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Platform Information Transparency and Effects on Third-Party Suppliers and Offline Retailers

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We examine a model in which a supplier sells products through an online platform and an offline retailer under conditions of demand uncertainty. The actual demand potential can be observed (or predicted accurately using rich sales data) by the platform and retailer, but not by the supplier. The model addresses the following issues. First, the supplier optimizes its multi-channel strategy, including a selling format choice in the online channel and optimal pricing. Specifically, although a traditional wholesale model is used offline, both wholesale and agency models are prepared online. Given a commission rate set by the platform for the agency model, the supplier chooses one selling format from the two models. The second one is related to the platform's information-sharing policy. The platform can commit to sharing its demand information with the supplier. This paper elucidates how the platform's information sharing alters the supplier's multi-channel management and subsequently affects the retailer eventually. Results show that the platform charges its commission rate so that the supplier chooses the agency model, unless the consumer demand is sufficiently uncertain. We also demonstrate that the platform's information sharing capability makes the agency model more likely to be adopted. However, information transparency arising from the platform's voluntary information disclosure can be unfavorable to the retailer. Finally, we demonstrate that, with information sharing, a shift from wholesale to agency models can be desirable not only for the platform and supplier, but also for the retailer (i.e., Pareto-improving).

Key words: demand uncertainty, e-commerce platforms, strategic contracting, information sharing
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1 Introduction

E-commerce platform giants such as Amazon in the United States, Rakuten in Japan, Tmall and JD.com in China, and Flipkart in India have been growing rapidly for over a decade. Accordingly, product suppliers and manufacturers must govern multiple distinct channels to sell online and offline. In fact, many suppliers use both traditional retail channels and new platform channels. [1] Multi-channel management is an important but difficult decision for those suppliers.

An important difference from earlier multi-channel management is that those platforms prepare selling formats of two types: *wholesale* and *agency.* [2] The former has also been used widely in traditional retail channels. Suppliers sell products to the platforms; then the platforms resell them to consumers. The latter became widespread with the recent development of e-commerce platforms, by which suppliers are delegated to make various decisions independently (pricing, advertising, inventory, shipping, etc.), whereas platforms charge commissions for the sale of goods (Johnson 2017). [3] Suppliers choose a selling format from wholesale and agency models depending on various factors, including competition intensity (Tian et al. 2018) and the market size potential (Zennyo 2020).

The presence of the new selling format makes suppliers' multi-channel management more difficult and complicated. The agency model has both benefits and shortcomings. An important benefit is that suppliers can make pricing (and other) decisions by themselves, which can be a shortcoming depending on the circumstances. This can be the case in which suppliers have little information about consumer demand (Guo 2009a, Scott Morton et al. 2019). Under the agency model, suppliers must make decisions based on their inaccurate knowledge, which can engender harm not only to themselves, but also to platforms that earn commissions from each sale of suppliers' products (designated as a *less-information* effect).

In practice, to support less-informed suppliers, some platforms share demand information with them voluntarily (Zhang and Zhang 2020). For example, Amazon provides useful reports based on their accumulated big data (Amazon Retail Analytics), which present information related to demand forecasts and market trends, along with customer behavior and customer reviews. This support of information sharing from platforms helps suppliers charge appropriate prices by themselves, thereby accelerating the movement towards the agency from wholesale models.

A close relation exists between suppliers' multi-channel management and platforms' information sharing. If a platform discloses demand information with a supplier, then the supplier will revise its multi-channel management, including the selling format choice and pricing, to change the allocation of sales across online and offline channels. Moreover, changes in multi-channel management can affect the strategy and profit of retailers the supplier uses.

This paper elucidates the relation between platforms' information sharing and suppliers' multi-channel management. The consequent effects on retailers also matter. Specifically, we address the following research questions: *Which selling format is selected by suppliers using multiple channels: agency or wholesale? How does demand uncertainty affect a supplier's choice of selling format? Do platforms have an incentive to establish an information-sharing alliance with their suppliers? If so, does information sharing make agency models more likely to be selected? How does the spread of agency models affect platforms and suppliers, and retailers?*

To address these research questions, we employ a model that includes three firms: a product supplier, an online platform, and an offline retailer. The supplier distributes products through both online and offline channels. In the model, decisions are divided into long-term and short-term ones, which are then classified according to whether each is determined before or after realization of the actual demand size. Before ascertaining the actual demand size, firms make the following long-term decisions. The platform decides whether to commit to information sharing with the supplier. Then it charges a commission rate that is used when the agency model is selected later by the supplier. The supplier who observed the platform's decisions chooses between wholesale and agency models.

After these long-term strategies are determined, actual demand is realized on a short-run basis, such as daily or weekly. It is observed by the platform and retailer, or it is predicted accurately from their sales data. This demand information (or prediction) is shared with the supplier according to the information-sharing policy determined preliminarily. Thereafter, the firms make short-term pricing decisions. The supplier ascertains a wholesale price for the offline retailer and sets a wholesale price for the online platform if the wholesale model was chosen. Finally, an offline retail price is charged by the retailer. An online retail price is determined either by the platform under the wholesale model or by the supplier under the agency model.

We first present a benchmark result for the case of information sharing, in which all firms know the actual demand size when choosing short-term decisions. This case is equivalent to a model with no demand uncertainty. The platform sets its commission rate at the highest level possible while still inducing the supplier to choose the agency model, above which the wholesale model is chosen. This finding implies that the platform prefers the agency model over the wholesale model. The reasons are twofold. First, the agency model enables the platform to receive a first-mover advantage, i.e., a commission rate is established before third-party suppliers charge prices (hereinafter designated as a *leadership* effect). Second, revenue-sharing of the agency model mitigates the double marginalization problem, which expands the quantities demanded in the platform (hereinafter designated as a *revenue-sharing* effect).

Additionally, we demonstrate that the resulting agency model can Pareto-dominate the wholesale model in terms of firm payoffs, i.e., all firms (a supplier, retailer, and platform) benefit from a change from wholesale to agency models when online and offline channels are highly substitutable. Specifically, the revenue-sharing nature of agency models mitigates the double marginalization problem in the platform channel, which increases the supplier and platform profits. Moreover, the agency model makes the platform a first-mover in the online channel, which reduces the supplier markup. The supplier attempts to shift its profit center to the offline channel by charging a low wholesale price to the retailer, which can benefit the retailer as well.

Next, we demonstrate the effects of demand uncertainty on the supplier's selling format choice and the platform's incentive to share its demand information with the supplier. With demand uncertainty, the less-information effect becomes a key factor. The platform can be either a victim or a beneficiary of the less-information effect depending on the selling format which is chosen. Under the agency model, online retail pricing is delegated to the uninformed supplier, implying that the less-information effect works negatively not only for the uninformed supplier itself, but also for the informed platform. By contrast, under the wholesale model, the shortcoming in demand information compels the supplier to charge a low wholesale price in terms of expectation (e.g., Li 2002, Zhang 2002), which might benefit the platform. Therefore, as the demand uncertainty increases, the platform increasingly wants the supplier to choose the wholesale model. To do so, the platform charges a sufficiently high commission rate for the use of agency models.

Instead of accepting the wholesale model reluctantly, the platform can establish an information sharing policy with the supplier. Information disclosure cancels out the less-information effect, which is profitable (detrimental) to the platform provided that the supplier will choose the agency (wholesale) model later. We demonstrate that the equilibrium outcome depends on the degree of demand uncertainty: (i) For less uncertain situations, the agency model is selected (irrespective of the presence or absence of information sharing); the platform prefers to share its demand information. (ii) For moderately uncertain situations, although the wholesale model ought to have been selected without information sharing, the platform commits to information sharing to have the supplier's decision turned into the agency model. (iii) For highly uncertain situations, the wholesale model is selected, irrespective of the presence or absence of information sharing. The platform prefers not to share its information. Therefore, the platform's information sharing capability leads to higher likelihood of the agency model being adopted.

Here, revisiting one of our preliminary results is worthwhile: A shift from wholesale to agency models in the platform might achieve Pareto-improvement. This result indicates that the socially desirable shift might be occurring, with assistance by information sharing from e-commerce platforms.

The remainder of this paper is structured as described below. Section 2 explains the related literature. In Section 3, we describe the setting of the game examined in this paper. Sections 4 and 5 present derivation of the equilibrium of the game. Section 6 presents discussion of several issues that are left out of the main analysis. Section 7 concludes the discussion.

2 Related Literature

This paper relates to two strands of literature. The first strand comprises studies of platform contracting between wholesale and agency contracts, which are the two simplest and most popular contracts adopted by online platforms and their suppliers. The two contracts are compared from various perspectives in the fields of economics (Foros et al. 2017, Johnson 2017, 2020) and management (Geng et al. 2018, Gerchak and Wang 2004, Guo et al. 2021, Hagiu and Wright 2019, Hao and

Fan 2014, Hao and Tan 2019, Jiang et al. 2011, Tan et al. 2016, Yan et al. 2019). Some papers have identified several important factors, including product substitutability (Jerath and Zhang 2010) and online reviews (Kwark et al. 2017), which might determine which contract is chosen in online platform channels. Moreover, Abhishek et al. (2015), Tan and Carrillo (2017), Lu et al. (2018), and Yan et al. (2018) allow suppliers to distribute their products through offline retail channels in addition to online platform channels.

Recent studies are also conducted in consideration of incomplete information between platforms and their suppliers. Hagiu and Wright (2015) assume that an intermediary and suppliers have private information about the ideal choice of marketing activities. They show that the wholesale (agency) mode is selected when the platform (independent supplier) has more accurate information for each specific product. Unlike the present paper, their analysis examines a monopoly platform: suppliers have no other channels. Belhadj et al. (2020) examine a signaling model by which a platform knows demand information, but a seller does not. They show that there might exist a separating equilibrium such that the platform acts as a reseller for high-demand products, while adopting a marketplace mode for low-demand products. The present study differs from theirs in that we specifically examine the extent of demand uncertainty, not whether the demand is high or low.

The previously described papers describe no examination of strategic contracting between wholesale and agency contracts, whereby suppliers choose whether to accept or reject the contract that is unilaterally offered by the platform. In other words, suppliers cannot choose another contract that has not been offered. Only two papers of the relevant literature describe studies examining strategic contracting in platforms (Tian et al. 2018, Zennyo 2020). They consider a model consisting of an online platform and two competing suppliers, in which the platform charges a royalty rate before the suppliers choose between wholesale and agency contracts. Consequently, the platform must determine the royalty rate strategically while anticipating the resulting contract choices by the suppliers. That study shows that asymmetric contracting, by which only one supplier adopts the agency contract, can arise in equilibrium when the degree of substitution between competing suppliers is at an intermediate level. However, unlike the present paper, their models allow for neither the presence of traditional channels nor information asymmetry on consumer demands.

The second strand comprises studies of information asymmetry and information sharing in supply chains. Many existing papers examine effect of information sharing in a fixed supply chain structure, including bilateral monopoly (e.g., Cachon and Lariviere 2001, Desiraju and Moorthy 1997, Guan and Chen 2017, Guo 2009a,b, Guo and Iyer 2010), exclusive dealer channels (e.g., Ha and Tong 2008, Ha et al. 2011, 2017), monopoly manufacturer channels (e.g., Gal-Or et al. 2008, Li 2002, Li and Zhang 2008, Zhang 2002), and monopoly common retailer channels (Shang et al. 2016). [4]

Some recent papers present consideration of more strategic situations in which information sharing might alter supply chain structures endogenously. Arya and Mittendorf (2013) demonstrate that an incumbent retailer selling products of a supplier might disclose favorable market information to invite new entrants into the retail market. The presence of an entrant induces the supplier to recognize its incumbent retailer as a partner to fight against the entrant, letting the incumbent have lower wholesale prices. Huang et al. (2018) indicate that a retailer has an incentive for sharing demand information with a supplier in an effort to prevent it from encroaching on the retail market through direct sales. In a different sense, Li et al. (2014) and Li et al. (2015) reach a similar conclusion: a retailer leverages its information advantage to deter supplier encroachment. In their model, unlike Arya and Mittendorf (2013), Huang et al. (2018), and the present paper, the retailer cannot completely disclose its demand information with the supplier. The retailer reduces its order quantities in the face of low demand to convey unfavorable market information to the supplier, which might prevent the supplier from encroaching. These papers specifically examine information sharing by retailers.

By contrast, Guan et al. (2020) investigate information sharing by suppliers. Encroachment with direct selling enables a supplier to have an opportunity to interact directly with consumers. The encroaching supplier is implicitly forced to disclose information related to its product quality because, if it does not do so, consumers would infer that the product is of poor quality. As a result, retailers can profitably free-ride the aggressive information disclosure by the supplier. Our study differs from theirs in that we consider information sharing by e-commerce platforms intermediating direct transactions between buyers and third-party sellers.

More recently, several studies have examined the issue of information sharing by platforms that deploy agency models. Li et al. (2021), Liu et al. (2021), Wang et al. (2021), and Wei and Huang (2019) assume for their studies that a platform decides whether to share demand information with sellers active on that platform. They demonstrate that the platform can have incentives for information sharing that differ greatly from the conventional wisdom of wholesale models, such that downstream firms are averse to sharing demand information with upstream firms because it exacerbates the double-marginalization problem (e.g., Li 2002, Zhang 2002). This finding stems from the revenue sharing nature of agency models. However, unlike the present paper, they do not allow multi-channel management of sellers, i.e., sellers have no channels other than the platform channel.

One exception is a study reported by Zhang and Zhang (2020), which examines a model consisting of a platform and a product supplier. The supplier is allowed to establish an offline direct channel. Similarly to our study, their analysis addresses how the platform's information sharing affects the supplier's multi-channel management. However, little or nothing has been explored about the

Table 1 Position of this paper among the relevant literature

	Information sharing by a platform	Multi-channel management	Strategic selling format choice	Endogenous commission rate
Abhishek et al. (2015)		✓		✓
Tian et al. (2018)			✓	✓
Zennyo (2020)			✓	✓
Wei and Huang (2019)	✓			
Wang et al. (2021)	✓			
Zhang and Zhang (2020)	✓	✓		
Li et al. (2021)	✓	✓		
Liu et al. (2021)	✓			
This paper	✓	✓	✓	✓

strategic effects of information sharing on other unrelated firms outside the platform. Regarding this point, this paper differs greatly from theirs in that we consider the presence of a retailer. That consideration enables us to review information-sharing effects on firms outside and inside the platform.

Moreover, compared with Zhang and Zhang (2020), we analyze the richer model including the following points: (i) the platform sets a commission rate endogenously and (ii) the supplier chooses between wholesale and agency models given the commission. In their analyses, Zhang and Zhang (2020) assume that a commission rate is fixed exogenously and that the platform unilaterally establishes a selling format between wholesale and agency models. Consequently, their results depend crucially on the value of the exogenous commission rate. By analyzing the richer model, we can ascertain and specify a relation between the extent of demand uncertainty and the resulting selling format, and can demonstrate further that the platform may choose to disclose its demand information to reverse the supplier's selling format choice. Moreover, our model can investigate how retailers are affected by recent movements from wholesale to agency models in e-commerce platforms.

Table 1 highlights the specific contributions of this paper in the relevant literature.

3 The Model

This section presents a description of a model with three firms: a product supplier, a traditional offline retailer, and an online platform. In the model, the supplier sells products through two channels: a traditional retail channel and an e-commerce platform channel. The platform provides two selling formats: wholesale and agency models. Details are described below.

The supplier sells its products through the retailer in a traditional wholesale manner, where the supplier sets a wholesale price, w_T, before the retailer chooses a retail price for the good as p_T. Subscript T is used to represent a *traditional* channel.

Additionally, the supplier sells its products through the platform, which prepares selling formats of two types. The first is a wholesale model, whereby the supplier sets a wholesale price w_E before the platform charges a retail price p_E as in the offline channel. Subscript E then denotes an *e-commerce* platform channel. The second one is an agency model, where the supplier can charge its retail price p_E directly while sales revenues are shared with the platform according to a commission rate, r, that is determined preliminarily by the platform. The supplier, given commission rate r, chooses one from the two models.

Consumers have two channels (i.e., offline and online) through which to purchase the goods. Following Raju et al. (1995), Li and Zhang (2008) and Shang et al. (2016), demand in the retail market is captured through the following demand functions:

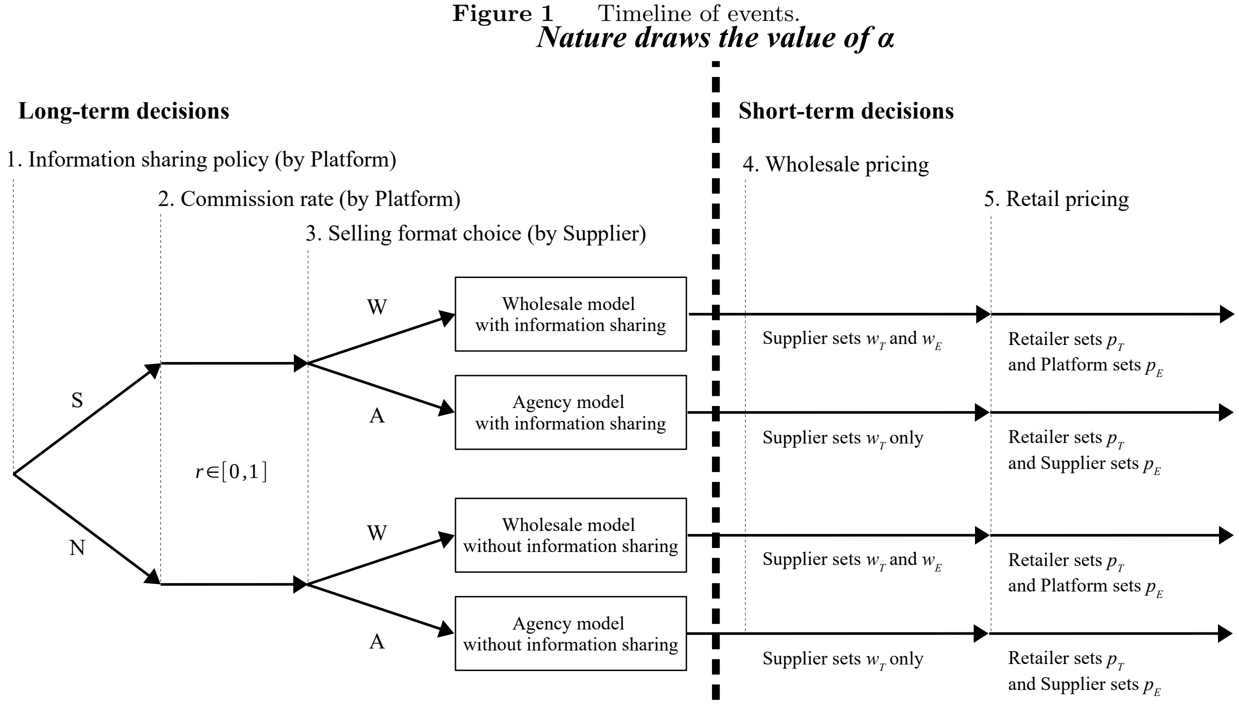
$$q_T = \alpha - (1+\gamma)p_T + \gamma p_E, \quad q_E = \alpha - (1+\gamma)p_E + \gamma p_T. \tag{1}$$

In the demand functions, α represents a common market potential for the product of the supplier, which is assumed to be uncertain and distributed on the interval $[\underline{\alpha}, \overline{\alpha}]$, according to distribution function $G(\alpha)$, with mean $\mu > 0$ and variance $\sigma^2 \geq 0$. Parameter μ denotes the expected market size; σ^2 represents the variance of the market size distribution. One can use the term σ^2/μ^2 to measure the standardized degree of demand uncertainty, which represents the degree to which the market size is volatile. In our analysis, as demonstrated later, σ^2/μ^2 plays a key role in determining the equilibrium selling format choice.

The actual realization of α is observed (or predicted accurately) by the platform and retailer: not by the supplier. To model the supplier's disadvantage in demand information, we assume for simplicity that the supplier knows nothing other than the characteristics of the distribution of α, whereas the platform and retailer learn the realization of α accurately. The informed platform is allowed to share its demand information truthfully with the uninformed supplier (e.g., Aviv 2001, Cachon and Fisher 2000, Lee et al. 2000). Details of the timing of the game are explained below.

Parameter $\gamma > 0$ denotes the degree of substitution between offline and online channels. For larger (smaller) γ, the two channels are found to be highly substitutable (differentiated). Although products sold in offline and online channels are manufactured by the same supplier, we assume them to be horizontally differentiated, as in Abhishek et al. (2015) and Lu et al. (2018). Consumers probably have different preferences for the two channels. Several factors affect their preferences for offline and online channels, such as immediate availability and savings in traveling and purchase time. Consequently, parameter γ can be regarded as representing the degree of cross-channel

Figure 1 Timeline of events.



substitution for consumers. It is also worth noting that the total demand $q_T + q_E = 2\alpha - p_T - p_E$ is independent of γ, which ensures that the degree of substitution does not change the market potential directly.

For simplicity, we normalize the unit production cost of the supplier to zero. Therefore, the profit functions for the supplier, traditional retailer, and e-commerce platform, respectively, are given as presented below.

$$\pi_S = \begin{cases} w_T q_T + w_E q_E & \text{if Supplier chooses Wholesale model} \\ w_T q_T + (1-r) p_E q_E & \text{if Supplier chooses Agency model} \end{cases} \tag{2}$$

$$\pi_T = (p_T - w_T) q_T \tag{3}$$

$$\pi_E = \begin{cases} (p_E - w_E) q_E & \text{if Supplier chooses Wholesale model} \\ r p_E q_E & \text{if Supplier chooses Agency model} \end{cases} \tag{4}$$

At the time of the suppliers' selling format choice, a commission rate must already be offered by the platform. To capture those realities, as illustrated in Figure 1, the game has the following timeline.

Long-term decisions: Before an actual demand size is realized, firms make the following decisions.

1. Information sharing policy: The e-commerce platform chooses whether to commit to sharing its demand information with the supplier after realization of the actual demand size.

2. Commission rate: The platform determines a commission rate r used only when the supplier chooses the agency model in the next stage.

3. Selling format choice: The supplier selects either a wholesale model or an agency model.

Short-term decisions: Nature determines an actual demand size α, which is observed by the platform and retailer, but not by the supplier. This demand information is shared with the supplier according to the information sharing policy determined in Stage 1. Thereafter, the firms make the following pricing decisions based on information they have.

4. Wholesale pricing: The supplier sets a wholesale price to the retailer, w_T. Additionally, if the wholesale model was chosen in Stage 3, the supplier sets a wholesale price to the platform, w_E. [5]

5. Retail pricing: The retailer charges a retail price p_T for the offline channel. An online retail price p_E is determined either by the platform if the wholesale model was chosen or by the supplier if the agency model was chosen.

Decisions of Stages 1–5 are listed in order of difficulty to change frequently: The platform's information sharing policy (i.e., Stage 1) is the most difficult to revise, whereas retail pricing (i.e., Stage 5) is the easiest to change. [6] We divide these decisions into short-term and long-term ones according to whether they are changed more or less frequently than updating of information (or prediction) about the actual demand size. In practice, actual demand situations change over time. For example, at the beginning of every day, using huge amounts of transaction data, the platform and retailer make a prediction about the actual market size of the day, which is shared with the supplier according to the platform's information sharing policy. Using demand prediction, pricing decisions (Stages 4 and 5) are made several times a day. By contrast, the remaining decisions related to information sharing policy, commission rate, and selling format choice (Stages 1, 2, and 3) are not meant to change more often than once a day. Therefore, we classify Stages 1, 2, and 3 as long-term decisions and classify Stages 4 and 5 into short-term decisions for this study.

It is worth emphasizing that the order of Stages 1 and 2 does not dictate the results derived in this paper because both decisions are made by the same player, i.e., the platform. Our results explained below remain unchanged even if the platform determines its information-sharing policy and commission rate simultaneously. As described herein, for ease of exposition, we presume that an information sharing policy is determined in Stage 1 and presume that a commission rate is set in Stage 2.

Additionally, we assume that the platform moves (Stages 1 and 2) before the supplier does (Stage 3). This timing assumption stems from the fact that a platform's decisions are about the overall design of its marketplace, whereas each supplier's decision merely reflects an individual's decision-making. In practice, platforms cannot discriminate among their suppliers. It must offer an equivalent policy for its information sharing and commission rate to all suppliers, which should be regarded as a longer-term decision than individual suppliers' selling format choices.

By contrast, an earlier study by Zhang and Zhang (2020) assesses a different timeline in which an e-tailer (i.e., the platform in our model) chooses between agency or wholesale models in Stage 1 and subsequently chooses whether to establish an information sharing policy in Stage 2. That is, the selling format choice is made before the decision on information sharing, which differs from our setting. However, because both decisions are made by the same player (i.e., e-tailer) in their model, the order of Stages 1 and 2 does not dictate their results. Therefore, an important difference between theirs and ours is that we allow the supplier to select a selling format.

One might consider that the platform's information sharing is available conditionally upon the choice of agency model. We examine this conditional information sharing policy in Section 6.1.

The equilibrium concept used for this study is the subgame perfect equilibrium. We solve the game using backward induction. Detailed proofs are presented in the Online Appendix.

4 Analysis of Short-Term Decisions

This section specifically explains short-term decisions. After long-term decisions are made, four possible cases exist: (i) wholesale model with information sharing, (ii) agency model with information sharing, (iii) wholesale model without information sharing, and (iv) agency model without information sharing. Herein, we solve pricing subgames (i.e., Stages 4 and 5) for the respective cases.

4.1 Wholesale model with information sharing

Consider case (i), in which information about the actual demand size is shared with the supplier who adopts the wholesale model in the online channel. The supplier chooses wholesale prices to the retailer and to the platform simultaneously in Stage 4. Then, after observing those wholesale prices, the retailer and platform determine their retail prices independently in Stage 5. It is noteworthy that all firms determine their pricing decisions based on accurate information about demand size α.

Maximization problems that the retailer and the platform face in Stage 5 are given respectively as $\max_{p_T} \pi_T = (p_T - w_T)q_T$ and $\max_{p_E} \pi_E = (p_E - w_E)q_E$. Solving these problems yields

$$p_T = \frac{\alpha(2+3\gamma) + 2(1+\gamma)^2 w_T + \gamma(1+\gamma)w_E}{(2+\gamma)(2+3\gamma)}, \quad p_E = \frac{\alpha(2+3\gamma) + 2(1+\gamma)^2 w_E + \gamma(1+\gamma)w_T}{(2+\gamma)(2+3\gamma)}. \quad (5)$$

In Stage 4, given the retail pricing described above, the supplier chooses w_T and w_E to maximize its profit, $\pi_S = w_T q_T + w_E q_E$, implying

$$w_T^{WS} = w_E^{WS} = \frac{\alpha}{2}, \quad (6)$$

where superscript 'WS' denotes the case of the *wholesale* model with information *sharing*. The expected profit of the supplier is computed as

$$E\left[\pi_S^{WS}\right] = \frac{(1+\gamma)(\mu^2+\sigma^2)}{2(2+\gamma)}, \tag{7}$$

where σ^2 represents the measure of informational gains which the supplier gains from information sharing. Other outcomes are also derived. They are presented in Table A.1 in the Appendix.

4.2 Agency model with information sharing

We address case (ii), in which information related to the actual demand size is shared with the supplier who adopts the agency model in the platform. Given a commission rate r, the supplier sets a wholesale price to the retailer in Stage 4. Then, in Stage 5, an offline retail price is determined by the retailer, whereas an online retail price is set directly by the supplier. As in case (i), all firms determine their pricing decisions based on accurate demand information.

Maximization problems confronting the retailer and supplier face in Stage 5 are given respectively as $\max_{p_T} \pi_T = (p_T - w_T)q_T$ and $\max_{p_E} \pi_S = w_T q_T + (1-r)p_E q_E$. The supplier determines its retail price for the online channel while considering the quantities sold through the offline channel. Solving these maximization problems yields the following:

$$p_T = \frac{\alpha}{2+\gamma} + \frac{2+4\gamma+3\gamma^2-2r(1+\gamma)^2}{(1-r)(2+\gamma)(2+3\gamma)} w_T, \quad p_E = \frac{\alpha}{2+\gamma} + \frac{(3-r)\gamma(1+\gamma)}{(1-r)(2+\gamma)(2+3\gamma)} w_T. \tag{8}$$

In Stage 4, anticipating the retail pricing above, the supplier chooses w_T to maximize its profit as $\pi_S = w_T q_T + (1-r)p_E q_E$, thereby yielding

$$w_T^{AS} = \frac{(1-r)\alpha(2+3\gamma)\left\{(1+2\gamma)(4+6\gamma+3\gamma^2) - 2\gamma(1+\gamma)^2 r\right\}}{2(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3 - 8(1+\gamma)^2(1+2\gamma)r - \gamma^2(1+\gamma)^2 r^2\right\}}, \tag{9}$$

where superscript 'AS' denotes the case of the *agency* model with information *sharing*. The expected profit of the supplier is the following.

$$E\left[\pi_S^{AS}\right] = \frac{(1-r)(\mu^2+\sigma^2)(1+2\gamma)(2+3\gamma)\left\{6+11\gamma+6\gamma^2-4(1+\gamma)^2 r\right\}}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2 r^2\right\}} \tag{10}$$

As in case (i), the supplier gains from information sharing, which is represented by σ^2. Other outcomes are also derived. They are presented in Table A.1.

To ensure that all resulting outcomes shown in Table A.1 take non-negative values, it must hold that $r \le (4+7\gamma+4\gamma^2)/(4+9\gamma+6\gamma^2+\gamma^3) \equiv \overline{r}$. Otherwise, if $r > \overline{r}$, then the resulting online demand is equal to zero (i.e., $q_E^{AS} = 0$), implying that the platform earns no profit (i.e., $\pi_E^{AS} = 0$). In equilibrium, the platform never charges such a high commission rate, as demonstrated later. In other words, this case is off the equilibrium path.

4.3 Wholesale model without information sharing

We consider case (iii), in which the actual demand information is not shared with the supplier who adopts the wholesale model in the online channel. In Stage 4, the supplier must determine wholesale prices to the retailer and the platform based on expectations about α. In Stage 5, after observing those wholesale prices, offline and online retail prices are set respectively by the retailer and platform, who know the actual market size.

The maximization problems confronting the informed retailer and platform in Stage 5 are the same as those described for case (i). Consequently, their pricing decisions are equivalent to those derived in Equation (5).

In Stage 4, the supplier chooses w_T and w_E to maximize its expected profit as $E[\pi_S] = E[w_T q_T + w_E q_E]$, based on expectations about α. Solving this maximization problem yields

$$w_T^{WN} = w_E^{WN} = \frac{\mu}{2}, \tag{11}$$

where superscript 'WN' denotes the case of the *wholesale* model with *no* information sharing. As Equation (11) shows, wholesale pricing is determined according to the ex-ante demand expectation: μ. Other outcomes are derived using these wholesale prices. They are presented in Table A.2 in the Appendix.

Comparing the firms' expected profits under the wholesale model between two cases with and without information sharing (i.e., cases [i] and [iii]), one can notice that, without information sharing, the term representing informational gains (i.e., σ^2) disappears from the uninformed supplier's expected profit. In contrast, provided that the wholesale model is adopted, both the informed retailer and platform benefit from not sharing demand information with the supplier.

LEMMA 1. *Suppose that the wholesale model is adopted in the online channel. Information sharing benefits the supplier, but it hurts the offline retailer and online platform. Formally,* $E[\pi_S^{WS}] > E[\pi_S^{WN}]$, $E[\pi_T^{WS}] < E[\pi_T^{WN}]$, *and* $E[\pi_E^{WS}] < E[\pi_E^{WN}]$ *hold.*

4.4 Agency model without information sharing

Finally, case (iv) is examined, where actual demand information is not shared with the supplier who adopts the agency model in the online channel. Given commission rate r, the supplier sets a wholesale price to the retailer based on expectations about α in Stage 4. In Stage 5, subsequently, the supplier must charge an online retail price based on the expectation, whereas the retailer determines an offline retail price using accurate demand information.

Maximization problems that the retailer and supplier face in Stage 5 are given respectively as $\max_{p_T} \pi_T = (p_T - w_T)q_T$ and $\max_{p_E} E[\pi_S] = E[w_T q_T + (1-r)p_E q_E]$. Solving these maximization problems yields the following:

$$p_T = \frac{1}{2(1+\gamma)}\left(\alpha + (1+\gamma)w_T + \frac{(1-r)\mu\gamma(2+3\gamma) + (3-r)\gamma^2(1+\gamma)w_T}{(1-r)(2+\gamma)(2+3\gamma)}\right), \tag{12}$$

$$p_E = \frac{\mu}{2+\gamma} + \frac{(3-r)\gamma(1+\gamma)}{(1-r)(2+\gamma)(2+3\gamma)}w_T. \tag{13}$$

Here, the online price determined by the uninformed supplier consists of *ex ante* information only (i.e., μ), whereas the offline price set by the informed retailer reflects *ex post* information (i.e., α) as well.

In Stage 4, the supplier chooses w_T to maximize its expected profit, $E[\pi_S] = E[w_T q_T + (1-r)p_E q_E]$, implying

$$w_T^{AN} = \frac{(1-r)\mu(2+3\gamma)\{(1+2\gamma)(4+6\gamma+3\gamma^2) - 2\gamma(1+\gamma)^2 r\}}{2(1+\gamma)\{8+32\gamma+41\gamma^2+18\gamma^3 - 8(1+\gamma)^2(1+2\gamma)r - \gamma^2(1+\gamma)^2 r^2\}}, \tag{14}$$

where superscript 'AN' denotes the case of the *agency* model with *no* information sharing. The other outcomes are derived using this wholesale price. They are presented in Table A.2. As in case (ii), the commission rate charged by the platform must be sufficiently small to satisfy $r \le \overline{r}$ to ensure that all the resulting outcomes presented in Table A.2 take non-negative values.

By comparing the firms' expected profits under the agency model between two cases with and without information sharing (i.e., cases [ii] and [iv]), we obtain the following lemma.

LEMMA 2. *Suppose that the agency model is adopted in the online channel. Information sharing benefits the supplier and platform (i.e.,* $E[\pi_S^{AS}] > E[\pi_S^{AN}]$ *and* $E[\pi_E^{AS}] > E[\pi_E^{AN}]$*). However, its effects on the retailer depend on the commission rate value as* $E[\pi_T^{AS}] < E[\pi_T^{AN}]$ *if and only if*

$$r < \min\left\{\overline{r}\ ,\ \frac{2+6\gamma+5\gamma^2+2\gamma^3 - \sqrt{4+16\gamma+20\gamma^2+12\gamma^3+13\gamma^4+12\gamma^5+4\gamma^6}}{2\gamma(1+\gamma)^2}\right\}. \tag{15}$$

As Tables A.1 and A.2 show, it is particularly interesting that, without information sharing, the uninformed supplier and the informed platform gain nothing from demand information (i.e., σ^2 does not appear in their profits). This outcome is true because, in the agency model, retail pricing in the online channel is delegated to the supplier. Without information sharing, the platform might be adversely affected by incorrect pricing by the uninformed supplier (i.e., the less-information effect).

In contrast, information sharing is fundamentally detrimental to the retailer, unless the predetermined commission rate is too high, as shown in condition (15). As presented later, in equilibrium, the platform never charges such a high commission rate: then information sharing hurts the retailer provided that the agency model is adopted.

5 Analysis of Long-Term Decisions

We turn next to the analyses of the long-term decisions (i.e., Stages 1, 2, and 3). Depending on whether the platform commits to sharing its demand information with the supplier or not in Stage 1, two subgames emerge. We specifically examine the subgame with information sharing in Sections 5.1 before the other is considered in Section 5.2. Finally, Section 5.3 examines the platform's incentive for information sharing.

5.1 Information sharing case

We consider the subgame starting after the platform commits to sharing its demand information with the supplier in Stage 1. We first examine the supplier's selling format choice given commission rate r in Section 5.1.1. Then, in Section 5.1.2, we present the optimal commission rate in the case of information sharing.

It is noteworthy that the following analysis for this subgame also presents the outcome that occurs when information disclosure is mandatory.

5.1.1 Supplier selling format choice with information sharing

We examine the supplier's decision of choosing either the wholesale or agency model in Stage 3. The decision is done on a long-term basis so that either model is selected before actual potential demand is realized. In other words, the supplier chooses between wholesale and agency models based on expectations. Comparing $E\left[\pi_S^{WS}\right]$ and $E\left[\pi_S^{AS}\right]$, which are shown in Equations (7) and (10), yields the following lemma regarding the supplier's selling format choice given commission rate r.

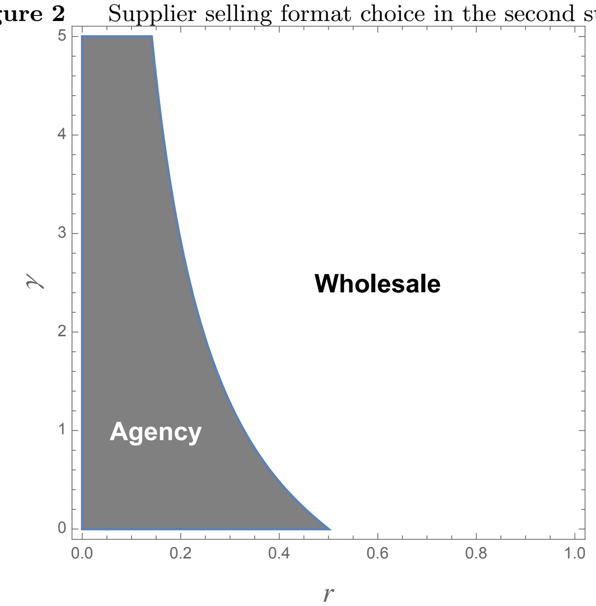
Lemma 3. *The supplier chooses the agency model if and only if* $0 \leq r \leq \tilde{r}(\gamma)$, *where*

$$\tilde{r}(\gamma) \equiv \frac{24 + 140\gamma + 310\gamma^2 + 325\gamma^3 + 160\gamma^4 + 28\gamma^5 - (2+3\gamma)\sqrt{\rho}}{4(1+\gamma)^2(8 + 32\gamma + 39\gamma^2 + 14\gamma^3 + \gamma^4)}, \tag{16}$$

with $\rho = 16 + 160\gamma + 696\gamma^2 + 1720\gamma^3 + 2625\gamma^4 + 2512\gamma^5 + 1464\gamma^6 + 472\gamma^7 + 64\gamma^8$. *Otherwise, if* $r > \tilde{r}(\gamma)$, *then the supplier selects the wholesale model.*

This lemma characterizes the threshold value of commission rate, denoted by $\tilde{r}(\cdot)$, below which the supplier chooses the agency model. It is noteworthy that $\tilde{r}(\cdot)$ is independent of market potential α's prior distribution (i.e., μ and σ^2). In words, the threshold value depends only on the degree of substitution between online and offline channels, but not on other parameters, including the extent of demand uncertainty and the average market potential. As depicted in Figure 2, in the gray (white) area, the agency (wholesale) model is chosen.

Figure 2 Supplier selling format choice in the second stage.



Moreover, as the figure shows, the threshold value $\tilde{r}(\gamma)$ is a decreasing function in $\gamma \geq 0$ that takes $1/2$ for $\gamma = 0$. When two channels are perfectly differentiated (i.e., $\gamma = 0$), the supplier makes a selling format choice irrespective of decisions made in the offline channel; the agency model is selected unless more than half of online sales are taken by the platform. By contrast, as the two channels becomes nearly homogeneous (i.e., γ increases), under the agency model, the supplier gets involved in fiercer price competition with the retailer in the retail market. Otherwise, under the wholesale model, online retail pricing is delegated to the platform. By charging high wholesale prices to both channels, the supplier can mitigate price competition in the retail market and prevent the resulting retail prices from being too low. Therefore, choosing the wholesale model is likely to be more profitable for the supplier as the degree of substitution becomes larger.

5.1.2 Commission rate and the resulting selling format with information sharing

We present how the platform sets a commission rate with consideration of the supplier's selling format choice shown above. From Lemma 3, the platform chooses r to maximize its expected profit as shown below:

$$E\left[\pi_E^S(r)\right] = \begin{cases} E\left[\pi_E^{AS}(r)\right] & \text{if } r \leq \tilde{r}(\gamma) \\ E\left[\pi_E^{WS}\right] & \text{otherwise} \end{cases} \tag{17}$$

The profit function has the following features.

Lemma 4. *When demand information is shared with the supplier, the following statements hold:*

(i) The platform's expected profit is increasing in $r \in [0, \tilde{r}(\gamma)]$ and is constant in $r \in (\tilde{r}(\gamma), 1]$.

(ii) It holds that $E[\pi_E^{AS}(\tilde{r})] > E[\pi_E^{WS}]$ *for* $\mu > 0$*,* $\sigma^2 \geq 0$*, and* $\gamma \in [0,1)$*.*

Lemma 4 (i) implies that the platform's optimal commission rate is either charging $r = \tilde{r}(\gamma)$ to induce the supplier to choose the agency model, or charging $r > \tilde{r}(\gamma)$ to force the supplier to choose the wholesale model. Lemma 4 (ii) shows that the former pricing dominates the latter pricing. In total, the following proposition regarding the optimal commission rate and the resulting selling format is derived.

Proposition 1. *When demand information is shared with the supplier, the commission rate is set at* $r = \tilde{r}(\gamma)$*; then the resulting selling format chosen by the supplier is the agency model.*

Proposition 1 shows that the platform offers $r = \tilde{r}(\gamma)$ to induce the supplier to choose the agency model. By the definition of $\tilde{r}(\gamma)$, it turns out that $E[\pi_S^{AS}(\tilde{r})] = E[\pi_S^{WS}]$, which means that the expected profit for the supplier is equal to the expected profit it could obtain if it were to choose the wholesale model. Therefore, the supplier has no incentive to deviate.

The platform prefers the agency model over the wholesale model for two reasons. First, as described by Johnson (2017), moving first is advantageous. In the wholesale model, a larger share of online sales revenues is taken by the supplier because the supplier is the first-mover. In contrast, under the agency model, the platform can take the first-mover advantage (i.e., the leadership effect). Second, revenue-sharing of the agency model mitigates the double marginalization problem (e.g., Johnson 2017), which in turn lowers the online retail price and expands the online demand (i.e., the revenue-sharing effect). For these effects, the platform manipulates its commission rate to lead the supplier to choose the agency model, provided that demand information is shared with the supplier.

Comparing the resulting wholesale and retail prices in the two channels, the following corollary is obtained.

Corollary 1. *For* $\alpha > 0$ *and* $\gamma \in [0,1)$*, it holds that* $w_T^{AS}(\tilde{r}) < p_E^{AS}(\tilde{r}) < p_T^{AS}(\tilde{r})$ *and* $q_E^{AS}(\tilde{r}) > q_T^{AS}(\tilde{r})$*.*

This corollary shows that the retail price is lower under the e-commerce channel than under the traditional channel. As a result, larger quantities are demanded in the e-commerce channel. One can infer that this result is consistent with anecdotal evidence that Amazon handles a huge amount of demand. In other words, Corollary 1 formally confirms the revenue-sharing effect that the agency model mitigates the double marginalization problem. This result is consistent with Johnson (2017). His model, however, differs from ours in that there is no traditional channel and that the strategic contracting between the supplier and the platform is not examined.

Next, we demonstrate the effects of movements to agency models from traditional wholesale models, which is an influential change that occurs with recent e-commerce platforms. Consequently, the respective effects of the movement on the platform, supplier, and retailer become apparent.

COROLLARY 2. *The following statements hold:*
(i) $E[\pi_E^{AS}(\tilde{r})] > E[\pi_E^{WS}]$ *for* $\gamma > 0$*,*
(ii) $E[\pi_S^{AS}(\tilde{r})] = E[\pi_S^{WS}]$ *for* $\gamma > 0$*, and*
(iii) $E[\pi_T^{AS}(\tilde{r})] > E[\pi_T^{WS}]$ *if and only if* $\gamma > \tilde{\gamma}$*, where* $\tilde{\gamma} \simeq 1.20025$*.*

As explained above, the revenue-sharing effect of the agency model reduces the extent of inefficiency associated with the double marginalization problem in the platform channel. Gains from increased efficiency are extracted by the platform. The platform sets its commission rate at the level at which the expected profit of the supplier is equal to the profit it can earn when choosing the wholesale model. Therefore, the supplier's profit in the two models is the same.

Of special interest is the effect on the retailer. Corollary 2(iii) shows that, when online and offline channels are highly substitutable, industrial movements to the agency model can increase the expected profit of the retailer. A key driver generating this result is relocation of the supplier's profit center. Under the agency model, a large share of online sales revenues is taken by the platform because of its first-mover advantage (i.e., the leadership effect). This effect incentivizes the supplier to shift its profit center from online to offline channels. To this end, the supplier lowers its wholesale price for the retailer. Moreover, it is easier for the supplier to switch the profit center as the two channels become highly substitutable. Therefore, as γ becomes larger, the retailer can receive greater benefits from the transition of the supplier's profit center.

In an environment with information transparency, irrespective of whether it is voluntary or mandatory, all players (a supplier, retailer, and platform) are weakly benefited with a change from wholesale to agency agreements when online and offline channels are highly substitutable. Recent improvements in online purchasing (e.g., short delivery time, rich photographs of products, user-friendly web design, and security) have been able to provide consumers with better experiences and have thereby reduced the weaknesses compared with purchases made at brick-and-mortar retailers. Future development of online channels can be to engender high substitutability with existing physical channels, possibly provoking a (weakly) Pareto-improvement situation. [7]

5.2 No information sharing case

We consider the subgame that would be played given no information sharing. As in the case described earlier with information sharing, we first examine the supplier's selling format choice given commission rate r in Section 5.2.1 before presenting the optimal commission rate decision in Section 5.2.2.

5.2.1 Supplier's selling format choice without information sharing

We investigate the supplier's selling format choice in Stage 3 when no demand information is disclosed. Comparison of $E[\pi_S^{WN}]$ and $E[\pi_S^{AN}]$ yields the following lemma.

LEMMA 5. *The supplier chooses the agency model if and only if $0 \le r \le \tilde{r}(\gamma)$, where $\tilde{r}(\gamma)$ is defined in Lemma 3.*

Lemma 5 uncovers that the threshold value of commission rate, at which the supplier is indifferent between choosing the wholesale and agency models, is the same as the one derived in the subgame of information sharing described earlier.

Therefore, in the present model, the supplier's selling format choice depends on the commission rate value, but not on the information disclosure policy. This result might depend on our assumption that the supplier's marginal cost is zero. With a positive marginal cost, the threshold value would take different values depending on the presence or absence of information sharing. One can infer that the platform lowers its commission rate when it does not disclose demand information with the supplier.

5.2.2 Commission rate and the resulting selling format without information sharing

We examine the platform's optimal choice on its commission rate. As Lemmas 3 and 5 indicate, given a commission rate, the supplier's selling format choice is independent of whether demand information is shared or not. Consequently, the platform's objective function has the same threshold value, $\tilde{r}(\cdot)$, as that of the information-sharing subgame.

$$E\left[\pi_E^N(r)\right] = \begin{cases} E\left[\pi_E^{AN}(r)\right] & \text{if } r \le \tilde{r}(\gamma) \\ E\left[\pi_E^{WN}\right] & \text{otherwise} \end{cases} \tag{18}$$

Even given the same threshold, functional forms (i.e., $E[\pi_E^{AN}(r)]$ and $E[\pi_E^{WN}]$) differ from those of the information sharing subgame. Therefore, hereinafter, we check whether two important properties for the platform profit (i.e., Lemmas 4 still hold or not).

LEMMA 6. *When demand information is not shared with the supplier, the following statements hold.*

(i) The platform's expected profit is increasing in $r \in [0, \tilde{r}(\gamma)]$ and is constant in $r \in (\tilde{r}(\gamma), 1]$.

(ii) A threshold value exists, denoted by Σ, such that $E[\pi_E^{AN}(\tilde{r})] > E[\pi_E^{WN}]$ holds if and only if $\sigma^2/\mu^2 < \Sigma$.

First, Lemma 6 (i) mirrors the result of Lemma 4 (i), implying that the platform's optimal commission rate is either charging $r = \tilde{r}(\gamma)$ to induce the supplier to choose the agency model, or charging $r > \tilde{r}(\gamma)$ to lead the supplier to choose the wholesale model. However, the result of Lemma 4 (ii), by which the former pricing invariably dominates the latter one, does not necessarily arise in the current subgame, as described in Lemma 6 (ii). The result of Lemma 4 (ii) remains unchanged, unless consumer demands are highly uncertain ($\sigma^2/\mu^2 \geq \Sigma$).

From Lemma 6, we derive the following proposition.

PROPOSITION 2. *Suppose that demand information is not shared with the supplier. If demand uncertainty is sufficiently low to satisfy $\sigma^2/\mu^2 < \Sigma$, then the platform sets its commission rate at $r = \tilde{r}(\gamma)$ to induce the supplier to choose the agency model. Otherwise, if $\sigma^2/\mu^2 \geq \Sigma$, then the commission rate is set so high that the supplier chooses the wholesale model.*

The result of Proposition 2 partially complements that of Proposition 1 showing that the agency model is chosen by the supplier. This result remains unchanged when demand uncertainty is known to be low (i.e., $\sigma^2/\mu^2 < \Sigma$).

However, when confronting highly uncertain demand (i.e., $\sigma^2/\mu^2 \geq \Sigma$), the platform gives up forcing the supplier to select the agency model. The agency model is favorable to the platform for two reasons (i.e., the leadership and revenue-sharing effects), but unfavorable for one reason (i.e., the less-information effect). The negative less-information effect is more likely to dominate the positive effects as consumer demands become increasingly uncertain. Therefore, the platform hesitates over delegating retail pricing to the uninformed supplier.

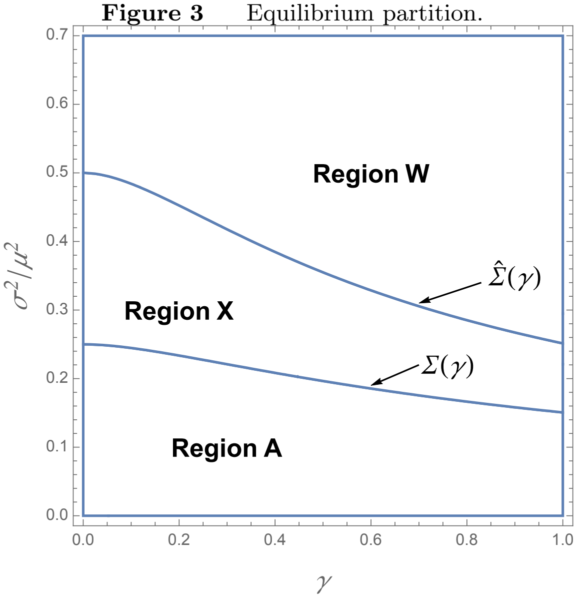
In other words, under the wholesale model, the less-information effect works positively for the platform, which is consistent with the well-known result that information sharing in a supply chain exacerbates the double marginalization effect (e.g., Li and Zhang 2008). Specifically, even for very large actual demand size, the uninformed supplier would charge a low wholesale price, which benefits the platform and offline retailer. One might consider that the reverse would also happen: even for very small actual demand size, the supplier would change a high wholesale price. Although that is true, gains from the former are greater than losses from the latter in terms of expectations. The platform can benefit from the supplier's ignorance about the actual demand situation with the wholesale model in the face of highly uncertain demands. Therefore, a very high commission rate is set to induce the supplier to select the wholesale model.

5.3 Information sharing decision

Finally, we study the platform's incentive for information sharing. The equilibrium information sharing policy is characterized as presented below.

PROPOSITION 3. *A threshold value $\hat{\Sigma}$ exists such that the platform commits to information sharing in equilibrium if and only if $\sigma^2/\mu^2 \leq \hat{\Sigma}$, where $\hat{\Sigma}$ solves $E[\pi_E^{AS}(\tilde{r})] = E[\pi_E^{WN}]$ and is greater than*

Figure 3 Equilibrium partition.



Note: Region A (W) shows the area in which the *agency* (*wholesale*) model is selected irrespective of the presence or absence of information sharing. Region X shows the area in which the resulting model depends extensively on the existence of information sharing.

Σ. Subsequently, the commission rate is set at $r = \tilde{r}(\gamma)$. The supplier adopts the agency model. Otherwise, if demand uncertainty is sufficiently high to satisfy $\sigma^2/\mu^2 > \hat{\Sigma}$, then the platform conceals its demand information. The supplier adopts the wholesale model.

Figure 3 presents results of Proposition 3.

Region A in the figure represents the parameter range of $\sigma^2/\mu^2 < \Sigma$, in which the resulting selling format is the agency model, irrespective of the information sharing policy. Provided that the agency model is adopted, the platform benefits from sharing its demand information with the supplier who is entrusted with pricing for its online marketplace. Therefore, in equilibrium, the platform commits to information sharing. Then the supplier chooses the agency model.

In contrast, in Region W, where consumer demand is too uncertain (i.e., $\sigma^2/\mu^2 > \hat{\Sigma}$), the resulting selling format is the wholesale model, irrespective of the information sharing policy. Under the wholesale model, the less-information effect works positively for the platform, as explained below Proposition 2. Therefore, the platform conceals its information to prevent the supplier from choosing the agency model.

Of special interest is the situation when the extent of demand uncertainty is at an intermediate level (i.e., $\Sigma \leq \sigma^2/\mu^2 \leq \hat{\Sigma}$), which is depicted as Region X in Figure 3. In this parameter range, without information sharing, the supplier would select the wholesale model. In equilibrium, however, the platform commits to information sharing to compel the supplier to change its selling format choice. The agency model is adopted eventually. The platform's information disclosure alters the resulting selling format that the supplier uses in the online marketplace.

Proposition 3 implies that the resulting selling format depends strongly on the extent of ex ante demand uncertainty. Fundamentally, the platform prefers to make the supplier choose the agency model, unless consumer demand is highly uncertain. High demand uncertainty induces the platform hesitate over delegating retail pricing to the uninformed supplier. Consequently, depending on circumstances, the platform has an incentive to commit to sharing demand information with the supplier. This voluntary disclosure eventually raises the likelihood of the agency model being selected.

6 Discussion

This section presents discussion of several issues missing from the main analysis.

6.1 Conditional information sharing

For the main analysis, we assumed that committing to information sharing requires the platform to disclose its demand information with the supplier, irrespective of which selling format the supplier will choose. Possibly, however, e-commerce platforms might want to share demand information only with their third-party suppliers adopting the agency model. Therefore, we examine the profitability of information sharing conditional on the selection of the agency model.

It is noteworthy that the game with conditional information sharing which we consider here is (analytically) equivalent to a game with the following timeline. The platform charges a commission rate in Stage 1. The supplier chooses either a wholesale or agency model in Stage 2. The platform decides whether to disclose its information or not in Stage 3.

With this conditional information sharing, the supplier compares $E\left[\pi_S^{WN}\right]$ and $E\left[\pi_S^{AS}(r)\right]$ when choosing between wholesale and agency models.

Proposition 4. *In an environment of conditional information sharing, the threshold value of the commission rate at which the supplier is indifferent between wholesale and agency models is higher than $\tilde{r}$.*

This proposition implies that conditional information sharing makes the agency model more likely to be selected by the supplier.

Let us consider a low-uncertainty or moderate-uncertainty case of $\sigma^2/\mu^2 < \hat{\Sigma}$, where full information sharing is superior to no information sharing. From Lemma 4, an increase in the threshold value enables the platform to charge a higher commission rate while still inducing the supplier to choose the agency model, which increases the resulting profit for the platform. Therefore, conditional information sharing, if possible, would dominate full information sharing.

6.2 Information sharing from offline retailers

Heretofore, the platform has been assumed as a decision maker of whether to disclose demand information with the supplier or not. If the other informed player (i.e., the retailer) can also disclose demand information, does it alter the equilibrium outcome? Therefore, we investigate whether the retailer has an incentive for information sharing when the platform does not (i.e., $\sigma^2/\mu^2 > \hat{\Sigma}$).

PROPOSITION 5. *When the platform conceals demand information from the supplier, the retailer also has no incentive to disclose it. Formally, it follows that* $E[\pi_T^{AS}(\tilde{r})] < E[\pi_T^{WN}]$ *for* $\sigma^2/\mu^2 \geq \hat{\Sigma}$.

This proposition ensures that the equilibrium outcome we derived in the main analysis remains unchanged even if demand information can be disclosed by the retailer as well as the platform.

Additionally, it becomes apparent how the platform's voluntary information sharing in equilibrium affects the retailer profit.

PROPOSITION 6. *The retailer is adversely affected by information sharing between the platform and supplier. Formally,* $E[\pi_T^{AS}(\tilde{r})] < E[\pi_T^{AN}(\tilde{r})]$ *for* $\sigma^2/\mu^2 < \Sigma$ *and* $E[\pi_T^{AS}(\tilde{r})] < E[\pi_T^{WN}]$ *for* $\sigma^2/\mu^2 \in [\Sigma, \hat{\Sigma}]$.

In the low-uncertainty case (i.e., $\sigma^2/\mu^2 < \Sigma$), the agency model is selected irrespective of the presence or absence of information sharing. Information sharing simply cancels out the less-information effect, which prevents the retailer from receiving gains from information advantages over the supplier.

In the moderate-uncertainty case (i.e., $\Sigma \leq \sigma^2/\mu^2 \leq \hat{\Sigma}$), information sharing changes the resulting selling format from wholesale to agency models in addition to canceling out the less-information effect. The latter effect is detrimental to the retailer, whereas the former effect can be beneficial depending on parameters, as shown in Corollary 2. Eventually, however, the negative effect dominates the positive one, as demonstrated in Proposition 6.

6.3 Pre-commitment to a selling format

In the main model, the platform is presumed to prepare both wholesale and agency models for the supplier to sell online. In equilibrium, depending on parameters such as γ and σ^2/μ^2, the supplier selects one of the two selling formats. One might wonder why the platform offers only one selling format, not both, that is eventually selected by the supplier. In practice, products sold in the platform are classified into several product categories. Moreover, in each category, various products are sold through either a wholesale or agency model. Various market factors, such as the degree of substitution between online and offline channels (i.e., γ), the extent of demand uncertainty (i.e., σ^2), and the market potential (i.e., μ) might vary across categories. Moreover, they can change over time. Therefore, the platform might need to prepare the two selling formats to use them for different categories and to respond to temporal changes in market environments.

That said, it would be important to discuss how robust our results are. Specifically, we consider herein the case in which the platform can offer either a wholesale or agency model, or both in Stage 1 along with the decision on its information-sharing policy. That is, the platform has three options about selling formats prepared for the supplier: *A only* (offering the agency model only), *W only* (offering the wholesale model only), and *Both* (offering both the two models, which is equivalent to the original model). It is noteworthy that choosing *W only* is equivalent to choosing *Both* and charging $r > \tilde{r}(\gamma)$ afterward. That is, no need exists to examine the case of *W only* additionally. Consequently, in what follows, we discuss how our results can be expected to change if the platform can choose *A only* in Stage 1.

In the case of *Both* (i.e., the original model), to induce the supplier to adopt the agency model, the platform cannot charge a commission higher than the threshold $\tilde{r}(\gamma)$, above which the supplier chooses the wholesale model. This constraint disappears if the platform chooses *A only* preliminarily. In other words, choosing *A only* makes it possible for the platform to charge a higher commission while still inducing the supplier to choose the agency model. [8]

Therefore, one can infer that, if the platform can commit to a selling format ex ante, then the agency model becomes more likely to be selected in equilibrium (i.e., Regions A and X expand), whereas the wholesale model is selected only when demand uncertainty is sufficiently high (i.e., Region W shrinks). Such pre-commitment might reduce the flexibility of the platform when facing many product categories and fluctuating market environments.

7 Conclusion

This paper presents an investigation of how a platform's information-sharing policy affects a third-party supplier's multi-channel management online and offline in the face of demand uncertainty. The platform's capability to share its demand information makes the agency model more likely to be selected by the less-informed supplier, which exerts both positive and negative effects on a retailer the supplier uses to sell offline. The negative effect is that the supplier obtains accurate demand information because the retailer wants the supplier to be less-informed to win a low wholesale price. By contrast, the positive effect stems from changes in the supplier's multi-channel management. The agency model enables the platform to derive a large share of revenues generated in the online channel, which encourages the supplier to shift its revenue source to offline activities. In doing so, the supplier reduces its wholesale price, which is beneficial to the retailer. When the positive effect dominates the negative one, the spread of agency models can be desirable not only for the platform and supplier, but also for the retailer (i.e., Pareto-improvement).

Hopefully, the framework developed can be a first step towards analyzing suppliers' multi-channel management across online and offline channels. We conclude by describing some limitations of the proposed model and discussing potential avenues for future research. First, we have presumed that both the online platform and offline retailer have perfect demand information, which is a strong assumption. In practice, it is conceivable that neither of them has perfect information and that their information is not the same because they actually collect data from different sources. With imperfect demand information, more complicated interaction might arise among three firms. For example, if the platform shares information with the supplier, then the retailer can infer the platform's private information from the supplier's wholesale price (e.g., Li and Zhang 2008). This inference is expected to add an interesting dimension to the problem.

Second, it is important to allow for either supplier competition or platform competition, or both. In practice, almost all goods sold on Amazon have competing goods. Amazon works diligently to make consumers aware of rival goods (e.g., "Customers who viewed this item also viewed..."). Introducing supplier competition into the model for further examination, as studied in Mizuno (2012), Hsiao and Chen (2013), and Matsui (2016), would be an interesting direction of future research. Actually, platforms set a common commission rate for all sellers in each product category. If multiple heterogeneous suppliers sell through a platform, then there might exist asymmetric contracting equilibria in which some suppliers choose the wholesale model whereas others choose the agency model, as shown in Tian et al. (2018) and Zennyo (2020). In doing so, it might also be interesting to revisit the issue of pre-commitment to a selling format in Section 6.3. Additionally, incorporating competition between e-commerce platforms would also be an interesting direction for investigation. One might infer that the presence of platform competition could lower commission fees. It would be important to identify how reduction in commissions affects pricing and multi-channel management of third-party suppliers.

Third, we have considered that the platform and the retailer observe wholesale prices in both online and offline channels before they make retail decisions. However, for example, the platform might be unable to observe the wholesale price which the supplier charges to the retailer (e.g., O'Brien and Shaffer 1992). It is expected to be important to assess whether our results remain robust even if wholesale prices are unobservable to parties in different channels.

Fourth, an alliance between offline retailers and online platforms (or merger and acquisition of brick-and-mortar retailers by online platforms) can be an interesting future research area. For example, Amazon bought Whole Foods in 2017. Consequently, it will be crucially important to investigate such new trends of e-commerce platform giants.

Finally, we allow the supplier to offer a wholesale price to the retailer and to the platform. One can consider other richer wholesale contracts between the parties, such as two-part tariff and nonlinear pricing. Moreover, such richer contracts can be regarded as long-term decision-making: they should be determined before realization of the actual demand size. Extending the present model in those ways are anticipated as important directions for future research.

Endnotes

1. One can refer to the following source: `https://www.aboutamazon.com/news/small-business/survey-says-small-businesses-find-success-with-amazon`. Retrieved June 22, 2021.
2. According to Amazon's 2018 annual report, net sales from online stores (i.e., the wholesale model) were $123.0 billion, whereas those from third-party seller services (i.e., the agency model) were $42.7 billion.
3. See `https://sell.amazon.com/pricing.html#referral-fees`. Retrieved June 22, 2021.
4. Bilateral monopoly channels consist of one manufacturer and one retailer. Exclusive dealer channels include competing supply chains, each consisting of one manufacturer and one retailer. Monopoly manufacturer channels comprise one manufacturer and multiple retailers, while monopoly common retailer channels comprise one retailer and multiple manufacturers. Choi (1996) presents additional explanations of this terminology.
5. This paper allows the supplier to set different wholesale prices for the two channels. In reality, however, legal restrictions usually prevent a firm from setting different wholesale prices arbitrarily for different retailers that cannot be justified by different volumes, or costs of doing business. Notable among them is the Robinson–Patman Act of 1936 in the United States. In the analyses described herein, when the supplier selects the wholesale model, wholesale prices for the two channels are set at the same level, as demonstrated later.
6. For instance, on the Amazon platform, prices change more than 2.5 million times a day. Source: `https://www.businessinsider.com/amazon-price-changes-2018-8`. Retrieved June 22, 2021.
7. In these discussions, we present only that a change from wholesale to agency models increases all firms' payoffs. Indeed, this selling format change also improves consumer surplus and social welfare. Details are available upon request.
8. The resulting higher commission can be beneficial to the platform but detrimental to the supplier. Accordingly, as discussed in Corollary 2, the supplier might shift its profit center towards offline activities, which can yield greater retailer profits.

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References

Abhishek, V., K. Jerath, Z. J. Zhang. 2015. Agency selling or reselling? Channel structures in electronic retailing. *Management Science*, 62 (8), 2259–2280.

Arya, A., B. Mittendorf. 2013. Discretionary disclosure in the presence of dual distribution channels. *Journal of Accounting and Economics*, 55 (2-3), 168–182.

Aviv, Y. 2001. The effect of collaborative forecasting on supply chain performance. *Management Science*, 47 (10), 1326–1343.

Belhadj, N., D. Laussel, J. Resende. 2020. Marketplace or reselling? A signalling model. *Information Economics and Policy*, 50, 100834.

Cachon, G. P., M. Fisher. 2000. Supply chain inventory management and the value of shared information. *Management Science*, 46 (8), 1032–1048.

Cachon, G. P., M. A. Lariviere. 2001. Contracting to assure supply: How to share demand forecasts in a supply chain. *Management Science*, 47 (5), 629–646.

Choi, S. C. 1996. Price competition in a duopoly common retailer channel. *Journal of Retailing*, 72 (2), 117–134.

Desiraju, R., S. Moorthy. 1997. Managing a distribution channel under asymmetric information with performance requirements. *Management Science*, 43 (12), 1628–1644.

Foros, Ø., H. J. Kind, G. Shaffer. 2017. Apple's agency model and the role of most-favored-nation clauses. *The RAND Journal of Economics*, 48 (3), 673–703.

Gal-Or, E., T. Geylani, A. J. Dukes. 2008. Information sharing in a channel with partially informed retailers. *Marketing Science*, 27 (4), 642–658.

Geng, X., Y. Tan, L. Wei. 2018. How add-on pricing interacts with distribution contracts. *Production and Operations Management*, 27 (4), 605–623.

Gerchak, Y., Y. Wang. 2004. Revenue-sharing vs. wholesale-price contracts in assembly systems with random demand. *Production and Operations Management*, 13 (1), 23–33.

Guan, X., Y.-J. Chen. 2017. The interplay between information acquisition and quality disclosure. *Production and Operations Management*, 26 (3), 389–408.

Guan, X., B. Liu, Y.-J. Chen, H. Wang. 2020. Inducing supply chain transparency through supplier encroachment. *Production and Operations Management*, 29 (3), 725–749.

Guo, L. 2009a. The benefits of downstream information acquisition. *Marketing Science*, 28 (3), 457–471.

Guo, L. 2009b. Quality disclosure formats in a distribution channel. *Management Science*, 55 (9), 1513–1526.

Guo, L., G. Iyer. 2010. Information acquisition and sharing in a vertical relationship. *Marketing Science*, 29 (3), 483–506.

Guo, X., S. Zheng, Y. Yu, F. Zhang. 2021. Optimal bundling strategy for a retail platform under agency selling. *Production and Operations Management*, forthcoming.

Ha, A. Y., Q. Tian, S. Tong. 2017. Information sharing in competing supply chains with production cost reduction. *Manufacturing & Service Operations Management*, 19 (2), 246–262.

Ha, A. Y., S. Tong. 2008. Contracting and information sharing under supply chain competition. *Management Science*, 54 (4), 701–715.

Ha, A. Y., S. Tong, H. Zhang. 2011. Sharing demand information in competing supply chains with production diseconomies. *Management Science*, 57 (3), 566–581.

Hagiu, A., J. Wright. 2015. Marketplace or reseller? *Management Science*, 61 (1), 184–203.

Hagiu, A., J. Wright. 2019. Controlling vs. enabling. *Management Science*, 65 (2), 577–595.

Hao, L., M. Fan. 2014. An analysis of pricing models in the electronic book market. *MIS Quarterly*, 38 (4), 1017–1032.

Hao, L., Y. Tan. 2019. Who wants consumers to be informed? Facilitating information disclosure in a distribution channel. *Information Systems Research*, 30 (1), 34–49.

Hsiao, L., Y.-J. Chen. 2013. The perils of selling online: Manufacturer competition, channel conflict, and consumer preferences. *Marketing Letters*, 24 (3), 277–292.

Huang, S., X. G. Guan, Y.-J. Chen. 2018. Retailer information sharing with supplier encroachment. *Production and Operations Management*, 27 (6), 1133–1147.

Jerath, K., Z. J. Zhang. 2010. Store within a store. *Journal of Marketing Research*, 47 (4), 748–763.

Jiang, B., K. Jerath, K. Srinivasan. 2011. Firm strategies in the "mid tail" of platform-based retailing. *Marketing Science*, 30 (5), 757–775.

Johnson, J. P. 2017. The agency model and MFN clauses. *The Review of Economic Studies*, 84 (3), 1151–1185.

Johnson, J. P. 2020. The agency and wholesale models in electronic content markets. *International Journal of Industrial Organization*, 69, 102581.

Kwark, Y., J. Chen, S. Raghunathan. 2017. Platform or wholesale? A strategic tool for online retailers to benefit from third-party information. *MIS Quarterly*, 41 (3), 763–785.

Lee, H. L., K. C. So, C. S. Tang. 2000. The value of information sharing in a two-level supply chain. *Management Science*, 46 (5), 626–643.

Li, L. 2002. Information sharing in a supply chain with horizontal competition. *Management Science*, 48 (9), 1196–1212.

Li, L., H. Zhang. 2008. Confidentiality and information sharing in supply chain coordination. *Management Science*, 54 (8), 1467–1481.

Li, Z., S. M. Gilbert, G. Lai. 2014. Supplier encroachment under asymmetric information. *Management Science*, 60 (2), 449–462.

Li, Z., S. M. Gilbert, G. Lai. 2015. Supplier encroachment as an enhancement or a hindrance to nonlinear pricing. *Production and Operations Management*, 24 (1), 89–109.

Li, G., H. Zheng, L. Tian. 2021. Information sharing in an online marketplace with co-opetitive sellers. *Production and Operations Management*, forthcoming.

Liu, Z., D. J. Zhang, F. Zhang. 2021. Information sharing on retail platforms. *Manufacturing & Service Operations Management*, 23 (3), 606–619.

Lu, Q., V. Shi, J. Huang. 2018. Who benefit from agency model: A strategic analysis of pricing models in distribution channels of physical books and e-books. *European Journal of Operational Research*, 264 (3), 1074–1091.

Matsui, K. 2016. Asymmetric product distribution between symmetric manufacturers using dual-channel supply chains. *European Journal of Operational Research*, 248 (2), 646–657.

Mizuno, T. 2012. Direct marketing in oligopoly. *Journal of Economics & Management Strategy*, 21 (2), 373–397.

O'Brien, D. P., G. Shaffer. 1992. Vertical control with bilateral contracts. *The RAND Journal of Economics*, 23 (3), 299–308.

Raju, J. S., R. Sethuraman, S. K. Dhar. 1995. The introduction and performance of store brands. *Management Science*, 41 (6), 957–978.

Scott Morton, F., P. Bouvier, A. Ezrachi, B. Jullien, R. Katz, G. Kimmelman, D. Melamed, J. Morgenstern. 2019. Report: Committee for the study of digital platforms-market structure and antitrust subcommittee. `https://www.judiciary.senate.gov/imo/media/doc/market-structure-report%20-15-may-2019.pdf`.

Shang, W., A. Y. Ha, S. Tong. 2016. Information sharing in a supply chain with a common retailer. *Management Science*, 62 (1), 245–263.

Tan, Y., J. E. Carrillo. 2017. Strategic analysis of the agency model for digital goods. *Production and Operations Management*, 26 (4), 724–741.

Tan, Y., J. E. Carrillo, H. K. Cheng. 2016. The agency model for digital goods. *Decision Sciences*, 47 (4), 628–660.

Tian, L., A. J. Vakharia, Y. Tan, Y. Xu. 2018. Marketplace, reseller, or hybrid: Strategic analysis of an emerging e-commerce model. *Production and Operations Management*, 27 (8), 1595–1610.

Wang, T.-Y., Y.-L. Li, H.-T. Yang, K.-S. Chin, Z.-Q. Wang. 2021. Information sharing strategies in a hybrid-format online retailing supply chain. *International Journal of Production Research*, 59 (10), 3133–3151.

Wei, Y., P. Huang. 2019. Information sharing in the hybrid-format supply chain. *Available at SSRN*, 3301639

Yan, Y., R. Zhao, Z. Liu. 2018. Strategic introduction of the marketplace channel under spillovers from online to offline sales. *European Journal of Operational Research*, 267 (1), 65–77.

Yan, Y., R. Zhao, T. Xing. 2019. Strategic introduction of the marketplace channel under dual upstream disadvantages in sales efficiency and demand information. *European Journal of Operational Research*, 273 (3), 968–982.

Zennyo, Y. 2020. Strategic contracting and hybrid use of agency and wholesale contracts in e-commerce platforms. *European Journal of Operational Research*, 281 (1), 231–239.

Zhang, H. 2002. Vertical information exchange in a supply chain with duopoly retailers. *Production and Operations Management*, 11 (4), 531–546.

Zhang, S., J. Zhang. 2020. Agency selling or reselling: E-tailer information sharing with supplier offline entry. *European Journal of Operational Research*, 280 (1), 134–151.

Appendix: Tables

Table A.1 Short-term outcomes with information sharing given a commission rate

	Wholesale with sharing	Agency with sharing
w_T	$\frac{\alpha}{2}$	$\frac{(1-r)\alpha(2+3\gamma)\left\{(1+2\gamma)(4+6\gamma+3\gamma^2)-2\gamma(1+\gamma)^2 r\right\}}{2(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
w_E	$\frac{\alpha}{2}$	–
p_T	$\frac{\alpha(3+\gamma)}{2(2+\gamma)}$	$\frac{\alpha\left\{(1+2\gamma)(12+32\gamma+30\gamma^2+9\gamma^3)-2(1+\gamma)^2(6+17\gamma+9\gamma^2)r+2\gamma(1+\gamma)^3r^2\right\}}{2(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
p_E	$\frac{\alpha(3+\gamma)}{2(2+\gamma)}$	$\frac{\alpha(2+3\gamma)\left\{(1+2\gamma)(4+3\gamma)-(4+9\gamma+4\gamma^2)r\right\}}{2\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
q_T	$\frac{\alpha(1+\gamma)}{2(2+\gamma)}$	$\frac{\alpha(1+2\gamma)\left\{2(2+4\gamma+3\gamma^2)-(4+6\gamma-3\gamma^3)r-2\gamma(1+\gamma)^2r^2\right\}}{2\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
q_E	$\frac{\alpha(1+\gamma)}{2(2+\gamma)}$	$\frac{\alpha(1+2\gamma)(2+3\gamma)\left\{4+7\gamma+4\gamma^2-(1+\gamma)^2(4+\gamma)r\right\}}{2(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
$E\left[\pi_S\right]$	$\frac{(1+\gamma)(\mu^2+\sigma^2)}{2(2+\gamma)}$	$\frac{(1-r)(\mu^2+\sigma^2)(1+2\gamma)(2+3\gamma)\left\{6+11\gamma+6\gamma^2-4(1+\gamma)^2r\right\}}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
$E\left[\pi_T\right]$	$\frac{(1+\gamma)(\mu^2+\sigma^2)}{4(2+\gamma)^2}$	$\frac{\mu^2+\sigma^2}{4(1+\gamma)}\left(\frac{(1+2\gamma)\left\{2(2+4\gamma+3\gamma^2)-(4+6\gamma-3\gamma^3)r-2\gamma(1+\gamma)^2r^2\right\}}{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2}\right)^2$
$E\left[\pi_E\right]$	$\frac{(1+\gamma)(\mu^2+\sigma^2)}{4(2+\gamma)^2}$	$\frac{r(\mu^2+\sigma^2)(1+2\gamma)(2+3\gamma)^2\left\{4+7\gamma+4\gamma^2-(1+\gamma)^2(4+\gamma)r\right\}\left\{4+11\gamma+6\gamma^2-(4+9\gamma+4\gamma^2)r\right\}}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}^2}$

Table A.2 Short-term outcomes without information sharing given a commission rate

	Wholesale without sharing	Agency without sharing
w_T	$\frac{\mu}{2}$	$\frac{(1-r)\mu(2+3\gamma)\left\{(1+2\gamma)(4+6\gamma+3\gamma^2)-2\gamma(1+\gamma)^2 r\right\}}{2(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
w_E	$\frac{\mu}{2}$	–
p_T	$\frac{2\alpha+(1+\gamma)\mu}{2(2+\gamma)}$	$\frac{1}{2(1+\gamma)}\left(\alpha+\frac{(1+\gamma)(2+3\gamma)\left\{2+7\gamma+6\gamma^2-2(1+4\gamma+3\gamma^2)r+\gamma(1+\gamma)r^2\right\}}{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2}\mu\right)$
p_E	$\frac{2\alpha+(1+\gamma)\mu}{2(2+\gamma)}$	$\frac{\mu(2+3\gamma)\left\{4+11\gamma+6\gamma^2-(4+9\gamma+4\gamma^2)r\right\}}{2\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
q_T	$\frac{(1+\gamma)(2\alpha-\mu)}{2(2+\gamma)}$	$\frac{1}{2}\left(\alpha-\frac{(2+3\gamma)\left\{2+5\gamma+2\gamma^2-(2+6\gamma+5\gamma^2+2\gamma^3)r+\gamma(1+\gamma)^2r^2\right\}}{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2}\mu\right)$
q_E	$\frac{(1+\gamma)(2\alpha-\mu)}{2(2+\gamma)}$	$\frac{2+3\gamma}{2(1+\gamma)}\left(\alpha-\frac{(1+\gamma)\left\{4+13\gamma+10\gamma^2-(4+11\gamma+5\gamma^2-2\gamma^3)r-\gamma^2(1+\gamma)r^2\right\}}{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2}\mu\right)$
$E\left[\pi_S\right]$	$\frac{(1+\gamma)\mu^2}{2(2+\gamma)}$	$\frac{(1-r)\mu^2(1+2\gamma)(2+3\gamma)\left\{6+11\gamma+6\gamma^2-4(1+\gamma)^2r\right\}}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}}$
$E\left[\pi_T\right]$	$\frac{(1+\gamma)(\mu^2+4\sigma^2)}{4(2+\gamma)^2}$	$\frac{\mu^2(1+2\gamma)^2\left\{2(2+4\gamma+3\gamma^2)-(4+6\gamma-3\gamma^3)r-2\gamma(1+\gamma)^2r^2\right\}^2}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}^2}+\frac{\sigma^2}{4(1+\gamma)}$
$E\left[\pi_E\right]$	$\frac{(1+\gamma)(\mu^2+4\sigma^2)}{4(2+\gamma)^2}$	$\frac{r\mu^2(1+2\gamma)(2+3\gamma)^2\left\{4+7\gamma+4\gamma^2-(1+\gamma)^2(4+\gamma)r\right\}\left\{4+11\gamma+6\gamma^2-(4+9\gamma+4\gamma^2)r\right\}}{4(1+\gamma)\left\{8+32\gamma+41\gamma^2+18\gamma^3-8(1+\gamma)^2(1+2\gamma)r-\gamma^2(1+\gamma)^2r^2\right\}^2}$