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Manufacturer marketing initiatives and retailer information sharing

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Abstract This research examines a retailer's incentive to share information with its supplier when the supplier can also undertake initiatives to increase retail demand. It is well known that a retailer is averse to sharing market information with a manufacturer due to concern for a manufacturer's strategic use of such information. This research shows that despite such strategic exploitation of market information, a retailer may want to establish information sharing channels with its supplier. Information sharing essentially shifts power upstream which, in turn, enhances the manufacturer's incentive to bear costs to boost retail demand: the manufacturer is induced to invest merely by knowing that information is on its way. Hence, the retailer benefits from information sharing ex ante despite the costly ex post exploitation by

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the manufacturer. This finding is a stark contrast to the most of previous results which consistently point out how bad it is for the manufacturer to have the retailer's demand information before setting prices. In fact, due to the investment effect, information sharing can lead to gains for the retailer, manufacturer, and consumers alike.

Keywords Disclosure · Information sharing · Supply chain management · Marketing investment

JEL Classification D82 · L11 · M31

1 Introduction

Retailers in highly volatile demand markets such as fashion apparel have increasingly deployed information technologies to gain market knowledge to better adjust retail pricing decisions to meet market demand conditions (Fisher et al. 1994). At the same time, the volume and the quality of customer and market data accessible to retailers has been exploding due to advances in data collection technologies such as scanner systems and online data processing.

The increasing importance of and access to information at the retail level makes the issue of information sharing in supply chains particularly relevant. Further, better informed retailers can now share market information with their suppliers more easily thanks to electronic data interchange relationships (Srinivasan et al. 1994; Wang and Seidmann 1995). Ideally, such shared information can help better manage an upstream manufacturer's tasks, thereby boosting efficiency at all levels of the supply chain (Gavirneni et al. 1999; Cachon and Fisher 2000; Lee et al. 2000). For example, sales forecast data shared by a retailer enables a manufacturer to reduce inventory costs by lowering inventory holdings and streamlining logistics processes. Despite the potential advantages of information sharing, extant research has questioned the incentives for retailers to share their proprietary information with other channel memebers; the literature has been quick to point out that the strategic use of such information by a manufacturer at the expense of the retailer may preclude a retailer from fully "opening its books" to its suppliers (e.g., Li 2002; He et al. 2008; Guo 2009; and Guo and Iyer 2010). For example, most U.S. automotive vendors are concerned that if they share their information with manufacturers, the Big Three auto manufacturers will use information to squeeze the vendors' margins (Narayanan and Raman 2004).

Despite the warning that information can be used against them, retailers have been increasingly willing to communicate their retail information with suppliers. For example, according to the Grocery Manufacturers Association, most U.S. grocery retailers and mass merchandisers with more than $5 billion in annual sales are sharing weekly and even daily store sales and other data directly with their suppliers at no cost (Supermarket News 2009). In this paper, we seek to provide one explanation for the gap between the prevalence of information sharing in practice and the seemingly

unequivocal theoretical result that retailers should maintain their information advantage over their suppliers. In particular, we suggest that one reason for the growing pattern of supply chain information interlinkages may be that information sharing provides a manufacturer with an incentive to allocate more resources to enhancing consumer demand. Knowing it can influence the level of the manufacturer's investment, the retailer is more willing to share its information. Information sharing as a means to coax additional manufacturer investment implies that information sharing (by the retailer) and investment (by the manufacturer) represent a mutually-beneficial tit-for-tat relationship that arises naturally.

In short, this paper's analysis notes that the propriety of a retailer providing information to a supplier hinges on the importance of supplier investments in demand. In this vein, we note that such supplier investments are commonplace in practice. When a manufacturer introduces a new product or fashion item to the marketplace, it often offers several different marketing support activities such as local advertising and promotion, financial support to properly equip and furnish the retail outlet to suit the new product, sales training for retail managers and employees, and equipment for service and repair (Besanko and Perry 1993). As an example, VF Corporation, a major manufacturer of clothing and lingerie, with a compliance from the retailer, developed a supply chain information system (Sender 1998). The core of the system is the analysis of market data (consumer information, point-of-sale data, and so forth) at the level of a retail store in a given location. This retail information allows VF to develop a recommended optimal in-store display and a floor-space plan to maximize the local sales by accommodating its local preferences (Discount Store News 1998).

Also, manufacturers routinely undertake widespread brand advertising to boost demand for their products. Of course, local retailers of these products are one beneficiary of such advertising. Also, manufacturers often expend substantial resources to create point-of-purchase (POP) advertising and displays for in-store use to help retailers increase demand. Even when advertising is undertaken and paid for exclusively at the local retail level, manufacturers often willingly undertake co-op advertising, whereby they share the cost of local advertising undertaken by downstream channel members (Bergen and John 1997; Coughlan et al. 2001). It is the prevalence of such manufacturer investment in retail demand that forms the crux of the current paper's premise.

To elaborate on our setting, we revisit the standard vertical information sharing model wherein a distribution channel consists of one manufacturer and one retailer. The retailer initially gets an early read of market demand, after which the manufacturer sets a (unit) wholesale price at which it will provide products to the retailer. The retailer, in turn, decides how many units to procure and provide to final market consumers (or, equivalently, the retailer decides its retail price). As a benchmark case, we confirm the result in extant work that in the absence of (endogenous) demand-enhancing investment by the manufacturer, the retailer does not have incentive to share its private information about demand with its upstream supplier. In this case, the provision of information allows the manufacturer to tailor its wholesale price to the particulars of retail demand. Though the responsive wholesale price benefits the retailer in the event of low demand (due to a lower

wholesale price), it hurts the retailer in the event of high demand (due to a higher wholesale price). Since potential profits are greatest when demand is high, the cost of information sharing is more pronounced than the benefit from an ex ante sense (as in Li 2002; Guo 2009).

Next, we incorporate the distinct aspect of our analysis—demand-enhancing investment undertaken by the manufacturer. In doing so, we consider a circumstance in which investment by the manufacturer must be made up front, i.e., prior to the retailer's observation of its private information (ex ante case).[1] This reflects the practical aspect that manufacturer investment such as brand advertising is often undertaken prior to fully understanding the extent of demand (e.g., advertising is typically greatest at the product launch stage). This formulation also serves to "stack the deck" against finding an investment-related benefit to information sharing since it precludes the manufacturer from conditioning its investment on the realized market information. In other words, under this "ex ante investment" case, one may wonder how unrealized demand information can affect the manufacturer's investment decision.

Surprisingly, the result shows that when a retailer agrees to share information, the manufacturer makes a higher investment in demand-enhancing marketing activity even without learning the actual realization of demand information: the manufacturer is induced to invest merely by knowing that information is on its way. Though the information is not directly helpful to the manufacturer investment choice, its impending release ensures the manufacturer a greater marginal benefit from such investment due to the prospect of demand-contingent wholesale pricing. In effect, the supply chain suffers from both (1) double-marginalization due to strategic wholesale pricing and retail procurement and (2) a hold-up problem due to unilateral manufacturer investment. By permitting environment-contingent wholesale pricing, information sharing gives the manufacturer a leg up in terms of the double-marginalization problem which, in turn, helps alleviate the manufacturer hold-up problem. Our results indicate that as long as the potential gain of investment is sufficiently large relative to the extent of private information, the retailer uses its information sharing as a tool for inducing a higher demand-enhancing manufacturer investment. Further, since information sharing can alleviate attendant supply chain inefficiencies, information sharing can also achieve Pareto gains among supply chain parties.

The primary result that a retailer shares information in order to encourage a manufacturer's additional investment in enhancing product demand, comes with some caveats. First, the reason information sharing is able to benefit the retailer is that it not only encourages manufacturer investment, but that a portion of the benefits of this investment spill over to the retailer. However, if the manufacturer can

[1] We also consider the case in which investment is made after retailer's observation of its private demand information (ex post case). The main results are quite intuitive and consistent with ex ante case. We present a simple ex post case in the Appendix.

make use of two-part tariffs or other contractual means of extracting the entire surplus from the retailer under information sharing, the retailer's incentive to disclose would disappear and the result will revert to the traditional result of no information sharing.

Second, the retailer's pre-commitment to sharing information is critical in inducing the manufacturer's investment. If the retailer were able to observe the manufacturer investment and then to renege on its commitment to sharing information, the manufacturer would understandably ignore such noncredible promises to share information. We discuss these two important assumptions and their implications in detail in Section 7.1.

The remainder of this paper proceeds as follows. In Section 2, we relate our paper to the existing literature in marketing and supply chain. Section 3 represents the model and Section 4 shows a benchmark case. Section 5 examines a retailer's disclosure decision in the presence of a manufacturer's demand enhancing investment. We provide closed form results for social welfare ananlysis by considering a quadratic investment cost function in Section 6 and Section 7 concludes this paper.

2 Literature review

The results of this paper fit into the broader literature on information sharing in imperfect markets. There have been a large number of papers on the effect of information disclosure on horizontal markets. Gal-Or (1985, 1986) and Li (1985) demonstrate that a firm would be better off by committing to disclosure when demand (cost) information is available in Bertrand (Cournot) competition while they should commit to no disclosure when cost (demand) information is available. As in the previous papers, our paper shows the effect of disclosure in an imperfect product market but instead focuses on vertical information sharing. In this vein, there are also many papers which have investigated the direct effect of information sharing between channel members (e.g., Gavirneni et al. 1999; Cachon and Fisher 2000; Lee et al. 2000; and Raghunathan 2001). These papers ostensibly examine the effect of information sharing on operational efficiency such as inventory management and improved order function in the absence of strategic tensions among supply chain partners.

Most germane to the present paper is the stream of research examining the issue of a retailer's information disclosure and its effect on a manufacturer's wholesale pricing and market competition (Desiraju and Moorthy 1997; Li 2002; Arya et al. 2012). Desiraju and Moorthy (1997) deal with information disclosure by a retailer (who is better informed about the market demand) under two-part tariff and performance requirements. They show that through the performance requirement (or direct monitoring of retailer compliance about the price and/or service), the manufacturer can control the retailer's behavior directly while the two-part tariff can induce the retailer to reveal the demand information. Hence, they show that the performance requirement can enhance supply chain efficiency. Li (2002) examines an information leakage effect in a vertical relationship in the presence

of horizontal competition. He shows that in the presence of Cournot retail competition a retailer shares cost information with a manufacturer but does not share demand information due to the potential for information leakage to horizontal competitors. In that setting, while the strategic wholesale price effect of information sharing is uniformly detrimental to the retailer, it can be offset by demand-side effects on competition. Arya et al. (2012) integrate these effects and the competitive effects of disclosure to examine how information correlation affects the desire to share information.

In a related vein, Guo (2009) shows that a monopolist retailer's disclosure of demand information lowers both a retailer's expected profit and a supply chain efficiency. In contrast, our paper shows that a monopolistic retailer is not always unwilling to share information in the distribution channel when a manufacturer's demand enhancing activity is considered. The manufacturer's demand enhancing activity benefits a retailer by boosting market demand and, therefore, the manufacturer's investment can work as a countervailing incentive to induce a retailer to disclose its information in the supply chain.

In a recent paper, Li and Zhang (2008) examine the effect of confidentiality on information sharing in a supply chain when there exists Bertrand competition in a retail market. They show that higher confidentiality leads to a lower wholesale price and confidentiality induces truth telling and coordinates the supply chain. In this case, strategic wholesale pricing again serves to undercut information sharing incentives, while market competition can provide an offsetting incentive for information sharing. In contrast, the current paper focuses on the interplay between a retailer's information disclosure and a manufacturer's demand enhancing investment and identifies the conditions under which a retailer can induce a higher demand-enhancing investment from manufacturer by sharing its information, thereby achieving Pareto gain in the channel. While the emphasis herein is on retailer information sharing, other work has also examined circumstances wherein manufacturers gain information advantage (Gal-Or et al. 2008; Guo and Iyer 2010).

While most papers in operations research have shown the benefits of a retailer's demand information sharing by focusing on the improvement in operational efficiency when there are inventory costs (Gavirneni et al. 1999; Cachon and Fisher 2000; Lee et al. 2000; Raghunathan 2001), the role of demand-enhancing marketing investment has been largely ignored in the literature. Marketing research in disclosure area has spent the last several years pointing out the strategic disadvantages of sharing information: it only improves the upstream supplier's ability to extract surplus from the retailer. The current paper restores the marketing angle for information sharing by showing how it incentivizes the manufacturer to invest in the channel even without inventory cost concerns.

Since manufacturer investment represents the distinguishing aspect of our analysis vis a vis the information sharing literature, it is worth noting there are several papers which investigate the effect of manufacturer investment on supply chain efficiency. Besanko and Perry (1993) examine the relationship between a manufacturer's demand enhancing activity and exclusive dealing. They show that exclusive dealing induces more investment from a manufacturer by eliminating interbrand demand externality but in ex post the more efficient investment

may intensify market competition. Chu and Desai (1995) examine a manufacturer's investment to improve customer satisfaction, thereby enhancing future demand. They find that such manufacturer's investment is more useful when dealing with a long-term oriented retailer. Gupta and Loulou (1998) show that channel structure affects a manufacturer's investment incentive and lack of channel coordination results in a manufacturer's lower investment for process innovation. Compared to these papers, our research investigates a manufacturer's demand enhancing investment in the context of information sharing and suggests that an impending manufacturer investment choice may be the linchpin for a retailer's information sharing.

3 Model

Consider a model in which a manufacturer produces a product and sells it to a retailer who, in turn, provides it to end users. Demand in the retail market is captured through the following demand function:

$$q = \alpha(1 + I) - p. \tag{1}$$

In the demand function, α, denotes the underlying consumer demand, p is the retail price charged by the retailer, and q is the quantity of the end product demanded in the market. Consumer demand α is uncertain and distributed on the interval $[\underline{\alpha}, \overline{\alpha}]$, according to the density function $G(\alpha)$, with mean μ and variance $\sigma^2 > 0$.[2] Also, the manufacturer has the opportunity to undertake investment which increases demand. For example, the manufacturer can undertake a brand-level marketing campaign, make investments in point-of-purchase (POP) advertising and displays for in-store use to help retailers increase the demand, modify its product to meet a specific local market preference, or undertake an investment in technology to enhance product quality. When the manufacturer invests in these demand-enhancing marketing activities, it increases the baseline consumer demand. This effect is reflected in the demand function by I. The investment cost necessary to increase the demand intercept to $\alpha(1 + I)$ is $C(I)$ and, to ensure interior investment levels in equilibrium, we assume $C(I)$ is twice differentiable, $C(0) = C'(0) = 0$, and $C''(I)$ for $I > 0$ is sufficiently large that second-order conditions are satisfied throughout (hereafter, we will refer to I as the investment level). For simplicity, we normalize the unit production cost of the manufacturer to be zero. Given this formulation, the profit functions for the retailer and the upstream manufacturer, respectively, are:

$$\Pi_R = (p - w)q; \Pi_M = wq - C(I),$$

where w is the (unit) wholesale price charged by the manufacturer.

[2] As is standard, we assume $\underline{\alpha}$ is sufficiently large that the first-order approach provides positive equilibrium prices and quantities throughout.

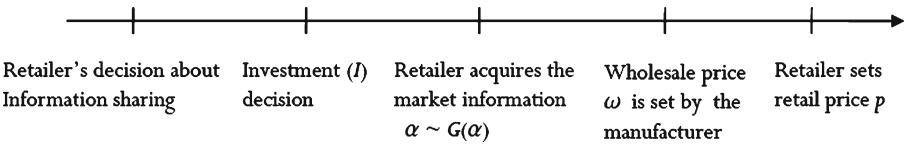

Fig. 1 Sequence of the Game

Under this basic structure, the sequence of events is as follows. First, the retailer decides whether to establish a formal information sharing channel with the manufacturer. Following the stream of literature (Gal-Or 1985; Li 1985, 2002; Cachon and Fisher 2000), it is presumed that the retailer can pre-commit to this disclosure decision and any disclosures are necessarily truthful (i.e., subject to third-party audit). Next, the manufacturer decides its investment level for activities which can enhance the ultimate demand for the product. Third, the retailer privately observes α, the critical information about market demand, and discloses (or not) according to its information sharing arrangement. Fourth, the manufacturer decides its wholesale price reflecting the manufacturer's information about the market and its investment level. Finally, the retailer sets its optimal retail price based on the market demand and wholesale price. We use the Subgame Perfect Equilibrium (SPE) as our solution concept and throughout the paper, backward induction is employed to examine the equilibrium behavior of the retailer and the manufacturer. Figure 1 summarizes the sequence of events.[3]

4 Benchmark: exogenous investment

Before we analyze our main model, we investigate the benchmark case in which the manufacturer's investment is exogenously given so that the manufacturer does not have an option to change its investment level in demand-enhancing activities. This benchmark case will highlight the role of the manufacturer's endogenous investment decision on a retailer's information sharing incentive, which will be examined in next sections.

[3] Alternatively, one may consider the case when a manufacturer chooses its precise investment level after demand information is realized (i.e., ex post investment decision). In this case, the manufacturer can adjust its investment level as well as price according to the realized demand level: if the retailer announces a high (low) demand, a manufacturer would make a high (low) investment. We can easily show that even under this ex post case, our main results in ex ante case still hold (see the Appendix). In reality, a manufacturer often needs to make investments long before a market demand is realized because the manufacturer's investment may be too late in meeting consumers demand if it is made after demand is realized. For this reason, our analysis focuses on an ex ante case where investment by the manufacturer must be made up front, i.e., prior to the retailer's observation of its private information.

This benchmark case can be easily seen by setting an exogenous level of I in our model. Consider first the outcome when the retailer opts to disclose its information. Using backward induction, the retailer's chosen retail price maximizes profit given the manufacturer's chosen wholesale price, the exogenous investment level, and realized consumer demand, as in Eq. 2:

$$\underset{p}{Max}\ \Pi_R \Leftrightarrow \underset{p}{Max}\ [p - w][\alpha(1 + I) - p]. \tag{2}$$

The unique solution to Eq. 2 yields the retailer's optimal pricing choice, $p^*(w, I, \alpha) = [\alpha(1 + I) + w]/2$. Given this optimal retail price, the manufacturer chooses a wholesale price to maximize its profit given the exogenous investment level and disclosed consumer demand, as in Eq. 3:

$$\underset{w}{Max}\Pi_M \Leftrightarrow \underset{w}{Max}\, w[\alpha(1 + I) - p^*(w, I, \alpha)] - C(I). \tag{3}$$

The first order condition of Eq. 3 reveals that the manufacturer's optimal wholesale price is $w^*(I, \alpha) = \alpha(1 + I)/2$. From the wholesale price, one consequence of information sharing is immediate. When consumer demand is high (low), the wholesale price, too, is high (low). As such, the state-contingent nature of the wholesale price helps protect the retailer when demand is low but also serves to dilute its profits when demand is high. Taking investment level as given, the expected profits of the retailer and the manufacturer under disclosure (reflected by the D superscript) are, respectively,

$$\begin{aligned}\Pi_R^D(I) &= E_\alpha\{[p^*(w^*(I, \alpha), I, \alpha) - w^*(I, \alpha)][\alpha(1 + I) - p^*(w^*(I, \alpha), I, \alpha)]\} \\ &= \frac{[\mu^2 + \sigma^2][1 + I]^2}{16}, \end{aligned} \tag{4}$$

$$\begin{aligned}\Pi_M^D(I) &= E_\alpha\{w^*(I, \alpha)[\alpha(1 + I) - p^*(w^*(I, \alpha), I, \alpha)] - C(I)\} \\ &= \frac{[\mu^2 + \sigma^2][1 + I]^2}{8} - C(I). \end{aligned} \tag{5}$$

On the other hand, if the retailer does not disclose its information, the manufacturer must choose its wholesale price based on its expectation of market demand. In this case, the wholesale price is chosen to solve Eq. 6:

$$\underset{w}{Max}\ E_\alpha\{\Pi_M\} \Leftrightarrow \underset{w}{Max}\ E_\alpha\{w[\alpha(1 + I) - p^*(w, I, \alpha)] - C(I)\}. \tag{6}$$

As might be expected, the solution to Eq. 6 yields a wholesale price of $w^*(I) = E_\alpha\{w^*(I, \alpha)\} = \mu(1+I)/2$. In this case, wholesale price reflects expected consumer demand. The expected profits for the retailer and the manufacturer, respectively, under no disclosure (reflected by the N superscript) are:

$$\begin{aligned}\Pi_R^N(I) &= E_\alpha\{[p^*(w^*(I), I, \alpha) - w^*(I)][\alpha(1 + I) - p^*(w^*(I), I, \alpha)]\} \\ &= \frac{[\mu^2 + 4\sigma^2][1 + I]^2}{16}, \end{aligned} \tag{7}$$

$$\begin{aligned}\Pi_M^N(I) &= E_\alpha\{w^*(I)[\alpha(1 + I) - p^*(w^*(I), I, \alpha)] - C(I)\} \\ &= \frac{\mu^2[1 + I]^2}{8} - C(I). \end{aligned} \tag{8}$$

A comparison of the retailer's expected profits under disclosure and no disclosure leads to the following lemma.

Lemma 1 *In the absence of endogenous manufacturer investment, the retailer prefers not to share market information for any level of given* $I \geq 0$*:*

$$\Pi_R^D(I) < \Pi_R^N(I) \text{ for } \forall I \geq 0.$$

The lemma implies that in the absence of an investment effect of information disclosure, the retailer's net benefit of information sharing is negative for any level of manufacturer's investment $I \geq 0$. Further, it is readily confirmed that the net benefit of withholding information is increasing in the extent of the retailer's information advantage (as reflected in σ^2). Intuitively, since the retailer's profit is convex in consumer demand, the loss from disclosure realized when demand is high exceeds the potential gain from information sharing realized when demand is low. As a result, the retailer is always better off by not sharing information with a manufacturer.

One immediate implication of the lemma is that even under the extreme case of $I = 0$, where the manufacturer does not invest in demand enhancing activities at all, the retailer is better off by not sharing information with a manufacturer. This result conforms to analogous findings in the previous literature (e.g., Li 2002; Guo 2009).

5 Manufacturer investment in retail demand

In this section, the effects of a manufacturer's strategic use of investment in retail demand on a retailer's disclosure incentive are analyzed. In practice, there are various types of manufacturer activity that can enhance market demand: training of a retailer's employees, advertising, investment in a retailer's chain stores, increasing quality control, and so on. In light of the ubiquity of manufacturer investment, the ensuing results examine how it can be a tool to elicit a retailer's information sharing.

5.1 Endogenizing the investment choice

Given the result of the Lemma 1 in the previous section, one may wonder how considering investment could change the desirability of disclosure since (i) any disclosure happens after investment and thus the manufacturer's investment choice cannot be influenced by the realized demand information, and (ii) the retailer prefers not to share information regardless of the investment level (Lemma 1). If the investment level is chosen after the disclosure (ex post investment), it is easy to see how the manufacturer's investment level is influenced by the disclosed information and how the retailer's information sharing incentive can be changed by such investments conditioned on the demand information. Clearly, the retailer's disclosure of high (low) demand will induce the manufacturer's high (low) investment although the manufacturer will charge the high (low) wholesale price. We can show that the retailer

commits to sharing its market information only if the demand-enhancing investment effect is sufficiently large that it outweighs the concern for increased wholesale pricing (see the Appendix).

However, in practice the manufacturer commonly makes investments before the demand is realized and thus it is not clear how the retailer's undisclosed information can affect the manufacturer's investment decision. As we will show, surprisingly, the manufacturer makes higher investment even without realization of demand information. The retailer's commitment to information sharing ensures the arrival of information to a manufacturer and the anticipation of information arrival makes the manufacturer increase the investment level: the manufacturer is induced to invest merely by knowing that information is on its way. To see this, we first consider the outcome under no disclosure.

5.1.1 No disclosure

As in previous sections, we solve this game using backward induction. Under no disclosure, the manufacturer's chosen wholesale price and ensuing expected profit for a given investment level are $w^*(I)$ and $\Pi_M^N(I)$, as derived previously. Given this, the manufacturer chooses investment to solve:

$$\underset{I}{Max}\,\Pi_M^N(I) \Leftrightarrow \underset{I}{Max}\,\frac{\mu^2[1+I]^2}{8} - C(I). \tag{9}$$

The first-order condition for Eq. 10 yields the manufacturer's investment level under no disclosure, denoted I^N.

$$\frac{4C'(I^N)}{1+I^N} = \mu^2. \tag{10}$$

Using the first-order condition for investment level in the wholesale price, retail price, and profit expressions, the equilibrium outcomes under no disclosure are presented in Lemma 2.

Lemma 2 *With endogenous investment, the equilibrium outcomes under no disclosure are as follows:*

(i) *Investment level,* I^N*, solves* $\frac{4C'(I^N)}{1+I^N} = \mu^2$.
(ii) *Wholesale price is* $w^*(I^N) = \mu[1+I^N]/2$.
(iii) *Retail price is* $p^*(w^*(I^N), I^N, \alpha) = [2\alpha+\mu][1+I^N]/4$.
(iv) *Expected Retailer profit is* $\Pi_R^N(I^N) = \frac{[\mu^2+4\sigma^2][1+I^N]^2}{16}$.
(v) *Expected Manufacturer profit is* $\Pi_M^N(I^N) = \frac{\mu^2[1+I^N]^2}{8} - C(I^N)$.

5.1.2 Disclosure

If the retailer opts to share information, the manufacturer investment choice changes. This occurs despite the fact that information does not arrive prior to the

investment choice. To elaborate, the manufacturer's chosen wholesale price and ensuing expected profit for a given investment level are $w^*(I, \alpha)$ and $\Pi_M^D(I)$, as derived previously. Given this, the manufacturer chooses investment to solve:

$$\underset{I}{Max}\,\Pi_M^D(I) \Leftrightarrow \underset{I}{Max}\,\frac{[\mu^2+\sigma^2][1+I]^2}{8} - C(I). \tag{11}$$

The first-order condition for Eq. 11 yields the manufacturer's investment level under disclosure, denoted I^D.

$$\frac{4C'(I^D)}{1+I^D} = \mu^2 + \sigma^2. \tag{12}$$

Given this and the expressions for wholesale price, retail price, and each party's profits, the equilibrium outcomes under disclosure are presented in Lemma 3.

Lemma 3 *With endogenous investment, the equilibrium outcomes under disclosure are as follows:*

(i) *Investment level,* I^D*, solves* $\frac{4C'(I^D)}{1+I^D} = \mu^2 + \sigma^2$.
(ii) *Wholesale price is* $w^*(I^D, \alpha) = \alpha(1 + I^D)/2$.
(iii) *Retail price is* $p^*(w^*(I^D, \alpha), I^D, \alpha) = 3\alpha[1 + I^D]/4$.
(iv) *Expected Retailer profit is* $\Pi_R^D(I^D) = \frac{[\mu^2+\sigma^2][1+I^D]^2}{16}$.
(v) *Expected Manufacturer profit is* $\Pi_M^D(I^D) = \frac{[\mu^2+\sigma^2][1+I^D]^2}{8} - C(I^D)$.

Given these equilibrium outcomes, we now compare the disclosure and no disclosure regimes to determine if and how manufacturer investment can alter the retailer's disclosure choice.

5.2 Disclosure vs. no disclosure

In comparing disclosure regimes, we first examine the consequence of information disclosure on manufacturer investment. From Lemma 3, the manufacturer's investment under disclosure solves $\frac{4C'(I^D)}{1+I^D} = \mu^2 + \sigma^2$. Differentiation of the first-order condition with respect to σ^2 yields:

$$\begin{aligned} &\frac{4C''(I^D)\frac{\partial I^D}{\partial \sigma^2}}{1+I^D} - \frac{4C'(I^D)\frac{\partial I^D}{\partial \sigma^2}}{(1+I^D)^2} = 1 \\ &\Leftrightarrow \frac{\frac{\partial I^D}{\partial \sigma^2}[4C''(I^D) - \mu^2 - \sigma^2]}{1+I^D} = 1. \end{aligned} \tag{13}$$

From the second-order condition of Eq. 11, we know that $[4C''(I^D) - \mu^2 - \sigma^2] > 0$. Hence, from Eq. 13, we can see that $\frac{\partial I^D}{\partial \sigma^2} > 0$. In other words, when information is shared with the manufacturer, the greater the "information content" (i.e., demand

uncertainty σ^2 is high), the greater the investment level. Intuitively, when information is shared, uncertainty introduces opportunity for the manufacturer. When demand is at its peak, the manufacturer can utilize demand-contingent wholesale pricing to take advantage of such a circumstance. Further, when demand is low, the manufacturer can tailor its wholesale price to better respond to consumer (and thus retailer) demand. Since investment essentially intensifies the degree to which these fluctuations can be exploited by the manufacturer, greater information content translates into greater investment. Further, since, the investment level under no disclosure corresponds to that under disclosure with $\sigma^2 = 0$, the subsequent proposition follows.

Proposition 1

(i) *The manufacturer's investment is higher under information sharing, i.e.,* $I^D > I^N$.
(ii) *The incremental investment under information sharing increases as information content increases, i.e.,* $I^D - I^N$ *is increasing in* σ^2.

Proposition 1 confirms that the retailer's establishment of an information sharing arrangement encourages the manufacturer to more aggressively invest in enhancing market demand. In other words, the information transparency due to the retailer's disclosure motivates a manufacturer to prepare for the upcoming high demand by making a higher investment. Without an information sharing arrangement, the manufacturer can only charge its wholesale price based on its prior and then ex post gains from its investment in demand enhancing activities cannot be fully captured. Therefore, the retailer's commitment to share its market information alleviates the manufacturer's hold-up concern which causes underinvestment in demand enhancing marketing activities up-front. Moreover, this effect becomes more pronounced as the demand uncertainty becomes higher. The higher the demand uncertainty, the greater the manufacturer's concern for hold-up problem. Hence, the incremental investment from the information sharing increases as "information content" increases (i.e., demand uncertainty σ^2 becomes high).

This enhanced investment effect can change the retailer's information sharing incentive despite the fact that concern for a manufacturer's opportunistic wholesale pricing remains. From the retailer's perspective, there exists a trade-off between investment efficiency and an exploitative wholesale price. The retailer weighs the net benefit of disclosure by considering the advantage from the enhanced investment efficiency and the disadvantage from the higher wholesale price. A comparison of $\Pi_R^D(I^D)$ and $\Pi_R^N(I^N)$ leads to the retailer's decision rule stated in the following proposition.

Proposition 2 *In the presence of an endogenous manufacturer's demand enhancing investment, the retailer prefers to disclose its market information if and only if*

$$\left[\frac{1+I^D}{1+I^N}\right]^2 > \frac{\mu^2+4\sigma^2}{\mu^2+\sigma^2}.$$

Proof The result comes directly from comparing $\Pi_R^D(I^D) = \frac{[\mu^2+\sigma^2][1+I^D]^2}{16} > \Pi_R^N(I^N) = \frac{[\mu^2+4\sigma^2][1+I^N]^2}{16} \Leftrightarrow \left[\frac{1+I^D}{1+I^N}\right]^2 > \frac{\mu^2+4\sigma^2}{\mu^2+\sigma^2}$. □

Proposition 2 indicates that a retailer prefers to disclose the information when the incremental investment from disclosure is greater than the incremental wholesale price effect. The left-hand side of the condition ($\frac{1+I^D}{1+I^N}$) captures the relative benefit of information sharing to the retailer from enhanced manufacturer investments. Intuitively, the greater the left-hand side of the condition ($\frac{1+I^D}{1+I^N}$), the greater the new benefits of information sharing to the retailer of enhanced manufacturer investment (i.e., reduction of the hold-up problem). On the other hand, the right-hand side of the condition ($\frac{\mu^2+4\sigma^2}{\mu^2+\sigma^2}$) captures the loss to the retailer from sharing its information with the manufacturer. This loss arises because by sharing demand-specific information with the supplier, the retailer effectively grants the supplier pricing power when demand is high (precisely when the retailer wishes not to give such pricing power). Hence, the loss becomes more severe when the retailer's information advantage is high (as reflected in σ^2).

The result emphasizes that a retailer may prefer information disclosure which allows the manufacturer to set its wholesale prices after observing the information. This finding is a stark contrast to the most of previous results which consistently points out how bad it is for the manufacturer to have the retailer's demand info before setting prices.

In sum, we find that in the presence of manufacturer's endogenous investment, the retailer may prefer to disclose its demand information when the loss from sharing its information is more than compensated by the benefit of information sharing (i.e., the incremental benefit of enhanced manufacturer investments).

Another interesting question is how information sharing affects supply chain efficiency. After all, in the exogenous investment case, it is readily confirmed that supply chain profit is lower under disclosure. In effect, the potential gain in efficiency from information sharing is dwarfed by the expansion of the double-marginalization problem it engenders. However, just as the investment effect can benefit the retailer, it can also benefit the supply chain as a whole. Consider the expected manufacturer profit from disclosure. In particular, note that $\Pi_M^D(I^N) - \Pi_M^N(I^N) = \frac{\sigma^2[1+I^N]^2}{8} > 0$. And, since $\Pi_M^D(I^D) > \Pi_M^D(I^N)$ by the derivation of I^D, it follows that

$$\Pi_M^D(I^D) > \Pi_M^N(I^N). \tag{14}$$

Hence, the manufacturer always benefits from information sharing.

Finally, consider the consequence of information sharing on consumer surplus. In order to calculate the consumer surplus from the inverse linear demand function ($q = \alpha(1 + I) - p$) used here, we follow Singh and Vives (1984) and consider a representative consumer in the market with the utility function, $u(q) = \alpha(1 + I)q - \frac{q^2}{2} - pq$. That is, the first-order condition of the utility function with regard to q yields the same linear demand function, $q = \alpha(1 + I) - p$ we are considering. Given this, the consumer surplus (CS) is derived by substituting

$p = \alpha(1 + I) - q \ (\Leftrightarrow q = \alpha(1 + I) - p)$ into the utility function as follows:

$$u(q) = CS = \alpha(1 + I)q - \frac{q^2}{2} - (\alpha(1 + I) - q)q$$
$$= \frac{q^2}{2} = \frac{[\alpha(1 + I) - p]^2}{2}. \tag{15}$$

Using equilibrium retail prices from Lemmas 2 and 3 and taking expectations yields expected consumer surplus for the no disclosure ($CS^N(I^N)$) and disclosure ($CS^D(I^D)$) cases, respectively:

$$CS^N(I^N) = E_\alpha\{[\alpha(1 + I^N) - p^*(w^*(I^N), I^N, \alpha)]^2/2\} = \frac{[\mu^2 + 4\sigma^2][1 + I^N]^2}{32}, \tag{16}$$

$$CS^D(I^D) = E_\alpha\{[\alpha(1 + I^D) - p^*(w^*(I^D, \alpha), I^D, \alpha)]^2/2\} = \frac{[\mu^2 + \sigma^2][1 + I^D]^2}{32}. \tag{17}$$

One immediate implication of Eqs. 16 and 17 is that for exogenous manufacturer investment (i.e., $I^N = I^D$), expected consumer surplus is higher under no information sharing. Intuitively, just as the retailer benefits more from high demand when the manufacturer is unable to exploit such demand with higher wholesale prices, so too do consumers. After all, the underlying source of the retailer's preference for no disclosure is that disclosure intensifies the effects of double-marginalization. Like the retailer, consumers are also willing to overlook such strategic wholesale pricing if disclosure permits sufficient additional investment by the manufacturer. In fact, comparison of Eqs. 16 and 17 confirms that the consumers' condition for a preference for disclosure is precisely that of the retailer found in Proposition 2. Hence, the next proposition follows.

Proposition 3 *When the retailer chooses to disclose its information, such disclosure also benefits the manufacturer and consumers, and, thus, yields Pareto gains.*

While the above results indicate how consideration of manufacturer investments can alter the prevailing views about retailer information sharing in a relatively general setting, the general nature of the formulation prevents closed form solutions for investment levels. Next, we consider a particular (and commonly examined) class of investment cost functions to derive closed form results and, in the process, better highlight the intuition.

6 Quadratic cost function

6.1 Investment and disclosure decisions

Consider the analysis above under a quadratic cost function ($C(I) = \frac{kI^2}{2}$), which represents a simple formulation that also satisfies the property of the general cost

function $C(I)$.[4] Using this cost function, we now revisit the manufacturer's endogenous investment and the ensuing equilibrium outcomes under disclosure and no disclosure cases. The closed form of equilibrium outcomes using the function will provide us with a better understanding about the effect of investment on the retailer's information sharing incentive.

We first find the optimal ex ante investment levels under the quadratic cost function in the following Lemma 4.

Lemma 4 *Under the quadratic cost function,* $C(I) = \frac{kI^2}{2}$*, the optimal investment levels under each regime are as follows:* $I^N = \frac{\mu^2}{4k-\mu^2}$ *and* $I^D = \frac{\mu^2+\sigma^2}{4k-(\mu^2+\sigma^2)}$.

Lemma 4 confirms the previous result that the investment level is higher under disclosure. Moreover, it shows more explicitly that the investment level under disclosure increases in uncertainty (σ^2) while it is not affected by uncertainty under no disclosure. Using the investment levels in the lemma, we can then derive the expected profits of both the retailer and the manufacturer as follows:

$$\Pi_R^N(I^N) = \frac{k^2[\mu^2+4\sigma^2]}{[4k-\mu^2]^2}\ ;\ \Pi_M^N(I^N) = \frac{k\mu^2}{2[4k-\mu^2]};$$
$$\Pi_R^D(I^D) = \frac{k^2[\mu^2+\sigma^2]}{[4k-\mu^2-\sigma^2]^2}\ ;\ \Pi_M^D(I^D) = \frac{k[\mu^2+\sigma^2]}{2[4k-\mu^2-\sigma^2]}. \tag{18}$$

Comparing the retailer's expected profit under disclosure with that under no disclosure, the result in Proposition 4 is obtained.

Proposition 4 *Under a quadratic cost function,* $C(I) = \frac{kI^2}{2}$*, the retailer prefers to disclose its market information if and only if*

$$k < k^R = \frac{1}{12}\left[4(\mu^2+\sigma^2) + \sqrt{(\mu^2+\sigma^2)(\mu^2+4\sigma^2)}\right].$$

Proposition 4 suggests that a retailer discloses its market information if investment cost is not so high ($k < k^R$). As k becomes higher, the manufacturer's investment is more costly and then its investment level will be lower at given market profitability. Therefore, when k is smaller than k^R, the investment efficiency is high enough to convince the retailer of disclosing his information, thereby increasing its profit. Further, the limiting case of $k \to \infty$ represents the traditional analysis of information disclosure without consideration of manufacturer investment.

One may expect that as uncertainty increases, private information becomes more valuable and thus the informed retailer may be less willing to share the information. However, as demonstrated previously, greater uncertainty also increases the wedge in manufacturer investment levels under disclosure and no disclosure. Which effect

[4]The sufficient condition to guarantee that investment levels are positive is $k > \frac{\mu^2+\sigma^2}{4}$.

is more pronounced in this case can be gleaned from inspection of k^R which is increasing in σ^2. We investigate this in the following Corollary.

Corollary 1 *Under quadratic investment cost, $C(I) = \frac{kI^2}{2}$, information sharing is more attractive the greater the information content of disclosure, i.e., k^R is increasing in σ^2.*

Proof From the first-order condition of k^R, $\frac{\partial k^R}{\partial \sigma^2} = \frac{1}{12}\left(8\sigma + \frac{5\mu^2\sigma + 8\sigma^3}{\sqrt{(\mu^2+\sigma^2)(\mu^2+4\sigma^2)}}\right) > 0$, which implies that k^R increases as uncertainty (σ^2) increases. □

6.2 Social welfare

As derived in the general investment cost function, when the retailer benefits from disclosure, so too do the manufacturer and consumers. One question that may arise is since disclosure by the retailer benefits others, how does the retailer's preference match up with total welfare. In particular, even when the retailer prefers not to disclose, is there a welfare benefit from such disclosure? Such a question may be relevant in circumstances where mandatory disclosure regulations are under consideration.[5]

It is readily confirmed that in the benchmark case of exogenous investment, welfare considerations and retailer considerations are perfectly aligned—disclosure is always harmful to welfare. This equivalence, however, does not carry forward to the case of endogenous investment.

Using the expressions in Lemmas 2, 3, and 4, the expected welfare under information disclosure (W^D) and non-disclosure (W^N) are as follows:

$$W^D = \Pi_M^D(I^D) + \Pi_R^D(I^D) + \lambda CS^D(I^D) = \frac{k[\mu^2+\sigma^2][(6+\lambda)k - \mu^2 - \sigma^2]}{2[4k-\mu^2-\sigma^2]^2}, \tag{19}$$

$$W^N = \Pi_M^N(I^N) + \Pi_R^N(I^N) + \lambda CS^N(I^N) = \frac{k[(6+\lambda)k\mu^2 - \mu^4 + 4k(2+\lambda)\sigma^2]}{2[4k-\mu^2]^2}. \tag{20}$$

In Eqs. 19 and 20, $\lambda \geq 0$ represents the relative importance of consumer surplus in evaluating overall welfare (see, e.g., Baron 1988; Shapiro 1986). Comparing the welfare in the two cases yields the following corollary.

[5]For instance, the regulatory reporting requirement, Statement of Financial Accounting Standards No. 131 mandates disclosure of firms' segment performance and the disclosure naturally reveals a retailer's market information to a manufacturer even if the retailer does not prefer to share the information. Extant research in accounting (e.g., Arya et al. 2010; Botosan and Stanford 2005, Street et al. 2000) examines the effect of mandatory segment disclosure on market competition, information sharing, and a firm's disclosure behavior in a capital market.

Corollary 2 *Under quadratic investment costs, $C(I) = \frac{kI^2}{2}$, disclosure increases expected welfare if and only if $k < k^W$, where*

$$k^W = \frac{1}{8+12\lambda}\Big[4(1+\lambda)\mu^2 + (6+4\lambda)\sigma^2 + \sqrt{(2+\lambda)^2\mu^4 + 5(2+\lambda)^2\mu^2\sigma^2 + 4(5+4\lambda+\lambda^2)\sigma^4}\Big].$$

The result in Corollary 2 indicates that, unlike in the benchmark case of exogenous manufacturer investment, the preference for disclosure from a welfare perspective diverges from that of the retailer. In particular, while the retailer prefers disclosure if and only if $k < k^R$, welfare is enhanced by disclosure if and only if $k < k^W$. Importantly, an algebraic comparison reveals that $k^W > k^R$ indicating that disclosure is more attractive to the economy as a whole than it is to the retailer. Taken together, these results imply the following proposition.

Proposition 5 *The relationship between the retailer's disclosure choice and welfare maximization is as :*

(i) *If $k \geq k^W$, the retailer does not disclose and no disclosure also maximizes total welfare;*
(ii) *If $k^R \leq k < k^W$, the retailer does not disclose although disclosure maximizes total welfare;*
(iii) *If $k < k^R$, the retailer discloses and disclosure also maximizes total welfare.*

As k increases, the manufacturer's incentive to invest in demand-enhancing activities decreases because of a higher investment cost. Therefore, when the investment cost is extremely large ($k \geq k^W$), the endogenous investment effect is minimal and the usual no disclosure result applies: withholding information is better for both the retailer and overall welfare. For intermediate values of k (between k^R and k^W), the ability for disclosure to increase manufacturer investment outweighs the double-marginalization effect in terms of overall welfare. Yet, since only part of those benefits (and a preponderance of the cost) is borne by the retailer, the retailer is unwilling to share its information. This range introduces a role for mandatory disclosure regulations that compels the retailer to provide information it would otherwise be unwilling to for the sake of overall welfare. Finally, when $k < k^R$, the benefit from the increased demand through the manufacturer's investment dominates the double-marginalization cost, both economy-wide and retailer-specific. In this case, the retailer's voluntary information sharing always improves the manufacturer's expected profit and consumer surplus. Hence, a Pareto gain is obtained in the supply chain when $k < k^R$.

To highlight the results about a retailer's disclosure decision and welfare consequences of disclosure, Fig. 2 plots each under disclosure and no disclosure when $\mu = 1$, $\sigma^2 = 0.2$, and $\lambda = 1$. The graph demonstrates that the retailer decides

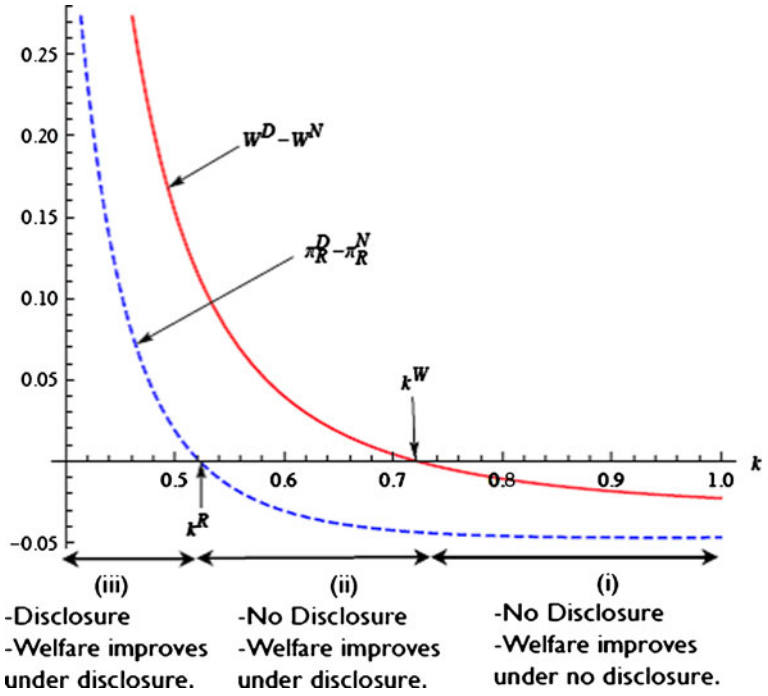

Fig. 2 A Retailer's Disclosure Decision and Total Welfare

to share its demand information if $k \leq k^R = 0.522$ and total welfare is greater under information sharing when $k \leq k^W = 0.721$. Thus, when the retailer decides to share its market information (i.e., $k \leq 0.522$), the welfare also increases. On the other hand, when k is between 0.522 and 0.721, welfare is enhanced under disclosure but the retailer does not disclose because the concern for the higher wholesale price dominates the benefit from the incremental investment under disclosure.

It is worth noting the distinction between our result and the welfare analysis in a recent study in economics (Dukes et al. 2011). Similar to our setting, Dukes et al. (2011) examine the information sharing decision in a supply chain and investigate its impact on social welfare. They show that the retailer is induced to exchange information when the manufacturer's cost saving is large enough. On the other hand, our results show that the retailer's disclosure always leads to the higher consumer welfare, and thus yields Pareto gains when we consider the role of demand-enhancing investments from the manufacturer.

7 Discussion and conclusion

7.1 Discussion

At this point, we would be remiss if we did not discuss two key assumptions underlying these results. The first key assumption in the analysis is that if the retailer opts

to share information, it does so truthfully and cannot renege on that promise. The temptation to renege on disclosure policy once manufacturer marketing investments are sunk is real. After all, for high demand realizations, the retailer would much prefer that the manufacturer be left in the dark rather than face the high wholesale price that ensues after disclosure of high demand. However, for the disclosure commitment to be credible, all one needs to presume is that in the (off-equilibrium) event of no disclosure, the supplier naturally infers high demand. In other words, the canonical "unraveling" result (e.g., Grossman 1981) ensures that a commitment to disclosure ex ante is enforceable ex post.

However, perhaps the bigger issue is that the retailer's information acquisition is sometimes uncertain and unobservable to the manufacturer (Guo 2009). In this case, the manufacturer does not necessarily infer high demand (since it may be the case that the retailer simply could not gather the information) and thus, the retailer has an incentive to renege on its pledge to share information. For this reason, the results in the setting apply best to circumstances wherein the retailer can make a credible commitment to not only sharing its information, but also gathering the information.[6]

Moreover, another interesting issue related to the commitment to sharing the information is that the disclosures can be distorted by the retailer. Here again, the incentives are clear—a retailer observing high demand seeks to convince the supplier demand is low in order to get a lower wholesale price. Such distortions, if possible, do not come without cost. In addition to the possible presence of a third-party audit, we also note that all parties will learn the private information ex-post, so any distortion becomes public knowledge eventually. Hence, if there is some reputational or other cost associated with adding such distortion, it is in the retailer's best interest to make it truthfully.

We note that in practice, credible commitments to gathering and sharing the information can take the form of, for example, formal technology infrastructure (Sender 1998), joint real-time accounting systems through which their demand information can be transmitted to the manufacturer in real time, and/or explicit contractual arrangements. More informal means of sharing knowledge between firms, on the other hand, are less likely to achieve the objective due to ex post incentives to renege.

A second key assumption in the analysis is that the contract between a retailer and a manufacturer entails linear pricing, which is critical to our results. If the manufacturer could instead make use of a more general pricing contract such as two-part tariffs, he could fully extract the entire surplus under information sharing. That is, with two part tariffs, the manufacturer offers a unit price equal to marginal cost and makes use of a fixed fee to extract the industry surplus. Absent information sharing, however, the retailer's retained information advantage gives it an opportunity to earn information rents (presuming the manufacturer wants to ensure that its contract is accepted by the retailer—see Desiraju and

[6] We thank an anonymous reviewer to point out this important disctinction for us.

Moorthy (1997) for the analysis of two-part tariffs under asymmetric information where the retailer is better informed about the demand). As such, general contracts ensure the retailer wishes to withhold information, since it stands to get no benefit from any increases in manufacturer investment under information sharing. Thus, it should be stressed that our results apply only to circumstances wherein contracts are sufficiently simple such that the manufacturer cannot entirely extract supply chain profits (a circumstance reflected in the common linear pricing assumption).

These caveats suggest that results here are most apropos for industries wherein (i) retailer information sharing takes the form of formal technology infrastructure (rather than promises to reveal demand indicators) and (ii) contractual imperfections result in both suppliers and retailers extracting profits from the relationship. The examples discussed in Introduction, notably automotive, clothing, and grocery sales often fit this mold. In contrast, service industries (due to (i)) and defense contracting (due to (ii)) are less likely to exhibit the key features of the current study.

7.2 Conclusion

This research examines a retailer's information sharing incentive in the presence of investment by suppliers that can enhance product demand (e.g., advertising, quality control, etc.). A large number of previous papers have investigated retailer disclosure incentives in various contexts. While much of the previous work has focused on the strategic consequence of information sharing on wholesale pricing choices, the prevalence of manufacturer investments that can affect retail demand motivated our revisitation of such analyses. We find that information sharing naturally has an impact on a manufacturer's investment decision in that the impending ability to condition wholesale prices on retailer information boosts the manufacturer's incentive to invest in demand in the first place. Our analysis shows that the real (investment) effect of information can change a retailer's information sharing incentive and, as a result of investment efficiencies, such information sharing can be welcomed by all economic participants.

More precisely, this paper first examines a baseline case wherein a manufacturer's investment in demand is taken as exogenously given. This benchmark is largely consistent with existing results in this realm (e.g. Li 2002). We show that absent investment incentives, the retailer opts to withhold information from the manufacturer since such information is ostensibly used by the manufacturer to fine-tune wholesale prices to the detriment of the retailer. The primary contribution of the present analysis is to introduce manufacturer investment to the set of strategic manufacturer decisions. We demonstrate that, while the manufacturer does tailor wholesale prices in response to retailer information sharing, such additional "pricing power" serves to boost the manufacturer's investment. Also, interestingly the manufacturer is induced to invest merely by knowing that information is on its way. If these investment effects are more pronounced than the pricing effects, the retailer may actually voluntarily share its information despite

the obvious downsides to induce a manufacturer's investment. This finding is a stark contrast to the most of previous results which consistently points out how bad it is for the manufacturer to have the retailer's demand information before setting prices.

In practice, there has been a growing trend that a manufacturer makes various investments to enhance market demand. However, there is a paucity of evidence as to how a retailer can induce more such investment by the manufacturer. In this vein, the present paper suggests that information sharing can be a tool through which the retailer can establish such mutually beneficial investment behavior. As a result, information sharing may benefit not only supply chain participants but also the ultimate consumers of such products.

Appendix: ex post investment case

We consider a simple case in which a manufacturer makes its investment decision after demand information is realized (i.e., ex post investment decision). This analysis serves as the robustness check for our main results in the ex ante case where investment by the manufacturer must be made up front, i.e., prior to the retailer's observation of its private information. More specifically, we consider a special case of binary market demand for simplicity: the market demand is either high, $\alpha = A_H = a + \delta$, or low, $\alpha = A_L = a - \delta$ with an equal probability ($\Pr(A_H) = \Pr(A_L) = \frac{1}{2}$).

No disclosure

Using backward induction, the retailer first decides the product price in the final market, considering the wholesale price. Second, the manufacturer decides the wholesale price by considering the market demand. If the retailer does not share the information, the manufacturer is ignorant of the market demand and uses its prior belief when charging the wholesale price as follows:

$$\underset{w}{Max}\ \Pr(A_H)w(A_H(1+I)-p) + \Pr(A_L)w(A_L(1+I)-p), \tag{21}$$

where the optimal wholesale price is $w_N = \frac{a(A_H+A_L)}{2} = \frac{a(1+I)}{2}$.

Using the wholesale price, w_N, the manufacturer decides the investment level I^N in a following objective function:

$$\underset{I}{Max}\ w_N(I)q(w_N(I), I) - C(I) = \frac{1}{8}a^2(1+I) - C(I),\ \text{where } i = H, L. \tag{22}$$

Then, I^N solves the following first order condition:

$$\frac{\partial E(\Pi_M^N)}{\partial I} = \frac{1}{4}a^2(1+I) - C^{'}(I) = 0. \tag{23}$$

The obtained retail price, wholesale price, and investment level yield expected profits of two supply chain members as follows:

$$E(\Pi_R^N) = \frac{(a^2+4\delta^2)(1+I^N)^2}{16};\ E(\Pi_M^N) = \frac{a^2(1+I^N)^2}{8} - C(I^N). \tag{24}$$

Disclosure

When the retailer discloses information, the manufacturer charges different wholesale prices by the market demand as follows:

$$\underset{w_i}{Max}\ w_i(A_i(1+I) - p),\ \text{where } i = H, L. \tag{25}$$

From the Eq. 25, the optimal wholesale price under disclosure is $\frac{1}{2}A_i(1+I)$: the wholesale price under the high demand is $w_H = \frac{1}{2}A_H(1+I) = (a+\delta)(1+I)$ and the wholesale price under the low demand is $w_L = \frac{1}{2}A_L(1+I) = \frac{1}{2}(a-\delta)(1+I)$.

Because the investment is decided after market demand is realized, the manufacturer's investment level is naturally conditioned on the market profitability. Under high demand, the manufacturer's investment becomes higher because there exists more return on the investment due to the higher wholesale price. In the same fashion, the realization of low demand discourages the manufacturer's investment incentive because of the lower wholesale price. Thus, the manufacturer decides the investment in a following objective function.

$$\underset{I}{Max}\ w_i(I)q(w_i(I), I) - C(I) = \frac{1}{8}A_i^2(1+I)^2 - C(I), i = H, L. \tag{26}$$

Under each realization of demand, the optimal investment levels I_{DH} and I_{DL} solve following first order conditions:

$$\begin{aligned} \text{High}: \frac{\partial E\left(\Pi_M^{DH}\right)}{\partial I} &= \frac{1}{4}(a+\delta)^2(1+I) - C'(I) = 0; \\ \text{Low}: \frac{\partial E\left(\Pi_M^{DL}\right)}{\partial I} &= \frac{1}{4}(a-\delta)^2(1+I) - C'(I) = 0, \end{aligned} \tag{27}$$

where $DH(DL)$ denotes high (low) demand under disclosure. As shown in the first order conditions, given investment level, the marginal return on the investment is higher under high demand than under low demand, and the higher marginal return results in a higher investment level. The result shows that a manufacturer's investment incentive is endogenous and it is decided by the nature of information provided by the retailer. The optimal investment levels, wholesale price, and a retail price yields following expected profits for the retailer and the manufacturer, respectively:

$$\begin{aligned} E(\Pi_R^D) &= \frac{(1+I_{DL})^2(a-\delta)^2 + (1+I_{DH})^2(a+\delta)^2}{32}; \\ E(\Pi_M^D) &= \frac{(1+I_{DL})^2(a-\delta)^2 + (1+I_{DH})^2(a+\delta)^2}{16} - \frac{C(I_{DL}) + C(I_{DH})}{2}. \end{aligned} \tag{28}$$

Based on the results, we compare the investment levels and examine the retailer's information disclosure decision in a following proposition.

Proposition 6

(i) *The equilibrium investment levels are as follows:* $I_{DL} < I_N < I_{DH}$.
(ii) *The retailer commits to sharing information if and only if* $\frac{(1+I_{DL})^2(a-\delta)^2+(1+I_{DH})^2(a+\delta)^2}{2(1+I_N)^2(a^2+4\delta^2)} > 1$.

Proof

(i) As in Eq. 23, I^N solves a following first order condition: $\frac{\partial E(\Pi_M^N)}{\partial I} = \frac{1}{4}a^2(1+I) - C'(I) = 0$. If we substitute I^N for I in the first order conditions in Eq. 27,

$$\text{High}: \ \frac{\partial E(\Pi_M^{DH})}{\partial I} = \frac{1}{4}(a+\delta)^2(1+I^N) - C'(I^N) > 0; \qquad (29)$$
$$\text{Low}: \ \frac{\partial E(\Pi_M^{DL})}{\partial I} = \frac{1}{4}(a-\delta)^2(1+I^N) - C'(I^N) < 0.$$

which implies that $I_{DL} < I_N < I_{DH}$.
(ii) The result directly follows from comparing $E(\Pi_R^N)$ in Eq. 24 with $E(\Pi_R^D)$ in Eq. 28.

□

Under the ex post investment, the manufacturer can adjust its investment level as well as a wholesale price according to the realized demand level: if the retailer announces a high (low) demand, a manufacturer would make a high (low) investment. This manufacturer's responsive investment strategy will obviously affect the retailer's information sharing incentive. The retailer's disclosure of high (low) demand will induce the manufacturer's high (low) investment although the manufacturer will charge the high (low) wholesale price. The proposition shows that the retailer commits to sharing its market information if the demand-enhancing investment effect is sufficiently large that it outweighs the concern for increased wholesale pricing. This implies that a manufacturer's investment decision can induce the retailer's information sharing under the ex post investment case and thus shows the robustness of our main results under the ex ante case.

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