on the platform endogenously. The platform will strategically decide whether or not to provide demand

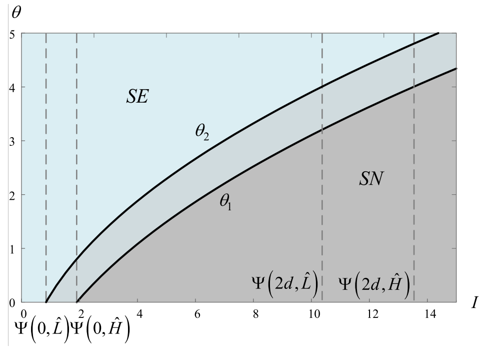


FIGURE 3. Information sharing-encroachment decisions.

information based on its anticipation of the supplier's delivery service and encroachment. Then we can characterize the platform's expected payoff under no information sharing as follows:

$$\Pi_R^{N^*}=\begin{cases}\dfrac{\begin{pmatrix}2\begin{pmatrix}3\hat{H}2\chi_0^2+d^2\chi_1-6\hat{H}(8-8b+2b^2-2b^3-b^4+b^5)d\chi_0-\\ 6\chi_2((8b-8-2b^2+2b^3+b^4-b^5)d+\hat{H}\chi_0)\bar{a}+3\chi_2^2\bar{a}^2\end{pmatrix}\\ +2\begin{pmatrix}(3\hat{L}^2\chi_0^2+d^2\chi_1-6\hat{L}(8-8b+2b^2-2b^3-b^4+b^5)d\chi_0-\\ 6\chi_2((8b-8-2b^2+2b^3+b^4-b^5)d+\hat{L}\chi_0)\bar{a}+3\chi_2^2\bar{a}^2\end{pmatrix}\end{pmatrix}}{3(b^2-4)^2\chi_0^2} & I\le\Psi(d,\bar{a})\\ \dfrac{\begin{pmatrix}(3\hat{H}2(\gamma^2-4)^2-12\hat{H}d(\gamma^2-4)+d^2(28-8\gamma^2+\gamma^4)+3(\gamma^2-2)\bar{a}(4d-2\hat{H}(\gamma^2-4)+(\gamma^2-2)\bar{a})\\ +3\hat{L}^2(\gamma^2-4)^2-12\hat{L}d(\gamma^2-4)+d^2(28-8\gamma^2+\gamma^4)+3(\gamma^2-2)\bar{a}(4d-2\hat{L}(\gamma^2-4)+(\gamma^2-2)\bar{a}))\end{pmatrix}}{24(\gamma^2-4)^2} & I>\Psi(d,\bar{a})\end{cases}. \tag{28}$$

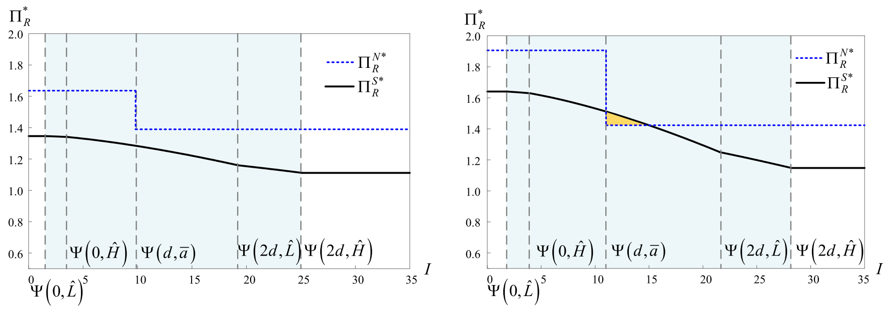
Before we get the platform's expected payoff under information sharing, we need to work out the platform's profit under different signals. $\Pi_R^{S^*}(a_i=\hat{H})$ and $\Pi_R^{S^*}(a_i=\hat{H})$ are described as follows:

$$\Pi_R^{S^*}(a_i=\hat{H})=\begin{cases}\frac{(4(2-2b+b^2-b^3)^2(3\hat{H}2+6\hat{H}d+4d^2)}{3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))^2} & I\le\Psi(0,\hat{H})\\ \frac{1}{6d}\left(\frac{4(b-1)^2(2+b^2)^2((\hat{H}+2d)^3-(\hat{H}+\theta_1)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{H}+\theta_1)^3-\hat{H}3}{(\gamma^2-4)^2}\right) & \Psi(0,\hat{H})<I\le\Psi(2d,\hat{H})\\ \frac{3\hat{H}2+6\hat{H}d+4d^2}{3(\gamma^2-4)^2} & I>\Psi(2d,\hat{H}))\end{cases}, \tag{29}$$

$$\Pi_R^{S^*}(a_i=\hat{L})=\begin{cases}\frac{(4(2-2b+b^2-b^3)^2(3\hat{L}^2+6\hat{L}d+4d^2)}{3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))^2} & I\le\Psi(0,\hat{L})\\ \frac{1}{6d}\left(\frac{4(b-1)^2(2+b^2)^2((\hat{L}+2d)^3-(\hat{L}+\theta_2)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{L}+\theta_2)^3-\hat{L}^3}{(\gamma^2-4)^2}\right) & \Psi(0,\hat{L})<I\le\Psi(2d,\hat{L})\\ \frac{3\hat{L}^2+6\hat{L}d+4d^2}{3(\gamma^2-4)^2} & I>\Psi(2d,\hat{L})\end{cases}. \tag{30}$$

The platform's expected payoff when the platform shares information is derived by

$$\Pi_R^{S^*}=\begin{cases}\frac{2(2-2b+b^2-b^3)^2(3\hat{H}2+6\hat{H}d+4d^2)}{3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))^2}\\ +\frac{2(2-2b+b^2-b^3)^2(3\hat{L}^2+6\hat{L}d+4d^2)}{3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))]^2} & (I\le\Psi(0,\hat{L})\\ \frac{2(2-2b+b^2-b^3)^2(3\hat{H}2+6\hat{H}d+4d^2)}{3(b^2(\gamma^2-2)+b^3(2+\gamma^2)+4b(4+\gamma^2)+4(3\gamma^2-4))^2}\\ +\frac{\left(\frac{4(b-1)^2(2+b^2)^2((\hat{L}+2d)^3-(\hat{L}+\theta_2)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{L}+\theta_2)^3-\hat{L}^3}{(\gamma^2-4)^2}\right)}{12d} & \Psi(0,\hat{L})<I\le\Psi(0,\hat{H})\\ \frac{\left(\frac{4(b-1)^2(2+b^2)^2((\hat{H}+2d)^3-(\hat{H}+\theta_1)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{H}+\theta_1)^3-\hat{H}3}{(\gamma^2-4)^2}\right)+\left(\frac{4(b-1)^2(2+b^2)^2((\hat{L}+2d)^3-(\hat{L}+\theta_2)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{L}+\theta_2)^3-\hat{L}^3}{(\gamma^2-4)^2}\right)}{12d} & (\Psi(0,\hat{H})<I\le\Psi(2d,\hat{L})\\ \frac{\left(\frac{4(b-1)^2(2+b^2)^2((\hat{H}+2d)^3-(\hat{H}+\theta_1)^3)}{(2(b-1)(8+b^2)+(2+b)(6+(b-1)b)\gamma^2)^2}+\frac{(\hat{H}+\theta_1)^3-\hat{H}3}{(\gamma^2-4)^2}\right)}{12d}+\frac{3\hat{L}^2+6\hat{L}d+4d^2}{6(\gamma^2-4)^2} & (\Psi(2d,\hat{L})<I\le\Psi(2d,\hat{H})\\ \frac{3\hat{H}2+6\hat{H}d+4d^2}{6(\gamma^2-4)^2}+\frac{3\hat{L}^2+6\hat{L}d+4d^2}{6(\gamma^2-4)^2})) & I>\Psi(2d,\hat{H}))\end{cases}. \tag{31}$$



(a) (b)

FIGURE 4. Information sharing decisions of the platform. (a) $\gamma = 0.18$. (b) $\gamma = 0.31$.

Proposition 3. *The platform is reluctant to share her information when* $I \leq \Psi(d, \bar{a})$ *or* $I > \Psi(2d, \hat{L})$*.*

Proposition 3 analyzes the conditions under no information sharing relied on the equations (28) and (31). We find that the platform can make a decision not to share simply by the cost of encroachment I. When the cost of encroachment is minimal $\Psi(d, \bar{a})$ or extremely high $\Psi(2d, \hat{L})$, the platform does not gain higher profits by sharing information. That is, the platform's abandonment of the information advantage exacerbates double marginalization. This directly leads to a reluctance of the platform regarding sharing information. In addition, the cutoff points for platforms' decisions not to share information are related to the market size updating signal and the margins of the uncertainty distribution. In this scenario, the platform should remain mysterious and use inaccurate information to interfere with the supplier's decisions on wholesale prices and delivery services.

Proposition 4. *There exists a threshold* $\bar{\gamma}$ *such that the platform prefers to share information when* $I \in [\Psi(d, \bar{a}), \bar{I}]$ *and* $\gamma > \bar{\gamma}$*, where* $\bar{\gamma}$ *is a solution of* $\Pi_R^S(\Psi(d, \bar{a})) = \Pi_R^N(\Psi(d, \bar{a}))$*; and* $\bar{I}$ *is a solution of* $\Pi_R^S(\bar{I}) = \Pi_R^N(\bar{I})$ *and* $\bar{I} \in (\Psi(d, \bar{a}), \Psi(2d, \hat{L}))$*.*

We discuss the conditions under which the platform shares information in Proposition 4. We discover that under specific circumstances, the platform will be more accepting in providing the supplier with information. The traditional wisdom is that the platform under the threat of supplier's encroachment should leverage its information advantage to gain more profits. In contrast, in a supply chain system where the supplier provides delivery services, the platform may share information to help the supplier correct its service decisions in order to improve delivery services. Figures 4a and4b depict the equilibrium profits when information is shared *versus* not shared (*i.e.*, $\Pi_R^{S^*}$ and $\Pi_R^{N^*}$). The solid line indicates the platform's profits with information sharing. The dashed line denotes the platform's profits with no information sharing. Specifically, in Figure 4a, when the supplier offers a lower quality of delivery service, the platform is always hesitant to share information. This is because lower delivery services do not improve demand. Even if the incentive for the supplier to encroach decreases as the cost of encroachment increases, it does not reverse the platform's decision not to share information. However, in Figure 4b, the platform will consider sharing information about market demand when the supplier delivery service is high (*i.e.*, $\gamma > \bar{\gamma}$) and the encroachment cost is moderate (*i.e.*, $I \in [\Psi(d, \bar{a}), \bar{I}]$). As shown in the yellow area of the Figure 4b. This is a result of the platform's willingness to amend the supplier's wholesale price and delivery service choices to enhance the delivery experience for customers. Even though sharing information exacerbates double marginalization, the positive effect of improved supplier delivery services compensates for the negative effect of double marginalization.

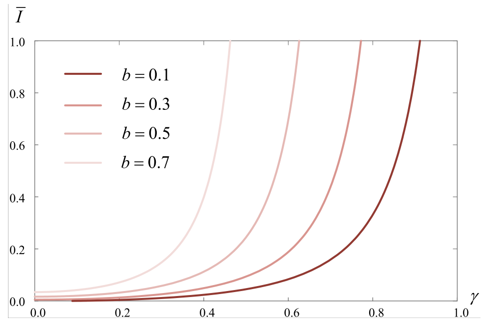


FIGURE 5. The threshold $\bar{I}$ with γ and b.

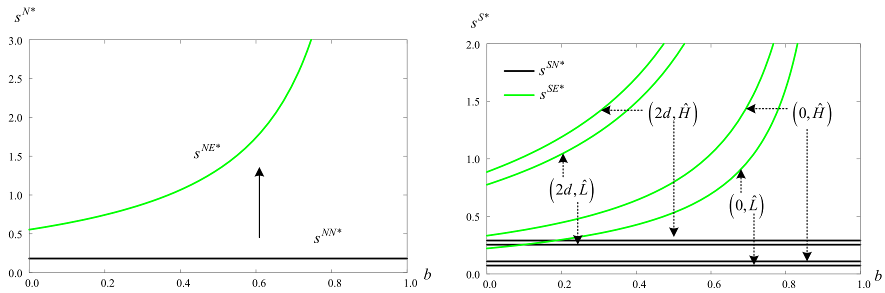
Corollary 1. $\bar{I}$ increases as γ increases; $\bar{I}$ increases as b increases.

Corollary 1 portrays the properties of threshold $\bar{I}$. We find that $\bar{I}$ increases with the sensitivity coefficient of the delivery service. Recalling Proposition 4, the platform will share information only if the encroachment cost is between $[\Psi(d, \bar{a}), \bar{I}]$. When the market is more sensitive to delivery services (*i.e.*, γ increases), the space of threshold becomes larger (as shown in Fig. 5). This indicates that the platform will be more willing to share information. This is because sharing information will motivate the supplier to improve the delivery service. Under the influence of the market being more concerned about the delivery service experience, the supplier's improved delivery service will lead to higher demand performance. This positive market effect will increase the platform's profits. Furthermore, we look into how the platform decides what information to share based on the intensity of channel competition. Figure 5 shows that as channel competition becomes more intense, the motivation of information sharing increases (the line shifts left in Fig. 5). Facing the threat of encroachment, the platform wants to counteract the supplier's incentive to encroach by sharing information.

Proposition 5. (a) *When the platform does not share information, there is* $s^{\mathrm{NE}^*} > s^{\mathrm{NN}^*}$ *and* $\frac{\partial s^{\mathrm{NE}^*}}{\partial b} > 0$*;*
(b) *When the platform shares information, there is* $s^{\mathrm{SE}^*} > s^{\mathrm{SN}^*}, s^{\mathrm{SE}^*}(2d, \hat{H}) > s^{\mathrm{SE}^*}(2d, \hat{L}), s^{\mathrm{SN}^*}(2d, \hat{H}) > s^{\mathrm{SN}^*}(2d, \hat{L}), s^{\mathrm{SE}^*}(0, \hat{H}) > s^{\mathrm{SE}^*}(0, \hat{L}), s^{\mathrm{SN}^*}(0, \hat{H}) > s^{\mathrm{SN}^*}(0, \hat{L})$*, and* $\frac{\partial s^{\mathrm{SE}^*}}{\partial b} > 0$.

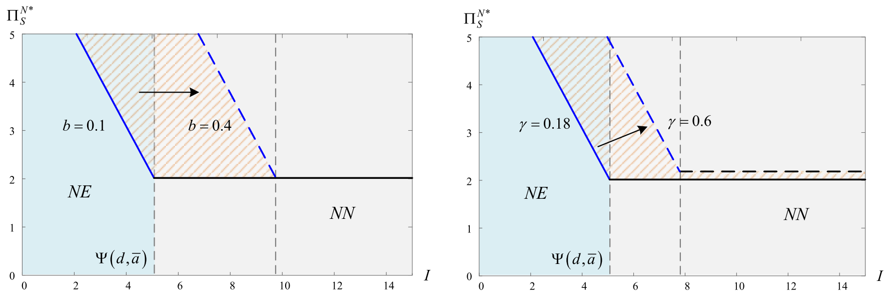
The impact of information sharing and encroachment decisions on supplier's delivery services is summarized in Proposition 5. Supplier's encroachment leads to higher service motivation, whether the platform shares information (*i.e.*, $s^{\mathrm{NE}^*} > s^{\mathrm{NN}^*}$ and $s^{\mathrm{SE}^*} > s^{\mathrm{SN}^*}$). In Figure 6a, the green line is above the black line. Interestingly, competition does not reduce the level of delivery service from the supplier. This is the bright side of competition to some degree. In a supply chain where the supplier provides delivery services, we know that encroachment increases channel competition. However, the positive effects of the supplier's increased channels coupled with its better delivery services outweigh the negative effects of channel competition. Therefore, the supplier will aggressively improve the quality of delivery services in order to expand its market size. Further, we find that the service level of the supplier is related to the level of the market size shared by the platform under information sharing. This can be inferred from Figure 6b. If the platform signals the size of the market as high, the supplier's delivery service is promoted. If the market size signal from the platform is low, it will be suppressed. But if demand uncertainty is high, the supplier will improve the delivery service. If demand uncertainty is low, the supplier will have no incentive to improve the delivery service experience. This implies that the supplier will use the delivery service to mitigate the risk of market demand uncertainty.

In the following, we explore the profits of each entity. We examine the effect of information structure and encroachment on profits in a supply chain system where the supplier provides delivery services.



(a) (b)

FIGURE 6. Impact of information sharing and encroachment strategies on delivery service. (a) Information sharing. (b) No information sharing.



(a) (b)

FIGURE 7. Supplier's profits when the platform does not share information. (a) $\Pi_S^{N^*}$ with respect to I and b. (b) $\Pi_S^{N^*}$ with respect to I and γ.

Proposition 6. *The supplier's profits,*

(a) *When the platform does not share information, the supplier can increase profits by encroachment. As b and γ increase, the supplier is more likely to encroach;*

(b) *When the platform shares information, the supplier benefits from signaling high demand in the market. The incentive to encroach is stronger under high market demand. As ρ increases, the supplier can only benefit from high market demand, and conversely, the supplier will be harmed by low market demand.*

Proposition 6 summarizes the characteristics of supplier's profits. Figure 7 indicates supplier's profits under no information sharing. Encroachment incurs a cost to the supplier. Thus, when the cost of encroachment rises, the supplier's profits fall. However, if encroachment comes at a high cost, the supplier won't decide to do so in order to increase the sales channel. As the intensity of competition increases, the incentive for the supplier to encroach increases (as illustrated in Fig. 7a). Entrenchment generates some channel competition. The more sensitive the market is to delivery services, the greater the incentive for the supplier to encroach. At the same time, the supplier's enhancement of delivery services improves its profitability (as illustrated in Fig. 7b). Therefore, it is possible for the supplier to gain profits from the encroachment. Figure 8 shows supplier's profits under information sharing. Sharing information brings a certain amount of complexity compared to a situation under no information sharing. The profits of supplier depend on the size of the market a_i, the cost of encroachment I, and the accuracy of the signal shared by the platform ρ. The supplier's profits produce two cutoff points because of the encroachment (as showed in Fig. 8a). The cutoff point on the left represents the possibility that a partial encroachment by a supplier may result in higher profits compared to a full encroachment. In addition,

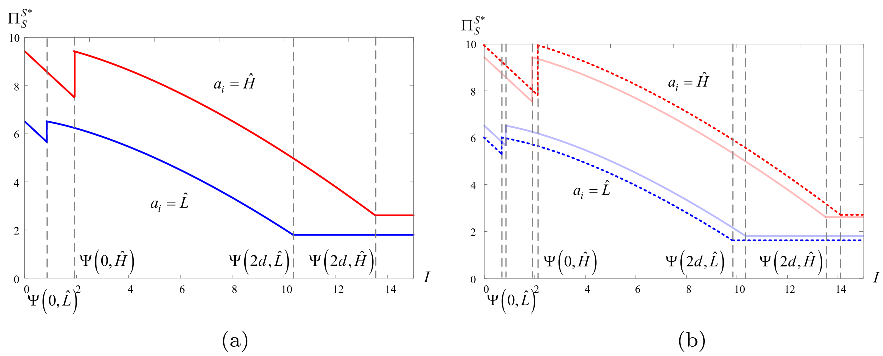


FIGURE 8. Supplier's profits when the platform shares information. (a) $\rho = 0.7$. (b) $\rho = 0.77$.

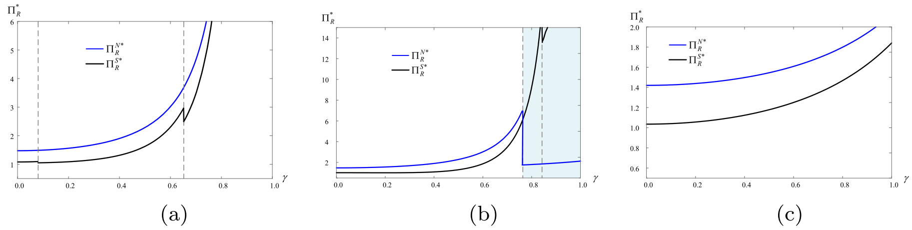


FIGURE 9. Platform's profits with respect to I and γ. (a) $I = 17.88$. (b) $I = 18$. (c) $I = 19$.

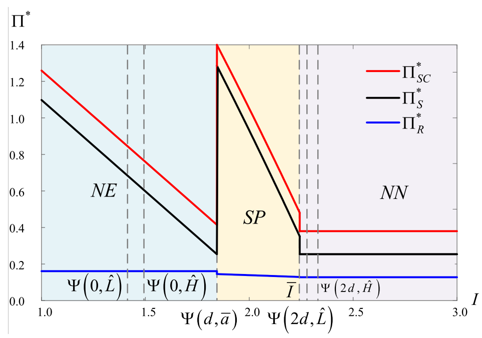
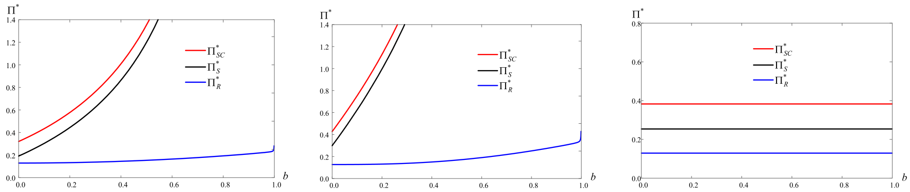


FIGURE 10. The profits of supply chain with respect to I.

if the signal of market size shared by the platform is high ($a_i = \hat{H}$), it is favorable to the supplier's profits. But as signal accuracy increases, only high market size signals boost supplier profits. Low market size signals hurt suppliers' profits. The red dashed line in Figure 8 has moved up and to the right, while the blue dashed line has moved down. This means that the incentive to encroach is stronger under high market demand.

Proposition 7. *The platform's profits, (a) When* $I < \Psi(0,\hat{H})$, $[\Pi_R^{N^*} > \Pi]_R^{S^*}$; *(b) when* $\Psi(0,\hat{H}) < I \leq \Psi(2d,\hat{L})$ *and* $\gamma > \bar{\gamma}$, $[\Pi_R^{N^*} < \Pi]_R^{S^*}$; *(c) when* $I > \Psi(2d,\hat{L}), \Pi_R^{N^*} > \Pi_R^{S^*}$.

The equilibrium profits of the platform are summarized in Proposition 7. Based on equation (31), we conclude that platform information sharing decisions are not simple. When the cost of encroachment is high or low (*i.e.*, $I < \Psi(0,\hat{H})$ and $I > \Psi(2d,\hat{L})$), the platform does not benefit from sharing information. As shown in



(a) (b) (c)

FIGURE 11. The profits of supply chain with respect to b. (a) $I < \Psi(d, \bar{a})$. (b) $\Psi(d, \bar{a}) \leq I < \Psi(2d, \hat{L})$. (c) $I \geq \Psi(2d, \hat{L})$.

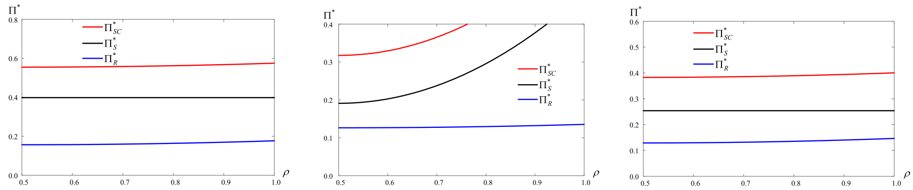
Figures 9a and 9c, the blue line is always higher than the black line. Figure 9b reflects the fact that only when the cost of encroachment is moderate (*i.e.*, $\Psi(0, \hat{H}) < I \leq \Psi(2d, \hat{L})$) and the market's attention to delivery services is high (*i.e.*, $\gamma > \bar{\gamma}$), the platform is willing to share information in order to improve the supplier's delivery service level. The blue area in Figure 9b indicates the space where the platform's information is shared. And the conventional wisdom is that when the incentive for the supplier to encroach is higher, the platform chooses to retain the information and maintain its information advantages. However, we find that this is not the truth. The information sharing decisions are not only related to the encroachment cost, but also depend on the degree of market attention to the delivery services.

Proposition 8. *Proposition 8 (a) The profits of supply chain are non-monotonic with respect to I. The profits of the supplier and platform with respect to I are also non-monotonic; (b) when $\Psi(d, \bar{a}) < I \leq \bar{I}$, the supply chain will get higher benefits.*

Proposition 8 explores the characterization of equilibrium profits. The equilibrium profits of supply chain entities present non-monotonous with respect to encroachment cost. Figure 10 compares the supplier's equilibrium profits, the platform's profits, and the total supply chain profits. There is no doubt that the supplier will profit more from encroachment when the cost is low. Due to the perceived threat, the platform will not divulge information that could skew the supplier's decisions. The platform is protected by not disclosing information. As shown in the blue area of Figure 10. Nevertheless, the supplier has little incentive to encroach when the cost of doing so is high. Even though the platform is not threatened by encroachment, the supplier can still influence the market response by changing the level of delivery service. Hence the platform remains reluctant to share information. As shown in the purple area of Figure 10. Interestingly, we discover that the profits of the whole supply chain improve only when it is in the yellow region of Figure 10 (*i.e.*, $\Psi(d, \bar{a}) < I \leq \bar{I}$). This is attributed to the platform's information sharing and the supplier's partial encroachment. The supplier can respond to signals by modifying the wholesale price and the degree of delivery service through the platform's information sharing feature. On the one hand information sharing will exacerbate double marginalization. On the other hand, the improvement of delivery services will expand market demand and improve overall profitability. Therefore, the platform is willing to voluntarily share information in order to improve the level of delivery services.

Proposition 9. *Proposition 9 (a) When $I < \Psi(2d, \hat{L}), \Pi_S C^*, \Pi_S^*$, Π_R^* increase with b; When $I \geq \Psi(2d, \hat{L}), \Pi_S C^*, \Pi_S^*, \Pi_R^*$ are independent of b; (b) When there is a threat of encroachment, $\Pi_{SC}^*, \Pi_S^*, \Pi_R^*$ grow sharply with ρ.*

We find that when the cost of encroachment is small, the platform is reluctant to share information due to the high motivation of suppliers to intrude. Both the supplier and the supply chain can benefit from the increased distribution channels. And as the intensity of competition increases, the increase in supplier profits becomes larger. This is beneficial to the supply chain and contributes little to the platform margin increase



(a) (b) (c)

Figure 12. The profits of supply chain with respect to ρ. (a) $I < \Psi(d, \bar{a})$. (b) $\Psi(d, \bar{a}) \leq I < \Psi(2d, \hat{L})$. (c) $I \geq \Psi(2d, \hat{L})$.

(as showed in Fig. 11a). However, as the cost of encroachment increases, the platform will choose to share information in the face of the threat of encroachment. Despite in the presence of some competition, a win-win situation will be realized (as showed in Fig. 11b). However, as the cost of encroachment continues to increase, the supplier is reluctant to open new channel. This is because profit changes will be independent of b (as showed in Fig. 11c). Figure 12 shows that supply chain profits are also affected by the accuracy of information. When the encroachment cost is low as well as high, information accuracy does not contribute much to profits (as showed in Figs. 12a and 12c). This is because the platform does not share information at this point. However, when the platform faces the threat of encroachment, the platform will choose to share information. Supplier and supply chain profits will increase significantly (as showed in Fig. 12b). The stronger the information accuracy is, the faster profits increase. This means that the supplier will benefit from accurate information.

7. Conclusions

We study two-dimensional information sharing strategies where the supplier provides delivery services considering the possibility of encroachment based on game theory model. The first step is to discuss encroachment decisions of the supplier under different information structures. Then the platform's information sharing strategies are examined. We try to interpret the encroachment strategies and information sharing strategies under the influence of supplier delivery services with the help of a game model. The findings of our study are as follows. (1) The level of supplier delivery service increases with the intensity of competition. This is the bright side of competition to some degree. (2) Platform profits increase as the sensitivity of the delivery service increases. Under the influence of the market being more concerned about the delivery service experience, the supplier's improved delivery service will lead to higher demand performance. This positive market effect will increase the platform's profits. (3) The supplier's encroachment strategy is influenced by the cost, the degree of demand uncertainty, and the market size signaling level when the platform shares information. Furthermore, because the platform shares unfavorable information, the motivation for the supplier to encroach decreases. (4) Surprisingly, the platform might share information to improve the customer's delivery services experience in some certain conditions. This is a result of the platform's willingness to amend the supplier's wholesale price and delivery service selections to enhance the delivery experience for customers. Although information sharing makes double marginalization worse, the benefits of better supplier delivery services outweigh the drawbacks of double marginalization. Previous papers that ignore a supplier's decision on delivery services may have underestimated the scope for platform profitable information sharing. (5) The equilibrium profits of supply chain entities present non-monotonous with respect to encroachment cost. The supply chain will get higher benefits under some conditions. The platform often faces a tradeoff. Sharing information, on the one hand, enables the supplier to gain a better understanding of the impact on demand and encourages enhancements to delivery services, which is advantageous to the platform. However, sharing information allows the supplier to absorb the impact of demand information by making modifications to the wholesale price and delivery services, which benefits the supplier but hurts the platform. This makes the negative effects of double marginalization worse. This paper provides a basis for information sharing strategies under a supplier delivery services system, especially in the presence of encroachment threats. However, this paper only focuses on the impact of supplier delivery services on equilibrium strategies. Market demand performance is influenced by other consumer preferences. And these preferences may have an impact on platform information sharing strategies as well as supplier delivery decisions. In the future, other consumer concerns (*i.e.*, product greenness, customer customization, etc.) can be further considered. Second, we do not consider more complex structures of supply chain. Different structures may have an impact on the equilibrium strategies. The exploration of different modes of encroachment will also be of great importance. For example, whether the supplier encroachment model is direct sales or agency sales. And whether the platform is considering introducing self-brands. The introduction of self-brands may change its information sharing range. Finally, we do not regard the effect of time factor. If consumers have strategic waiting behaviors or multi-period purchase, the platform's information sharing strategies may change accordingly. It's valuable to combine strategic consumption behavior with different consumption preferences.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] J. Chen, W. Zhang and Z. Liu, Joint pricing, services and quality decisions in a dual-channel supply chain. *RAIRO-Oper. Res.* **54** (2020) 1041–1056.

[2] G. Donaker, H. Kim, M. Luca and M. Weber, Designing better online review systems. *Harvard Bus. Rev.* **97** (2019) 122–129.

[3] H. Elahi, H. Pun and S. Ghamat, The impact of capacity information on supplier encroachment. *Omega* **117** (2023) 102818–102828.

[4] Z. Guan, X. Zhang, M. Zhou and Y. Dan, Demand information sharing in competing supply chains with manufacturer-provided service. *Int. J. Prod. Econ.* **220** (2020) 107450–107460.

[5] A.Y. Ha, H. Luo and W. Shang, Supplier encroachment, information sharing, and channel structure in online retail platforms. *Prod. Oper. Manage.* **31** (2022) 1235–1251.

[6] A.Y. Ha, W. Shang and Y. Wang, Supplier audit information sharing and responsible sourcing. *Manage. Sci.* **69** (2023) 308–324.

[7] J. Hall and E. Porteus, Customer service competition in capacitated systems. *Manuf. Serv. Oper. Manage.* **2** (2000) 144–165.

[8] P. He, Y. He, X. Tang, S. Ma and H. Xu, Channel encroachment and logistics integration strategies in an e-commerce platform service supply chain. *Int. J. Prod. Econ.* **244** (2022) 108368–108383.

[9] S. Huang, X. Guan and Y.J. Chen, Retailer information sharing with supplier encroachment. *Prod. Oper. Manage.* **27** (2018) 1133–1147.

[10] G.Q. Huang, R. de Koster and Y. Yu, Online-to-offline ecommerce operations management (EOM). *Transp. Res. Part E: Logistics Transp. Rev.* **138** (2020) 101920–101925.

[11] H. Huang, F. Liu and P. Zhang, To outsource or not to outsource? Warranty service provision strategies considering competition, costs and reliability. *Int. J. Prod. Econ.* **242** (2021) 108298–108320.

[12] Y. Huang, B. Zheng and Z. Wang, The value of information sharing in a dual-channel closed-loop supply chain. *RAIRO-Oper. Res.* **55** (2021) 2001–2022.

[13] L. Jiang and Z. Hao, Incentive-driven information dissemination in two-tier supply chains. *Manuf. Serv. Oper. Manage.* **18** (2016) 393–413.

[14] J. Lee, C. Ko and I. Moon, E-commerce supply chain network design using on-demand warehousing system under uncertainty. *Int. J. Prod. Res.* **62** (2024) 1901–1927.
[15] Z. Li, D. Wang, W. Yang and H.S. Jin, Price, online coupon, and store service effort decisions under different omnichannel retailing models. *J. Retail. Consum. Serv.* **64** (2022) 102787–102802.
[16] M. Liu, B. Dan, S. Zhang and S. Ma, Information sharing in an E-tailing supply chain for fresh produce with freshness-keeping effort and value-added service. *Eur. J. Oper. Res.* **290** (2021) 572–584.
[17] P.P. Maruthasalam and G. Balasubramanian, Supplier encroachment in the presence of asymmetric retail competition. *Int. J. Prod. Econ.* **264** (2023) 108961–108974.
[18] Y.Z. Mehrjerdi and M. Shafiee, A resilient and sustainable closed-loop supply chain using multiple sourcing and information sharing strategies. *J. Clean. Prod.* **289** (2021) 125141–125155.
[19] S.R. Pathy and H. Rahimian, A resilient inventory management of pharmaceutical supply chains under demand disruption. *Comput. Ind. Eng.* **180** (2023) 109243–109256.
[20] S. Paul, N. Craig and E. Bendoly, Ordering behavior in a supply chain with customers that respond to changes in service level. *Decis. Sci.* **55** (2024) 88–103.
[21] D. Shin and A. Zeevi, Product quality and information sharing in the presence of reviews. *Manage. Sci.* **70** (2023) 1343–2022.
[22] Y. Tang, S.P. Sethi and Y. Wang, Games of supplier encroachment channel selection and e-tailer's information sharing. *Prod. Oper. Manage.* **32** (2023) 3650–3664.
[23] J. Wang and W. Zhuo, Strategic information sharing in a supply chain under potential supplier encroachment. *Comput. Ind. Eng.* **150** (2020) 106880–106898.
[24] J. Wu, J. Yu and X. Wang, Platform information sharing and selling contract strategies with blockchain adoption. *Comput. Ind. Eng.* **183** (2023) 109506–109521.
[25] Z. Xu, S. Pokharel and A. Elomri, An eco-friendly closed-loop supply chain facing demand and carbon price uncertainty. *Ann. Oper. Res.* **320** (2023) 1041–1067.
[26] H. Yang, J. Luo and Q. Zhang, Supplier encroachment under nonlinear pricing with imperfect substitutes: bargaining power versus revenue-sharing. *Eur. J. Oper. Res.* **267** (2018) 1089–1101.
[27] M. Yang, T. Zhang and C. X. Wang, The optimal e-commerce sales mode selection and information sharing strategy under demand uncertainty. *Comput. Ind. Eng.* **162** (2021) 107718–107731.
[28] X. Zha, X. Zhang, Y. Liu and B. Dan, Bonded-warehouse or direct-mail? Logistics mode choice in a cross-border e-commerce supply chain with platform information sharing. *Electron. Commerce Res. App.* **54** (2022) 101181–101197.
[29] Y. Zha, Q. Li, T. Huang and Y. Yu, Strategic information sharing of online platforms as resellers or marketplaces. *Marketing Sci.* **42** (2023) 659–678.
[30] S. Zhang and J. Zhang, Agency selling or reselling: E-tailer information sharing with supplier offline entry. *Eur. J. Oper. Res.* **280** (2020) 134–151.
[31] Z. Zhang, H. Song, X. Gu, V. Shi and J. Zhu, How to compete with a supply chain partner: retailer's store brand vs. manufacturer's encroachment. *Omega* **103** (2021) 102412–102428.
[32] X. Zhang, Y. Liu, B. Dan, X. Zha and R. Sui, Selling mode choice and information sharing in an online tourism supply chain under channel competition. *Electron. Commerce Res.* (2023) 1–28.
[33] Y. Zhao, J. Chen, P. Shi and R. Hou, The value of information acquisition and sharing on an online intermediary platform. *Electron. Commerce Res.* (2022) 1–27.