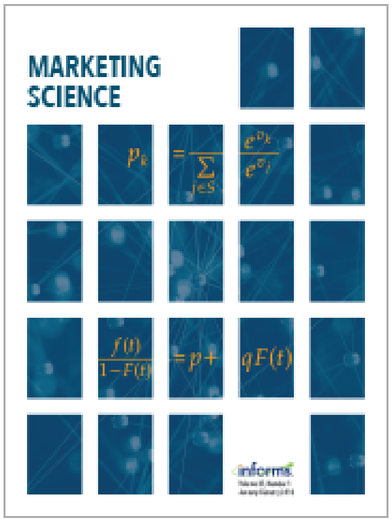

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The Benefits of Downstream Information Acquisition

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This study investigates the effects of turning terabytes of raw retail data into managerial insights (i.e., downstream information acquisition) in a strategic channel setting. Two effects of information acquisition are identified—the *efficiency* effect that improves retail pricing decision making in an uncertain environment, and the *strategic* effect whereby the retailer voluntarily discloses the acquired private information to influence the upstream manufacturer's wholesale pricing behavior. It is shown that the efficiency effect benefits the retailer without affecting the manufacturer, while the strategic effect works to the detriment of the retailer but to the advantage of the manufacturer. Nevertheless, unobservable information acquisition can mitigate the retailer's loss and the manufacturer's benefit from the strategic effect of information disclosure. Moreover, an increasing expected information acquisition cost may benefit the retailer, when that cost is low and information acquisition is unobservable to the manufacturer. The implications of this paper can shed light on how firms interact in a channel where the downstream market is data intensive, but information gleaning is costly.

Key words: disclosure; distribution channel; information acquisition; voluntary information sharing
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Data is critical.
—Billy Payton, VP of Neiman Marcus
(*Chain Store Age*, January 2000)

Gathering data is one thing. Retrieving it, analyzing it, and using it for the good of the organization is another thing completely.
—Ken Clark (*Chain Store Age*, November 2002)

1. Introduction

The ubiquity of data collection technologies (e.g., UPC scanner systems, Internet, etc.) has led to an explosion in both the scope and volume of customer and market data that are accessible to retailers. Retailers across a number of industries have installed data acquisition infrastructures that allow them to routinely collect abundant transaction-level data. For example, Amazon's Web logs gather over 30 gigabytes of data every day, and the world's largest commercial data warehouse at Wal-Mart records more than 100 terabytes of data for 65-week historical transactions. Nevertheless, it has been increasingly recognized that the potential value of data cannot be realized if the data are not processed, analyzed, and converted into communicable insights (i.e., information). Essentially, raw data itself cannot automatically be called information that can guide decision making.[1]

Despite the prevalence of data collection infrastructures and the exploding volume of retail data, the extent to which retailers have harnessed the wealth of data at their disposal is mixed in practice.[2] Retailers such as RadioShack and Toys Я Us "weren't doing anything with" the customer databases they have been stocking for years (Collett 2004, p. 36). On the other hand, according to International Data Corporation (IDC), there is a growing market for decision-support technologies, softwares, and techniques, e.g., Marketing Information Systems (MKIS), that can facilitate enterprise-wide data mining, integration, and information distribution. Sainsbury's and Sears, for instance, started to adopt information-generating technologies that improve their data management and decision making (*Chain Store Age* 2002).

In this paper, I investigate the economic effects and payoff implications of a retailer turning terabytes of raw data into managerial insights (i.e., downstream

[1] A distinction is drawn in this paper between data and information, and between data collection and information acquisition. See Blattberg et al. (1994), Lilien and Rangaswamy (2004), and Niraj et al. (2004) for more discussion.

[2] Retailers' adoption of information-gleaning applications has been slow. According to a recent survey by the Aberdeen Group, for example, only 38% of the companies polled used market basket analysis, a data-mining technique exploring the correlation between customers' shopping basket items (Nishi 2005). See also Bucklin and Gupta (1999) for a survey on the gap between academic and commercial uses of scanner data.

information acquisition) in a strategic channel setting. The analysis takes into account the *acquisition* and the *use* of managerially relevant information generated from the collected retail data, as well as the impact on the firms' decision making. In particular, two features that generally characterize the practice of retail information acquisition are captured.

First, there can be ongoing uncertainty about a retailer's efforts to leverage the collected data in its managerial decision making. Despite retail data being routinely available, a variety of factors may contribute to the uncertainty of information acquisition. To convert the collected data into information, substantial human and technological resources may be involved. The costs and difficulties in generating timely and meaningful information from retail data have frequently been recognized by both practitioners (e.g., *Chain Store Age* 2002) and academics (e.g., Lilien and Rangaswamy 2004). For example, in-house market research personnel have to be trained, or outside consulting experts need to be hired, to process, understand, and analyze the huge amount of raw data using sophisticated techniques. The availability/expertise of data analysts, or the market price for consulting advice, may fluctuate (Bucklin and Gupta 1999). Moreover, internal communication between and the analytical sophistication of decision makers may influence the quality of information integration and transmission within an organization.[3] As a result, if the opportunity cost of information acquisition (i.e., the resources devoted to generating and disseminating information relative to the expected insights) turns out to be too high to justify the use of its limited resources, a retailer may end up gaining no information from its raw data. Note also that, even when the investment and the collection of retail data are common knowledge, a retailer's opportunity cost (and hence its information acquisition efforts) can be unobservable to the upstream firm in a channel (i.e., the manufacturer).

Second, retailers increasingly communicate their acquired retail information with suppliers. According to the extensive surveys conducted in recent years by BearingPoint Management and Technology Consultants, retailers in the United States indicated an accelerated interest and growth in the frequency and scope of communication with vendors (*Chain Store Age* 2003). For example, 62% of the retailers surveyed in 2003 reported that they communicated at least every week with suppliers. The percentage of respondents sharing sales forecasts increased dramatically, from less than 30% in 2001 to almost 60% in 2002. Nevertheless, substantial variation exists across industries, with supermarkets being more inclined than specialty or drug stores to communicate with their suppliers. Interestingly, traditional communication channels (e.g., e-mail, phone, and fax) remain dominant over recently emerging data-sharing vehicles such as Electronic Data Interchange (EDI). This seems to suggest that the respondents are more inclined to share their insights than their raw retail data.

To capture these features, I investigate three factors that may influence the firms' equilibrium payoffs when the retailer may be engaged in information acquisition: the availability of a communication channel, the observability, and the expected magnitude of the retailer's opportunity cost of information acquisition. In particular, two potential effects of information acquisition on the firms' equilibrium behaviors and benefits are captured. First, information gleaning from retail data can improve a retailer's decision making in an uncertain environment. Being better informed of market characteristics, the retailer can adjust its retail pricing decisions according to the fluctuation of market demand (Collett 2004). One may therefore expect that the retailer can benefit from this efficiency effect of information acquisition. Second, there might be a strategic effect of information acquisition whereby a better-informed retailer can leverage its superior market knowledge to elicit better transaction terms from the manufacturer (Messinger and Narasimhan 1995). For example, the retailer may strategically disclose acquired information to the manufacturer when the realized market demand is low to induce a lower wholesale price.

These issues are addressed in a dyadic channel setup where the retailer's information acquisition and disclosure decisions are followed by the setting of the wholesale and retail prices. Whether the retailer acquires demand information depends on the realization of the opportunity cost. After obtaining the demand information, the retailer can voluntarily decide whether to share it with the manufacturer. A few interesting results are obtained. First, while the efficiency effect of information acquisition benefits the retailer without affecting the manufacturer, the strategic effect works to the detriment of the retailer, but to the advantage of the manufacturer. This is because a retailer's ability to disclose favorable private information also leads it to share unfavorable information in equilibrium. As a result, the demand information acquired at the downstream level can be communicated to the upstream market and improve the manufacturer's decision making. As the wholesale price is fine tuned and becomes more fluctuating, the channel's double-marginalization problem is intensified, decreasing the retailer's equilibrium profits.

[3] According to a survey of more than 260 executives, only 36% understand price promotion sensitivity and 29% understand consumer shopping behavior (Jagtiani and Berry 1993).

Second, I show that unobservable information acquisition can mitigate the strategic effect. That is, the retailer's loss (and the manufacturer's benefit) from information disclosure is lower when information acquisition is unobservable to the manufacturer. This is because the amount of information disclosed in equilibrium by the retailer is influenced by whether the manufacturer can observe the retailer's information acquisition. When the retailer's opportunity cost (and hence its information acquisition efforts) is observable, the manufacturer can infer that unfavorable information is being withheld if favorable information is not being received. On the other hand, in the absence of information acquisition observability, the manufacturer cannot determine the reasons underlying a retailer's silence: either the retailer is concealing unfavorable information, or no information of any kind has been acquired. Therefore, when information acquisition is unobservable, the retailer can partially withhold unfavorable information, leading to less fluctuation in wholesale price and mitigation of the double-marginalization problem.

Third, the retailer's equilibrium profit may not necessarily decrease with the expected opportunity cost of information acquisition. In particular, the retailer may benefit from an increasing expected opportunity cost, if the cost is unobservable to the manufacturer and the ex ante probability that the cost is high is sufficiently low. This has to do with the two counteracting effects of the expected opportunity cost of information acquisition. On one hand, the more likely that the cost is high, the less likely that the retailer would benefit from acquiring demand information. On the other hand, the more likely that the retailer incurs a high information acquisition cost, the lower the wholesale price that would be charged when the manufacturer receives no demand information from the retailer because it is less likely that the retailer's silence signals the withholding of unfavorable information. When the expected information acquisition cost is sufficiently low, the gain from the *information withholding* effect is more important, which offsets the loss of acquiring less information because of increases in expected information acquisition cost.

The unravelling result on voluntary provision of verifiable information was first investigated by Grossman and Hart (1980), Grossman (1981), and Milgrom (1981). Subsequent studies investigate the factors that may lead to partial information disclosure, e.g., disclosure costs (Jovanovic 1982) and information acquisition costs (Matthews and Postlewaite 1985, Farrell 1986, Shavell 1994). This study extends the literature to a channel setting while focusing on the equilibrium payoff implications of retail information acquisition and disclosure.

This research also adds to the literature on strategic information transmission in distribution channels. It is usually assumed that information asymmetry exists between channel members and that information cannot be verified. As a result, a credibility issue may arise suggesting that the informed firm has an incentive to withhold (disclose) information that is unfavorable (favorable). Thus, the focal research issue is how the informed firm can use various devices (e.g., price, advertising, slotting allowance, etc.) to credibly communicate private information to its channel partner, i.e., signaling (Chu 1992, Desai and Srinivasan 1995, Lariviere and Padmanabhan 1997). Recently, Li (2005) considered the role of cheap talk in channel communication where the communication device is plain conversation. He shows that communication credibility can be achieved even when the device used does not involve any signaling cost. Tangentially, this study examines how private information can be strategically communicated in a channel setting when the unverifiability assumption is removed. I show that the retailer in equilibrium fully reveals its private information when the disclosed information can be verified, while the unobservability of information acquisition can lead to partial information withholding.

This paper is closely related to the literature on information acquisition and sharing in distribution channels.[4] Chu and Messinger (1997) investigated the efficiency effect of information acquisition in a channel in a simultaneous-move context. Here, I examine sequential pricing decisions, focusing on the effects of information acquisition cost/observability on voluntary information disclosure. Some recent studies examined channel members' incentives to enter into vertical information-sharing contracts (Chen 1998, Cachon and Fisher 2000, Lee et al. 2000, Li 2002, Niraj and Narasimhan 2004, Gu and Chen 2005). By contrast to this stream of research in which a firm signing an information-sharing contract pre commits to disclose its information, this paper investigates voluntary ex post information sharing in the absence of contractual enforcement (Farrell 1986, Milgrom and Roberts 1986). In particular, I consider the scenario in which information can be truthfully disclosed by a retailer when the content of information becomes privately known. This allows us to isolate the impact of commitment from that of truth telling, which are both embodied in ex ante information-sharing contracts. The truth-telling premise captures long-term channel

[4] There is a literature on information acquisition by competing firms (e.g., Li et al. 1987, Hwang 1993). For a sample of research on information-sharing contracts in a horizontal setting with competing firms, see Vives (1984), Gal-Or (1985), Shapiro (1986), and Villas-Boas (1994).

interaction and can be sustained when reputation is a major concern in developing and maintaining a trustworthy channel relationship and/or when verification cost is negligible.

The current study is also related to the literature on the value of information in a channel setting. This stream of research usually investigates the efficiency effects of information in improving decision making. For example, Lee et al. (2000) focused on the quantification and the drivers of the benefits of information sharing in a supply chain where the value of information is to ameliorate demand distortion and reduce excessive inventory cost. Iyer et al. (2007) investigate a manufacturer's trade-off between information and inventory in extracting retail surplus. In their model, because there is no information asymmetry between the channel members, the issue of information transmission is immaterial. Other related research studies an information vendor's optimal selling strategies (Sarvary and Parker 1997, Iyer and Soberman 2000). This paper is also related to Liu and Zhang (2006), who investigate a retailer's incentive to acquire customer information to obtain personalized pricing. Although the role of information is different, both studies focus on a retailer's information acquisition efforts and the strategic influence on the upstream manufacturer.

The rest of this paper is organized as follows. The next section describes the model. Section 3 presents the main analysis and results, highlighting the roles of information disclosure and information acquisition observability in the effects of downstream information acquisition on the firms' equilibrium payoffs. The last section discusses managerial implications, identifies potential directions for future research, and concludes the paper.

2. The Model

Consider a distribution channel where an upstream manufacturer can sell to end consumers through a downstream retailer. The firms are risk neutral and maximize expected payoffs. For simplicity, the firms' marginal costs are normalized to zero. The aggregate market demand is given by

$$D(P) = A - P, \tag{1}$$

where A denotes the market potential and P is the price charged by the retailer. To capture the uncertainty about market demand, I assume that the market potential is stochastic and can take two possible values, $A_H = a(1+d)$ and $A_L = a(1-d)$. The two realizations of the market potential, A_H and A_L, are denoted as the High and the Low state, respectively. The firms share common prior beliefs about the realizations of the market potential, with equal probability: $\Pr(A_H) = \Pr(A_L) = 1/2$. Under this setup, the parameter $a > 0$ captures the expectation of the market potential, which is assumed to be sufficiently large to insure nonnegative demand, and $d \in (0,1)$ represents the uncertainty level of the market potential. Similar setups have commonly been used in the literature to capture market demand uncertainty (e.g., Lariviere and Padmanabhan 1997, Niraj and Narasimhan 2004, Gu and Chen 2005).

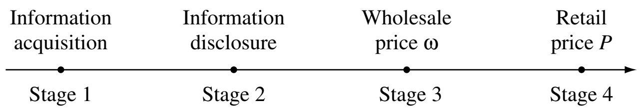
Consider a scenario in which a retailer is evaluating the expected return on investment (ROI) in a data collection technology (e.g., a UPC scanner system), which may involve a fixed cost and can allow the retailer to routinely collect masses of downstream market data. The collected data, if translated into managerial insights (i.e., information), can inform the retailer of market potential. The retailer must gauge the expected benefit of the information acquired from the collected data during each of the future decision cycles when the investment becomes sunk, which is the focus of this study. However, as discussed previously, whether the retailer would actually acquire the market potential information in a particular decision interval is uncertain. This ongoing uncertainty can be attributed to the variation in the retailer's opportunity cost of information acquisition, e.g., the costs to retrieve, process, and analyze the raw data and to transmit the information to the decision makers, the analytical sophistication of data analysts and/or executives (e.g., because of employee turnover), and so on.[5] I assume without loss of generality that the retailer's overall opportunity cost of processing and disseminating the information in a particular decision period takes two possible values, $c \in \{c_h, c_l\}$, where c_h is prohibitively high and c_l is negligible. The probabilities for the opportunity cost c_h and c_l are λ and $1-\lambda$, respectively, where $\lambda \in (0,1)$. As a result, the retailer would remain uninformed about the market potential if c_h is realized, while it may choose to become fully informed (if doing so is beneficial) if c_l is realized instead.[6] Note also that λ is a sufficient measure of the expected cost of information acquisition (i.e., λc_h), hereafter called the *expected information cost*.

The timing of the game for a representative decision cycle is shown in Figure 1. In the first stage, the retailer's opportunity cost of information acquisition in this decision period, $c \in \{c_h, c_l\}$, is realized and revealed to the retailer. The realization of the market

[5] To simplify exposition, where no confusion arises, I shall call the opportunity cost of information acquisition the *information acquisition cost* or the *information cost*.

[6] The model can be readily extended to capture imperfection of information acquisition. One extension is to assume that the collected data are completely noisy or perfectly informative, with probability γ or $1-\gamma$, respectively. Under this extension, the results of the paper remain unchanged, with the re-parametrization $\lambda^* = \lambda + \gamma(1-\lambda)$.

Figure 1 Timing of the Model



potential, $A \in \{A_H, A_L\}$, is also determined at this time. Conditional on the realization of the information cost, the retailer may or may not become informed of the market potential. By contrast, it is assumed that the manufacturer has no means to improve its information about market demand unless it is disclosed by the informed retailer. This captures the asymmetry in the firms' ability to acquire retail information, which can be justified by the fact that the retailer has much better access to the retail market and its own sales data than the manufacturer. Nonetheless, I shall discuss the potential implications of upstream information acquisition in §4.

Conditional on information being acquired, the retailer decides whether to disclose the information to the manufacturer in the second stage of the game.[7] It is assumed that the disclosed information is truthful, and as a result, the disclosure decision amounts to either revealing the truth or remaining silent. The truth-telling assumption would hold if the retailer takes a long-term perspective and cares about its reputation in dealing with the manufacturer, or if the verification cost is negligible. Moreover, there is some empirical evidence that supports the truth-telling premise. For example, Doyle and Snyder (1999) find that informative production announcements are made in the motor vehicle industry and that the market responds to these announcements.

In the third stage, the manufacturer decides on the per-unit wholesale price, ω, for the transfer of its product to the retailer. The wholesale price can be conditional on the market potential realization, if the manufacturer learns about it in the second stage. The adoption of a constant wholesale price in vertical relationships is frequently implemented in practice and commonly used in the literature (e.g., Liu and Zhang 2006). Its rationalization has been addressed in the literature (e.g., Iyer and Villas-Boas 2003, Cui et al. 2007) and is beyond the scope of this paper. Conditional

[7] Note the implicit assumption that the retailer incurs only a negligible transaction cost (Williamson 1979) in information transmission and in managing its disclosure decision. Similarly, it is implicitly assumed that the manufacturer's cost in receiving and acting on the information disclosed by the retailer is negligible. These assumptions are reasonable given that the retailer incurs costs in processing the raw data and that the disclosed information is usually summarized insights, but not raw data. Furthermore, the dominant communication vehicles used by U.S. retailers, e.g., e-mail, phone, and fax (*Chain Store Age* 2003), are likely to involve only minor cost.

Table 1 Model Notation

Notation	Explanation
D	Market demand
A	Market potential ($A \in \{A_H, A_L\}$)
P	Retail price
A_H	The "High" state of market potential ($A_H = a(1+d)$)
A_L	The "Low" state of market potential ($A_L = a(1-d)$)
a	The expectation of market potential
d	The uncertainty level of market potential
c	Opportunity cost of information acquisition ($c \in \{c_h, c_l\}$)
λ	Probability of $c = c_h$ (i.e., expected information cost)
ω	Wholesale price
ω_S	Optimal wholesale price when the state $A_S \in \{A_H, A_L\}$ is learned
P_S	Optimal retail price when the state $A_S \in \{A_H, A_L\}$ is learned
π	Retailer profit
π^s	Retailer equilibrium profit conditional on $c = c_s$, $s \in \{h, l\}$
Π	Manufacturer profit
Π^s	Manufacturer equilibrium profit conditional on $c = c_s$, $s \in \{h, l\}$
m	Retailer's message
M	Retailer's overall message set
M_S	Retailer's message set when the state is $A_S \in \{A_H, A_L\}$
θ	Manufacturer's updated probability of "High" market potential
$\theta(m)$	Manufacturer's updated probability conditional on m
ω_m	Optimal wholesale price conditional on m
$\theta^1(m)$	Manufacturer's conditional probability that the information "High" is acquired
$\theta^2(m)$	Manufacturer's conditional probability that the information "Low" is acquired
r	Retailer's information disclosure strategy
δ_S	Indicator equal to 1 (0) if information is disclosed (withheld) in state $S \in \{H, L\}$

on the wholesale price, the retailer in the fourth stage sets the retail price, P. In deciding on the retail price, it is assumed that the retailer remains uninformed about the market potential unless the relevant information has been acquired. Finally, the retailer orders the product from the manufacturer and completes the transactions according to the realized demand. This completes the model specification. A summary of the model notation is presented in Table 1.

This four-stage sequential setup imbeds the retailer's information acquisition and disclosure into a standard model of distribution channel (see, e.g., Jeuland and Shugan 1983, McGuire and Staelin 1983, Moorthy 1987). It allows us to capture two potential impacts of downstream information acquisition. A well-informed retailer can benefit from adjusting its pricing decision in response to market fluctuation. Moreover, the retailer can influence the upstream partner's decision by sharing its updated knowledge about the market. For example, the retailer could induce the manufacturer to charge a lower wholesale price by convincing the manufacturer that the market is in the Low state. The model setup, however, departs from the literature in that it deliberately captures the retailer's ex post incentive to disclose private information. It does not require the retailer to precommit to information sharing before the acquisition of information. Instead, it permits the retailer to voluntarily decide whether to share the acquired information with the manufacturer.

Let us first assess the expected ROI on a data collection technology for an integrated channel. In the absence of demand information, the optimal retail price would be $P = a/2$, which leads to an equilibrium expected profit of $a^2/4$ for the integrated channel. In contrast, when it is learned that the state is A_S, the optimal retail price is given by $P_S = A_S/2$, where $S \in \{H, L\}$. The expected profit with acquired information is then $A_H^2/8 + A_L^2/8 = (1+d^2)a^2/4$. As a result, the channel's equilibrium ex ante payoff with the data collection technology is given by $\lambda(a^2/4) + (1-\lambda) \cdot ((1+d^2)a^2/4) = [1+(1-\lambda)d^2]a^2/4$. Thus the expected return for the integrated channel adopting a data collection technology is $(1-\lambda)a^2d^2/4$.

3. Analysis and Results

I investigate how firms' equilibrium payoffs in a decentralized channel are influenced by the retailer installing a data collection system. I start with the benchmark when the system is absent and no information can be acquired. I then derive firms' equilibrium ex ante payoffs with the data collection system under several scenarios, depending on whether the retailer's acquired information can be disclosed to the manufacturer. This allows me to isolate the efficiency and strategic effects of information acquisition in a channel. In each case, I also consider two alternative scenarios, depending on whether the manufacturer can observe the retailer's cost and information acquisition efforts. In solving the game, I use backward induction to ensure subgame perfection.

3.1. Benchmark

The model is reduced to a standard two-stage game in which the firms make pricing decisions sequentially, taking into account the possible realizations of market potential. In the last stage, the retailer maximizes its expected payoff, taking the wholesale price as given: $\pi = (P-\omega)[(A_H - P)/2 + (A_L - P)/2] = (P-\omega)(a-P)$. This leads to the optimal retail price as a function of ω: $P(\omega) = (a+\omega)/2$. Given this, the manufacturer's pricing problem is to maximize $\Pi = \omega[(A_H - P(\omega))/2 + (A_L - P(\omega))/2] = \omega(a-\omega)/2$. Solving this problem yields the equilibrium wholesale price, $\omega^B = a/2$, and the equilibrium retail price, $P^B = 3a/4$. Thus, in equilibrium the retailer's and the manufacturer's ex ante profits are, respectively, given by

$$\pi^B = \frac{a^2}{16} \quad \text{and} \quad \Pi^B = \frac{a^2}{8}. \tag{2}$$

This will serve as the benchmark against which to compare the firms' equilibrium ex ante payoffs when it is possible for the retailer to acquire downstream demand information.

3.2. No Information Disclosure

When the demand information acquired by the retailer cannot be disclosed, the manufacturer retains its prior belief about market demand in setting the wholesale price ω. This investigation allows us to capture the efficiency effect of information acquisition. It can be readily verified that the retailer would acquire the demand information if and only if c_l is realized. The retailer's problem, in the informed state A_S, $S \in \{H, L\}$, is given by $\pi = (P-\omega)(A_S - P)$. This leads to the optimal retail price $P_S(\omega) = (A_S + \omega)/2$, and the corresponding retail profit $\pi_S(\omega) = (A_S - \omega)^2/4$. Moreover, one can show that the manufacturer's expected profit function, taking into account the retailer's subsequent optimal response, is still given by $\Pi = \omega(a-\omega)/2$, irrespective of whether retailer information acquisition (but not the content of the information) is observable. This leads to $\omega^* = a/2$ in equilibrium.

I denote the retailer's and the manufacturer's equilibrium expected payoffs, conditional on c_s, as π^s and Π^s, respectively, where $s \in \{h, l\}$. Accordingly, the equilibrium ex ante payoffs in the case of no information disclosure can be defined as $\pi^N \equiv \lambda\pi^h + (1-\lambda)\pi^l$ and $\Pi^N \equiv \lambda\Pi^h + (1-\lambda)\Pi^l$, respectively. Therefore, $\Pi^h = \Pi^l = \Pi^B = a^2/8$. In addition, substituting $\omega^* = a/2$ yields $\pi^h = \pi^B = a^2/16$ and $\pi^l = (1+4d^2)a^2/16$. One can then obtain

$$\pi^N = \frac{[1+4(1-\lambda)d^2]a^2}{16} \quad \text{and} \quad \Pi^N = \frac{a^2}{8}. \tag{3}$$

In comparison to the benchmark case, the retailer's expected benefit from the data collection technology (i.e., $\pi^{NB} \equiv \pi^N - \pi^B$) is positive, increasing in market potential uncertainty d, and decreasing in expected information cost λ, while the manufacturer's equilibrium ex ante payoffs do not change with the retailer's downstream information acquisition; i.e., $\Pi^{NB} \equiv \Pi^N - \Pi^B = 0$. This result generalizes the main insight of Chu and Messinger (1997), which is in a simultaneous-move setting, by showing in a Stackelberg structure that information acquisition can be beneficial. Moreover, the impact of acquiring demand information, if not vertically shared, is driven only by the resulting flexibility in the retailer's pricing decision, i.e., the efficiency effect. Intuitively, this effect is stronger as the market demand becomes more uncertain or information acquisition is less costly. This efficiency effect influences the retailer's, but not the manufacturer's, equilibrium ex ante payoff.

3.3. Voluntary Information Disclosure

Next, I consider the case in which the retailer, on acquiring demand information, can voluntarily disclose it to the upstream firm. This allows capture of the strategic effect of information acquisition. Note that the retailer's information disclosure decision is conditional on the content of the acquired information. In particular, the retailer may selectively decide on the information to be shared, disclosing what is favorable while withholding what is unfavorable. In addition, the retailer's information disclosure strategy takes into account the manufacturer's subsequent response. The manufacturer, on receiving the information, may update its belief about market demand and adjust the wholesale price accordingly. In updating its belief, the manufacturer takes the retailer's information disclosure strategy into account. Therefore, one needs to simultaneously derive the retailer's optimal information disclosure strategy and the manufacturer's belief updating.

By contrast to the case without information disclosure, whether the manufacturer can observe the retailer's information acquisition may now play a critical role. This is because no information being disclosed by the retailer, given that disclosure is feasible, may convey some message about what the retailer knows about market demand. Clearly, however, no information can be disclosed without it first being acquired. The manufacturer would take these issues into account in interpreting the message in the retailer's disclosure decision.

3.3.1. Observable Information Acquisition. I start the analysis by deriving the retailer's equilibrium information disclosure strategy. To this end, I first characterize the manufacturer's optimal responses to the messages conveyed by the retailer's disclosure strategy, denoting the retailer's overall message set as $M = \{\bar{H}, \bar{L}, \bar{N}\}$, the elements of which represent High Demand, Low Demand, and No Information, respectively. On receiving one of the messages, the manufacturer may update its belief about market demand. I define the manufacturer's updated probability that the market potential is High or Low conditional on the message $m \in M$, as $\theta(m)$ or $1-\theta(m)$, respectively. Because information disclosure is truthful, $\theta(\bar{H}) = 1$ and $\theta(\bar{L}) = 0$. However, the value of $\theta(\bar{N})$ depends on the retailer's information disclosure strategy and awaits derivation. Conditional on an updated belief θ, the manufacturer's pricing problem is to maximize $\Pi = \omega[\theta(A_H - P_H(\omega)) + (1-\theta)\cdot(A_L - P_L(\omega))] = \omega[\theta A_H + (1-\theta)A_L - \omega]/2$, where $P_S(\omega) = (A_S + \omega)/2$ is the retailer's best-response function in the state $S \in \{H, L\}$. Solving this problem yields the manufacturer's optimal wholesale price $\omega(\theta) = (\theta A_H + (1-\theta)A_L)/2$, conditional on θ. One can also define ω_m as the wholesale price to be charged in equilibrium by the manufacturer if the message $m \in M$ is received.

I can then characterize the retailer's optimal information disclosure strategy. Given that the retailer cannot lie about the acquired information, the set of feasible messages M_S, conditional on the demand state $S \in \{H, L\}$, is only a subset of M. In particular, $M_H = \{\bar{H}, \bar{N}\}$ and $M_L = \{\bar{L}, \bar{N}\}$. Thus I denote the retailer's information disclosure strategy as $r = (m_H, m_L)$, where $m_H \in M_H$ and $m_L \in M_L$ represent the messages to be sent when the demand state is H or L, respectively. Note, however, that in equilibrium the retailer cannot partially withhold information. In other words, the retailer can only choose between fully revealing (separate) or fully withholding (pool) information in both states. For example, if the retailer decided to send $\bar{L}$ in the Low state, it would also truthfully reveal the demand to the manufacturer in the alternative High state. This is because the message $\bar{L}$ is not contained in M_H; if the retailer decided to disclose the Low state (i.e., $m_L = \bar{L}$), any message sent in the High state (either $\bar{H}$ or $\bar{N}$) would convey to the manufacturer that the message is generated from the High state. This implies that in equilibrium $(\bar{H}, \bar{L})$, $(\bar{H}, \bar{N})$, and $(\bar{N}, \bar{L})$ represent the same strategy, i.e., full information disclosure. Without loss of generality I can then define the set of possible information disclosure strategies as $R^1 = \{(\bar{H}, \bar{L}), (\bar{N}, \bar{N})\}$.

Lemma 1. *If information acquisition is observable to the manufacturer, in equilibrium the retailer fully discloses demand information to the manufacturer in both states; i.e.,* $r = (\bar{H}, \bar{L})$.

This lemma follows from Milgrom and Roberts (1986) that a decision maker can elicit all verifiable information from a party who can decide whether to disclose its private information to influence the decision maker. In the current setting, the retailer can strategically decide on the information to be disclosed to the manufacturer whose belief about the market is influenced by that information. The manufacturer's optimal wholesale price is positively related to its updated belief that the market potential is High. Knowing this, the retailer strictly prefers to communicate its private demand information to the manufacturer should the realized market potential be Low. Conversely, the retailer would strategically keep silent in the High state in an attempt to keep the manufacturer from knowing the actual demand. However, the manufacturer is not fooled by the retailer's strategic silence. If the manufacturer received no information, it would infer that the actual market potential must be High, otherwise a Low message would have been received. As a result, in equilibrium the retailer cannot (even partially) withhold its private information; all information must be shared with the manufacturer.

What remains to be determined is how the firms' equilibrium payoffs are influenced by full information sharing in the channel. To this end, note that conditional on the realized state $S \in \{H, L\}$, the channel pricing subgame is reduced to a standard Stackelberg setup with complete information. The equilibrium wholesale and retail prices are given by $\omega_S = A_S/2$ and $P_S = 3A_S/4$, respectively, where $S \in \{H, L\}$. The firms' equilibrium expected payoffs, conditional on the retailer acquiring information, are then $\pi^I = (1 + d^2)a^2/16$ and $\Pi^I = (1 + d^2)a^2/8$. One can now verify that when $c = c_l$, the retailer is better off acquiring demand information. Moreover, the firms' equilibrium ex ante profits, with information disclosure and observable information acquisition, are given by

$$\pi^{D1} = \frac{[1+(1-\lambda)d^2]a^2}{16} \quad \text{and} \quad \Pi^{D1} = \frac{[1+(1-\lambda)d^2]a^2}{8}.$$

Proposition 1. *If demand information can be voluntarily disclosed and information acquisition is observable to the manufacturer, in equilibrium*:

(1) *The firms' expected benefits from the data collection technology (i.e., $\pi^{D1B} \equiv \pi^{D1} - \pi^B$ and $\Pi^{D1B} \equiv \Pi^{D1} - \Pi^B$) are both positive, increasing in the market potential uncertainty d, and decreasing in the expected information cost λ.*

(2) *The retailer is worse off with information disclosure; i.e., $\pi^{D1} < \pi^N$.*

(3) *The manufacturer is better off with information disclosure; i.e., $\Pi^{D1} > \Pi^N$.*

(4) *The channel's total payoff is lower with information disclosure; i.e., $\pi^{D1} + \Pi^{D1} < \pi^N + \Pi^N$.*

This proposition suggests that downstream information acquisition can also benefit the upstream firm if communication between the channel members is feasible. This is because the efficiency effect of the retailer's information acquisition may spill over to the upstream level, allowing the manufacturer to be informed about market demand and thus to fine tune the wholesale price accordingly. In particular, without information disclosure, the manufacturer in equilibrium charges a constant wholesale price ω, while with the fully disclosed information from the retailer, the wholesale price can be adjusted according to the realization of the demand state (i.e., ω_S in the state A_S, $S \in \{H, L\}$). In addition, similar to that at the downstream level, this spillover efficiency effect can be strengthened by higher demand uncertainty or lower expected information cost. Note that vertical information spillover here is totally aligned with the retailer's self interest from an ex post perspective; the retailer in equilibrium volunteers to share its private information even though it is free not to do so. This implies that, for a manufacturer who does not have access to retail market data to obtain downstream demand information, an ex ante enforceable information-sharing contract with the retailer is not necessary. As a result, the manufacturer may want to switch its strategic focus in dealing with the retailer from maintaining and enforcing a contract-based relationship to facilitating channel communication.

Proposition 1 also suggests that the retailer can be hurt by the strategic effect of information acquisition, i.e., information disclosure. This is indicated by the difference in the retailer's equilibrium ex ante payoffs between the disclosure and no disclosure cases (i.e., $\pi^{D1} - \pi^N$), which is negative. Note that information disclosure here is a double-edged sword, which leads the retailer to induce the manufacturer to charge a lower (higher) wholesale price when the realized demand is Low (High). Intuitively, the benefit from the former scenario is more than offset by the loss in the latter because a higher wholesale price intensifies the double-marginalization problem and hurts the retailer more.[8] From an ex ante perspective, the retailer is worse off with information disclosure. Interestingly, the retailer may benefit from sharing its information with the manufacturer in some ex post scenario (e.g., in the Low demand state). This implies a time inconsistency in the retailer's incentive for vertical information sharing. Although the retailer ex ante prefers to remove its ability to disclose private information, it is in the retailer's best interest to disclose information in some ex post scenario.

From the channel's perspective, the firms are worse off with information disclosure. The increase in the manufacturer's payoff cannot compensate for the retailer's loss. This is because, with an informed manufacturer, the equilibrium wholesale price varies with demand realization, leading to a more fluctuating retail price that exaggerates the double-marginalization problem. Counterintuitively, this result suggests that channel communication may impede channel coordination.

3.3.2. Unobservable Information Acquisition. Next, I investigate how the unobservability of information acquisition may influence the firms' equilibrium behaviors and payoffs. I define the manufacturer's updated probability that the market potential information, High or Low, has been acquired by the retailer, conditional on the message $m \in M$, as $\theta^1(m)$ or $\theta^2(m)$, respectively. Interestingly, unlike the case with observable information acquisition, now the sum of $\theta^1(m)$ and $\theta^2(m)$ may not be equal to one.

[8] In particular, the retailer's expected conditional payoff is concave in the difference between the market potential and the wholesale price; i.e., $\pi(\omega) = [P_H(\omega) - \omega][A_H - P_H(\omega)]/2 + [P_L(\omega) - \omega][A_L - P_L(\omega)]/2 = (A_H - \omega)^2/8 + (A_L - \omega)^2/8$, where $P_S(\omega) = (A_S + \omega)/2$ is the optimal retail price in the state $S \in \{H, L\}$. The retailer's equilibrium ex ante payoff is therefore lower when the equilibrium wholesale price becomes more volatile. See also Ray et al. (2006) on asymmetric wholesale price adjustments.

This is because the manufacturer is uncertain not only about market demand, but also about whether demand information has been acquired by the retailer. The manufacturer's belief that no information is acquired by the retailer is captured by the probability $1 - \theta^1(m) - \theta^2(m)$. Nonetheless, if the demand information is disclosed by the retailer, the manufacturer would infer that demand information has been acquired. Thus, $\theta^1(\bar{H}) = 1$, $\theta^2(\bar{L}) = 1$, while $0 \le \theta^1(\bar{N}) + \theta^2(\bar{N}) < 1$.

The retailer's feasible information disclosure strategies are also different from those in the case of observable information acquisition. I continue to denote the retailer's information disclosure strategy as $r = (m_H, m_L)$, where $m_H \in M_H = \{\bar{H}, \bar{N}\}$ and $m_L \in M_L = \{\bar{L}, \bar{N}\}$. Note that now the disclosure strategies $(\bar{H}, \bar{L})$, $(\bar{H}, \bar{N})$, and $(\bar{N}, \bar{L})$ may not be ex ante equivalent to each other. This is also because of the manufacturer's uncertainty about the retailer's information acquisition. For example, even when the retailer decides to reveal the Low demand state to the manufacturer (i.e., $m_L = \bar{L}$), the feasible messages following the High state (i.e., $\bar{H}$ and $\bar{N}$) do not necessarily have the same meaning for the manufacturer. Although the message $\bar{H}$ reveals to the manufacturer that the state is High, the message $\bar{N}$ may be generated from two possibilities: (1) the retailer observed $A = A_H$ and decided to withhold the information (i.e., $m_H = \bar{N}$), or (2) the retailer did not acquire any demand information (i.e., $c = c_h$). As a result, one can represent the set of the retailer's information disclosure strategies when information acquisition is not observable to the manufacturer, as $R^2 = \{(\bar{H}, \bar{L}), (\bar{H}, \bar{N}), (\bar{N}, \bar{L}), (\bar{N}, \bar{N})\}$.

To facilitate characterizing the manufacturer's updated beliefs when no demand information is received from the retailer, $\theta^1(\bar{N})$ and $\theta^2(\bar{N})$, I equivalently denote the retailer's information disclosure strategy as δ_S, which is equal to one if $m_S = \bar{S}$ and zero if otherwise, where $S \in \{H, L\}$. Note that from the manufacturer's perspective, there could be three alternative scenarios for the message $\bar{N}$ to be received: (1) the retailer acquired and withheld the High information on the market potential (i.e., $c = c_l$ and $\delta_H = 0$), (2) the retailer acquired and withheld the Low information on the market potential (i.e., $c = c_l$ and $\delta_L = 0$), or (3) no information was acquired by the retailer since $c = c_h$. The probabilities for these three scenarios are given by $(1-\lambda)(1-\delta_H)/2$, $(1-\lambda) \cdot (1-\delta_L)/2$, and λ, respectively. Therefore

$$\theta^1(\bar{N}) = \frac{(1-\lambda)(1-\delta_H)/2}{\lambda + (1-\lambda)(2-\delta_H-\delta_L)/2},$$

$$\theta^2(\bar{N}) = \frac{(1-\lambda)(1-\delta_L)/2}{\lambda + (1-\lambda)(2-\delta_H-\delta_L)/2}.$$

I can then investigate how the retailer can influence the manufacturer's beliefs $\theta^1(m)$ and $\theta^2(m)$, and in turn the wholesale pricing decision on ω_m, through choosing the message m to be sent to the manufacturer. Given the updated beliefs $\theta^1(m)$ and $\theta^2(m)$, the manufacturer needs to maximize $\Pi = \omega[\theta^1(m)(A_H - P_H(\omega)) + \theta^2(m)(A_L - P_L(\omega)) + (1-\theta^1(m) - \theta^2(m))(a - P(\omega))]$, where $P_S(\omega) = (A_S + \omega)/2$, $S \in \{H, L\}$, and $P(\omega) = (a+\omega)/2$ are the retailer's best-response functions when the acquired demand information is High, Low, or no information is acquired, respectively. By substituting $\theta^1(\bar{H}) = 1$ and $\theta^2(\bar{L}) = 1$, I can solve the manufacturer's pricing problem to obtain $\omega_{\bar{H}} = A_H/2$ and $\omega_{\bar{L}} = A_L/2$, when the received message is $\bar{H}$ or $\bar{L}$, respectively. Similarly, if no demand information is received from the retailer, the optimal wholesale price would be given by $\omega_{\bar{N}} = [1 + (\theta^1(\bar{N}) - \theta^2(\bar{N}))d]a/2$. Noting that $0 \le \theta^1(\bar{N}) < 1$ and $0 \le \theta^2(\bar{N}) < 1$ for any δ_H and δ_L, therefore $\omega_{\bar{H}} > \omega_{\bar{N}} > \omega_{\bar{L}}$. This leads to the following lemma on the retailer's equilibrium information disclosure strategy:

Lemma 2. *If information acquisition is unobservable to the manufacturer, in equilibrium the retailer withholds* (*discloses*) *the demand information to the manufacturer in the High* (*Low*) *state; i.e.,* $r = (\bar{N}, \bar{L})$.

This lemma suggests that, by contrast to the case with observable information acquisition, in equilibrium partial information withholding can be achieved (Farrell 1986). The retailer can selectively withhold unfavorable information (e.g., $A = A_H$) while disclosing favorable information (e.g., $A = A_L$). The retailer's ability to remain silent when the demand is High without revealing the true information can be attributed to the manufacturer's inability to observe the retailer's information acquisition efforts. In particular, when no message is sent from the retailer, the manufacturer cannot determine whether it is because the High demand information is concealed, or because the retailer does not acquire any information. Given this uncertainty, the optimal wholesale price when no message is received (i.e., $\omega_{\bar{N}}$) is lower than that when the manufacturer is sure that the demand is High (i.e., $\omega_{\bar{H}}$). As a result, the manufacturer's uncertainty about the retailer's information acquisition permits the retailer to partially withhold the (unfavorable) information.

It follows that in equilibrium $\delta_H = 0$ and $\delta_L = 1$. This leads to the manufacturer's equilibrium beliefs $\theta^1(\bar{N}) = (1-\lambda)/(1+\lambda)$ and $\theta^2(\bar{N}) = 0$. The retailer's equilibrium expected profit, conditional on $c = c_h$ or $c = c_l$, is given by $\pi^h = (a - \omega_{\bar{N}})^2/4$ or $\pi^l = (A_H - \omega_{\bar{N}})^2/8 + (A_L - \omega_{\bar{L}})^2/8$, respectively, where $\omega_{\bar{N}} = [1 + \theta^1(\bar{N})d]a/2$ and $\omega_{\bar{L}} = A_L/2$. Similarly, the manufacturer's equilibrium conditional expected payoffs are $\Pi^h = \omega_{\bar{N}}(a - \omega_{\bar{N}})/2$ and $\Pi^l = \omega_{\bar{N}}(A_H - \omega_{\bar{N}})/4 + \omega_{\bar{L}}(A_L - \omega_{\bar{L}})/4$, respectively.

Proposition 2. *If demand information can be voluntarily disclosed and information acquisition is unobservable to the manufacturer*:

(1) *The retailer's equilibrium expected profits* π^h *and* π^l, *conditional on* $c = c_h$ *or* $c = c_l$, *are both increasing in the expected information cost* λ.

(2) *The manufacturer's equilibrium expected profit* Π^h (Π^l), *conditional on* $c = c_h$ ($c = c_l$), *is increasing* (*decreasing*) *in the expected information cost* λ.

Interestingly, when information acquisition is unobservable to the manufacturer, the retailer's equilibrium conditional expected payoffs would increase with the ex ante probability that the information cost is high, no matter whether information is actually acquired by the retailer. That is, both π^h and π^l are increasing in λ. The intuition for this result is as follows. Note first that these payoffs decrease with $\omega_{\bar{N}}$, the equilibrium wholesale price charged when no demand information is disclosed from the retailer. Retailer silence would occur when the information acquired by the retailer turns out to be High or when no information is acquired. In setting $\omega_{\bar{N}}$, the manufacturer takes the expectation of these two possible scenarios into account. As a result, in equilibrium $\omega_{\bar{N}}$ lies between ω_H and ω^B, the wholesale price the manufacturer would optimally charge if it had known that the actual market demand was High or that no information was acquired by the retailer. As λ increases, the latter scenario is more likely to happen and the manufacturer hence adjusts down $\omega_{\bar{N}}$, resulting in higher retailer equilibrium payoffs π^h and π^l.

It is also the manufacturer's uncertainty about the retailer's information acquisition that helps to explain why the manufacturer's equilibrium conditional payoff Π^h increases, while Π^l decreases, with the expected information cost λ. As discussed above, $\omega_{\bar{N}}$ is higher than ω^B, the optimal wholesale price when the high information acquisition cost c_h is realized and observable to the manufacturer. Conversely, $\omega_{\bar{N}}$ is lower than ω_H, the optimal wholesale price when the High demand information is acquired and disclosed to the manufacturer. Therefore, as λ increases, $\omega_{\bar{N}}$ drops and goes closer to ω^B and farther from ω_H, which leads to a higher equilibrium payoff in the former scenario while to a lower payoff in the latter scenario for the manufacturer.[9]

The firms' equilibrium ex ante payoffs, with information disclosure and unobservable information acquisition, are given by

$$\pi^{D2} = \frac{[1+\lambda+(1+\lambda(3-4\lambda))d^2]a^2}{16(1+\lambda)} \quad \text{and}$$

$$\Pi^{D2} = \frac{[1+\lambda+(1-\lambda)d^2]a^2}{8(1+\lambda)}.$$

Proposition 3. *If demand information can be voluntarily disclosed and information acquisition is unobservable to the manufacturer, in equilibrium*:

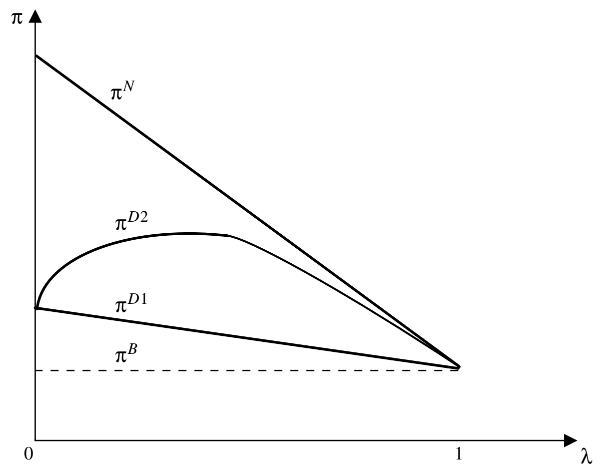
(1) *The retailer's expected benefit from the data collection technology* (*i.e.*, $\pi^{D2B} \equiv \pi^{D2} - \pi^B$) *is positive, increasing in the market potential uncertainty* d, *and increasing* (*decreasing*) *in the expected information cost* λ *when* λ *is low* (*high*).

(2) *The manufacturer's expected benefit from the data collection technology* (*i.e.*, $\Pi^{D2B} \equiv \Pi^{D2} - \Pi^B$) *is positive, increasing in the market potential uncertainty* d, *and decreasing and convex in the expected information cost* λ.

Similar to the case with observable information acquisition, the retailer's expected benefit from adopting the data collection technology, π^{D2B}, is positive and increasing with the uncertainty parameter d. However, when information acquisition is unobservable to the manufacturer, the retailer's benefit from data collection does not monotonically vary with the expected information cost λ. This is because of the interaction of the two counteracting impacts that the expected information cost λ exerts on the retailer's equilibrium ex ante payoff π^{D2}. First, from an ex ante perspective, the more likely that the information cost c is high, the less likely that the retailer would acquire information and benefit from being better informed about market demand. The equilibrium ex ante payoff is a weighted average of the equilibrium conditional profits; i.e., $\pi^{D2} = \lambda\pi^h + (1-\lambda)\pi^l$. Note also that $\pi^h < \pi^l$. All else being equal, the retailer is worse off as the probability becomes larger that the lower conditional payoff π^h would occur (i.e., increasing λ). On the other hand, as suggested by Proposition 2, the retailer's equilibrium conditional payoffs π^h and π^l increase with the expected information cost λ. This is because of the information withholding effect of the expected information cost, which is absent in the previous cases investigated when no information disclosure is feasible or when information acquisition is observable. As a result, when λ is sufficiently low, the retailer is better off with an increasing expected information cost because the gain from the information withholding effect outweighs the loss from acquiring less information. However, as λ increases, the loss from acquiring less information would loom larger and dominate the incremental gain from withholding information, which leads to a lower equilibrium ex ante payoff for the retailer when λ is sufficiently high. To summarize, as Figure 2 indicates, there is an inverted-U relationship between the retailer's equilibrium ex ante payoff π^{D2} and the expected information cost λ.

[9] Note that $\Pi^h = \omega_{\bar{N}}(a - \omega_{\bar{N}})/2$ and $\Pi^l = \omega_{\bar{N}}(A_H - \omega_{\bar{N}})/4 + \omega_{\bar{L}}(A_L - \omega_{\bar{L}})/4$ are increasing when $\omega_{\bar{N}}$ is closer to ω^B or ω_H, respectively.

Figure 2 **The Retailer's Equilibrium Ex Ante Profits**



Proposition 3 also suggests that the manufacturer's equilibrium ex ante payoff Π^{D2} is negatively and convexly related to the expected information cost λ, which is unlike the case with observable information acquisition. That is, as Figure 3 shows, the decline in the manufacturer's equilibrium ex ante profit Π^{D2} becomes slower as λ increases. This is because, as suggested in Proposition 2, the manufacturer's equilibrium payoff Π^h (conditional on no information being acquired by the retailer) is increasing in λ, which is caused by the information withholding effect.

Finally, comparing the firms' equilibrium ex ante payoffs across the different information disclosure/observability scenarios yields the following proposition:

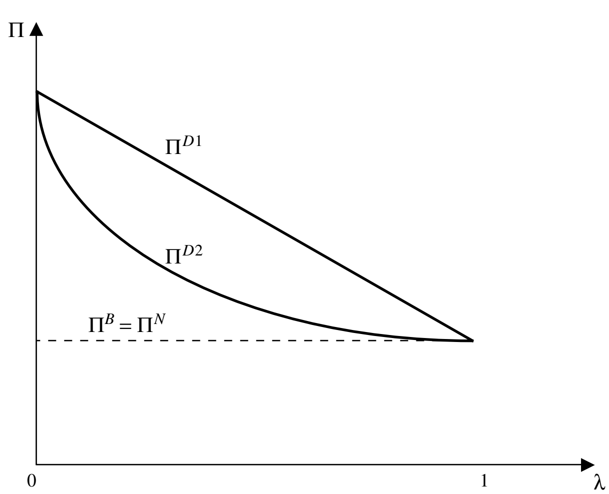
Proposition 4. (1) *The retailer's equilibrium ex ante payoff when information acquisition is unobservable is lower* (*higher*) *than that when information disclosure is infeasible* (*when information acquisition is observable*); *i.e.,* $\pi^{D1} < \pi^{D2} < \pi^N$.

(2) *The manufacturer's equilibrium ex ante payoff when information acquisition is unobservable is higher* (*lower*) *than that when information disclosure is infeasible* (*when information acquisition is observable*); *i.e.,* $\Pi^N < \Pi^{D2} < \Pi^{D1}$.

(3) *The channel's total equilibrium ex ante payoff when information acquisition is unobservable is lower* (*higher*) *than that when information disclosure is infeasible* (*when information acquisition is observable*); *i.e.,* $\pi^{D1} + \Pi^{D1} < \pi^{D2} + \Pi^{D2} < \pi^N + \Pi^N$.

This proposition further confirms that voluntary information disclosure can hurt the retailer, while benefitting the upstream manufacturer, when information acquisition is unobservable. Nevertheless, unobservable information acquisition may result in partial information withholding, mitigating the retailer's loss and the manufacturer's benefit from voluntary information transmission between the channel members. The changes in the retailer's equilibrium ex ante payoffs across the different information disclosure/observability scenarios analyzed here are driven by the severity of the channel's double-marginalization problem, which is in turn positively related to the amount of demand information disclosed in equilibrium to the manufacturer. A better-informed manufacturer charges more fluctuating wholesale prices, leading to, on average, larger demand recession (see Footnote 8). This also explains why the overall channel's equilibrium ex ante profit is the highest without information disclosure, while it is the lowest when information acquisition is observable.[10] The manufacturer's equilibrium payoffs are influenced by this demand recession as well, but the spillover efficiency effect of adjusting wholesale pricing according to demand realizations is more dominant. As a result, the manufacturer's equilibrium ex ante payoffs are positively related to the amount of demand information disclosed in equilibrium by the retailer.

Figure 3 **The Manufacturer's Equilibrium Ex Ante Profits**



4. Concluding Remarks

In this paper, I investigate the impact of retailer information acquisition on the firms' equilibrium behaviors and profits in a dyadic channel. Two effects of information acquisition are identified. A retailer can

[10] One may expect that a two-part tariff would remedy the demand distortion problem and achieve the first best outcome for the overall channel. This is because, in an optimal two-part tariff, the wholesale price is always set to marginal cost and does not respond to the demand information. Nevertheless, other mechanisms (e.g., quantity discounts, price ceiling), which can solve the double-marginalization problem in a standard channel setting, may not work here. These mechanisms essentially fix the retail price and hence nullify the efficiency effect of downstream information acquisition.

improve its pricing decision in an uncertain environment by translating the collected data into demand information, i.e., the efficiency effect. Moreover, the informed retailer can influence the upstream firm's pricing behavior by voluntarily disclosing its acquired private information to the manufacturer, i.e., the strategic effect. This paper presents several intriguing results that provide significant managerial insights into channel interaction in markets characterized by uncertain demand, exploding retail data, and costly information acquisition.

First, it demonstrates that although the efficiency effect of information acquisition benefits the retailer without affecting the manufacturer, the strategic effect works to the detriment of the retailer while to the advantage of the manufacturer. This suggests that retailers should be more cautious in sharing private information and probably make efforts to impede information disclosure. Practitioners echo similar concerns: "It is not uncommon for businesses to share data with partners, though they are careful about what they release"; "But now Wal-Mart has decided that sharing that information helps others more than it helps itself" (Heun 2001, p. 22).[11] Nonetheless, this does not necessarily mean that a retailer should always shun its communication with suppliers. There can be other benefits from sharing private information within a supply chain, e.g., inventory planning and cost reduction (Lee et al. 2000). The bottom line of the insights gained here is that retailers should take into account the potential issue of demand distortion (i.e., double marginalization) when communicating with manufacturers.

In addition, this paper explains why unobservable information acquisition can mitigate the retailer's loss and the manufacturer's benefit from the strategic effect of information disclosure. The economic force underlying this result hinges on the retailer's ability to credibly conceal unfavorable information when the manufacturer cannot determine whether or not the retailer has acquired information. It is important to emphasize that, for partial information withholding to be credible, the necessary condition is that it is unknown to the manufacturer whether the retailer has become informed; unobservable cost/efforts of information acquisition are sufficient but not necessary. For example, observing a retailer's investment in data collection infrastructures or in information-generating systems does not necessarily imply that the retailer is always engaged in information acquisition.[12] Similarly, information acquisition efforts may not always be fruitful because there can be randomness in a database's complexity/informativeness. As a result, although the focus here is the observability of the cost/efforts of information acquisition, the conceptual insights of this paper can be readily extended to more general situations when the outcome of information acquisition is uncertain (see Footnote 6).

While one may argue that opportunity costs are generally unobservable to a third party, whether retail information acquisition is observable boils down to an empirical question. More importantly, this paper pinpoints the rationale for a retailer to keep its information acquisition unobservable when communicating with manufacturers. For instance, a retailer may resort to third-party experts rather than to the upstream partner in outsourcing its data analysis. Similarly, sharing the same consulting company with suppliers may not be a wise strategy because that may increase the transparency of information acquisition. Conversely, it may be in the manufacturer's interest to be involved in the retailer's information acquisition and to track recent developments in information-generating infrastructures, technologies, and techniques.

There is empirical/anecdotal evidence that firms pursue the partial disclosure strategy studied in this paper. For example, Ackert et al. (2000) confirm that firms selectively disclose favorable cost information while withholding unfavorable information in an attempt to discourage rivals' production. In the channel setting, the partial disclosure strategy is best illustrated by Heun (2001, p. 24):

> ...collaboration lets manufacturers and distributors manage their inventories to ensure that popular products don't go out of stock. But despite these merits, analysts say retailers will seek the upper hand. "If I know if your product is helping me, and I let you know that, you may not give me the markdown or promotion that I'd like," Meta Group's Alvarez says. If a supplier thinks it has a poor-performing product and the retailer knows otherwise, it will keep that information to itself.

This paper also sheds light on the impact of the expected difficulty in information acquisition on a retailer's equilibrium payoff. It shows that an increasing difficulty in information acquisition (i.e., higher λ) may benefit the retailer, if λ is low and information acquisition is unobservable. This result is insightful for a retailer who is considering an investment in a data collection system (e.g., a data warehouse), particularly when whether the collected data would always be translated into meaningful information is

[11] Wal-Mart modified its disclosure of sales updates from weekly to monthly (*DSN Retailing Today* 2005). This suggests that Wal-Mart is sharing less information than it used to be.

[12] A retailer's investment in information-generating systems can reduce the ex ante probability λ that the realized opportunity cost of information acquisition is high, but not necessarily eliminate the fact that the opportunity cost of information acquisition is uncertain.

uncertain. The overall value of the system might increase when it becomes increasingly difficult to derive managerial insights from the collected data. This is because the retailer can strategically exploit the increase in the difficulty of information acquisition to partially withhold its private information, eliciting a lower wholesale price from the manufacturer. Another interesting implication is that investing in information-gleaning technologies (e.g., decision-support systems) may facilitate subsequent information acquisition and as a result may hurt the retailer. This theoretical result also suggests a direction for future research to empirically examine the relationship between retail profit margin and the adoption of information-generating technologies in the downstream market.

A central assumption in the model is that the disclosed information is truthful. Should the verification cost be sufficiently high, for example, this assumption will not hold and a credibility issue may arise. Furthermore, if information disclosure is costless (i.e., cheap talk), then the retailer has an incentive to lie, and as a result, the communication is completely uninformative. The equilibrium outcome would be the same as that without information disclosure in §3.2. Note also that in the current setup the retailer cannot use costly devices (e.g., price, quantity commitment, advertising, slotting allowance, etc.) to signal private information, which has been heavily researched in the literature (e.g., Chu 1992).

Here, I focus on the retailer's incentive to disclose private information. As a result, it is assumed that only the retailer has access to retail data and can acquire demand information, which can be reasonably justified for many markets. Conversely, a manufacturer may also have incentives to acquire demand information, especially when the market demand is very uncertain and/or when no information is disclosed from the downstream firm.[13] For example, the manufacturer may integrate into the downstream market, hire third-party consulting firms, or conduct independent market research to improve its knowledge about market demand.[14] Should the model be extended to allow for both retailer and manufacturer information acquisition, a number of interesting research issues may emerge. First, one may investigate the difference in the channel members' incentives for information transmission. Unlike the retailer, the manufacturer can use the wholesale price to signal its private information as well. This may lead to more information transmitted in equilibrium from the upstream to the downstream firm than that in the reverse direction. Second, a free-riding issue may arise that a channel member relies on the other party to obtain information, resulting in a lower incentive for information acquisition. One could also examine the retailer's incentive to share its proprietary data, which can then be analyzed by the manufacturer. Clearly, a thorough analysis of these issues is complicated and can be addressed in future research. Nevertheless, the primary insights about the retailer's incentive and ability to disclose favorable information while (partially) withholding the unfavorable are likely to be robust in this extension.

Other directions for future research are numerous. Different types of common/specific uncertainties (e.g., price sensitivity, cost, etc.) can be considered. It may be interesting to examine the effect of upstream or downstream competition on the firms' incentives to acquire and share information. Another exciting direction is to examine alternative sharing formats, e.g., raw data versus information. One may also extend the current model to consider multiple-period interaction. I plan to pursue these issues in future research. Although the main implications obtained in this paper are expected to hold under these extensions, it would be of interest to explore whether additional insights may arise. For example, there may be situations when the retailer's ability to disclose private information and the cost of that disclosure are unknown to the manufacturer. Nevertheless, this can be discerned by the manufacturer from the retailer's previous disclosure behaviors. In such a dynamic setting, the retailer may have an increasing incentive to withhold private information to manipulate the manufacturer's belief about the retailer's information disclosure ability/cost.

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Appendix

PROOF OF LEMMA 1. The retailer's expected payoff in the state $S \in \{H, L\}$, taking into account the manufacturer's and the retailer's optimal pricing decisions, and conditional on a message $m \in M$ being sent to the manufacturer, is given by $\pi_S(\omega_m) = (A_S - \omega_m)^2/4$, where $\omega_m = (\theta(m)A_H + (1-\theta(m))A_L)/2$. Because $\omega(\theta)$ is increasing in θ, and $\pi_S(\omega_m)$ is decreasing in ω_m, $\pi_S(\theta) \equiv \pi_S(\omega(\theta))$ is a decreasing function in θ. This implies that, independent of the realized demand state $S \in \{H, L\}$, it is always desirable for the retailer to convince the manufacturer that the demand is Low. Note that $\theta(\bar{H}) = 1 \geq \theta(\bar{N}) \geq \theta(\bar{L}) = 0$. It follows immediately that, if the realized state is Low, it is a dominant strategy for the

[13] See Guo and Iyer (2009) on the acquisition and transmission of information on consumer valuation from the upstream to the downstream firm.

[14] I thank the AE and an anonymous reviewer for pointing this out. However, it is unlikely that the manufacturer can subsidize the retailer to communicate the latter's private information because the channel's total equilibrium profit is lower with information disclosure (see Proposition 4).

retailer to disclose the demand information to the manufacturer; i.e., $m_L = \bar{L}$. Given this, the manufacturer would infer that it is impossible that the message $m = \bar{N}$ is sent by a retailer who decides to withhold the information in the realized Low state. That is, the only credible belief is $\theta(\bar{N}) = \theta(\bar{H}) = 1$. As a result, the manufacturer can infer the actual demand information no matter what message is sent by the retailer (either $\bar{H}$ or $\bar{N}$), if the realized state is High. The information disclosure strategy $r = (\bar{H}, \bar{L})$ would then arise as the unique equilibrium. □

Proof of Proposition 2. The retailer's equilibrium expected profits, conditional on the information acquisition cost being c_h or c_l, are given by $\pi^h = (a - \omega_{\bar{N}})^2/4$ or $\pi^l = (A_H - \omega_{\bar{N}})^2/8 + (A_L - \omega_{\bar{L}})^2/8$, respectively, where $\omega_{\bar{N}} = [1 + \theta^1(\bar{N})d]a/2$ and $\omega_{\bar{L}} = A_L/2$. Noting that both π^h and π^l are decreasing in $\omega_{\bar{N}}$, $\omega_{\bar{N}}$ is increasing in $\theta^1(\bar{N})$, and $\theta^1(\bar{N}) = (1 - \lambda)/(1 + \lambda)$ is decreasing in λ, I can immediately prove the first part of the proposition.

The manufacturer's equilibrium conditional expected equilibrium payoffs are given by $\Pi^h = \omega_{\bar{N}}(a - \omega_{\bar{N}})/2$ and $\Pi^l = \omega_{\bar{N}}(A_H - \omega_{\bar{N}})/4 + \omega_{\bar{L}}(A_L - \omega_{\bar{L}})/4$, respectively. Note that $\Pi = \omega(a - \omega)/2$ is a concave function of ω and has a maximum at $\omega = \omega^B = a/2$. Because $\omega_{\bar{N}} = [1 + \theta^1(\bar{N})d]a/2 > \omega^B$, Π^h is decreasing in $\omega_{\bar{N}}$. Similarly, Π^l is increasing in $\omega_{\bar{N}}$ because $\omega_{\bar{N}} = [1 + \theta^1(\bar{N})d]a/2 < \omega_H = A_H/2$, where ω_H is the optimal solution to $\omega(A_H - \omega)/4$. I can then prove the second part of the proposition by noting that $\omega_{\bar{N}}$ is decreasing in λ. □

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