Optimal Contracts Under Endogenous Demand Information Acquisition

Song Huang\(^a\), Wenqiang Xiao\(^b\)\(^,\)\(^1\), Jun Yang\(^c\)

\(^a\) College of Economics and Management, South China Agricultural University, Guangzhou 510642, China
\(^b\) Stern School of Business, New York University, New York, New York 10012
\(^c\) School of Management, Huazhong University of Science and Technology, Wuhan 430074, China

Abstract

We consider a supplier selling to a retailer who decides whether or not to exert a fixed cost to acquire private demand information. We show that quantity discounts, established by the extant literature to be the optimal response for exogenous information acquisition, are also optimal under the setting with endogenous information acquisition.

Keywords: information acquisition; quantity discounts; endogenous adverse selection

1 Introduction

The quantity discount contract, in which the marginal wholesale price decreases in the purchased quantity, has been extensively studied in the supply chain literature due to its popular use in practice (Cachon [3]).

Interestingly, quantity discounts emerge as the optimal response to private demand/inventory information (Burnetas et al. [2], Taylor and Xiao [14], Zhang et al. [15]), implying that quantity discounts are effective in differentiating among retailers with private demand-forecast information and inducing truthful information sharing. A critical assumption made to establish the optimality of quantity discounts is that the retailer is freely endowed with private demand information. In practice, however, demand information does not always come freely for retailers, who often need to invest resources on software, personnel, and consulting fees to acquire such valuable demand information (Aiyer and Ledesma [1]). Retailers’ information acquisition decisions influence not only their own ability of matching supply and demand but also their suppliers’ performance in meeting their service level. As evidence that the retailers’ demand information acquisition matters for their suppliers, Fraser [7] reports on a survey of 120 suppliers that they place “improvements in trading partner forecasting accuracy” at the top of the list of benefits. Therefore, it is important to explicitly consider the retailer’s costly information acquisition decision and to reexamine the effectiveness of quantity discounts in the setting with endogenous demand information acquisition.

To this end, we consider a supplier (she) selling to a retailer (he) who decides whether or not to exert a fixed cost to acquire demand information, based on which the retailer then makes his order quantity decision. Our key finding is that to the extent that the supplier is better off by inducing the retailer to acquire information, the supplier’s optimal contract takes the form of quantity discounts. This core result, together with the intuitive result that the supplier is better off by inducing the retailer to acquire information if and only if the information acquisition cost is lower than a threshold, implies that the optimality of quantity discounts established by the extant literature in settings with exogenous information acquisition continues to hold under the setting with endogenous information acquisition. An implication is that quantity discounts are

\(^1\)Corresponding author. E-mail address: wxiao@stern.nyu.edu.
effective not only in differentiating among retailers with distinct demand information but also in incentivizing them to acquire demand information in the first place.

We caution that such robustness result needs not to be true in general. The economics literature on endogenous information acquisition (see, e.g., Demski and Sappington [6], Lewis and Sappington [10], Crémé et al. [5]) suggests that the optimal contract incentivizing both information acquisition and information screening takes a different form from the optimal contract that incentivizes only information screening. Crémé et al. [5] consider a setting where a buyer procures goods from a supplier who can exert a fixed information acquisition cost to privately observe the production cost. They show that as the information acquisition cost grows, the buyer’s optimal response is to switch from quantity discounts to more sophisticated contracts with a “high powered” structure in the payment scheme and a discontinuity in order quantities in order to induce the supplier to acquire information. These results suggest that quantity discounts, an optimal tool in differentiating trading partners with acquired private cost information, may no longer be optimal in incentivizing them to acquire information in the first place. In contrast to this stream of literature that considers the suppliers’ acquisition of production cost information, we consider the retailer’s acquisition of demand information, under which we are able to establish the robustness of the optimality of quantity discounts. Such a contrast implies that the source of information asymmetry matters for the optimal choice of contracts.

Our paper is closely related to the supply chain contracting literature that explicitly considers the retailer’s decision of acquiring demand information. Depending on whether or not information acquisition precedes the contract offer timing, this stream of literature can be classified into two groups. The first group assumes that the retailer acquires information before the supplier offering contracts. The main research question in this group is on how the retailer’s information disclosure decision impacts the supplier’s subsequent contract decisions and the supply chain performance (see, e.g., Guo [9] and Li et al. [11]). The other group reverses the sequence and considers that the retailer acquires information after the supplier offering contracts. The main research question under this sequence is what are the optimal contracts that can effectively incentivize information acquisition and induce the retailer to make proper order quantity decisions. Our paper falls into the latter. This group of literature can be further classified into two subgroups depending on whether or not the retailer’s interim participation constraints (i.e., participation after observing demand information) are considered. The first subgroup assumes away these participation constraints, and their objective is to look for contracts that can coordinate the retailer’s information acquisition and order quantity decisions so as to achieve the first-best result for the supply chain. Fu and Zhu [8] show that the buy-back contract can coordinate a supply chain with a single retailer; Shin and Tunca [12] show that a marked-based pricing contract can coordinate a supply chain with multiple competing retailers; Chen et al. [4] show that a forecast-based contract can effectively coordinate both the retailer’s information acquisition and sales effort decisions thereby achieving the first-best profit for the supply chain. The other subgroup considers the interim participation constraints. This approach is also consistent with how the above-mentioned economics literature models the endogenous production cost information acquisition. Our paper belongs to this subgroup. Taylor and Xiao [9] compare the rebates and returns contracts and show that the latter can achieve the first-best profit for the supply chain. Our paper differs from Taylor and Xiao [9] in that we focus on characterizing the optimal contracts among the entire class of contracts in which payments cannot be contingent on the realized sales, whereas they focus on specific contract forms that allow the payments to be contingent on the realized sales.
2 The Model

Consider a supplier (she) selling a single product to a retailer (he) who faces the following inverse demand curve $p = \Theta - q + \varepsilon$, where the retail price $p$ is jointly determined by the market condition $\Theta$, the retailer’s order quantity $q$, and a random noise term $\varepsilon$. For analytical tractability, we assume that $\Theta$ follows the uniform distribution over $[\theta, \theta + 1]$ and will discuss the robustness of our core result with respect to this assumption via numerics. We allow the random noise term $\varepsilon$ to take a general distribution $G(\cdot)$ with the mean being normalized to zero. Such a simple linear inverse demand curve has been used by the literature to study the endogenous demand information acquisition (see, e.g., Shin and Tunca [12]). Let $c$ be the supplier’s unit production cost. We further assume that $\Theta \geq 1 + c$ to rule out trivial cases and ensure that the retailer’s order quantity is nonnegative for all $\Theta \geq \tilde{\theta}$.

To model the retailer’s endogenous information acquisition, we assume that the retailer can privately observe the realized value of $\Theta$ after exerting fixed forecasting cost $k$. Regardless of whether or not the retailer invests in information acquisition, the realized value of $\Theta$ is always unknown to the supplier. The assumption of perfect revelation of $\Theta$ by the retailer with information acquisition is made only for notational simplicity. If we relax this assumption by introducing an imperfect forecast signal of $\Theta$ similar to the modeling of forecast signals in Shin and Tunca [12] and in Taylor and Xiao [14], our core robustness result on the optimality of quantity discounts continues to hold.

The supplier is the Stackelberg leader, offering take-it-or-leave-it contracts to the retailer who then decides whether or not to exert forecasting cost to acquire demand information. In designing the contracts, the supplier first faces the question of whether or not to induce the retailer to acquire information. If the supplier intends to induce the retailer to become informed, then it follows from the revelation principle that without loss of generality we can restrict to the direct mechanisms $\{q(\theta), t(\theta)\}$, where $q(\theta)$ is the order quantity and $t(\theta)$ is the total payment from the retailer who has acquired information and observed $\Theta = \theta$; otherwise, the supplier can simply offer a single quantity-payment pair $\{q, t\}$ to induce the retailer not to acquire information.

The sequence of events is as follows. First, the supplier decides whether or not to induce the retailer to acquire information. Under the former, she offers a menu of quantity-payment pairs $\{q(\theta), t(\theta)\}$. Under the latter, she offers a single quantity-payment pair $\{q, t\}$. Second, the retailer decides whether or not to acquire information. If he decides to acquire information, then he invests the information acquisition cost $k$ and privately observes the realized market condition $\Theta = \theta$; otherwise he becomes uninformed. He then decides whether or not to accept the contract offered by the supplier by comparing to his reservation profit which is normalized to zero without loss of generality. If the menu is offered, then the retailer decides which pair to choose from the menu based on the realized market condition. The retailer orders the quantity and makes the payment based on the chosen pair. Finally, the random noise $\varepsilon$ is realized and the retailer collects the sales revenue.

3 The Optimal Contracts

We formulate the supplier’s optimal contracting problems in two scenarios in sequel: inducing the retailer to acquire information and deterring the retailer from acquiring information. The supplier’s optimal decision of whether or not to induce retail information acquisition then depends on which contracting problem yields higher expected profits for the supplier.

Under the former case with information acquisition, it follows from the revelation principle that the supplier can restrict the contract choices to the direct mechanism without loss of op-
timality. Specifically, the supplier offers a direct mechanism \( \{q(\cdot), t(\cdot)\} \) to induce the retailer to acquire information. Let \( \pi(\theta, \hat{\theta}) \) be the expected profits of the retailer who observes \( \Theta = \theta \) but chooses the contract \( (q(\hat{\theta}), t(\hat{\theta})) \) that is intended for the type-\( \hat{\theta} \) retailer who observes \( \Theta = \hat{\theta} \). By definition, we have

\[
\pi(\theta, \hat{\theta}) = E_{\hat{\theta}}[(\theta - q(\hat{\theta}) + \epsilon)q(\hat{\theta}) - t(\hat{\theta})] = (\theta - q(\hat{\theta}))q(\hat{\theta}) - t(\hat{\theta}).
\]

To ensure the retailer’s truth telling, we must have that the retailer who observes \( \Theta = \theta \) is better off by choosing the contract \( (q(\theta), t(\theta)) \) than under any other contract, i.e.,

\[
\pi(\theta) \geq \pi(\theta, \hat{\theta}), \forall \theta, \hat{\theta}, \quad (IC-T)
\]

where \( \pi(\theta) \equiv \pi(\theta, \theta) \).

To induce the retailer to acquire information, we must have that the retailer is better off by acquiring information than not acquiring information. It follows from (IC-T) that if the retailer acquires information, the retailer’s optimal expected profits are equal to \( E_{\Theta}[\pi(\Theta)] - k \). If the retailer chooses not to acquire information, then his expected profits under contract \( (q(\theta), t(\theta)) \) are equal to

\[
E_{\Theta, \epsilon}[(\Theta - q(\theta) + \epsilon)q(\theta) - t(\theta)] = (\theta + 1/2 - q(\theta))q(\theta) - t(\theta) = \pi(\theta + 1/2, \theta).
\]

This, together with (IC-T), implies that the uninformed retailer’s best contract choice is \( \theta = \theta + 1/2 \), resulting in his optimal expected profit \( \pi(\theta + 1/2) \) when he chooses not to acquire information. It is worth noting that (IC-T) also ensures that the retailer who observes \( \Theta = \theta \) is better off by choosing the contract \( (q(\theta), t(\theta)) \) than pretending that he does not acquire information and chooses the contract intended for the type \( \theta + 1/2 \). Consequently, to ensure that the retailer is better off by acquiring information, we must have that

\[
E_{\Theta}[\pi(\Theta)] - k \geq \pi(\theta + 1/2). \quad (IC-A)
\]

In addition to satisfying the two set of incentive constraints (IC-T) and (IC-A), the menu \( \{q(\cdot), t(\cdot)\} \) should also meet the retailer’s participation constraints both before and after information acquisition. To ensure that the retailer of any type \( \theta \) to accept his intended contract, it requires that

\[
\pi(\theta) \geq 0, \forall \theta. \quad (IR)
\]

Note that the retailer is also better off by acquiring information than rejecting the contract offer because under the former his optimal expected profit is \( E_{\Theta}[\pi(\Theta)] - k \), which is no less than his reservation profit 0 (a result that follows from (IC-A) and (IR)). The supplier’s optimal contracts that induce the retailer to acquire information can thus be formulated as follows, denoted by (P1),

\[
\max_{\{q(\cdot), t(\cdot)\}} E_{\Theta}[t(\Theta) - cq(\Theta)]
\]

subject to (IC-T), (IC-A) and (IR) constraints.

Under the latter case where the supplier intends to induce the retailer not to acquire information, it suffices to consider a single quantity-payment pair \( (q, t) \) that meets the retailer’s participation constraint and ensures the retailer is better off by not acquiring information. Taken
any contract \((q, t)\), the retailer’s expected profit under no information acquisition is equal to \(E_{\Theta, \varepsilon}[(\Theta - q + \varepsilon)q - t] = (\theta + 1/2 - q)q - t\), resulting in the following participation constraint:

\[
(\theta + 1/2 - q)q - t \geq 0.
\]

(R’)

Note that the (IR') constraint ensures that the retailer who observes any \(\theta \geq \theta + 1/2\) can earn more than his reservation profit. This implies that acquiring information may allow the retailer to reject the contract when the realized market condition is less favorable (i.e., \(\theta < \theta + 1/2\)) and only accept the contract otherwise. Consequently, the retailer’s maximum expected profit by acquiring information is equal to \(E_{\Theta} \max\{(\Theta - q)q - t, 0\} - k\). To induce the retailer not to acquire information, it requires that the retailer is better off by not acquiring information than by acquiring information and accepting the contract only when \(\theta \geq \theta + 1/2\), i.e.,

\[
(\theta + 1/2 - q)q - t \geq E_{\Theta} \max\{(\Theta - q)q - t, 0\} - k.
\]

(IC’)

The supplier’s optimal contract that induces the retailer not to acquire information can thus be formulated as follows, denoted by (P2),

\[
\max_{q,t} (t - cq)
\]

subject to (IC’) and (IR’) constraints.

Clearly, the optimal value of (P1) decreases in \(k\) whereas that of (P2) increases in \(k\), implying that there exists a threshold, denoted by \(K\), such that the supplier is better off by inducing the retailer to acquire information if and only if \(k \leq K\). In the remainder of the paper, we will restrict our analysis to the more interesting regime of \(k \leq K\) and characterize the optimal contracts that induce information acquisition. We remark that in the less interesting regime of \(k > K\), the supplier’s optimal contract consists of a single quantity-payment pair.

Now we are ready to present the core result of our paper, the supplier’s optimal contracts inducing retail information acquisition when it is in the supplier’s best interest to do so.

**Proposition 1.** To the extent that the supplier is better off by inducing demand information acquisition (i.e., \(k \leq K\)), the supplier’s optimal response is to offer the optimal menu of quantity-payment pairs, denoted by \((q^*(\theta), t^*(\theta))\), where given as follows

\[
q^*(\theta) = \frac{1}{2}(2\theta - c - \theta - 1),
\]

\[
t^*(\theta) = (\theta - q^*(\theta))q^*(\theta) - \int_{\theta}^{\theta} q^*(z)dz.
\]

Alternatively, the supplier can achieve the same expected profits by offering the retailer the quantity discount scheme \(T^*(q)\), where \(T^*(q) = t^*(\theta^*(q))\) with \(\theta^*(q)\) being the inverse function of \(q^*(\theta)\), i.e., \(\theta^*(q) = (2q + c + \theta + 1)/2\).

**Proof of Proposition 1.** We first solve (P1) by constructing the following relaxed problem. It follows from (IC-T) and the Envelope Theorem that \(\pi'(\theta) = \frac{\partial \pi(\theta, \hat{\theta})}{\partial \theta}|_{\hat{\theta} = \theta} = q(\theta)\). By integration, we have \(\pi(\theta) = \int_{\theta}^{\theta} q(z)dz + \pi(\hat{\theta})\). Obviously, \(\pi(\hat{\theta}) = 0\) at the optimal solution because \(\pi(\theta)\) increases in \(\theta\). Recall the definition of \(\pi(\theta) = (\theta - q(\theta))q(\theta) - t(\theta)\), we can express \(t(\theta)\) as \(t(\theta) = (\theta - q(\theta))q(\theta) - \int_{\theta}^{\theta} q(z)dz\). Substituting it into (IC-A) leads to \(\int_{\theta}^{\theta+1} q(\theta)[(\theta+1-\theta) - 1_{\theta \leq \mu_\theta}]d\theta \geq k\), where \(\mu_\theta = E(\hat{\theta}) = \theta + 1/2\).

Note that we can impose the constraint \(q(\theta) \leq (\theta - c)/2\) without loss of optimality. Further, we can impose the constraint \(dq(\theta)/d\theta \geq 0\) which is a necessary condition from (IC-T). Thus, (P1)
can be relaxed to the following problem, which yields an upper bound on the original problem (P1):

\[
\begin{aligned}
\max_{q(\cdot)} & \mathbb{E}_{\Theta, q} [(\Theta - q(\Theta) - c + \varepsilon)q(\Theta) - q(\Theta)(\theta + 1 - \Theta)] \\
\text{s.t.} & \int_{\frac{\theta}{2}}^{\theta + 1} q(\theta)[(\theta + 1 - \theta) - 1_{\theta \leq \mu_0}]d\theta \geq k, \\
& dq(\theta)/d\theta \geq 0, \\
& q(\theta) \leq \frac{1}{2}(\theta - c).
\end{aligned}
\]

Solving the above relaxed problem, the ordering quantity under information acquisition is

\[
q^A(\theta) = \begin{cases}
\frac{1}{2}[(\theta - c) - (\theta + 1 - \theta)] & \text{if } 0 \leq k \leq \frac{1}{24}, \\
\frac{1}{2}[(\theta - c) - (1 - \lambda_1^A)(\theta + 1 - \theta) - \lambda_1^A \cdot 1_{\theta \leq \mu_0}] & \text{if } \frac{1}{24} < k \leq \frac{1}{12}, \\
\frac{1}{2}[(\theta - c) - (1 - \lambda_1^A)(\theta + 1 - \theta) - \lambda_2^A \cdot 1_{\theta \leq \mu_0} + \frac{\theta - c}{2} \cdot 1_{\theta > \mu_0}] & \text{if } \frac{1}{12} < k \leq \frac{5}{48}, \\
\frac{1}{2}[(\theta - c) - 16k + \frac{2}{3}] \cdot 1_{\theta \leq \mu_0} + \frac{\theta - c}{2} \cdot 1_{\theta > \mu_0} & \text{if } k > \frac{5}{48},
\end{cases}
\]

where \(\lambda_1^A = 24k - 1\) and \(\lambda_2^A = 3(16k - 1)\). Correspondingly, \(t^A(\theta) = (\theta - q^A(\theta))q^A(\theta) - \int_{\theta}^{q^A(\theta)} dz\).

It can be shown that the ignored constraint (IC-T) always holds under the solution \((q^A(\theta), t^A(\theta))\) to the relaxed problem. Therefore, the solution \((q^A(\theta), t^A(\theta))\) is also optimal to the original problem (P1).

To solve the supplier’s optimal contract that induces the retailer not to acquire information, note that (IC’) is equivalent to \(t \leq -q^2 + \theta q + \sqrt{2kq}\), and (IR’) can also be rewritten as \(t \leq -q^2 + \theta q + q/2\). From the structure of the optimization problem (P2), we know that at least one of the two constraints (IR’) and (IC’) is binding at the optimal solution. Consequently, the problem (P2) reduces to the following equivalent problem with only one variable

\[
\max_{q \geq 0} \min\{-q^2 + \theta q + q/2 - cq, \ -q^2 + \theta q + \sqrt{2kq} - cq\}.
\]

Then, the optimal contract that induces the retailer not to acquire information is

\[
(q^N, t^N) = \begin{cases}
(\bar{q}(k), (\bar{q}(k) - q(k))q(k) + \sqrt{2kq(k)}) & \text{if } 0 \leq k \leq \frac{\mu_c - c}{16} - \frac{1}{64}, \\
(8k, 8k(\mu_0 - 8k)) & \text{if } \frac{\mu_c - c}{16} - \frac{1}{64} < k \leq \frac{\mu_c - c}{16}, \\
\left(\frac{1}{2}(\mu_0 - c), \frac{1}{2}(\mu_0^2 - c^2)\right) & \text{if } k > \frac{\mu_c - c}{16},
\end{cases}
\]

where \(\bar{q}(k) = \arg\max_{q \geq 0} ((\theta - c - q)q + \sqrt{2kq})\).

After solving (P1) and (P2), we next compare the two problems.

Let \(\Pi^N(k) = t^N - cq^N\) denote the supplier’s optimal profit under the contract \((q^N, t^N)\).

(i) If \(0 \leq k \leq \frac{\mu_c - c}{16} - \frac{1}{64}\), then \(\frac{d\Pi^N(k)}{dk} = \sqrt{\frac{\bar{q}(k)}{2k}} \geq 0\). (ii) If \(\frac{\mu_c - c}{16} - \frac{1}{64} < k \leq \frac{\mu_c - c}{16}\), then \(\frac{d\Pi^N(k)}{dk} = 8(\mu_0 - c - 16k) \geq 0\). (iii) If \(k > \frac{\mu_c - c}{16}\), then \(\frac{d\Pi^N(k)}{dk} = 0\). Thus, \(\Pi^N(k)\) is weakly increasing in \(k\).

The supplier’s optimal expected profit under (P1) is

\[
\Pi^A(k) = \begin{cases}
\frac{(\theta - c)^2}{4} + \frac{k}{12} & \text{if } 0 \leq k \leq \frac{1}{24}, \\
\frac{(\theta - c)^2}{4} - 12k^2 + k + \frac{1}{16} & \text{if } \frac{17}{12} < k \leq \frac{1}{12}, \\
\frac{(\theta - c)^2}{4} - 24k^2 + 3k - \frac{1}{32} & \text{if } \frac{1}{12} < k \leq \frac{5}{48}, \\
\frac{(\theta - c)^2}{4} - 32k^2 + \frac{14k}{3} - \frac{31}{288} & \text{if } k > \frac{5}{48}.
\end{cases}
\]
Thus, it is easy to verify that $\Pi^A(k)$ is weakly decreasing in $k$.

Combining the above results and the fact that $\Pi^N(0) = \frac{(\theta - c)^2}{4} < \frac{(\theta - c)^2}{4} + \frac{1}{12} = \Pi^A(0)$, and $\Pi^A(k) - \Pi^N(k) = -32k^2 + 14k - 31 < 0$ when $k > \frac{7 + 3\sqrt{5}}{8}$, there exist a threshold $K > 0$ such that the supplier prefers to induce the retailer to acquire information by offering a menu of contracts if and only if $k \leq K$, otherwise, the supplier prefers to induce the retailer not to acquire information by offering a single quantity-payment pair.

Next, we prove $\Pi^N(\frac{1}{27}) > \Pi^A(\frac{1}{27})$, which implies that the supplier’s optimal response is to offer the menu $(q^*(\theta), t^*(\theta))$ (defined in Proposition 1) when $k \leq K$. It suffices to show that $(\theta - c - \tilde{q}_o)q_o + \sqrt{\frac{9}{12} (\theta - c)^2} > \frac{(\theta - c)^2}{4} + \frac{1}{12}$, where $\tilde{q}_o = \arg\max_{q\geq0} \{(\theta - c - q)q + \sqrt{\frac{q}{12}}\}$, satisfying the first-order condition $\theta = 2\tilde{q}_o - \frac{1}{2} \sqrt{1 + \frac{12}{\theta - c}} + c$, then $\tilde{q}_o > \frac{1}{2}$ follows directly from the assumptions that $\theta \geq 1 + c$. Thus, it reduces to show that $(\tilde{q}_o - \frac{1}{2} \sqrt{1 + \frac{12}{\theta - c}})q_o + \sqrt{\frac{9}{12} q_o} > \frac{1}{4} (2\tilde{q}_o - \frac{1}{2} \sqrt{1 + \frac{12}{\theta - c}})^2 + \frac{1}{12}$, which can be simplified as $\sqrt{\frac{9}{12} q_o} > \frac{1}{192q_o} + \frac{1}{12}$. This inequality holds because the left hand side is larger than $\frac{\sqrt{9}}{12}$ and the right hand side is less than $\frac{3}{2}$.

Finally, it follows from the Taxation Principle that the optimal menu $\{q^*(\theta), t^*(\theta)\}$ can be equivalently implemented by offering the retailer a payment schedule $T^*(q) = t^*(\theta^*(q))$, where $\theta^*(q)$ is the inverse function of $q^*(\theta)$, i.e., $\theta^*(q) = (2q + c + \theta + 1)/2$. Clearly, $dT^*(q)/dq = \theta^*(q) - 2q = (c + \theta + 1)/2 - q$, which implies that $d^2T^*(q)/dq^2 < 0$ and thus the optimal payment schedule $T^*(q)$ is a quantity discount.

Proposition 1 conveys the following core message: The quantity discount contract, which has been shown by the extant literature to be effective in tailoring quantity-payment to retailers with private and distinct demand information, is also effective in incentivizing the retailer to acquire demand information in the first place. In particular, the supplier’s optimal contract inducing information acquisition is independent of the retailer’s information acquisition cost $k$, implying that the quantity discount contract that maximizes the supplier’s profits under the setting with exogenous information acquisition (i.e., $k = 0$) remains to be optimal under the setting with endogenous information acquisition (i.e., $k \leq K$). The intuition for such a robustness result of quantity discounts can be seen from the following explanations as to how the quantity discount contract incentivizes the retailer to acquire information.

Under the quantity discount contract, the retailer decides whether or not to acquire demand information by comparing two options. One is not to acquire demand information and simply orders the quantity $q^*(\theta + 1/2)$ corresponding to the mean of the market condition $\theta + 1/2$. The other option is to acquire demand information and then choose the order quantity $q^*(\theta)$ corresponding to the observed market condition $\theta$. The observed market condition can be divided into two classes. One is the favorable demand outcome (i.e., $\theta > \theta + 1/2$) and the other is the unfavorable demand outcome (i.e., $\theta < \theta + 1/2$). On one hand, when the retailer observes a favorable demand outcome, the retailer can increase the order quantity by paying a low marginal cost due to quantity discounts relative to the option of not acquiring demand information. Further, the incremental order quantity allows the favorable-outcome-observed retailer to satisfy more demand relative to the option of not acquiring demand information. The higher sales revenue, together with the lower incremental purchase cost, results in higher profits for the favorable-outcome-observed retailer. On the other hand, when the retailer observes an unfavorable demand outcome, the retailer can reduce the order quantity by saving large purchase costs due to quantity discounts relative to the option of not acquiring demand information, not hurting the sales revenue due to the limited demand. In either case, the profit increase for the retailer acquiring demand information is significant relative to the retailer not acquiring demand.
information. The concavity of the payment scheme is the key driver to achieve the significant value of demand information for the retailer. In contrast, under a convex (or linear) payment scheme, the value of demand information for the retailer is less significant.

Our analytical result, together with the intuitive explanations, reveals a novel feature of quantity discounts that has not been recognized in the literature on quantity discounts. That is, quantity discounts are effective in incentivizing the retailer to acquire demand information in the first place.

Our finding, however, is in sharp contrast with the result from the literature on endogenous production cost information acquisition. In particular, Crémér et al. [5] show that the optimality of quantity discounts fails to hold under the setting with endogenous production cost information acquisition. Such a contrast is caused by the source of information asymmetry. It can be explained by observing that quantity discounts are weak in incentivizing the supplier to acquire production cost information. Specifically, by acquiring the production cost information, the low-cost-observed supplier increases the quantity but only to receive a low incremental payment from the retailer due to quantity discounts; the high-cost-observed supplier reduces the quantity with a large drop in retailer’s payment due to quantity discounts. Unlike the strong incentives for retailer to acquire demand information, quantity discounts do not do as well in incentivizing the supplier to acquire production cost information. Therefore, the robustness of optimality of quantity discounts from exogenous information acquisition to endogenous information acquisition holds for demand information acquisition but not for production cost information acquisition.

Finally, as evidence that our core message is not driven by the uniform distribution assumption on the market condition, our extensive numerical study on other commonly used distributions (such as normal, exponential, etc) is consistent with our analytical result that the optimality of quantity discounts continues to hold.

4 Conclusions

This paper studies the supplier’s optimal contracts when the retailer can acquire demand information by exerting a fixed information acquisition cost. We show that quantity discounts are effective not only in eliciting the retailer’s private demand information but also in incentivizing the retailer to acquire such demand information. The robustness result of the optimality of quantity discounts complements the extant literature that established the optimality of quantity discounts in settings with exogenous information acquisition. Our robustness result stands in contrast with the literature on endogenous production cost information acquisition. Such a contrast emerges due to the source of information asymmetry, implying that quantity discounts are effective in incentivizing the retailer to acquire demand information, but not so for the supplier to acquire production cost information.

References


