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An Investigation into Direct Selling: Information Flow and Supply Chain Structure

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Abstract

Amid the rapid development of technology, an increasing number of suppliers sell directly as well as through the retail channel, competing with retailers in the market with uncertain demand. Each firm has exclusive access to a signal useful in updating market forecast. The quality of the signal received exclusively by a supplier is low when it adheres to the retail channel but improves after it engages in direct selling. Firms communicate signals along two directions. Competing suppliers or retailers may exchange signals in between, while suppliers may acquire retailers' signals with payments. A firm can voluntarily share its undisclosed signals – including its exclusive signal and the signals received from information flow – with other firms through vertical interactions as per the specified decision sequence. Firms rely on available signals to decide prices and quantities. Direct selling by suppliers produces structure and information effects. The structure effect arises as suppliers gain flexibility in balancing sales across channels. The information effect arises as suppliers receive exclusive signals of improved quality and initiate signal acquisition from retailers, influencing the availability and utilization of signals among firms in responsive decision making. Channel structure, competition intensity, and cost of direct sales are important factors affecting suppliers' incentive for direct selling and the magnitude of the arising structure and information effects on firms' profit performance.

Keywords

Direct selling; information sharing; channel management

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1. Introduction

Suppliers usually rely on reselling networks to sell products to consumers. Over the past years, with the advances in information technology, an increasing number of suppliers have started to manage online platforms or sell through franchised stores. A *New York Times* (Tedeschi 2000) survey reports that 42% of top suppliers – including IBM, Pioneer Electronics, and Cisco – sell to consumers directly. Major food and consumer product suppliers like Johnson & Johnson (J & J) and Tyson operate online stores worldwide. In the U.S., pharmaceutical companies have implemented novel direct-to-patient models to sell and distribute products (Coyle 2014). Direct selling endows suppliers with the flexibility in managing sales across channels for revenue generation, but it draws them to compete with their retailers for demand, termed supplier encroachment in literature (Arya et al. 2007). We present an information perspective on supplier encroachment.

Today's market typically exhibits strong volatility. Demand information enables firms to update market knowledge and tailor decisions accordingly. Retailers, due to their proximity to and adeptness at serving consumers, can receive information such as point-of-sales data, basket data, and consumer demographics, and gain unprecedented operations flexibility (Liu and Zhang 2006). They can leverage this advantage by exchanging information in between. For instance, Lands' End, which sells clothing online and in stores, trades consumer information with the companies whose products match the interest of Lands' End shoppers as well (Heun 2001). Cloud-based platforms, which can be deployed without costly software or lengthy implementation, make transaction-level data at the retailers easily accessible by their upstream partners. Walmart uses its Retail Link to share data with suppliers, empowering them to apply real-time intelligence to predict demand. LowesLink grants Lowes' suppliers access to in-store transactions, allowing them to analyze geographic penetration and cross-selling to develop insights (Seymour 2014). Whereas data sharing is common in vertical alliances, retailers can also charge a fee for providing data to independent suppliers.

Direct selling enables suppliers to identify and analyze the needs of the market, its size, and competition, sometimes through the assistance of tech firms. In the food industry, J & J works with SAP SE, its ERP provider, and Tyson works with Alibaba and Amazon Fresh on their ecommerce platforms to monitor consumer needs. Technology advances facilitate information exchange among suppliers, either directly among participants, through third parties, or on established information-sharing platforms. Nestle and Tyson are among the cohort of firms on a collaborative corporate platform that supports instant information updates and allows participants to share data across a trusted network (Churchill 2017). Such information exchange benefits innovation by mitigating the uncertainty in future demand and enables suppliers to build efficient distribution networks.

Notably, supplier encroachment critically influences firms' incentive for information flow, which can occur between horizontal competitors, termed signal exchange, and vertical partners, termed signal acquisition. The status of information flow adjusts the availability and utilization of signals by firms in making operations decisions responsively. This information perspective on direct selling has received little attention in prior literature despite the popularity of ecommerce and data-driven business models in practice. In this work, we investigate the effects of direct selling on the information flow in distribution networks and its implications for firms' profits. The results generate concrete insights into practical phenomena and can guide operations and information interactions.

We explicate three settings wherein suppliers sell substitutable products through retailers to a market with uncertain demand. Structure *B* is a bilateral monopoly that comprises a monopolistic supplier and a monopolistic retailer. Structure *R* includes horizontal competition between retailers,

and structure S includes horizontal competition between suppliers. A supplier who engages in direct selling balances the sales in its own channel, where it has monopolistic power, and those in the retail channel, where retailers serve as middlemen. This produces a structure effect. Compared to suppliers who start to manage direct selling, retailers have established presence with continuous advertising and service efforts, and are known and trusted by consumers. Thus, retailers incur lower costs in sales, marketing, and distribution in the retail channel than suppliers do in the direct channel. When retailers are sufficiently more efficient than suppliers in managing sales, suppliers, expectedly, lower wholesale prices to encourage retailer orders. This can benefit retailers, particularly in the presence of competition in a channel tier.

Information flow can occur along two directions. Horizontally, retailers in structure R or suppliers in structure S can exchange signals. Vertically, suppliers can acquire retailers' signals by offering them payments as incentives. Once signals are communicated as per the agreements, a firm can hold undisclosed signals – including its exclusive signal and signals received from information flow – in interacting with other firms. This produces signaling and inference issues (Li 2002; Zhang 2002). Li and Zhang (2008) analyze a setting of a supplier selling to multiple retailers with private signals and categorize three scenarios in increasing order of confidentiality in vertical information flow. We demonstrate that firms prefer the least confidential scenario categorized in Li and Zhang (2008) to manage undisclosed signals. By the prespecified decision sequence, retailers can discern suppliers' undisclosed signals from their wholesale prices, and encroaching suppliers can discern retailers' undisclosed signals from their orders. We refer to this as voluntary signal sharing through vertical interactions. It forms a premise on which we analyze the formation of information flow and study the effects of supplier encroachment on firms' operations policies and profit performance.

Our results reveal that direct selling by suppliers improves vertical information flow, but it is inconsequential to horizontal information flow between competitors in a channel tier. In a bilateral monopoly, the supplier acquires the retailer's signal only when the supplier engages in direct selling. As a monopolistic supplier sells to competing retailers, the retailers always forgo signal exchange, while the supplier acquires signals from both retailers when it adopts direct selling but does so on limited occasions when it adheres to retail channel. As competing suppliers sell to a monopolistic retailer, the suppliers always exchange signals, while they both acquire the retailer's signal in most circumstances when they adopt direct selling, but neither of them does so when they adhere to retail channel. Importantly, in the presence of supplier encroachment, incentive-driven information flow and voluntary signal sharing through vertical interactions result in information transparency in literally all supply chain settings.

In addition to more accurate exclusive signals obtained by direct selling, suppliers receive more signals by initiating signal acquisition. The improved signal quality and availability grant suppliers enhanced responsiveness in wholesale pricing and selling across dual channels. In contrast, the flexibility in retailers' order decisions is restricted, harming their profits. Competition between suppliers in selling to a monopolistic retailer forces the suppliers to yield a premium to the retailer for signal disclosure. In selling to competing retailers, however, a monopolistic supplier can practice differential payments to trap retailers into a Prisoner's Dilemma type of situation, inducing them to disclose signals at profit losses. Channel structure, competition intensity, and cost of direct sales are crucial factors influencing the incentive of suppliers to engage in direct selling, and the scale, in both relative and absolute terms, of the structure and information effects of supplier encroachment on firms' profit performance.

The remainder of this section presents a literature review. Section 2 introduces the settings and preliminary results. Section 3 analyzes the three structures and characterizes information flow with and without supplier encroachment. Section 4 studies the incentive of suppliers to engage in direct selling and discusses the effects of supplier encroachment on information flow and firms' profit performance. The issues pertaining to the quality of suppliers' exclusive signals received by direct selling are explored as well. Section 5 concludes the paper. All the mathematical proofs and supporting discussions are presented in Appendices A1-A4.

Literature Review

This research is related to the stream of literature on direct selling. Most studies consider a bilateral monopoly comprising a manufacturer and a retailer. Park and Keh (2003) find that a dual channel can benefit the manufacturer and lower the price but cause the retailer to suffer a profit loss. Liu and Zhang (2006) allow the retailer or manufacturer to tailor price schedules to consumers and obtain a similar result to that of Park and Keh (2003). Chiang et al. (2003) quantify the effects of consumer acceptance of direct selling and show that it increases the manufacturer's profit and can benefit the retailer as well. Tsay and Agrawal (2004) study the effect of the sales effort on demand and identify the conditions under which the manufacturer and retailer benefit from direct selling. Cattani et al. (2006) find that an equal-price policy, whereby the manufacturer commits to a direct-selling price equal to the retail price, benefits firms when direct selling is inefficient to manage. In our work, we assume that the prices for an individual product are the same across channels, and we assume away the effects of direct selling by suppliers on retailers' sales efforts and consumer acceptance.

Arya et al. (2007) show that, at a high cost of direct sales, a retailer can benefit from direct selling by a manufacturer due to the mitigated double marginalization effect in the retail channel. Yoon (2016) analyzes the cost-reduction effort by the manufacturer and reveals the situation where

direct selling benefits the retailer. Ha et al. (2016) allow the manufacturer to adjust product quality but find that direct selling always worsens the profit for the retailer. Lu and Chen (2014) categorize grocery and Internet shoppers who purchase through physical channel and online, respectively. They show that the manufacturer prefers channel separation through its own (retailer's) Internet channel when Internet shoppers are profitable (unimportant), and it can encroach grocery shoppers to steal demand from the retailer's physical channel.

Past works have moved beyond a bilateral monopoly to include more supply chain firms. Balasubramanian (1998) analyzes the price strategy of a manufacturer in the direct channel which competes with a number of traditional channels. Kurata et al. (2007) study a setting in which two manufacturers sell to a retailer, and only one of them opens a direct channel. Hendershott and Zhang (2006) consider a manufacturer selling to multiple retailers and find that direct selling causes the retail price to decrease but the profit for the manufacturer to increase. Yoo and Lee (2011) study a monopolistic manufacturer who sells to one or two retailers, with the firms independently or jointly making price decisions. They show that the effects of adopting a direct channel by the manufacturer depend on channel structure and market environment. With respect to this literature, we explore the settings wherein horizontal competition exists either between suppliers or between retailers, to study the role of channel structure in influencing the effects of supplier encroachment.

The aforementioned studies are framed in deterministic settings. Recent efforts are directed at incorporating demand uncertainty, in which case, information sharing is a critical issue. Huang et al. (2018) assume that the supplier has no information about the uncertain market size even when it engages in direct selling, whereas the retailer knows the actual market size. They find that, when the retailer reveals that the market size is small, the supplier foregoes direct selling. In contrast, suppliers in our work have exclusive signals whose quality improves with direct selling. Moreover, we follow Arya et al. (2007) to let encroaching suppliers directly sell after retailers order. Sequential decision making gives rise to signaling and inference issues in information flow. Zhao and Li (2018) analyze the effects of nonlinear production costs on retailer's incentive to share signals and manufacturer's incentive to encroach. Li et al. (2014) extend Arya et al. (2007) to the setting where the market size is uncertain and the retailer has exclusive market information. They show that the retailer is more likely to unveil the true market size when the manufacturer sells directly. Relative to Li et al. (2014), our work is based on general signal structures in settings which include competition in a channel tier.

Our work relates to the classical literature on incentive-based information sharing. Among others, Clarke (1983), Vives (1984), Gal-Or (1985), Li (1985) study horizontal information sharing, whereas Li (2002), Zhang (2002), Gal-Or et al. (2008) study vertical information sharing. Jiang and Hao (2016) integrate the two forms of information sharing but ignore signal inference via vertical

interactions. Li and Zhang (2008) analyze the signaling and inference processes triggered by vertical information flow between a manufacturer and multiple retailers who have exclusive signals, and they categorize three scenarios in increasing order of confidentiality. Hao et al. (2018) show, in a setting of a supplier selling to two retailers with exclusive demand signals, that information transparency is attainable in either the least or the most confidential scenario categorized in Li and Zhang (2008). These works are framed in fixed supply chain settings. Supplier encroachment alters the structure of distribution networks to influence the incentives of firms for horizontal or vertical information flow.

We investigate both the structure and information effects of direct selling. From the structure perspective, we extend the result in Arya et al. (2007) to the settings with competitors in a channel tier, where retailers can have a higher likelihood of benefiting from supplier encroachment. From the information perspective, we demonstrate that direct selling by suppliers improves signal acquisition but is inconsequential to signal exchange between horizontal competitors. This extends the finding of Li et al. (2014) and further reveals the strategic effects of supplier encroachment on the interplay of horizontal and vertical information flow. Depending on the channel structure, signal acquisition triggered by supplier encroachment has mixed effects on the profits for retailers. Regardless, the structure effect can dominate to make retailers better off as suppliers sell directly. We further show that our findings on strategic information flow are largely robust with respect to the quality of the signals received exclusively by suppliers through direct selling.

2. The Model

We consider two-tier supply chains. In structure B , a monopolistic supplier sells two substitutable products to a monopolistic retailer, who sells the products to a market with uncertain demand. In structure R , a monopolistic supplier sells to two retailers, each of whom manages a product, ordering independently from the supplier and competing in selling to the market. In structure S , two suppliers, each of whom carries a product, compete in selling to a monopolistic retailer who sells the products to the market. Besides selling through retailers, suppliers can sell directly online or in franchised stores. This results in suppliers competing with retailers for demand, termed supplier encroachment in literature (Arya et al. 2007). We call a supplier who engages in direct selling an encroaching supplier. In our work, $i = 1, 2$ is reserved for a product, and j is reserved for a firm that can be a monopolistic supplier s , one of the two suppliers $\{s_1, s_2\}$ in structure S , a monopolistic retailer r or one of the two retailers $\{r_1, r_2\}$ in structure R . Table A1.1 in Appendix A1 lists main definitions and notations for reference.

Market competition for substitutable products is in quantity, and the prices for a product are the same across channels. Let the inverse demand function for product i be:

$$p_i(q_r, q_s) = a + \mu - b(q_{r_i} + q_{s_i}) - b\beta(q_{r_{3-i}} + q_{s_{3-i}}), i = 1, 2. \quad (1)$$

In equation (1), a is the market potential, $q_r = (q_{r_1}, q_{r_2})$ where q_{r_i} is the retail quantity of product i , $q_s = (q_{s_1}, q_{s_2})$ where q_{s_i} is the direct sales quantity of product i , b is the sensitivity of price to quantity, and $\beta \in (0,1]$ is the extent of product substitution. With horizontal competition (structure R or S), β is a proxy for competition intensity. $q_{r_i} + q_{s_i}$ determines total quantity of product i , and the relative magnitude of q_{r_i} and q_{s_i} reflects the distribution of sales across channels. Normalizing the cost of retail sales to zero, we assume an encroaching supplier incurs a marginal cost $c \in [0, a)$ in the transaction, delivery, and return of each item sold in the direct channel, which captures the retailer's cost advantage. Arya et al. (2007) remark that this cost advantage stems from superior knowledge of consumer preferences by the retailer, its direct contact with consumers, and the economy of scope with other activities.

2.1 Market uncertainty and signal structure

In equation (1), μ models the uncertainty in market condition and has a normal prior $N(0, \sigma_\mu)$. A firm has exclusive access to a signal useful in updating market forecast. The following assumptions about signal structure are consistent with literature (e.g. Li 2002; Gal-Or et al 2008; Ha et al. 2011). The monopolistic retailer in structure B or S receives signal $x_r = \mu + \varepsilon_r$, while retailer r_i in structure R receives signal $x_{r_i} = \mu + \varepsilon_{r_i}$, where ε_r and ε_{r_i} are noise terms and follow $N(0, \sigma_r)$. Similarly, the monopolistic supplier in structure B or R receives signal $x_s = \mu + \varepsilon_s$, and supplier s_i in structure S receives signal $x_{s_i} = \mu + \varepsilon_{s_i}$, where ε_s and ε_{s_i} are noise terms and follow $N(0, \sigma_s)$. In the three structures, (μ, x_r, x_s) , $(\mu, x_r, x_{s_1}, x_{s_2})$, and $(\mu, x_{r_1}, x_{r_2}, x_s)$ are multi-variate normal. The noise terms and the uncertainty in market condition are uncorrelated.

As a supplier adheres to the retail channel, its signal is inferior in quality to that of retailer's signal ($\sigma_s > \sigma_r$) since retailers are in direct contact with consumers and better understand the market trend. Direct selling enables the supplier to reach consumers and learn their needs, thereby receiving a signal of higher quality. We assume that an encroaching supplier receives an exclusive signal of comparable quality to that of the retailer's signal ($\sigma_s = \sigma_r$). In a later section, we show that the form of information flow is largely robust to the quality of the supplier's exclusive signal.

2.2 Decision framework and information flow

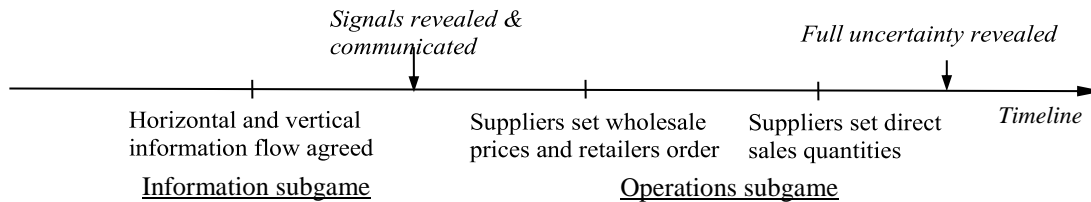


Figure 1. Decision framework given channel design

Figure 1 illustrates the decision framework. In the information subgame, which occurs before signals are revealed, suppliers and retailers sign agreements on horizontal and vertical information sharing. Vertically, a supplier can make a payment to acquire a retailer’s signal. A Capgemini study reveals that over 40% of retailers charge suppliers for the value that they could amass by analyzing consumer behavior from the provided data. Horizontally, retailers in structure R or suppliers in structure S can exchange signals. DeSanti and Nagata (1994) remark that “the communication of information [between competing firms] leads, through coordinated or oligopolistic interdependence, to the same results that the parties can seek to achieve through formal agreements.” In 2010, the Competition Committee in the OECD issued a report (DAF/COMP: 2010-37) on information exchange between horizontal competitors. Based on legal cases reported in 30 countries including the U.S. and U.K., the report concludes that, with few exceptions, competition laws on horizontal agreements do not list information exchange between competitors among anti-competitive practices because it contributes to enhanced allocative and productive efficiency.

We assume that signal exchange between horizontal competitors precedes signal acquisition by suppliers. The outcomes under the reverse sequence are similar, except for slight differences in the conditions needed to sustain specific forms of information flow and acquisition payments. For more detailed discussions about this sequencing issue, please refer to Appendix A3. Once signals are received and communicated as per the information agreements, the firms engage in an operations subgame, where price-only contracts govern vertical relationships. Suppliers decide wholesale prices $w = (w_1, w_2)$, retailers order $q_r = (q_{r_1}, q_{r_2})$, and encroaching suppliers decide direct sales quantities $q_s = (q_{s_1}, q_{s_2})$. Finally, demand is fully realized, and profits accrue to firms.

With the established form of information flow, firms can hold undisclosed signals in vertical interactions. For instance, the signal received exclusively by a supplier is undisclosed to retailers, and the signal it receives through acquisition from a retailer in structure R is undisclosed to the other retailer. This fosters signaling and inference. According to our decision sequence, retailers may infer suppliers’ undisclosed signals from their wholesale prices, while suppliers can manipulate wholesale pricing to affect retailers’ inference. Similarly, encroaching suppliers may infer retailers’ undisclosed signals from their orders, while retailers can manipulate ordering to affect suppliers’ inference. Hao and Jiang (2019), in a setting similar to structure B , show that suppliers and retailers prefer to share undisclosed signals rather than being involved in signaling and inference. Referring to Li and Zhang (2008), who categorize three scenarios in increasing order of confidentiality, this result indicates that firms prefer the least confidential means to share undisclosed signals through vertical interactions, termed voluntary signal sharing. Lemma 1 states that this result applies to our settings as well. The proof is provided in Appendix A2.

Lemma 1. *In addition to communicating signals according to information agreements, suppliers have an incentive to share undisclosed signals with retailers, who use the shared signals in ordering, and retailers have an incentive to share undisclosed signals with encroaching suppliers, who use the shared signals in direct selling.*

Thus, besides its exclusive signal, a firm receives signals from information flow according to ex-ante agreements and voluntary signal sharing through ex-post vertical interactions in the specified decision sequence. Let Θ_j be the set of signals received by a firm $j \in \{r, s, r_i, s_i\}$ at some stage in the operations subgame. The firm relies on available signals to update the forecast for market condition and the understanding of signals received by other firms. Lemma 2 states the outcomes.

Lemma 2. *Under the assumptions about signal structure, let $e_k = \sigma_r + k\sigma_\mu$, $k = 1, 2, 3$, $f_k = \sigma_s + k\sigma_\mu$, $k = 1, 2$, $f_3 = \sigma_s + \sigma_r$, $g_k = \sigma_r\sigma_\mu + k\sigma_s\sigma_\mu + \sigma_r\sigma_s$, $k = 1, 2$, and $g_3 = 2\sigma_r\sigma_\mu + \sigma_s\sigma_\mu + \sigma_r\sigma_s$. Given signal set Θ available by a firm:*

1) *The conditional expectations for market condition are as follows:*

Θ	$\{x_{s/s_i}\}$	$\{x_r, x_{s/s_i}\}$	$\{x_{r_i}, x_s\}$	$\{x_{s_1}, x_{s_2}\}$	$\{x_r, x_{s_1}, x_{s_2}\}$	$\{x_s, x_{r_1}, x_{r_2}\}$
$E[\mu \Theta]$	$\frac{\sigma_\mu x_{s/s_i}}{f_1}$	$\frac{\sigma_\mu(\sigma_s x_r + \sigma_r x_{s/s_i})}{g_1}$	$\frac{\sigma_\mu(\sigma_s x_{r_i} + \sigma_r x_s)}{g_1}$	$\frac{\sigma_\mu(x_{s_1} + x_{s_2})}{f_2}$	$\frac{\sigma_\mu(\sigma_s x_r + \sigma_r(x_{s_1} + x_{s_2}))}{g_3}$	$\frac{\sigma_\mu(\sigma_s(x_{r_1} + x_{r_2}) + \sigma_r x_s)}{g_2}$

2) *The conditional expectations for signals received by other firms are as follows:*

Θ	$\{x_s\}$	$\{x_{s_i}\}$	$\{x_{s_1}, x_{s_2}\}$	$\{x_r, x_{s_i}\}$	$\{x_{r_i}, x_s\}$
x	x_r/r_i	x_r/s_{3-i}	x_r	$x_{s_{3-i}}$	$x_{r_{3-i}}$
$E[x \Theta]$	$\frac{\sigma_\mu x_s}{f_1}$	$\frac{\sigma_\mu x_{s_i}}{f_1}$	$\frac{\sigma_\mu(x_{s_1} + x_{s_2})}{f_2}$	$\frac{\sigma_\mu(\sigma_s x_r + \sigma_r x_{s_i})}{g_1}$	$\frac{\sigma_\mu(\sigma_s x_{r_i} + \sigma_r x_s)}{g_1}$

2.3 Profit functions and decision policies

In structure B , given wholesale prices $w = (w_1, w_2)$ and retail quantities $q_r = (q_{r_1}, q_{r_2})$, the supplier, when encroaching, decides direct sales quantities $q_s^*(w, q_r)$ that maximize its conditional ex-ante profit as follows:

$$\pi_s(q_s|\Theta_s, w, q_r) = E[\sum_{i=1}^2 (w_i q_{r_i} + (p_i(q_r, q_s) - c)q_{s_i}) | \Theta_s], \quad (2)$$

where $p_i(q_r, q_s)$ is defined in (1), $w_i q_{r_i}$ is the profit for the supplier from wholesaling product i , and $(p_i(q_r, q_s) - c)q_{s_i}$ is the profit from direct selling product i . At this stage, the supplier's signal set Θ_s includes its own signal and the signals received through information flow and voluntary sharing at the previous stages. Anticipating direct sales quantities, if any, the retailer chooses order quantities $q_r^*(w)$ to maximize its conditional ex-ante profit as follows:

$$\pi_r(q_r|\Theta_r, w) = E[\sum_{i=1}^2 (p_i(q_r, q_s^*(w, q_r)) - w_i)q_{r_i} | \Theta_r], \quad (3)$$

where $(p_i(q_r, q_s^*(w, q_r)) - w_i)q_{r_i}$ is its profit from selling product i . The signal set Θ_r includes the retailer's exclusive signal and the signals received by information flow and voluntary signal sharing.

Anticipating sales quantities across channels, the supplier chooses wholesale prices w^* to

maximize its conditional ex-ante profit as follows:

$$\pi_s(w|\Theta_s) = E[\sum_{i=1}^2(w_i q_{r_i}^*(w) + (p_i(q_r^*(w), q_s^*(w, q_r^*)) - c)q_{s_i}^*) | \Theta_s], \quad (4)$$

where $q_r^*(w)$ and $q_s^*(w, q_r^*)$ are the retail and direct sales quantities, respectively. At this stage, the supplier's signal set Θ_s includes its exclusive signal and the signals received from information flow.

In structure R , the supplier offers the same wholesale price to the two retailers, and follows the same procedure as that in structure B to maximize its ex-ante profits in (2) and (4). A retailer r_i relies on its signal set to independently order $q_{r_i}^*$, given wholesale prices w and anticipating direct sales q_s^* , to maximize its conditional ex-ante profit:

$$\pi_{r_i}(q_{r_i}|\Theta_{r_i}, w, q_{r_{3-i}}) = E[(p_i(q_r, q_s^*(w, q_r)) - w_i)q_{r_i} | \Theta_{r_i}], i = 1, 2. \quad (5)$$

In structure S , the retailer follows the same procedure as that in structure B to maximize the ex-ante profit in (3). A supplier s_i , when encroaching, chooses a direct quantity $q_{s_i}^*$ to maximize its conditional ex-ante profit, given wholesale prices w and the retailer's order quantities q_r :

$$\pi_{s_i}(q_{s_i}|\Theta_{s_i}, w, q_r, q_{s_{3-i}}) = E[w_i q_{r_i} + (p_i(q_r, q_s) - c)q_{s_i} | \Theta_{s_i}], i = 1, 2, \quad (6)$$

and sets the wholesale price w_i^* to maximize the conditional ex-ante profit, anticipating the retailer's orders $q_r^*(w)$ and any direct sales quantities $q_s^*(w, q_r^*)$, as follows:

$$\pi_{s_i}(w_i|\Theta_{s_i}, w_{3-i}) = E[w_i q_{r_i}^*(w) + (p_i(q_r^*(w), q_s^*(w, q_r^*)) - c)q_{s_i}^* | \Theta_{s_i}], i = 1, 2. \quad (7)$$

In equations (3)-(5) and (7), $q_{s_i}^* = 0$ when the supplier forgoes direct selling of product i .

Given linear demand function and normally distributed signals, Radner (1962) and Gal-Or et al. (2008) state that it suffices to consider linear decision rules. Accordingly, with signal set $\Theta = \{x_1, x_2, \dots\}$, a firm's operations policy takes the form of $Z = Z_0 + \sum_i \alpha_i x_i$. The structure-based part Z_0 depends on channel structure and the position of the firm in interacting with other firms as per the decision sequence shown in Figure 1. The information-based part $\sum_i \alpha_i x_i$ reflects how the firm uses received signals to make decisions, and coefficients α_i 's depend heavily on the availability of signals among the firms. Its presence causes a firm's operations policy to exhibit variability, the magnitude of which reflects the extent of responsiveness. On the basis of ex-post operations policies, the ex-ante profit for a firm comprises structure-based and information-based parts, which underlie our exploration into supplier encroachment and information flow.

Notations in this work take a general form of $Q_{\kappa, j, i}^{t, v, z}$, where Q is quantity of interest that can be quantity, price, profit, or payment. Subscript $\kappa \in \{n, d\}$ shows the absence (n) or presence (d) of supplier encroachment, j denotes the identity of a firm, and i indicates specific product. Superscript $t \in \{B, R, S\}$ indicates channel structure, v reveals status of signal acquisition, and $z \in \{o, h\}$ shows that horizontal competitors forgo (o) or engage in (h) signal exchange.

3. Strategic Information Flow

We analyze horizontal and vertical information flow when suppliers engage in direct selling in three channel structures, benchmarking against the scenarios in which they adhere to the retail channel. A complete analysis is built on the characterization of ex-post operations policies by firms in various scenarios. Based on the results thus obtained, we explore the incentive of suppliers to employ direct selling and discuss the effects of supplier encroachment on firms' performance in Section 4.

3.1 Bilateral monopoly: structure B

In a bilateral monopoly, signal acquisition is the only valid form of information flow. Recall that x_s and x_r are the signals received exclusively by the supplier and retailer, respectively. The supplier offers payment m to the retailer, who decides whether to accept the payment and disclose its signal. Under voluntary signal sharing, the supplier shares its exclusive signal with the retailer in wholesale pricing, enabling the latter to rely on signal set $\Theta_r = \{x_r, x_s\}$ to order. When the supplier engages in direct selling but has not acquired the retailer's signal, the retailer shares its signal through its order quantities with the supplier, who relies on signal set $\Theta_s = \{x_r, x_s\}$ to sell directly. The supplier's set of signals for wholesale pricing is $\{x_s\}$ ($\{x_r, x_s\}$) when it forgoes (adopts) signal acquisition.

3.1.1. Benchmark: single-product setting

As a benchmark, we analyze a setting in which the system manages a single product. The inverse demand function is $p = a + \mu - b(q_r + q_s)$, where q_r (q_s) is the sales quantity in the retail (direct) channel and p is the selling price. Modifying the profit functions in (2) to (4) to ignore product substitution, we follow the specified procedure to analyze the firms' operations decisions.

Table 1. Outcomes in structure B when the supplier forgoes direct selling (single product)

$v = 0$	$v = 1$
$w^{(0)} = \frac{a}{2} + \frac{\sigma_\mu x_s}{2f_1}$	$w^{(1)} = \frac{a}{2} + \frac{\sigma_\mu(\sigma_s x_r + \sigma_r x_s)}{2g_1}$
$q_r^{(0)} = \frac{a}{4b} + \frac{\sigma_s \sigma_\mu x_r}{2bg_1} + \frac{\sigma_\mu(g_1 - 2\sigma_s \sigma_\mu)x_s}{4bf_1g_1}$	$q_r^{(1)} = \frac{a}{4b} + \frac{\sigma_\mu(\sigma_s x_r + \sigma_r x_s)}{4bg_1}$
$\pi_r^{(0)} = \frac{a^2}{16b} + \frac{\sigma_\mu^2(4\sigma_s^2 + g_1)}{16bf_1g_1}$	$\pi_r^{(1)} = \frac{a^2}{16b} + \frac{f_3 \sigma_\mu^2}{16bg_1} + m$
$\pi_s^{(0)} = \frac{a^2}{8b} + \frac{\sigma_\mu^2}{8bf_1}$	$\pi_s^{(1)} = \frac{a^2}{8b} + \frac{f_3 \sigma_\mu^2}{8bg_1} - m$

Notes. $v = 0$ ($v = 1$) indicates that the supplier forgoes (engages in) signal acquisition. This applies to the other tables for structure B.

Table 1 presents ex-post operations policies and ex-ante profits when the supplier forgoes direct selling. The expected wholesale price is $\frac{a}{2}$ and the expected order quantity is $\frac{a}{4b}$, irrespective of the status of signal acquisition. The firms tailor ex-post decisions to realized signals. Upon signal acquisition, the supplier relies on both the retailer's signal and its own signal, with a heavier weight assigned to the retailer's signal for its higher quality, in wholesale pricing to enhance responsiveness, as reflected by an increase in the variance of wholesale price ($Var(w^{(1)}) > Var(w^{(0)})$). It enables the

supplier to make more ex-ante profit exclusive of acquisition payment. However, the retailer has its order flexibility restricted, as reflected by a variance reduction in its order quantity ($Var(q_r^{(1)}) < Var(q_r^{(0)})$), undermining its ex-ante profit exclusive of acquisition payment.

Table 2. Outcomes in structure B when the supplier engages in direct selling (single product)

$v = 0$	$v = 1$
$w^{(0)} = \frac{3a-c}{6} + \frac{\sigma_\mu x_s}{2e_1}$	$w^{(1)} = \frac{3a-c}{6} + \frac{\sigma_\mu(x_r+x_s)}{2e_2}$
$q_r^{(0)} = \frac{2c}{3b} + \frac{\sigma_\mu}{2be_2} (x_r - \frac{\sigma_\mu x_s}{e_1})$	$q_r^{(1)} = \frac{2c}{3b}$
$q_s^{(0)} = \frac{3a-5c}{6b} + \frac{\sigma_\mu}{4be_2} (x_r + \frac{2e_1+\sigma_\mu}{e_1} x_s)$	$q_s^{(1)} = \frac{3a-5c}{6b} + \frac{\sigma_\mu(x_r+x_s)}{2be_2}$
$\pi_r^{(0)} = \frac{2c^2}{9b} + \frac{\sigma_\mu^2}{8be_1e_2}$	$\pi_r^{(1)} = \frac{2c^2}{9b} + m$
$\pi_s^{(0)} = \frac{3a^2-6ac+7c^2}{12b} + \frac{\sigma_\mu^2(5e_1+3\sigma_\mu)}{16be_1e_2}$	$\pi_s^{(1)} = \frac{3a^2-6ac+7c^2}{12b} + \frac{\sigma_\mu^2}{2be_2} - m$

Table 2 shows the outcomes when the supplier sells directly. The supplier sets an expected wholesale price of $\frac{3a-c}{6}$, at which the retailer's expected order quantity is $\frac{2c}{3b}$, and makes an expected direct sales of $\frac{3a-5c}{6b}$, irrespective of the status of signal acquisition. An increase in the cost of direct sales (value of c increases) reduces the expected sales in the direct channel, but it lowers wholesale price, mitigating the double marginalization effect in the retail channel to attract a larger retail order.

Information flow affects the availability and utilization of the signals. In the case where the supplier forgoes signal acquisition, the retailer relies on the difference between its own signal and the supplier's signal scaled by a quality-dependent factor ($x_r - \frac{\sigma_\mu}{\sigma_r+\sigma_\mu} x_s$) in ordering, and the supplier uses the weighted sum of the signals ($x_r + (2 + \frac{\sigma_\mu}{\sigma_r+\sigma_\mu}) x_s$) to sell directly. Through signal acquisition, the supplier uses aggregated signals ($x_r + x_s$) to enhance responsiveness in wholesaling ($Var(w^{(1)}) > Var(w^{(0)})$) but manage direct sales only, while the retailer no longer tailors its order quantity to the realized signals. It increases (decreases) the information-based profit for the supplier (retailer). Only when system profit improves can the supplier afford a payment that is high enough to compensate the retailer for its loss from signal disclosure and leaves the supplier with a profit gain.

Proposition 1. *In structure B with a single product, the supplier acquires the retailer's signal with $m_d^B = \frac{\sigma_r \sigma_\mu^2}{8be_1e_2}$ when it engages in direct selling, but it forgoes signal acquisition otherwise.*

Hence, direct selling incentivizes the supplier to acquire the retailer's signal. Together with voluntary signal sharing, it leads to information transparency in the system. This echoes the finding in Hao and Jiang (2019), who assume away signal availability by the supplier when it forgoes direct selling ($\sigma_s \rightarrow \infty$), and indicates that direct selling and signal acquisition are strategic complements for the supplier. Recall that the retailer has an advantage of committing to a retail quantity before the supplier directly sells. Through signal acquisition, the supplier bypasses the retail channel and uses

signals to manage direct sales only. It yields a higher profit than when the supplier sells through the retailer as a middleman, in which case, the double marginalization effect can weaken the value of information flow. The gain in information-based system profit enables the supplier to afford the payment for signal acquisition.

3.1.2 Product substitution

In structure B which manages two substitutable products, the outcomes when the supplier forgoes and engages in direct selling are shown in Table 3.

Table 3. Outcomes in structure B with substitutable products

$v = 0$	$v = 1$
$W_i^{(0)} = \frac{a}{2} + \frac{\sigma_\mu x_s}{2f_1}$ $q_{r_i}^{(0)} = \frac{a}{4b(1+\beta)} + \frac{\sigma_s \sigma_\mu x_r}{2b(1+\beta)g_1} + \frac{\sigma_\mu (g_1 - 2\sigma_s \sigma_\mu) x_s}{4b(1+\beta)f_1 g_1}$ $\pi_r^{(0)} = \frac{a^2}{8b(1+\beta)} + \frac{\sigma_\mu^2 (4\sigma_s^2 + g_1)}{8b(1+\beta)f_1 g_1}$ $\pi_s^{(0)} = \frac{a^2}{4b(1+\beta)} + \frac{\sigma_\mu^2}{4b(1+\beta)f_1}$	$W_i^{(1)} = \frac{a}{2} + \frac{\sigma_\mu (\sigma_s x_r + \sigma_r x_s)}{2g_1}$ $q_{r_i}^{(1)} = \frac{a}{4b(1+\beta)} + \frac{\sigma_\mu (\sigma_s x_r + \sigma_r x_s)}{4b(1+\beta)g_1}$ $\pi_r^{(1)} = \frac{a^2}{8b(1+\beta)} + \frac{f_3 \sigma_\mu^2}{8b(1+\beta)g_1} + m$ $\pi_s^{(1)} = \frac{a^2}{4b(1+\beta)} + \frac{f_3 \sigma_\mu^2}{4b(1+\beta)g_1} - m$
a) The supplier forgoes direct selling	
$v = 0$	$v = 1$
$W_i^{(0)} = \frac{3a-c}{6} + \frac{\sigma_\mu x_s}{2e_1}$ $q_{r_i}^{(0)} = \frac{2c}{3b(1+\beta)} + \frac{\sigma_\mu}{2b(1+\beta)e_2} (x_r - \frac{\sigma_\mu x_s}{e_1})$ $q_{s_i}^{(0)} = \frac{3a-5c}{6b(1+\beta)} + \frac{\sigma_\mu}{4b(1+\beta)e_2} (x_r + \frac{2e_1 + \sigma_\mu}{e_1} x_s)$ $\pi_r^{(0)} = \frac{4c^2}{9b(1+\beta)} + \frac{\sigma_r \sigma_\mu^2}{4b(1+\beta)e_1 e_2}$ $\pi_s^{(0)} = \frac{3a^2 - 6ac + 7c^2}{6b(1+\beta)} + \frac{\sigma_\mu^2 (5e_1 + 3\sigma_\mu)}{8b(1+\beta)e_1 e_2}$	$W_i^{(1)} = \frac{3a-c}{6} + \frac{\sigma_\mu (x_r + x_s)}{2e_2}$ $q_{r_i}^{(1)} = \frac{2c}{3b(1+\beta)}$ $q_{s_i}^{(1)} = \frac{3a-5c}{6b(1+\beta)} + \frac{\sigma_\mu (x_r + x_s)}{2b(1+\beta)e_2}$ $\pi_r^{(1)} = \frac{4c^2}{9b(1+\beta)} + m$ $\pi_s^{(1)} = \frac{3a^2 - 6ac + 7c^2}{6b(1+\beta)} + \frac{\sigma_\mu^2}{b(1+\beta)e_2} - m$
b) The supplier engages in direct selling	

Compared to the single-product setting, selling substitutable products in structure B does not cause the supplier to alter the wholesale price for an individual product. However, the retail quantity and direct sales quantity, if any, for a product are scaled by a factor of $\frac{1}{1+\beta}$, implying reductions in sales for each product. Product substitution downscales the profit, exclusive of acquisition payment, for each product by a factor of $\frac{1}{1+\beta}$. Profit reductions increase as product substitution strengthens. All the insights into the effects of signal acquisition and supplier encroachment on ex-post policies and ex-ante profits obtained in the benchmark setting still prevail.

Corollary 1. *In structure B , the supplier acquires the retailer's signal with $m_d^B = \frac{\sigma_r \sigma_\mu^2}{4b(1+\beta)e_1 e_2}$ when it engages in direct selling, but it forgoes signal acquisition when it adheres to the retail channel.*

As the supplier engages in direct selling of substitutable products, it acquires the retailer's signal with a payment that is $\frac{2}{1+\beta}$ times that in the single-product setting. While the supplier pays more for signal acquisition, the payment decreases as the extent of product substitution increases.

3.2. Retailer competition: structure R

Practical situations in which structure R fits can be found in electronics and automobile industries, where rounds of mergers and acquisitions over the past decade have given rise to mega suppliers providing a multitude of items for retailers. Compared to structure B , structure R admits more forms of information flow. Retailers may exchange signals, while the supplier can offer m_i to retailer i , who decides whether to disclose its signal. Under voluntary signal sharing, the supplier shares with a retailer, through its wholesale price, its exclusive signal and possibly the other retailer's signal that is obtained from acquisition, and the retailers can share undisclosed signals with the supplier, through order quantities, once the supplier engages in direct selling.

3.2.1 Supplier forgoes direct selling

Table 4 presents ex-post operations policies when the supplier forgoes direct selling. The expected wholesale price is $\frac{a}{2}$ and the expected order quantity of a retailer is $\frac{a}{2b(2+\beta)}$, which are determined by channel structure. Relative to the decisions in a bilateral monopoly, competition between retailers does not induce the monopolistic supplier to adjust wholesale price for each product, but it causes the retailers to order more for their respective products.

Table 4. Operations policies in structure R without direct selling

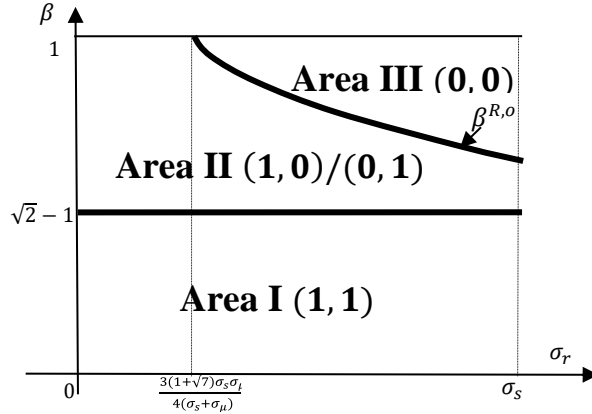
(v_1, v_2)	w/o signal exchange between retailers (o)	w/ signal exchange between retailers (h)
(0,0)	$w_i^{(0,0),o} = w_n^R + \frac{\sigma_\mu x_s}{2f_1}$ $q_{r_i}^{(0,0),o} = q_n^R + \frac{2\sigma_s \sigma_\mu (2+\beta) f_1 x_{r_1} + \sigma_\mu (2g_1 - (4+\beta) \sigma_s \sigma_\mu) x_s}{2b(2+\beta) f_1 (2g_1 + \beta \sigma_s \sigma_\mu)}$	$w_i^{(0,0),h} = w_n^R + \frac{\sigma_\mu x_s}{2f_1}$ $q_{r_i}^{(0,0),h} = q_n^R + \frac{2\sigma_s \sigma_\mu f_1 (x_{r_1} + x_{r_2}) + \sigma_\mu (g_1 - 3\sigma_s \sigma_\mu) x_s}{2b(2+\beta) f_1 g_2}$
(1,1)	$w_i^{(1,1),o} = w_n^R + \frac{\sigma_\mu (\sigma_s (x_{r_1} + x_{r_2}) + \sigma_r x_s)}{2g_2}$ $q_{r_i}^{(1,1),o} = q_n^R + \frac{\sigma_\mu (\sigma_s (x_{r_1} + x_{r_2}) + \sigma_r x_s)}{2b(2+\beta) g_2}$	$w_i^{(1,1),h} = w_n^R + \frac{\sigma_\mu (\sigma_s (x_{r_1} + x_{r_2}) + \sigma_r x_s)}{2g_2}$ $q_{r_i}^{(1,1),h} = q_n^R + \frac{\sigma_\mu (\sigma_s (x_{r_1} + x_{r_2}) + \sigma_r x_s)}{2b(2+\beta) g_2}$
(1,0)	$w_i^{(1,0),o} = w_n^R + \frac{\sigma_\mu (\sigma_s x_{r_1} + \sigma_r x_s)}{2g_1}$ $q_{r_1}^{(1,0),o} = q_n^R + \frac{\sigma_\mu (\sigma_s x_{r_1} + \sigma_r x_s)}{2b(2+\beta) g_1}$ $q_{r_2}^{(1,0),o} = q_n^R + \frac{\sigma_s \sigma_\mu x_{r_2}}{2bg_2} + \frac{\sigma_\mu (g_1 - (1+\beta) \sigma_s \sigma_\mu) (\sigma_s x_{r_1} + \sigma_r x_s)}{2b(2+\beta) g_1 g_2}$	$w_i^{(1,0),h} = w_n^R + \frac{\sigma_\mu (\sigma_s x_{r_1} + \sigma_r x_s)}{2g_1}$ $q_{r_i}^{(1,0),h} = q_n^R + \frac{\sigma_r \sigma_\mu f_1 (\sigma_s x_{r_1} + \sigma_r x_s) + 2\sigma_s \sigma_\mu g_1 x_{r_2}}{2b(2+\beta) g_1 g_2}$

Notes. $w_n^R = \frac{a}{2}$, $q_n^R = \frac{a}{2b(2+\beta)}$. $v_i = 0$ ($v_i = 1$) indicates that the supplier forgoes (acquires) retailer i 's signal.

As the retailers forgo signal exchange, absent signal acquisition, the supplier makes the same signal-based wholesale price as that in a bilateral monopoly. Once the supplier acquires both signals, termed bilateral signal acquisition, it relies more on the aggregated signals from retailers than on its own signal to manage wholesale price, and each retailer follows suit to manage order quantity. Once the supplier acquires a retailer i 's signal, termed unilateral signal acquisition, it sets the same signal-based wholesale price as that under signal acquisition in a bilateral monopoly. Retailer 3 – i , who can learn the signals available by the supplier and retailer i through voluntary sharing, relies most on its own signal but least on the supplier's signal to place order.

Acquiring more signals enables the supplier to enhance responsiveness, yielding a larger variance in wholesale price ($Var(w_i^{(0,0),o}) < Var(w_i^{(1,0),o}) < Var(w_i^{(1,1),o})$). The establishment of a vertical information link has mixed implications for retailers. Consider unilateral signal acquisition from retailer 1. Retailer 1's order flexibility is restricted, indicated by a reduction in order variance ($Var(q_{r_1}^{(1,0),o}) < Var(q_{r_1}^{(0,0),o})$). The spillover-over effect arising from product substitution restricts retailer 2's order flexibility as well, but retailer 2 learns retailer 1's signal to enhance responsiveness. Consequently, retailer 2's order flexibility is weakened ($Var(q_{r_2}^{(1,0),o}) < Var(q_{r_2}^{(0,0),o})$) when the quality of its own signal is high (σ_r is low), in which case, the signal learned by voluntary sharing has a relatively weaker effect. Regardless, retailer 1 suffers more flexibility restriction than retailer 2 ($Var(q_{r_1}^{(1,0),o}) < Var(q_{r_2}^{(1,0),o})$). Under bilateral signal acquisition, retailers have the same signal set to place the same order responsively, achieving the same order flexibility that is bounded between what they respectively achieve under unilateral acquisition ($Var(q_{r_1}^{(1,0),o}) < Var(q_{r_i}^{(1,1),o}) < Var(q_{r_2}^{(1,0),o})$).

For a given status of signal acquisition by the supplier, signal exchange between the retailers has no influence on the supplier's signal-based wholesale price, but it causes the retailers to converge in their orders. Signal acquisition by the supplier from a retailer makes both retailers rely less on the communicated signal but more on the other signals to order. More intense competition (a higher value of β) weakens the retailers' signal reliance to place orders. The supplier has enhanced responsiveness in wholesale pricing by acquiring more signals, which, however, harms retailers' order flexibility.



Note. The expression for $\beta^{R,o}$ is provided in Appendix A1.

Figure 2. Signal acquisition in structure R without direct selling and signal exchange

Lemma 3. In structure R, suppose the supplier adheres to the retail channel, let $m_{n,H}^{R,o}$, $m_{n,L}^{R,o}$, $m_{n,H}^{R,h}$ and $m_{n,L}^{R,h}$ be as defined in Appendix A1:

1) When the retailers forgo signal exchange, as shown in Figure 2, the supplier engages in bilateral signal acquisition with payments $m_n^{R,o} = (m_{n,H}^{R,o}, m_{n,L}^{R,o})$ in Area I and unilateral signal acquisition with payment $m_{n,H}^{R,o}$ in Area II, but forgoes signal acquisition in Area III.

2) When the retailers exchange signals, the supplier engages in bilateral signal acquisition with payments $m_n^{R,h} = (m_{n,H}^{R,h}, m_{n,L}^{R,h})$.

Part 1) of Lemma 3 states that, when the retailers forgo signal exchange, the supplier has an incentive to acquire their signals with differential payments when competition is weak ($\beta < \sqrt{2} - 1$). When competition is strong ($\beta \geq \sqrt{2} - 1$), the supplier acquires one signal when the retailer's signal quality is high, but it acquires no signal otherwise; its incentive for acquisition strengthens as the retailer's signal quality improves but weakens as competition intensifies. Part 2) of Lemma 3 states that, when the retailers exchange signals, the supplier always acquires signals from both of them.

Given the status $z \in \{o, h\}$ of signal exchange, the payment $m_{n,H}^{R,z}$ ($m_{n,L}^{R,z}$) makes a retailer indifferent between disclosing and hiding its signal when the competitor does not (does) disclose its signal. We can show that $m_{n,t}^{R,h} < m_{n,t}^{R,o}$, $t = H, L$; thus, signal exchange between retailers lowers the payments for signal acquisition. Recall that, once a retailer discloses its signal to the supplier, the other retailer can discern the disclosed signal from the supplier's wholesale price. This increases the retailers' pressure in ordering. Signal exchange mitigates this effect of voluntary signal sharing on the retailers, reducing their profit losses from signal disclosure. More intense competition compels retailers to order more, clamping down on the selling price. The profit losses thus incurred make the supplier pay more for signal acquisition. The payment $m_{n,H}^{R,z}$ decreases with σ_r , but the payment $m_{n,L}^{R,z}$ increases with σ_r if $\sigma_r < \frac{\sqrt{2}\sigma_s\sigma_\mu}{\sigma_s + \sigma_\mu}$. Thus, as the retailer's signal quality improves (σ_r has a lower value), disclosure by a retailer has a stronger effect on its profit when the competitor does not disclose its signal, or when the competitor discloses its signal but the signal quality is still low.

Proposition 2. *In structure R, suppose the supplier adheres to the retail channel, the retailers forgo signal exchange, and the supplier acquires either no, one, or two signals from the retailers, with the specific outcomes shown in part 1) of Lemma 3.*

Retailers have no incentive to exchange signals because doing so, despite improving their demand forecast to guide responsive decisions, would aggravate their quantity pressure. Moreover, it strengthens the supplier's incentive for signal acquisition to gain enhanced responsiveness in pricing, restricting the retailers' order flexibility and undermining their profits. Moreover, the retailers are less compensated for their signal disclosure. As the retailers forgo signal exchange, the supplier acquires their signals unless signal quality is too low, in which case, more signals create less value in improving market forecast, and competition is so intense as to result in substantial losses to retailers

by signal disclosure, disabling the supplier to afford the acquisition payment. Weaker competition or more accurate signal leads the supplier to acquire more signals.

3.2.2 Supplier engages in direct selling

Direct selling endows the supplier with more flexibility in managing sales across dual channels and grants it an exclusive signal of higher quality.

Table 5. Operations policies in structure R when the supplier engages in direct selling

(v_1, v_2)	No signal exchange between retailers (o)	Signal exchange between retailers (h)
(0,0)	$w_i^{(0,0),o} = w_d^R + \frac{\sigma_\mu x_s}{2e_1}$ $q_{r_i}^{(0,0),o} = q_{d,r}^R + \frac{\sigma_\mu(e_1 x_{r_i} - \sigma_\mu x_s)}{be_1(2e_2 + \beta\sigma_\mu)}$ $q_{s_i}^{(0,0),o} = q_{d,s}^R + R_{d1}x_{r_i} + R_{d2}x_{r_{3-i}} + R_{d3}x_s$	$w_i^{(0,0),h} = w_d^R + \frac{\sigma_\mu x_s}{2e_1}$ $q_{r_i}^{(0,0),h} = q_{d,r}^R + \frac{\sigma_\mu(e_1(x_{r_1} + x_{r_2}) - 2\sigma_\mu x_s)}{b(2+\beta)e_1e_3}$ $q_{s_i}^{(0,0),h} = q_{d,s}^R + \frac{\sigma_\mu e_1(x_{r_1} + x_{r_2}) + \sigma_\mu((2+\beta)e_2 + \beta\sigma_\mu)x_s}{2b(1+\beta)(2+\beta)e_1e_3}$
(1,1)	$w_i^{(1,1),o} = w_d^R + \frac{\sigma_\mu(x_{r_1} + x_{r_2} + x_s)}{2e_3}$ $q_{r_i}^{(1,1),o} = q_{d,r}^R$ $q_{s_i}^{(1,1),o} = q_{d,s}^R + \frac{\sigma_\mu(x_{r_1} + x_{r_2} + x_s)}{2b(1+\beta)e_3}$	$w_i^{(1,1),h} = w_d^R + \frac{\sigma_\mu(x_{r_1} + x_{r_2} + x_s)}{2e_3}$ $q_{r_i}^{(1,1),h} = q_{d,r}^R$ $q_{s_i}^{(1,1),h} = q_{d,s}^R + \frac{\sigma_\mu(x_{r_1} + x_{r_2} + x_s)}{2b(1+\beta)e_3}$
(1,0)	$w_i^{(1,0),o} = w_d^R + \frac{\sigma_\mu(x_{r_1} + x_s)}{2e_2}$ $q_{r_1}^{(1,0),o} = q_{d,r}^R$ $q_{r_2}^{(1,0),o} = q_{d,r}^R + \frac{\sigma_\mu(e_2 x_{r_2} - \sigma_\mu(x_{r_1} + x_s))}{2be_2e_3}$ $q_{s_1}^{(1,0),o} = q_{d,s}^R + \frac{\sigma_\mu(x_{r_1} + x_{r_2} + x_s)}{2b(1+\beta)e_3}$ $q_{s_2}^{(1,0),o} = q_{d,s}^R + \frac{\sigma_\mu(2e_2 + (1+\beta)\sigma_\mu)(x_{r_1} + x_s) + (1-\beta)\sigma_\mu e_2 x_{r_2}}{4b(1+\beta)e_2e_3}$	$w_i^{(1,0),h} = w_d^R + \frac{\sigma_\mu(x_{r_1} + x_s)}{2e_2}$ $q_{r_i}^{(1,0),h} = q_{d,r}^R + \frac{\sigma_\mu(e_2 x_{r_2} - \sigma_\mu(x_{r_1} + x_s))}{b(2+\beta)e_2e_3}$ $q_{s_i}^{(1,0),h} = q_{d,r}^R + \frac{\sigma_\mu((2+\beta)f_3 - \sigma_\mu)(x_{r_1} + x_s) + \sigma_\mu e_2 x_{r_2}}{2b(1+\beta)(2+\beta)e_2e_3}$

Notes. $w_d^R = \frac{a(3+\beta) - c(1+\beta)}{2(3+\beta)}$, $q_{d,r}^R = \frac{2c}{b(3+\beta)}$, $q_{d,s}^R = \frac{a(3+\beta) - c(5+3\beta)}{2b(3+4\beta+\beta^2)}$, $R_{d1} = \frac{\sigma_\mu((1-\beta)e_1 - \beta\sigma_\mu)}{2b(1+\beta)e_3(2e_2 + \beta\sigma_\mu)}$, $R_{d2} = \frac{\sigma_\mu}{2b(1+\beta)e_3}$, $R_{d3} = \frac{\sigma_\mu(2\sigma_r^2 + (7+2\beta)\sigma_r\sigma_\mu + (7+4\beta)\sigma_\mu^2)}{2b(1+\beta)e_1e_3(2e_2 + \beta\sigma_\mu)}$. (v_1, v_2) have the same meanings as in Table 4.

Table 5 presents ex-post operations policies when the supplier adopts direct selling. Relative to before the supplier encroaches, the expected wholesale price is reduced by $\frac{1+\beta}{2(3+\beta)}c$, the expected order quantity by a retailer changes to $\frac{2c}{b(3+\beta)}$, and the supplier manages an expected sales quantity of $\frac{a(3+\beta) - c(5+3\beta)}{2b(3+4\beta+\beta^2)}$ for each product in the direct channel. The addition of a direct channel relegates the retail channel to a secondary role in selling when direct selling is efficient (a low value of c). An encroaching supplier who forgoes signal acquisition can learn retailers' signals through voluntary sharing and rely on them, in addition to its exclusive signal, in direct selling. Specifically, it relies more on retailer i 's signal to directly sell product i than product $3 - i$ when retailers forgo signal exchange, but it utilizes retailers' aggregated signals to directly sell the two products when retailers exchange signals. Regardless, the supplier relies most on its exclusive signal to directly sell both products. Retailer i relies on the difference between retailers' aggregated signals (x_{r_i} without signal exchange and $x_{r_1} + x_{r_2}$ with signal exchange) and the supplier's signal to decide order quantities.

Under unilateral acquisition from retailer i , the supplier relies on the sum of its own signal and the acquired signal to set wholesale prices. Absent signal exchange between the retailers, retailer i stabilizes its order, while retailer $3 - i$ offsets its own signal by the aggregated signals from other firms, received by voluntary sharing, in ordering. The supplier, who learns all realized signals before selling in the direct channel, relies on their sum to sell product i , but it relies less on retailer $3 - i$'s signal than the other signals to sell product $3 - i$. Signal exchange endows retailers with the same signal set, enabling them to place the same signal-based order, which is similar in fashion to that by retailer $3 - i$ in the counterpart situation without signal exchange. The supplier sells the same quantity of the two products directly, similar to its direct sales of product $3 - i$ in the counterpart situation without signal exchange. Under bilateral acquisition, the supplier utilizes all signals to set wholesale price and manage direct sales, bypassing the retail channel. Signal exchange between the retailers is inconsequential to firms' policies, because it no longer affects their signal availability due to the presence of voluntary signal sharing in vertical interactions.

Lemma 4. *In structure R, under direct selling, the supplier engages in bilateral signal acquisition with payments $m_d^{R,o} = (m_{d,H}^{R,o}, m_{d,L}^{R,o}) = (\frac{\sigma_r \sigma_\mu^2 e_2}{2b e_1 (2e_2 + \beta \sigma_\mu)^2}, \frac{\sigma_r \sigma_\mu^2}{8b e_2 e_3})$ when the retailers forgo signal exchange, but with payments $m_d^{R,h} = (m_{d,H}^{R,h}, m_{d,L}^{R,h}) = (\frac{\sigma_r \sigma_\mu^2}{2b(2+\beta)^2 e_1 e_2}, \frac{\sigma_r \sigma_\mu^2}{2b(2+\beta)^2 e_2 e_3})$ when they exchange signals.*

Lemma 4 states that the supplier in structure R always engages in bilateral signal acquisition. It offers differential payments $m_d^{R,o}$ ($m_d^{R,h}$) when the retailers forgo (engage in) signal exchange. This empowers the supplier to utilize all signals to monopolistically set direct sales. Consequently, retail sales are no longer tailored to realized market conditions. Similar to the situation where the supplier adheres to the retail channel, signal exchange between retailers lowers supplier's acquisition payments ($m_{d,\iota}^{R,h} < m_{d,\iota}^{R,o}$, $\iota = H, L$). Moreover, we show that $m_{d,\iota}^{R,z} < m_{n,\iota}^{R,z}$, $\iota = H, L$; $z = o, h$; that is, direct selling lowers supplier's payments to acquire signals, strengthening its incentive for this move.

Proposition 3. *In structure R, when the supplier manages direct selling, the retailers forgo signal exchange and the supplier engages in bilateral signal acquisition with payments $m_d^{R,o}$.*

Recall that the retailers forgo signal exchange when the supplier adheres to the retail channel. Proposition 3 states that supplier encroachment does not alter this strategic choice by retailers, while the supplier now always acquires both signals. What drives the retailers to forgo signal exchange is the higher payment they could receive from the supplier compared to when they exchange signals. Bilateral signal acquisition by the supplier, together with voluntary sharing in vertical interactions, levels the information status among all firms to streamline their signal-driven operations policies.

In reality, Walmart and Target are two major competitors, but they source a large variety of their products from the same suppliers. For instance, J & J and Tyson are the main providers in their respective categories of consumer products and food. In 2011, Walmart and Target initiated efforts within the Merchant Customer Exchange (MCX) consortium to develop a mobile payment system called CurrentC. MCX's CurrentC was to support data collection by members, who cooperated by committing to CurrentC as the exclusive payment system. This platform has standard data format and transmission processes, paving the way for data sharing. However, the pilot run in 2015 in Columbus, Ohio was a failure. Recently, CurrentC was reportedly suspended.

Our results for structure R indicate that competing retailers should forgo signal exchange. To a certain extent, this explains the failure of MCX to pool consumer data for participating retailers. In the absence of data sharing between retailers, we predict that retailers shall facilitate communication with suppliers, allowing them to mine transaction-level data to improve market understanding amid the fast development of IT-enabled platforms. J & J has implemented a global e-commerce platform since 2015 and is striving to streamline website design to provide better online context and purchase features. Tyson is making significant progress in rebranding itself as an online solution provider. Against this backdrop, Walmart's Retail Link and Target's Supplier Gateway are at work to share timely product information with suppliers.

3.3. Supplier competition: structure S

We next analyze structure S , which admits upstream competition. In this structure, the retailer holds dominating power in the retail channel. Competing suppliers can exchange signals, and a supplier s_i can offer payment m_i to the retailer to acquire its signal. Under voluntary sharing through vertical interactions, a supplier s_i shares its exclusive signal with the retailer, and the retailer shares with an encroaching supplier its exclusive signal (and the other supplier's signal) when the supplier has not acquired its signal (and has not engaged in signal exchange).

3.3.1. Suppliers forgo direct selling

As the suppliers adhere to the retail channel, irrespective of signal exchange between the suppliers, voluntary signal sharing enables the retailer to learn the signals received exclusively by suppliers and obtain signal set $\{x_r, x_{s_1}, x_{s_2}\}$. Without (with) signal exchange, a supplier s_i 's signal set to decide wholesale price is $\{x_{s_i}\}$ ($\{x_{s_1}, x_{s_2}\}$) when it forgoes signal acquisition but is $\{x_r, x_{s_i}\}$ ($\{x_r, x_{s_1}, x_{s_2}\}$) when it acquires the retailer's signal.

Table 6. Operations policies in structure S when the suppliers forgo direct selling

(v_1, v_2)	No signal exchange between suppliers (o)	Signal exchange between suppliers (h)
(0,0)	$w_i^{(0,0),o} = w_n^S + \frac{(1-\beta)\sigma_\mu}{2f_1-\beta\sigma_\mu} x_{s_i}$.	$w_i^{(0,0),h} = w_n^S + \frac{(1-\beta)\sigma_\mu(x_{s_1}+x_{s_2})}{(2-\beta)s_2}$. $q_{r_i}^{(0,0),h} = q_n^S + \frac{\sigma_3\sigma_\mu(2-\beta)f_2x_r+\sigma_\mu(g_3-(2-\beta)\sigma_s\sigma_\mu)(x_{s_1}+x_{s_2})}{2b(2-\beta)(1+\beta)f_2g_3}$.

	$q_{r_i}^{(0,0),o} = q_n^S + \frac{\sigma_s \sigma_\mu (2f_1 - \beta \sigma_\mu) x_r - \sigma_\mu (\beta \sigma_r \sigma_\mu + \sigma_s (\sigma_\mu - \sigma_r)) x_{s_i} + \sigma_\mu ((2+\beta) g_1 - 2\sigma_s \sigma_\mu) x_{s_{3-i}}}{2b(1+\beta)(2f_1 - \beta \sigma_\mu) g_3}$	
(1,1)	$w_i^{(1,1),o} = w_n^S + \frac{(1-\beta)\sigma_\mu(2\sigma_s x_r + (2-\beta)\sigma_r x_{s_i})}{(2-\beta)(2g_1 - \beta \sigma_\mu)}$ $q_{r_i}^{(1,1),o} = q_n^S + \frac{\sigma_s \sigma_\mu (2g_1 - (2-\beta)^2 \sigma_r \sigma_\mu) x_r}{2b(2-\beta)(1+\beta)(2g_1 - \beta \sigma_r \sigma_\mu) g_3} + \frac{\sigma_r \sigma_\mu (g_1 - (1+\beta)\sigma_r \sigma_\mu) x_{s_i}}{2b(1+\beta)(2g_1 - \beta \sigma_r \sigma_\mu) g_3} + \frac{\sigma_r \sigma_\mu (2+\beta) g_1 x_{s_{3-i}}}{2b(1+\beta)(2g_1 - \beta \sigma_r \sigma_\mu) g_3}$	$w_i^{(1,1),h} = w_n^S + \frac{(1-\beta)\sigma_\mu(\sigma_s x_r + \sigma_r(x_{s_1} + x_{s_2}))}{(2-\beta)g_3}$ $q_{r_i}^{(1,1),h} = q_n^S + \frac{\sigma_\mu(\sigma_s x_r + \sigma_r(x_{s_1} + x_{s_2}))}{2b(2-\beta)(1+\beta)g_3}$
(1,0)	$w_1^{(1,0),o} = w_n^S + \frac{(1-\beta)(2f_1 + \beta \sigma_\mu)\sigma_\mu(\sigma_r x_{s_i} - \sigma_s x_r)}{(4-\beta^2)f_3 \sigma_\mu^2 + 4g_3 \sigma_s}$ $w_2^{(1,0),o} = w_n^S + \frac{(1-\beta)\sigma_\mu((2+\beta)g_1 - \beta \sigma_s \sigma_r) x_{s_2}}{(4-\beta^2)f_3 \sigma_\mu^2 + 4g_3 \sigma_s}$ $q_{r_1}^{(1,0),o} = q_n^S + S_{n1} x_r + S_{n2} x_{s_1} + S_{n3} x_{s_2}$ $q_{r_2}^{(1,0),o} = q_n^S + S_{n4} x_r + S_{n5} x_{s_1} + S_{n6} x_{s_2}$	$w_1^{(1,0),h} = w_n^S + \frac{(1-\beta)\sigma_s \sigma_\mu x_r}{2g_3} + \frac{(1-\beta)\sigma_\mu(2g_3 - (2-\beta)\sigma_s \sigma_\mu)(x_{s_1} + x_{s_2})}{2(2-\beta)f_2 g_3}$ $w_2^{(1,0),h} = w_n^S + \frac{(1-\beta)\sigma_\mu(x_{s_1} + x_{s_2})}{(2-\beta)f_2}$ $q_{r_1}^{(1,0),h} = q_n^S + \frac{\sigma_s \sigma_\mu (2-\beta) f_2 x_r + \sigma_\mu (2g_3 - (2-\beta)\sigma_s \sigma_\mu)(x_{s_1} + x_{s_2})}{4b(2-\beta)(1+\beta)f_2 g_3}$ $q_{r_2}^{(1,0),h} = q_n^S + \frac{\sigma_s \sigma_\mu (4-\beta^2) f_2 x_r + \sigma_\mu (2g_3 - (4-\beta^2)\sigma_s \sigma_\mu)(x_{s_1} + x_{s_2})}{4b(2-\beta)(1+\beta)f_2 g_3}$

Notes. $w_n^S = \frac{a(1-\beta)}{2-\beta}$, $q_n^S = \frac{a}{2b(2-\beta)(1+\beta)}$. The expressions for $S_{n1}, S_{n2}, \dots, S_{n6}$ are provided in Appendix A1. $v_i = 0$ ($v_i = 1$) indicates that the retailer does not (does) disclose its signal to supplier i .

Table 6 presents the ex-post policies in this case. The expected wholesale price by a supplier is $\frac{a(1-\beta)}{2-\beta}$, and the expected order quantity by the retailer for a product is $\frac{a}{2b(2-\beta)(1+\beta)}$. Compared to those in structure B , competition causes the suppliers to lower wholesale prices, inducing the retailer to order more. This becomes more prominent as competition intensifies.

Suppose suppliers forgo signal exchange. Under unilateral signal acquisition by a supplier, this supplier uses the retailer's signal to offset its own signal in wholesale pricing. Under bilateral acquisition, a supplier reinforces its own signal by the retailer's signal to decide wholesale price. In either case, a supplier relies more on the retailer's signal as its quality improves. The retailer, though receiving all the signals, relies on them to different extents in ordering. Through signal exchange, the suppliers rely on their aggregated signals in pricing, forcing the retailer to follow suit in ordering. Under unilateral signal acquisition, the retailer relies less on its own signal but more on suppliers' aggregated signals to order from the supplier who acquires its signal. However, under bilateral signal acquisition, the retailer places the same signal-based order with the two suppliers.

Lemma 5 states the signal-acquisition decisions of the suppliers who forgo direct selling.

Lemma 5. *In structure S , when the suppliers forgo direct selling, neither of them acquires the retailer's signal, irrespective of the status of signal exchange between the suppliers.*

Having access to the retailer's signal grants a supplier enhanced responsiveness in wholesale pricing, which boosts the other supplier's responsiveness as well due to product substitution. That is, horizontal competition between suppliers in selling to the same retailer amplifies their reliance on available signals to manage wholesale prices. This aggravates the retailer's profit loss from restricted order flexibility to worsen the system profit, disabling suppliers to afford the retailer's signal.

Proposition 4. *In structure S, when competing suppliers forgo direct selling, they exchange signals and neither of them has an incentive to acquire the retailer's signal.*

Absent direct selling, suppliers have an incentive to exchange signals. Recall that the retailer can always learn the suppliers' signals from their wholesale prices, regardless of the status of signal exchange between them. This induces suppliers to trade signals to counter the information advantage of the retailer. In this case, given that vertical signal acquisition is unsustainable, the two forms of strategic flow are strategic substitutes as suppliers compete to sell through the retail channel.

3.3.2. Suppliers engage in direct selling

As both suppliers own channels to make direct sales, the firms' ex-post policies are shown in Table 7. Each supplier decreases its expected wholesale price ($w_d^S < w_n^S$), but the retailer orders more ($q_{d,r}^S > q_{n,r}^S$), implying a mitigated double marginalization effect in the retail channel, when the cost of direct sales is high. Higher efficiency of direct selling (value of c decreases) leads the suppliers to increase direct sales but raise wholesale prices to lower retail orders. Even as c reduces to zero, however, the retail quantity for a product is $\frac{a\beta^2}{2b(1+\beta)(3-\beta-\beta^2)}$, which indicates the indispensability of retail channel for competing suppliers under encroachment.

Table 7. Operations policies in structure S when the suppliers engage in direct selling

(v_1, v_2)	No signal exchange between suppliers (o)	Signal exchange between suppliers (h)
(0,0)	$w_i^{(0,0),o} = w_d^S + \frac{(3-\beta-2\beta^2)\sigma_\mu x_{s_i}}{(2+\beta)((3-\beta^2)e_1-\beta\sigma_\mu)}$ $q_{r_i}^{(0,0),o} = q_{d,r}^S + \frac{\sigma_\mu x_r}{2b(1+\beta)e_3} + S_{d1}x_{s_i} + S_{d2}x_{s_{3-i}}$ $q_{s_i}^{(0,0),o} = q_{d,s}^S + \frac{\sigma_\mu(x_{s_{3-i}}+x_r)}{2b(2+\beta)e_3} + S_{d3}x_{s_i}$	$w_i^{(0,0),h} = w_d^S + \frac{(3-\beta-2\beta^2)\sigma_\mu(x_{s_1}+x_{s_2})}{(2+\beta)(3-\beta-\beta^2)e_2}$ $q_{r_i}^{(0,0),h} = q_{d,r}^S + \frac{\sigma_\mu(3-\beta-\beta^2)e_2x_r - \sigma_\mu((3-\beta-3\beta^2)\sigma_\mu - \beta^2e_1)(x_{s_1}+x_{s_2})}{2b(1+\beta)(3-\beta-\beta^2)e_2e_3}$ $q_{s_i}^{(0,0),h} = q_{d,s}^S + \frac{\sigma_\mu(3-\beta-\beta^2)e_2x_r + \sigma_\mu((6-2\beta-3\beta^2)\sigma_r + (15-5\beta-8\beta^2)\sigma_\mu)(x_{s_1}+x_{s_2})}{2b(2+\beta)(3-\beta-\beta^2)e_2(\sigma_r+3\sigma_\mu)}$
(1,1)	$w_i^{(1,1),o} = w_d^S + S_{d4}x_r + \frac{(3-\beta-2\beta^2)\sigma_\mu x_{s_i}}{(2+\beta)((3-\beta^2)e_2-\beta\sigma_\mu)}$ $q_{r_i}^{(1,1),o} = q_{d,r}^S + S_{d5}x_r + S_{d6}x_{s_i} + S_{d7}x_{s_{3-i}}$ $q_{s_i}^{(1,1),o} = q_{d,s}^S + S_{d8}x_r + S_{d9}x_{s_i} + \frac{\sigma_\mu x_{s_{3-i}}}{2b(2+\beta)e_3}$	$w_i^{(1,1),h} = w_d^S + \frac{(3-\beta-2\beta^2)\sigma_\mu(x_{s_1}+x_{s_2}+x_r)}{(2+\beta)(3-\beta-\beta^2)e_3}$ $q_{r_i}^{(1,1),h} = q_{d,r}^S + \frac{\beta^2\sigma_\mu(x_{s_1}+x_{s_2}+x_r)}{2b(1+\beta)(3-\beta-\beta^2)e_3}$ $q_{s_i}^{(1,1),h} = q_{d,s}^S + \frac{(6-2\beta-3\beta^2)\sigma_\mu(x_{s_1}+x_{s_2}+x_r)}{2b(2+\beta)(3-\beta-\beta^2)e_3}$
(1,0)	$w_1^{(1,0),o} = w_d^S + S_{d,10}(x_{r_1} + x_r)$ $w_2^{(1,0),o} = w_d^S + S_{d,11}x_{s_2}$ $q_{r_1}^{(1,0),o} = q_{d,r}^S + S_{d,12}x_r + S_{d,13}x_{s_1} + S_{d,14}x_{s_2}$ $q_{r_2}^{(1,0),o} = q_{d,r}^S + S_{d,15}x_r + S_{d,16}x_{s_1} + S_{d,17}x_{s_2}$ $q_{s_1}^{(1,0),o} = q_{d,s}^S + S_{d,18}(x_r + x_{s_1}) + \frac{\sigma_\mu x_{s_2}}{2b(2+\beta)e_3}$ $q_{s_2}^{(1,0),o} = q_{d,s}^S + \frac{\sigma_\mu(x_{s_1}+x_r)}{2b(2+\beta)e_3} + S_{d,19}x_{s_2}$	$w_1^{(1,0),h} = w_d^S + \frac{(3-\beta-2\beta^2)\sigma_\mu x_r}{(2+\beta)(3-\beta^2)e_3} + S_{d,20}(x_{s_1} + x_{s_2})$ $w_2^{(1,0),h} = w_d^S + \frac{(3-\beta-2\beta^2)\sigma_\mu(x_{s_1}+x_{s_2})}{(2+\beta)(3-\beta-\beta^2)e_2}$ $q_{r_1}^{(1,0),h} = q_{d,r}^S - \frac{\beta(1-\beta-\beta^2)\sigma_\mu x_r}{2b(1+\beta)(2+\beta)(3-\beta^2)e_3} + S_{d,21}(x_{s_1} + x_{s_2})$ $q_{r_2}^{(1,0),h} = q_{d,r}^S + \frac{(6+6\beta-\beta^3)\sigma_\mu x_r}{2b(1+\beta)(2+\beta)(3-\beta^2)e_3} + S_{d,22}(x_{s_1} + x_{s_2})$ $q_{s_1}^{(1,0),h} = q_{d,s}^S + \frac{(6-\beta-3\beta^2)\sigma_\mu x_r}{2b(2+\beta)(3-\beta^2)e_3} + S_{d,23}(x_{s_1} + x_{s_2})$ $q_{s_2}^{(1,0),h} = q_{d,s}^S + \frac{\sigma_\mu x_r}{2b(2+\beta)e_3} + S_{d,24}(x_{s_1} + x_{s_2})$

Notes. $w_d^S = \frac{(1-\beta)(3a-c+2a\beta-c\beta)}{(2+\beta)(3-\beta-\beta^2)}$, $q_{d,r}^S = \frac{a\beta^2+c(4+2\beta-3\beta^2-\beta^3)}{2b(1+\beta)(3-\beta-\beta^2)}$, and $q_{d,s}^S = \frac{a(6-2\beta-3\beta^2)-c(10-5\beta^2-\beta^3)}{2b(2+\beta)(3-\beta-\beta^2)}$. The expressions for $S_{d,i}$, $i = 1, \dots, 24$, are provided in Appendix A1. (v_1, v_2) have the same meanings as those in Table 6.

As suppliers adopt direct selling, the retailer tailors its order quantity from a supplier to realized signals even after the supplier acquires its signal. This differs from that in structure B or R, in which cases, the monopolistic supplier, once encroaching, utilizes received signals to manage

direct sales only. This is because, in structure S , the suppliers share a channel in which the retailer holds monopolistic power. Even when both suppliers adopt direct selling, competition pressure maintains retail channel as a battleground for them to compete for sales and, thus, revenue.

Lemma 6. *In structure S , suppose that the suppliers engage in direct selling:*

1) *If the suppliers forgo signal exchange, they both acquire the retailer's signal with $(m_{d,H}^{S,o}, m_{d,H}^{S,o})$ if $0 < \beta < \beta^{S,o}$; only one supplier acquires the retailer's signal with $m_{d,L}^{S,o}$ if $\beta^{S,o} \leq \beta < \hat{\beta}^{S,o}$; neither supplier acquires the retailer's signal if $\hat{\beta}^{S,o} \leq \beta \leq 1$, where the thresholds $\beta^{S,o}$ and $\hat{\beta}^{S,o}$, and the payments $m_{d,H}^{S,o}$ and $m_{d,L}^{S,o}$ are presented in Appendix A1.*

2) *If the suppliers exchange signals, they both acquire the retailer's signal with $(m_{d,H}^{S,h}, m_{d,H}^{S,h})$ if $0 < \beta < \beta^{S,h}$, but only one supplier acquires the retailer's signal with $m_{d,L}^{S,h}$ if $\beta^{S,h} \leq \beta \leq 1$, where $\beta^{S,h} \approx 0.92$ and the payments $m_{d,H}^{S,h}$ and $m_{d,L}^{S,h}$ are presented in Appendix A1.*

As the suppliers engage in direct selling, without (with) signal exchange, they acquire the retailer's signal with the same payment $m_{d,H}^{S,o}$ ($m_{d,H}^{S,h}$) when competition is not intense, i.e., $\beta < \beta^{S,o}$ ($\beta < \beta^{S,h}$). Otherwise, only one supplier acquires the retailer's signal with payment $m_{d,L}^{S,z}$, $z = o, h$ except when the suppliers forgo signal exchange, in which case, neither of them acquires signal if competition is too intense ($\beta \geq \hat{\beta}^{S,o}$). It can be verified that $\beta^{S,o} > \beta^{S,h} \approx 0.92$; high competition intensity thresholds imply that both suppliers acquire the retailer's signal in most circumstances.

Given status z of signal exchange between suppliers, the payment $m_{d,L}^{S,z}$ equals the retailer's profit loss from signal disclosure to a supplier and the payment $m_{d,H}^{S,z}$ equals its incremental loss by disclosing its signal to the other supplier. The retailer suffers a larger incremental loss by disclosing its signal to more suppliers ($m_{d,L}^{S,z} < m_{d,H}^{S,z}$). Under bilateral signal acquisition, the retailer's total profit loss is $m_{d,L}^{S,z} + m_{d,H}^{S,z}$, while it receives a total payment of $2m_{d,H}^{S,z}$; thus, competition pressure forces the suppliers to yield a premium ($m_{d,H}^{S,z} - m_{d,L}^{S,z}$) to the retailer for signal disclosure. Recall that, in structure R , signal exchange between competing retailers lowers the monopolistic supplier's acquisition payments. It also applies to structure S , where we can show that $m_{d,l}^{S,h} < m_{d,l}^{S,o}$, $l = H, L$; that is, signal exchange between the suppliers makes them pay less in signal acquisition.

Notably, under bilateral signal acquisition in structure R , the encroaching supplier relies on all the signals to manage direct sales, bypassing the retail channel. It makes a smaller incremental payment to acquire an additional signal from the retailers and takes advantage of their competitive relationship to trap them in an information game to disclose signals at profit losses. In structure S , the retail channel remains indispensable to the suppliers when they both sell directly, even after they have acquired the retailer's signal. The suppliers have to pay more to set up more information links

with the retailer. Consequently, they yield a premium to acquire the retailer's signal, to mitigate the advantage that the retailer could have gained by committing to sales quantities in retail channel.

Proposition 5 states the information flow as the suppliers in structure S adopt direct selling.

Proposition 5. *In structure S , when competing suppliers engage in direct selling, they have an incentive to exchange signals, and they both acquire the retailer's signal in most circumstances.*

Under horizontal competition, suppliers, once adopting direct selling, still have an incentive to exchange signals. In contrast to when they adhere to the retail channel, in which case they both forgo signal acquisition, the suppliers now have a strong incentive to further acquire the retailer's signal, leveling the information statuses among all firms. The suppliers benefit from the enhanced responsiveness in wholesale pricing and direct selling. Their operations policies, which are better tailored to the realized market conditions, to a large extent weaken the power that the retailer could have gained in selling.

In pharmaceutical industry, major drug makers sell to the CVS-Walgreen-Walmart alliance that holds monopolistic power in the retail market, for which structure S provides an approximate fit. Our results predict that drug makers should benefit from signal exchange, which echoes the recent move whereby pharmaceutical companies share consumer information by various means and co-develop products. Moreover, as major drug makers start direct consumer services (Coyle 2014), they profit from acquiring and utilizing the information from the retailer, even at a premium. It infuses rationality into the reality that drug makers paid up to \$25 million to the CVS-Walgreen-Walmart alliance for the up-to-the-minute consumer data from their thousands of stores (Heun 2001).

4. Discussions: Channel Structure and Signal Quality

In this section, we investigate the incentive of suppliers to engage in direct selling, and discuss the effects of direct selling by suppliers on the formation of information flow and firms' profits, with channel structure being the differentiation factor. Moreover, we comment on the practical issues pertaining to signal quality.

4.1 Incentive for direct selling and implications for information flow

Arya et al. (2007) analyze a setting that is similar to our benchmark setting without uncertainty in market condition. They indicate that a monopolistic supplier prefers direct selling only when the cost of direct sales is not too high, in which case, the sales quantity in the direct channel is positive. For our settings where market condition is uncertain while firms have exclusive signals and can engage in information sharing, we use a modified version of the criterion used in Arya et al. (2007) to study suppliers' incentive for direct selling. Specifically, suppliers prefer direct selling only when they can make positive expected sales in the direct channel.

Direct selling produces a structure effect, which arises from the change in the distribution network that alters interactions among firms, and an information effect, which adjusts the availability and utilization of signals by firms in operations decisions. Encroaching suppliers access exclusive signals of higher quality and can initiate signal acquisition to more responsively tailor pricing and selling to actual market conditions. Nevertheless, under linear decision policies, the communication of signals among firms through information flow has no influence on the expected sales quantities across channels, despite its effects on firms' operations responsiveness and profit performance. Thus, the structure effect dominates suppliers' incentive for direct selling.

Proposition 6. *In the two-tier supply chain settings, suppliers have an incentive for direct selling iff $c < c_s^t$ in structure $t \in \{B, R, S\}$, where $c_s^B = \frac{3a}{5}$, $c_s^R = \frac{a(3+\beta)}{5+3\beta}$, and $c_s^S = \frac{a(6-2\beta-3\beta^2)}{10-5\beta^2-\beta^3}$.*

Proposition 6 asserts that suppliers prefer direct selling only when the cost of direct sales is not too high ($c < c_s^t, t = B, R, S$). This is consistent with that in Arya et al. (2007) for a bilateral monopoly and extends to more practical settings that admit competition in a tier. Hence, efficiency of managing direct sales is a prerequisite for supplier encroachment, which grants suppliers more flexibility and enhanced responsiveness in managing sales in dual channels. It can be verified that $c_s^B > c_s^R > c_s^S$, while c_s^R and c_s^S decrease with β . The presence of horizontal competition between firms in a tier, particularly the one between suppliers, weakens the incentive of suppliers to engage in direct selling, and this effect becomes more prominent as competition intensifies.

Table 8. Information flow

Structure	Without supplier encroachment		With supplier encroachment	
	Horizontal	Vertical	Horizontal	Vertical
B	NA	Not sustainable	NA	Always sustainable
R	Not sustainable	Bilateral if $0 < \beta \leq \sqrt{2} - 1$ Unilateral $\sqrt{2} - 1 < \beta < \text{Min}\{\beta^{R,o}, 1\}$ No acquisition otherwise	Not sustainable	Always bilateral
S	Always sustainable	Not sustainable	Always sustainable	Most likely bilateral: $0 < \beta < \beta^{S,h} \approx 0.92$; Unilateral otherwise

Table 8 shows the effects of direct selling by suppliers on the information flow in the three structures. Notably, direct selling has no effect on signal exchange between horizontal competitors in a tier but facilitates vertical information flow. While the retailers in structure *R* always refrain from signal exchange, the suppliers in structure *S* always exchange signals. Through direct selling, the monopolistic supplier in structure *B* or *R* engages in signal acquisition, and the competing suppliers in structure *S* acquire signal from the monopolistic retailer in most circumstances. By contrast, as suppliers adhere to retail channel, signal acquisition from a monopolistic retailer is unsustainable,

while bilateral signal acquisition by a monopolistic supplier from competing retailers is sustainable only when competition is weak.

Our results demonstrate the strategic complementarity of direct selling and signal acquisition for suppliers. This echoes the finding of Li et al. (2014) and extends to the settings with horizontal competition. Channel structure and supplier encroachment intricately influence the interplay of horizontal and vertical information flow. Under retailer competition, the two forms of information flow are strategic substitutes, and their substitutability strengthens with supplier encroachment. Under supplier competition, they are strategic substitutes in the absence of supplier encroachment but are strategic complements in its presence. Regardless, system-wide information transparency is realizable in almost all the circumstances after suppliers engage in direct selling.

4.2 Effects of direct selling on suppliers' profits

Once engaging in direct selling, suppliers benefit from the arising structure and information effects.

We measure the structure effect on suppliers' profits by $\tilde{\Delta}_s^t \triangleq \frac{\tilde{\pi}_{d,s}^t - \tilde{\pi}_{n,s}^t}{\tilde{\pi}_{n,s}^t}$, $t = B, R, S$, where $\tilde{\pi}_{d,s}^t$ and $\tilde{\pi}_{n,s}^t$ are, respectively, the structure-based profits for suppliers who engage in and forgo direct selling in structure t . Lemma 7 compares $\tilde{\Delta}_s^t$ across the three settings.

Lemma 7. *From the structure perspective of direct selling: 1) $\tilde{\Delta}_s^B \leq \tilde{\Delta}_s^R$ if $c \geq c^R$ & $\text{Max}\{\beta^R(c), 0\} < \beta \leq 1$, but $\tilde{\Delta}_s^B > \tilde{\Delta}_s^R$ otherwise; 2) $\tilde{\Delta}_s^B \leq \tilde{\Delta}_s^S$ if $c \geq c^S$ or $\beta \geq \beta^S(c)$ but $\tilde{\Delta}_s^B \leq \tilde{\Delta}_s^S$ otherwise; 3) $\tilde{\Delta}_s^R < \tilde{\Delta}_s^S$, where c^R , $\beta^R(c)$, c^S and $\beta^S(c)$ are provided in Appendix A1.*

A monopolistic supplier profits more from direct selling in structure R than in structure B when direct sales are inefficient to manage and competition is intense. In this case, retail channel gains importance in revenue generation, and direct selling alleviates more burden off the supplier, who manages product substitution in selling to competing retailers. Similarly, suppliers profit more from direct selling in structure S than in structure B when direct sales are inefficient to manage or competition is strong, in which case, competing suppliers reap a larger gain by leveraging channel substitution to shift sales to direct channels instead of yielding to the monopolistic power by the retailer. Moreover, suppliers always benefit more in structure S to leverage channel substitution in selling to a monopolistic retailer than in structure R to manage product substitution in selling to competing retailers.

We measure the information effects of direct selling on suppliers' profits by $\hat{\Delta}_s^t \triangleq \frac{\hat{\pi}_{d,s}^t - \hat{\pi}_{n,s}^t}{\hat{\pi}_{n,s}^t}$, $t = B, R, S$, where $\hat{\pi}_{d,s}^t$ and $\hat{\pi}_{n,s}^t$ are, respectively, the information-based profits for suppliers who engage in and forgo direct selling in structure t . Figure 3 illustrates pairwise comparisons, where σ_s is the quality of suppliers' exclusive signals before encroaching. Recall that an encroaching monopolistic

supplier acquires retailers' signals and relies on all signals to manage direct sales only. In structure R , it practices differential payments to induce the retailers, who forgo signal exchange, to disclose signals at profit losses. Without influencing signal quality ($\sigma_s \rightarrow \sigma_r$), direct selling benefits the supplier more in structure R than in structure B when competition is not too intense. The benefit from bypassing managing product substitution in selling to competing retailers and the surplus it extracts by exploiting their competitive relationship for signal disclosure contribute to its gain in structure R . As signal quality improves with direct selling, the enhanced responsiveness increases the supplier's chance of benefiting more in structure B , where it integrates the selling of products. As it receives a sufficiently accurate signal through direct selling ($\sigma_r \ll \sigma_s$), the supplier always reaps a larger profit gain from direct selling in structure B than in structure R . In this case, absent direct selling, the supplier forgoes the retailer's signal in structure B but acquires at least one signal from retailers in structure R . It causes direct selling to have a weaker effect on the supplier's gain from information flow in the latter case.

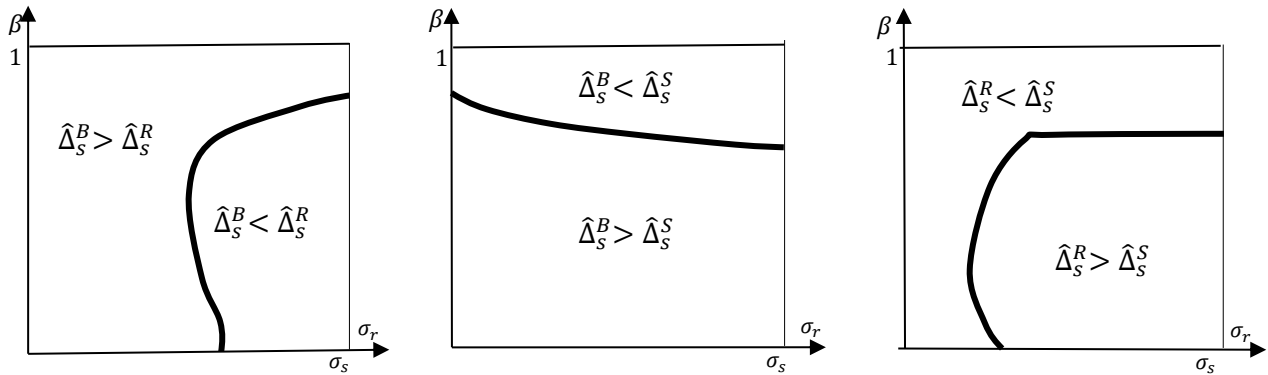


Figure 3. Information effects of direct selling on retailers' profits

Recall that suppliers in structure S exchange signals and have strong incentives to acquire the retailer's signal despite yielding it a premium. Granted full signal availability, suppliers leverage channel substitution to responsively balance sales across the dual channels, with the retail channel remaining indispensable. By contrast, the supplier in structure B only manages direct sales once it acquires the retailer's signal with a payment that enables the supplier to retain the net gain from information flow. Suppliers benefit more from direct selling in structure S than in structure B when competition is intense, in which case, channel substitution in responsive selling has a crucial role in alleviating the burden off suppliers in selling to the monopolistic retailer. As signal quality improves, enhanced responsiveness due to better forecast decreases the likelihood that horizontal competition makes the suppliers better off, which is similar to that under retailer competition. Between the two structures including competition in a tier, from the information perspective, sufficient accuracy in the

signals received from market access or intense market competition enables suppliers to reap greater profit gains under supplier competition (structure S) than under retailer competition (structure R).

4.3. Effects of direct selling on retailers' profits

Next, we study how direct selling by suppliers influences the profits for retailers.

Proposition 7. *Compared to when suppliers adhere to the retail channel, in structure $t \in \{B, R, S\}$, supplier encroachment improves the structure-based profits for retailers if $c > \tilde{c}_r^t$, worsens the information-based profits for retailers, and improves the overall profits for retailers if $c > c_r^t$, where \tilde{c}_r^t and c_r^t are thresholds and defined in Appendix A1.*

From the structure perspective, supplier encroachment improves the profits for retailers when direct sales are less efficient to manage than retail sales ($c > \tilde{c}_r^t$, $t = B, R, S$). In these cases, suppliers rely more on retail channel to make sales. To that end, they lower wholesale prices, mitigating the double marginalization effect to improve retailers' profits. It can be verified that $\tilde{c}_r^R < \tilde{c}_r^B$, $\tilde{c}_r^S < \tilde{c}_r^B$, and $\tilde{c}_r^S \geq \tilde{c}_r^R$ if $\beta \leq \beta_0 \approx 0.82$. Associated with an increase in cost of direct sales, competition in a channel tier increases suppliers' reliance on retail channel and has a stronger effect of mitigating the double marginalization effect. This is likely to be more prominent under retailer competition, in which case, a supplier manages product substitution to sell in retail channels, than under supplier competition, in which case, suppliers manage retail channel as a substitute to their respective direct channels.

Table 9. Effects of supplier encroachment on the profits for retailers

Structure	Structure-based profit	Information-based profit	Overall profit	Effects of signal acquisition by encroaching suppliers
B	↑ when $c > \tilde{c}_r^B$	↓	↑ when $c > c_r^B$	Unaffected
R	↑ when $c > \tilde{c}_r^R$	↓	↑ when $c > c_r^R$	↓
S	↑ when $c > \tilde{c}_r^S$	↓	↑ when $c > c_r^S$	↑

Recall that, in either structure, direct selling by suppliers does not alter the status of signal exchange, if any, between horizontal competitors. For a given status of signal acquisition, compared to when suppliers adhere to the retail channel, their direct selling has a negative effect on the profits for retailers. This is because encroaching suppliers have access to improved exclusive signals, gaining enhanced responsiveness in wholesale pricing and in balancing sales in the dual channels. Supplier encroachment triggers signal acquisition, which, as shown in Table 9, has mixed effects on retailers' profits. In a bilateral monopoly, the supplier's acquisition payment enables the retailer to retain its profit as before. Under retailer competition, the supplier applies differential payments to manage the retailers' incentive for signal disclosure: the retailer receiving the higher payment retains its profit as before, but the retailer receiving the lower payment is worse off. Thus, the retailers are trapped in a Prisoners' Dilemma type of situation to disclose signals at profit losses. Under supplier

competition, the retailer receives a premium to disclose its signal to both suppliers. Regardless, supplier encroachment causes retailers to make less information-based profits.

Proposition 7 further states that the structure effect dominates, making retailers better off with direct selling by suppliers when the cost of direct sales is high or, equivalently, retailing is more efficient ($c > c_r^t > \tilde{c}_r^t$, $t = B, R, S$). We show that c_r^B is insensitive to and c_r^R is stable with respect to β , while c_r^S decreases with β . Thus, competition intensity plays an active role in subjecting retailers' profits to the influence of supplier encroachment in the presence of supplier competition, in which case, more intense competition increases retailers' likelihood of benefiting from direct selling. Over the past years, an increasing number of retailers – including Macy's, Kohl's, and Walmart – shift to online operations and develop apps to facilitate product search and transactions in stores. Our results suggest that all these efforts, which aim to lower retail costs and enhance the efficiency in retailing, enable retailers to cater to and even benefit from direct-selling efforts by suppliers, particularly for retailers who sell highly substitutable items.

4.4 Quality of suppliers' exclusive signals

In addition to their exclusive signals, firms receive signals through information flow and voluntary sharing in vertical interactions. These signals differ in quality. Specifically, the quality of the signal received exclusively by a supplier is low when it adheres to the retail channel, but improves after it adopts direct selling. We have assumed that firms rely on all received signals to make operations decisions. However, a practical issue is: would firms be selective in signal utilization by ignoring the signals with inferior quality? Our answer is that, provided that firms can anticipate potential signal discrimination by other firms and take actions accordingly, they have no incentive to disregard any signals, despite relying less on the signals with inferior quality. Thus, from the perspective of signal utilization, a non-discriminating policy is optimal. For more details, please refer to Appendix A4.

Our analysis so far is premised on the assumption that the quality of the signal received exclusively by an encroaching supplier (direct signal, for short) is comparable to that of the retailer's signal, i.e., $\sigma_s = \sigma_r$. Next, we extend the analysis to the situation where the supplier's direct signal can be even better than the retailer's signal, i.e., $\sigma_s < \sigma_r$, and examine to what extent the insights into information flow based on our main analysis prevail.

Proposition 8. *Suppose that a supplier receives, through direct selling, an exclusive signal of accuracy σ_s .*

1) in structure B, the supplier forgoes signal acquisition if $\sigma_s < \sigma_s^B$, where σ_s^B is some threshold and $\sigma_s^B < \sigma_r$, but acquires the retailer's signal with payment \bar{m}_d^B otherwise.

2) in structure R , the retailers exchange signals if $\sigma_s < \sigma_s^R$ but forgo signal exchange otherwise, where σ_s^R is some threshold and $\sigma_s^R < \sigma_r$, and the supplier always acquires both signals, with payments $(\overline{m}_{d,H}^{R,h}, \overline{m}_{d,L}^{R,h})$ in the former case and $(\overline{m}_{d,H}^{R,o}, \overline{m}_{d,L}^{R,o})$ in the latter case.

3) in structure S , the suppliers exchange signals; both acquire the retailer's signal with $(\overline{m}_{d,H}^{S,h}, \overline{m}_{d,H}^{S,h})$ if $0 < \beta < \beta^{S,h}$, and only one supplier acquires the retailer's signal with $\overline{m}_{d,L}^{S,h}$ if $\beta^{S,h} \leq \beta \leq 1$.

Proposition 8 reveals that the quality of suppliers' direct signals weakly influences the formation of information flow under supplier encroachment. It has influence only in the settings with a monopolistic supplier and when the supplier's direct signal is substantially more accurate than the retailer's signal. Specifically, in a bilateral monopoly (structure B), an encroaching supplier forgoes signal acquisition when $\sigma_s < \sigma_s^B$, where the threshold σ_s^B is significantly below σ_r . In this case, the retailer's signal has a low value in improving market forecast, and the profit gain from enhanced responsiveness in managing sales is thin, disabling the supplier to afford signal acquisition.

In the presence of horizontal competition in a channel tier, contrasting with that in a bilateral monopoly, the quality of suppliers' direct signals is inconsequential to their signal acquisition. Under retailer competition (structure R), the retailers exchange signals when the supplier's direct signal is sufficiently accurate, i.e., $\sigma_s < \sigma_s^R$, where the threshold σ_s^R decreases in β . In this situation, retailers exchange signals to counteract the improved quality of the supplier's signal. However, this incentive weakens as competition intensifies to increase quantity pressure, clamping down on price and worsening their profits. Regardless, the supplier adopts bilateral signal acquisition. Thus, the two forms of information flow alter from strategic substitutes to strategic complements. Under supplier competition (structure S), the formation of strategic information flow is insensitive to the suppliers' signal quality. This is because the retailer can always discern the suppliers' signals under voluntary sharing through vertical interactions, inducing the suppliers to counteract by exchanging signals and acquire signal from the retailer.

Given the dominance of structure effect in determining suppliers' incentive for direct selling (Proposition 6), suppliers still prefer direct selling when managing direct sales is not too inefficient ($c < c_s^t$, $t \in \{B, R, S\}$). Once suppliers adopt direct selling, similar to those stated in Proposition 7, retailers can be better off in structure t when the cost of direct sales is high ($c > \bar{c}_d^t$). We find that the threshold \bar{c}_d^t decreases with σ_s ; that is, an improvement in the quality of the supplier's direct signal makes the retailers less likely benefit from supplier encroachment.

5. Concluding Remarks

Direct selling enables suppliers to sell in their own channels in addition to retail channel and grants them access to signals of improved quality. Importantly, it plays an intricate role in influencing the

strategic information flow, which can occur between horizontal competitors (signal exchange) and vertical partners (signal acquisition), to disseminate demand signals in the system. On the one hand, direct selling incentivizes suppliers to acquire signals from retailers. This justifies the increasing popularity of data sharing programs between retailers and suppliers in parallel to the direct selling efforts of suppliers amid technology advances. On the other hand, it is inconsequential to signal exchange between horizontal competitors in a channel tier and critically impacts the interplay of horizontal and vertical information flow. Incentive-driven information flow, together with voluntary signal sharing whereby firms share undisclosed signals through vertical interactions according to the specified decision sequence, influences firms' decisions to respond to realized market conditions.

Direct selling yields a structure effect that enables suppliers to manage sales across the dual channels and an information effect that influences the availability and utilization of signals to make tailored decisions. The structure effect dominates suppliers' incentive for direct selling. Specifically, suppliers prefer direct selling only when managing direct sales is efficient. This preference weakens as horizontal competition between firms exists in a tier, particularly the one between suppliers, and competition becomes more intense. Once suppliers engage in direct selling, both the structure and information effects benefit suppliers, while they have mixed effects on the profits for retailers. From the structure perspective, retailers are better off when the cost of direct sales is high, which is more prominent with horizontal competition. From the information perspective, a monopolistic supplier can offer differential payments to competing retailers, trapping them in a game to disclose signals at profit losses, while competing suppliers have to yield a premium to a monopolistic retailer for signal disclosure. Nevertheless, enhanced responsiveness and flexibility by suppliers in selling in the dual channels and the downgraded role of retail channel in revenue generation undermine the profits for retailers. Circumstances exist in which the structure effect dominates, making retailers benefit from supplier encroachment. Thus, it is possible for direct selling by suppliers to make every supply chain firm better off.

While the signals received through exclusive access, information flow, and voluntary sharing differ in quality, firms tend to be indiscriminate in utilizing the signals to make responsive decisions, despite relying less on the signals with inferior quality. In reality, with heavy investments in IT and supports from high-tech firms, encroaching suppliers may access exclusive direct signals of higher quality than that of the retailer's signal. We find that the form of information flow is largely robust to the quality of suppliers' exclusive signals, except in the settings with a monopolistic supplier and when its signal is substantially more accurate than the retailer's signal. In selling to a monopolistic retailer, a monopolistic supplier may no longer acquire the retailer's signal. In selling to competing

retailers, the supplier still acquires signals from both retailers, but the interplay of the two forms of information flow can alter to deter signal exchange between retailers.

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