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Revenue Sharing and Information Leakage in a Supply Chain

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This work explores the potential of revenue-sharing contracts to facilitate information sharing in a supply chain and mitigate the negative effects of information leakage. We consider a supplier who offers a revenue-sharing contract to two competing retailers, one of whom has private information about uncertain market potential and orders first. This order information may be leaked to the uninformed retailer by the supplier to realize higher profits. We show that the incentives of the supplier and retailers are better aligned under a revenue-sharing contract, as opposed to under a wholesale-price contract, reducing the supplier's incentive to leak. This is true for a wide range of wholesale prices and revenue-share percentages and is more likely when the revenue-share percentage is higher and when variation in demand is greater. Preventing information leakage may result in higher profits not only for the informed retailer and supplier but surprisingly even for the uninformed retailer. Our results are robust when the model is generalized along various dimensions.

Key words: games-group decisions; game theory and bargaining theory; supply chain management; information asymmetry
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1. Introduction

Advances in information technology have had a dramatic impact on the ability of firms in a supply chain to share information, and numerous firms have taken advantage of these advances. Greater collaboration between firms in a supply chain has resulted in initiatives such as Collaborative Planning, Forecasting, and Replenishment (CPFR), in which well-known manufacturers such as Procter & Gamble and Black & Decker as well as major retailers such as Home Depot and Walmart have participated. But a major challenge has been the reluctance of some firms to share information vertically with suppliers because of the fear of leakage of this information to their competitors. In this case, the benefits of information sharing are not realized and all the parties in the supply chain may be worse off. Wisner et al. (2008, p. 162) point out that "retailers are reluctant to share the type of proprietary information required by CPFR." Adewole (2005, p. 359) points out that retailers in the UK clothing industry are "reluctant to share information with suppliers, recognizing that those suppliers might also be supplying competitors and could wittingly or unwittingly divulge sensitive information." Anand and Goyal (2009) provided several other examples of information leakage and evidence of firms' reluctance to share information. Several recent academic works have explored the issues of information sharing, distortion, and leakage in a strategic context. Many of these works, such as Li and Zhang (2008), show that firms competing with each other will be reluctant to share information vertically with a supplier for fear of leakage. Anand and Goyal (2009) show that a supplier will always leak information from an informed retailer to an uninformed one under a wholesale-price regime.

The issue of information sharing and leakage is most salient when the information is valuable, and demand information is often particularly valuable in a supply chain. One retailer may have a considerable advantage over others in access to or in acquiring demand information, and the retailer can exploit this informational advantage, for instance by producing and selling more if demand is likely to be higher and thus achieving higher revenues. A toy retailer may be popular with young mothers and may be able to identify market trends earlier than, say, discount or mass market retailers selling toys. The same may be true for a retailer selling computers, video games, or other products exclusively. A retailer may be able to exploit this informational advantage only with the cooperation of the supplier who manufactures the product. But the advantage may dissipate if the common supplier leaks the demand information or an equivalent signal to a competitor. The supplier also derives several benefits from advance information such as the ability to better plan capacity or inventory levels and achieve better service levels. Although we have framed our discussion in terms of retailers sharing information with a supplier, the same issues are salient in the context of a manufacturer sharing information with the supplier of, say, a critical part.

Our goal in this work is to explore the potential of revenue-sharing contracts to facilitate information sharing in a supply chain without the negative effects of information leakage. Thus, the paper bridges and makes a contribution to two streams of research in operations management that have been fairly disparate: (1) contracting mechanisms and (2) information leakage in a supply chain. There have been numerous papers on contracting mechanisms, including revenue-sharing contracts that can help coordinate a supply chain. There have been fewer works on information leakage in a supply chain. Although the role of revenue sharing in coordinating a supply chain is well known, their potential in mitigating the harmful effects of information leakage (or the threat thereof) on firm and channel profits has not been explored.

In particular, we consider a stylized supply chain with one supplier selling to two retailers who compete for customers. One of these retailers (the incumbent) is privy to private information about market potential and places an order based on this information. The supplier may leak this information to the second retailer (the entrant) if it benefits her, and in turn this would impact the order quantity placed by the first retailer. The two retailers engage in Cournot competition; i.e., they sell in a market where the price is a decreasing function of their cumulative order quantities. Anand and Goyal (2009) analyzed an identical scenario and showed that the supplier will always leak information under a wholesale-price contract. The information leakage may result in a less efficient supply chain with lower profits potentially for all parties. If the supplier can make a credible commitment not to leak, the supplier might benefit from it. So we consider what would happen if the supplier uses a revenue-sharing contract wherein she sells the product to the two retailers at a possibly lower wholesale price but also receives a share of the retail revenue. Revenue-sharing contracts are common in several industries including entertainment (see Rentrak.com), sports leagues, software (Drkarlpopp.com), laser-based devices used in plastic surgery (Frentzen 2010), and consumer goods in India (Livemint.com 2009). The site Techagreements.com provides specific examples of revenue-sharing agreements in several industries. We explore the potential of a revenue-sharing contract to reduce the supplier's incentive to leak information and the impact of such a contract on the decisions and profits of the supplier and retailers in the supply chain.

Our analysis reveals that a revenue-sharing contract leads to many interesting effects on the actions and profits of the supplier and retailers. First, we show that a revenue-sharing contract reduces a supplier's incentive to leak demand information and there exist many combinations of wholesale price and revenue-share percentage under which the supplier will not leak. Second, preventing information leakage may result in higher profits for both the incumbent and supplier relative to a scenario where the supplier leaks information—and, interestingly, even the entrant may be better off sometimes. Third, we show that nonleakage is more likely when the supplier's revenue-share percentage is relatively high and when the demand variation is greater. Finally, we show that our conclusions are robust when some of the model assumptions are relaxed or altered. Overall, the incentives of the supplier and retailers are better aligned under revenue sharing: the supplier is no longer trying to push product under all circumstances as in a wholesale-price contract, and a noncooperative "partnership" is achieved between the supplier and retailers.

Although revenue-sharing contracts represent one approach to enabling information sharing in a supply chain, there are other enablers—for instance, the level of trust between parties can play a crucial role. In fact, Özer et al. (2011) show that trust and trustworthiness play a crucial role in sharing forecast information in the face of uncertainty and asymmetric information. They consider a supply chain in which a manufacturer has private information and has an incentive to exaggerate her demand forecast to a supplier, and they explore the role of trust and trustworthiness between supply chain partners using controlled laboratory experiments. Interestingly, they find that supply chain partners may share information truthfully without distortion even under a simple wholesale-price contract depending on their willingness to trust and the trustworthiness of their partner, contradicting the results of game-theoretic models, and provide an innovative model that incorporates trust. Although we do not model trust and trustworthiness, which are important elements, we provide mechanisms to faciltate information sharing even when parties do not necessarily trust each other.

2. Review of Literature

There are several streams of research that have explored the role of information sharing in supply chains. Early work on information sharing, primarily in the economics literature, studied the incentives for sharing information in oligopoly markets; some examples are Gal-Or (1985), Vives (1984), Li (1985), and Raith (1996). In the operations area, the initial stream of research focused on the value of information sharing in improving supply chain decisions and supply chain efficiency. Lee and Whang (2000) provide numerous examples of firms in a supply chain that benefit from sharing demand and forecast information, but they point out, based on an empirical study, that the benefits of sharing information may vary greatly among the different parties in a supply chain. They suggest that vertical information sharing usually leads to horizontal information leakage, which in turn can be a serious deterrent to sharing information. Chen (2003) surveys various models in the literature that quantify the value of information sharing arising from reduction of inventories, alleviation of the bullwhip effect, etc., but these models do not consider strategic issues related to information sharing and leakage, which is our focus. Our work does not explicitly consider the direct benefits of information sharing but focuses on the potential of revenue-sharing contracts to mitigate the possible negative effects of information sharing. So the supply chain would be even better off if the benefits of information sharing were incorporated.

A more recent stream of research has focused on vertical information sharing between two supply chain partners, one of whom may be better informed about some key element such as demand or capacity and has an incentive to be strategic in sharing information. Özer and Wei (2006) show that a wholesale-price contract can result in distortion of demand forecast information and an appropriately designed contract can achieve credible information sharing and channel coordination between a manufacturer and its supplier. Mishra et al. (2007) show that a profit margin sharing agreement can facilitate information sharing and make both parties better off in a one-retailer one-manufacturer supply chain. Oh and Özer (2012) show how a supplier can elicit credible demand information from its customer and how forecasts evolve in a multiperiod setting with asymmetric information. Even though these papers analyze a supply chain in an asymmetric information setting, they do not consider either information leakage or horizontal competition, which is our focus.

Ha and Tong (2008) consider the problem of vertical information sharing between a manufacturer and its retailer when there are two competing supply chains and emphasize the importance of contract type in inducing information sharing. In follow-up work, Ha et al. (2011) consider two competing supply chains and show when information sharing can benefit a supply chain under both Bertrand and Cournot competition. Shin and Tunca (2010) show that retailers may overinvest in improving their forecasts when there is more intense retail competition and greater demand uncertainty under wholesale-price or two-part tariff contracts and suggest alternative contracts that can mitigate these problems and improve supply chain efficiency. But these works do not consider information leakage issues.

Another stream of research considers vertical information sharing when there is horizontal competition along with information leakage. Li (2002) and Zhang (2002) consider a model with one supplier supplying retailers who compete by offering substitute products. Both works suggest that retailers will not share private demand information voluntarily with the supplier, and Zhang (2002) suggests that they will need special incentives to do so. Li and Zhang (2008) also consider a similar supply chain and explore the effects of information leakage. They assume that information leakage is through the supplier's observable behavior as a response to the information shared by a retailer. Jain et al. (2011) consider an identical setup and develop pricing mechansims that will induce truthful information sharing by all parties. However, in these works, firms decide their information revelation behavior before receiving the private information; moreover, the supplier has the information, if shared, before making its pricing decision. We adopt a different approach, similar to that of Anand and Goyal (2009) in terms of when information becomes available to the supplier. Although they show that information leakage by the supplier always occurs under wholesale-price contracts, we demonstrate that information can be protected by a properly designed revenue-sharing contract.

The final stream of research related to our work is on revenue-sharing contracts, which have been shown to be an effective tool in aligning firms' incentives by inducing appropriate behavior in a supply chain. Mortimer (2008) shows that revenue-sharing contracts have improved the profits of firms in the supply chain and social welfare in the video rental industry. Cachon (2003) shows that revenue-sharing contracts achieve coordination in a one-supplier one-retailer supply chain. Dana and Spier (2001), Cachon and Lariviere (2005), and Yao et al. (2008) consider downstream competition and show that a revenue-sharing contract is a powerful tool in coordinating a supply chain with competing retailers. Although these papers study downstream competition in the face of uncertain demand, they assume that the demand information is "symmetric" among downstream retailers—either every retailer only knows the common distribution of demand or they know their own demand but their demands are independent. As a result, the revenue-sharing-contract literature has not considered the effects of information leakage in a supply chain, unlike in our work.

3. Model Framework

The basic framework of the model is similar to that in Anand and Goyal (2009). We discuss some important features of the model below for the reader's convenience. We consider a supply chain with one upstream supplier serving two competing retailers (or two manufacturers selling directly to consumers), an *incumbent* retailer and an *entrant* retailer. The retailers compete in a market characterized by demand uncertainty. The supplier, the incumbent, and the entrant are indexed by s, i, and e, respectively. All firms are risk neutral and aim to maximize their own expected profits. We study a dynamic game among the three players under incomplete information (Gibbons 1992).

3.1. Demand Information

The incumbent and the entrant engage in a Cournot competition, i.e., compete on quantity. The market clearing price is given by $P = A - Q$, where $Q = q_i + q_e$ is the total supply in the market, and q_i and q_e are the incumbent's and entrant's order quantities, respectively. We assume that the intercept A of the (linear) inverse demand function is uncertain, which takes the value A_H with probability $p \in (0,1)$ and A_L with probability $1-p$, for some $A_H > A_L > 0$. We denote the mean demand potential by $\mu = pA_H + (1-p)A_L$. The distribution of A is common knowledge to all parties, yet only the incumbent knows the exact value of A, which will be referred to as the "demand information" or "demand state" throughout this paper. This assumption is motivated by the observation that a retailer who has been in a market long enough often has an advantage over a retailer that has entered recently or an upstream supplier in acquiring market information. This is why we refer to the retailer with private information on A as the *incumbent*.

3.2. Revenue-Sharing Contract

We assume that the transactions between the supplier and the retailers are governed by a revenue-sharing contract. This represents a crucial difference between our model and that of Anand and Goyal (2009), who consider a wholesale-price contract. Under the latter contract, a retailer pays a wholesale price w for each unit purchased from the supplier. Under a revenue-sharing contract, a retailer not only pays a wholesale price for each unit purchased but also shares part of the revenue with the supplier at a certain rate α. In this work, we explore whether a revenue-sharing contract affects the supplier's incentive to leak the information obtained from the incumbent retailer. Because a wholesale-price contract is a special case of a revenue-sharing contract with the revenue-sharing rate $\alpha = 0$, this study also generalizes the results of Anand and Goyal (2009) and provides broader managerial insights.

Under a revenue-sharing contract, denoted by (α, w), if the marginal supply cost is normalized to zero (without loss of generality), the supplier's profit is given by

$$\pi_s = w(q_i + q_e) + \alpha(q_i + q_e)P, \tag{1}$$

where the first term is the supplier's payment from selling the product at the wholesale price w, and the second term is her share of the retail revenue. The incumbent's and the entrant's profits are

$$\pi_i = (1-\alpha)q_i P - wq_i = (1-\alpha)\left(P - \frac{w}{1-\alpha}\right)q_i \quad \text{and}$$

$$\pi_e = (1-\alpha)q_e P - wq_e = (1-\alpha)\left(P - \frac{w}{1-\alpha}\right)q_e,$$

respectively. We assume that the retailers bring to market their entire order quantities. No free disposal is assumed in other work in the literature—e.g., Anand and Goyal (2009), Ha and Tong (2008), Li (2002)—and one does not observe significant deliberate disposal of products such as toys, computers, etc. in practice. We will relax this assumption in §7.1.

3.3. Sequence of Events

The following events take place in sequence. (1) The supplier offers a revenue-sharing contract, consisting of a wholesale price w and a revenue-sharing rate α. (2) The incumbent observes the actual demand state A, which is either A_H (high) or A_L (low). (3) The incumbent places an order q_i to the supplier. (4) The supplier may leak the incumbent's order quantity to the entrant. (5) The entrant places an order q_e to the supplier. (6) The demand state A is revealed to all parties, the market price is determined by $P = A - q_i - q_e$, and the profit for each player is realized. In this paper, we will initially focus on the situation where the wholesale price w and revenue-sharing rate α are exogenously given (§§4 and 5) and later allow the supplier to optimally choose w for any given α (§6). We do not consider the situation where the supplier selects both α and w, because her optimal choice would be $\alpha = 1$ and $w = 0$, which is not particularly interesting or realistic (see Footnote 7 for more details).

3.4. Players' Incentives and Decisions

Next, we discuss the players' decisions in the game and, in particular, how the supplier's decision on information leakage would impact the decisions and profits of the two retailers.

Supplier. A major decision faced by the supplier is whether or not to leak the incumbent's order quantity to the entrant. Anand and Goyal (2009) show that the supplier always benefits from leaking under a wholesale-price contract. However, as will be discussed in the next section, information leakage not only reduces the incumbent's profit but also may hurt the supplier, and if the supplier can make a credible commitment not to leak, both parties may benefit. Thus, we assume that the supplier can communicate to the incumbent whether or not she intends to leak the incumbent's order quantity to the entrant, which is credible if the supplier can make a higher profit with the intended action. Our question is whether there exists a revenue-sharing contract under which the supplier will not leak the incumbent's order information. To focus on the main issue, we assume that the supplier has unlimited capacity and that she may not lie about the incumbent's order quantity when she leaks it.[1]

Incumbent. The incumbent's decision in the game is his order quantity and he plays a signaling game with the supplier and the entrant. Because the incumbent has access to the private demand information, the order placed by the incumbent would naturally reflect this information. However, because the incumbent realizes that the supplier may leak this information to the entrant, the incumbent will be strategic when placing the order. Specifically, the incumbent may distort his order quantity, which may negatively impact all the parties in the supply chain.

Entrant. The entrant's only decision in the game is also his order quantity. Nevertheless, the entrant plays a passive role compared to the incumbent and makes his decision based on the supplier's leakage decision and the incumbent's order decision. The type of game played between the entrant and the incumbent is determined by the supplier's leakage decision: if the supplier does not leak information, the two retailers play a simultaneous game; if the supplier leaks, the retailers play a Stackelberg game in which the incumbent is the leader and the entrant is the follower. We consider games with alternative sequences of moves in §7.

4. Benchmark Analysis

In this section, we consider benchmark scenarios in which the order quantities and profits of the players are determined *given* the supplier's leakage decision. Section 4.1 discusses the case in which the supplier never leaks information, and §4.2 considers the scenario in which the supplier always leaks. We also study the supplier's first-best scenario in §4.3, assuming that the supplier can control the total order quantity in the channel. The benchmark analysis will be helpful in deriving and understanding the nonleakage equilibrium in subsequent sections. Our analysis in §§4.1 and 4.2 is similar to that in Anand and Goyal (2009) except that we are considering a revenue-sharing contract instead of a wholesale-price contract. Propositions 1 and 2 in these subsections can be proved in the same way as in Anand and Goyal (2009), by replacing A_H and A_L with $A_H - w/(1-\alpha)$ and $A_L - w/(1-\alpha)$, respectively; thus, the proofs are omitted for brevity. The proofs for all subsequent results in this paper are available from the authors or online appendices at http://ssrn.com/abstract=2033619.

The notational scheme used for order quantities and profits is as follows. In general, q_{ad}^{E*} and π_{ad}^{E*} denote the order quantity and profit, respectively, of player a in equilibrium (or game) E given demand state d: a can be i (incumbent), e (entrant), or s (supplier); E can be N (nonleakage), S (separating leakage), or P (pooling leakage); and d can be H (high) or L (low). For example, q_{iH}^{N*} denotes the incumbent's order quantity in a nonleakage equilibrium when the demand is high. The subscript d may be absent when a nonleakage or pooling (leakage) equilibrium is considered, as in q_e^{N*} and π_s^{P*}. Additional notation will be introduced later.

4.1. Benchmark: Supplier Never Leaks

We first consider the situation in which the supplier can make a credible commitment not to leak the incumbent's order quantity to the entrant. Because neither retailer knows the other retailer's order quantity, the game between the incumbent and the entrant is a simultaneous-move game, and we have the following result.

Proposition 1. *Suppose that the supplier can credibly commit in advance not to leak the incumbent's order information. If $w/\mu \le (1/2)(3A_L/\mu - 1)(1-\alpha)$, the high-type incumbent will order $q_{iH}^{N*} = (1/2)A_H - (1/6)\mu - (1/3)w/(1-\alpha)$, the low-type incumbent will order $q_{iL}^{N*} = (1/2)A_L - (1/6)\mu - (1/3)w/(1-\alpha)$, and the entrant will order $q_e^{N*} = (1/3)(\mu - w/(1-\alpha))$ in both demand states.*

Under nonleakage, the incumbent's order quantity depends on the demand state, whereas the entrant's order quantity only depends on the mean demand. Intuitively, if the supplier can make a credible commitment not to leak, the incumbent will place an order that truthfully reveals the demand state to the supplier. In other words, vertical information sharing is enabled, whereas horizontal information leakage is prevented (Li 2002). Note that nonleakage is *assumed* in this benchmark, whereas in §5, when we analyze the sustainability of the nonleakage equilibrium under various revenue-sharing contracts, nonleakage will be the supplier's *equilibrium decision*.

The *participation constraint* $w/\mu \le (1/2)(3A_L/\mu - 1) \cdot (1-\alpha)$ is equivalent to $q_{iL}^{N*} \ge 0$, which implies $q_{iH}^{N*} \ge 0$ and $q_e^{N*} \ge 0$. Because the entrant places the same order

[1] In our model, the incumbent's order quantity is fully revealed to the entrant through their competition and the market price. Thus, the supplier's misrepresentation of the incumbent's order can be verified by the entrant, whereas information leakage is difficult to verify (by the incumbent) and arguably poses a more severe incentive problem in the situation we study.

in both demand states under nonleakage, it is harder to guarantee the incumbent's participation and maintain a positive market price when the demand is low.

4.2. Benchmark: Supplier Always Leaks

Next we consider the case in which the supplier always leaks the incumbent's order quantity to the entrant. In such a case, when placing the order, the incumbent would take into account the entrant's updated belief of the demand state and corresponding action after learning the incumbent's order. As is common in the literature, we study two types of pure strategy perfect Bayesian equilibria—the separating equilibrium and the pooling equilibrium.

4.2.1. Separating Equilibrium. In a separating equilibrium, the incumbent orders different quantities in the two demand states, and the entrant can infer the demand information from the incumbent's order. The entrant believes that the demand is low if the incumbent's order q_i is low enough and that the demand is high otherwise. Denote the low-type incumbent's order quantity in equilibrium by q_{iL}^{S*} and that of the high type by $q_{iH}^{S*} (> q_{iL}^{S*})$. Suppose that, as in Anand and Goyal (2009), the entrant's belief is

$$\Pr_e(A = A_H) = \begin{cases} 0 & \text{if the supplier leaks and } q_i \le q_{iL}^{S*}, \\ 1 & \text{if the supplier leaks and } q_i > q_{iL}^{S*}. \end{cases} \quad (2)$$

The main incentive issue here is that the high-type incumbent is tempted to signal a low demand (i.e., pretend to be a low type) in hoping that the entrant orders less. Thus, the separating equilibrium requires that (i) it is valuable for the low-type incumbent to separate and (ii) it is too costly for the high-type incumbent to pool with the low type. We have the following result.

Proposition 2. *Define*

$$\theta = \frac{A_H - w/(1-\alpha)}{A_L - w/(1-\alpha)}.$$

Suppose the supplier always leaks the incumbent's order quantity to the entrant and the entrant's belief about the demand is given by (2). *Then the following separating equilibrium exists*: (i) *The incumbent orders* $q_{iH}^{S*} = (1/2)(A_H - w/(1-\alpha))$ *if the demand is high and*

$$q_{iL}^{S*} = \begin{cases} q_{iL}^{S1*} \triangleq \dfrac{1}{2}\left(A_L - \dfrac{w}{1-\alpha}\right) & \text{if } \theta \ge 3, \\ q_{iL}^{S2*} \triangleq A_H - \dfrac{A_L}{2} - \dfrac{1}{2}\dfrac{w}{1-\alpha} \\ \quad - \sqrt{\left(A_H - \dfrac{A_L}{2} - \dfrac{w}{2(1-\alpha)}\right)^2 - \dfrac{1}{4}\left(A_H - \dfrac{w}{1-\alpha}\right)^2} & \text{if } \theta < 3 \end{cases} \quad (3)$$

if the demand is low. (ii) *The entrant orders* $q_{eH}^{S*} = (1/4)(A_H - w/(1-\alpha))$ *if* $\Pr_e(A = A_H) = 1$ *and*

$$q_{eL}^{S*} = \begin{cases} \dfrac{1}{4}\left(A_L - \dfrac{w}{1-\alpha}\right) & \text{if } \theta \ge 3, \\ \dfrac{3}{4}A_L - \dfrac{A_H}{2} - \dfrac{1}{4}\dfrac{w}{1-\alpha} \\ \quad + \dfrac{1}{2}\sqrt{\left(A_H - \dfrac{A_L}{2} - \dfrac{w}{2(1-\alpha)}\right)^2 - \dfrac{1}{4}\left(A_H - \dfrac{w}{1-\alpha}\right)^2} & \text{if } \theta < 3 \end{cases}$$

if $\Pr_e(A = A_H) = 0$.

It can be shown that in a sequential-move (Stackelberg) game under perfect information (i.e., the demand is public information and the incumbent is the Stackelberg leader), the incumbent's order quantity under a revenue-sharing contract (α, w) is $(1/2)(A_H - w/(1-\alpha))$ or $(1/2)(A_L - w/(1-\alpha))$, depending on the demand state. We observe that when the demand is high, the incumbent's order quantity in the separating equilibrium q_{iH}^{S*} is the same as the one in the perfect information game; however, when the demand is low, his order quantity q_{iL}^{S*} depends on θ. Note that θ measures the relative variation in demand from the retailers' point of view and under a given contract (α, w). If $\theta \ge 3$, q_{iL}^{S*} is still equal to the order quantity under perfect information; in this case, the high- and low-demand states are far apart, so the low-type incumbent separates out at no cost. Whereas if $\theta < 3$, q_{iL}^{S*} is strictly less than $(1/2)(A_L - w/(1-\alpha))$; in this case, because the two demand states are relatively close, the low-type incumbent has to order less to prevent the high-type incumbent from mimicking. Thus, one consequence of the supplier's leakage behavior is the downward distortion inflicted on the low-type incumbent. The supplier's leakage behavior may have a negative impact on herself as well because she sells less to the incumbent when the demand is low. Therefore, the total supply chain profit may fall because of information leakage.

We note that the incumbent would participate in the separating leakage game in both demand states if the contract parameters satisfy $w/\mu \le (A_L/\mu) \cdot (1-\alpha)$, which is implied by the participation constraint in the nonleakage case. The entrant would participate as long as the incumbent does.

4.2.2. Pooling Equilibrium. In a pooling equilibrium, the incumbent's order quantity is independent of the demand, and hence the entrant cannot infer the demand state from it and would not update his belief. A pooling equilibrium differs from a nonleakage equilibrium even though the entrant retains the same belief in both cases. In a nonleakage equilibrium, the entrant has to guess the incumbent's order quantity and they effectively play a simultaneous-move game, whereas in a pooling equilibrium, the entrant makes his best response to the incumbent's order and they play a sequential-move game. In the rest of this paper, we ignore pooling because a pooling equilibrium does not exist in a fairly general situation and even when it exists the incumbent may be better off playing a nonleakage game. Intuitively, pooling does not exist when demand variation is high and is likely to be dominated by nonleakage when demand variation is smaller. A detailed discussion is provided in Online Appendix B.

4.3. Benchmark: Supplier's First-Best Scenario

The supplier's profit under a given revenue-sharing contract is determined by the total order quantity in the channel, $Q = q_i + q_e$, whether in a leakage or nonleakage game. It would be revealing to compare the channel quantities in those benchmark cases with the one in the *supplier's first-best scenario* in which the supplier has perfect information and can control the channel quantity. We call the optimal Q in the latter setting the *supplier's first-best channel quantity*, denoted by $Q_H^{FB} = \arg\max_Q\{wQ + \alpha Q(A_H - Q)\}$ when the demand is high and $Q_L^{FB} = \arg\max_Q\{wQ + \alpha Q(A_L - Q)\}$ when the demand is low. We identify the quantity distortion from the first-best values in both leakage and nonleakage equilibria.

Proposition 3. (i) *The supplier's first-best channel quantity is* $Q_H^{FB} = (1/2)A_H + (1/2)(w/\alpha)$ *when the demand is high or* $Q_L^{FB} = (1/2)A_L + (1/2)(w/\alpha)$ *when the demand is low.*

(ii) *Under a nonleakage Cournot competition, in both demand states, the retailers as a whole underorder (i.e.,* $Q_H^{N*} < Q_H^{FB}$ *and* $Q_L^{N*} < Q_L^{FB}$*) if* $w/\mu > \alpha(1-\alpha)/(3+\alpha)$*, overorder (i.e.,* $Q_H^{N*} > Q_H^{FB}$ *and* $Q_L^{N*} > Q_L^{FB}$*) if* $w/\mu < \alpha(1-\alpha)/(3+\alpha)$*, and perfectly align with the supplier's objective if* $w/\mu = \alpha(1-\alpha)/(3+\alpha)$.

(iii) *Let* $UB_N = (\alpha(1-\alpha)/(2+\alpha))(A_H/\mu)$ *and*

$$LB_N = \begin{cases} \dfrac{\alpha(1-\alpha)}{2+\alpha}\dfrac{A_L}{\mu} & \text{if } \theta \geq 3, \\[2ex] \dfrac{w}{\mu} \text{ such that } Q_L^{S2*} = Q_L^{FB} & \text{if } \theta < 3, \end{cases}$$

where

$$Q_L^{S2*} = q_{iL}^{S2*} + \frac{1}{2}\left(A_L - q_{iL}^{S2*} - \frac{w}{1-\alpha}\right).$$

Under a leakage Cournot competition with the incumbent being the Stackelberg leader, the retailers as a whole underorder if $w/\mu > UB_N$*, overorder if* $w/\mu < LB_N$*, and underorder (overorder) when the demand is low (high) if* $LB_N \leq w/\mu \leq UB_N$.

In the next section, we allow the supplier to decide whether or not to leak the incumbent's order information and show that the nonleakage equilibrium exists under certain revenue-sharing contracts.

5. Nonleakage Equilibria

Under a wholesale-price contract, as shown in Anand and Goyal (2009), the supplier always benefits from leaking the incumbent's order quantity. Because a larger order translates into higher profit for the supplier, the supplier would always like to inform the entrant when the demand is high. This is no longer true under a revenue-sharing contract, where a larger quantity is not always better. As shown in Proposition 3, in the separating (leakage) case, the downstream retailers together may underorder when the demand is low and overorder when the demand is high, compared with the supplier's first-best quantity. This type of quantity distortion may be mitigated in both demand states simultaneously if the supplier does not pass the demand information to the entrant so that the entrant has to order an intermediate quantity, aimed at the average demand. Thus, the supplier may benefit from nonleakage in both demand states.

In this section, we first show the existence of the nonleakage equilibrium under a given revenue-sharing contract (α, w) and then characterize the set of α and w that sustains such an equilibrium. We assume that in the leakage case the demand state can be inferred from the incumbent's order quantity. Ignoring the pooling equilibria is justified in Online Appendix B.

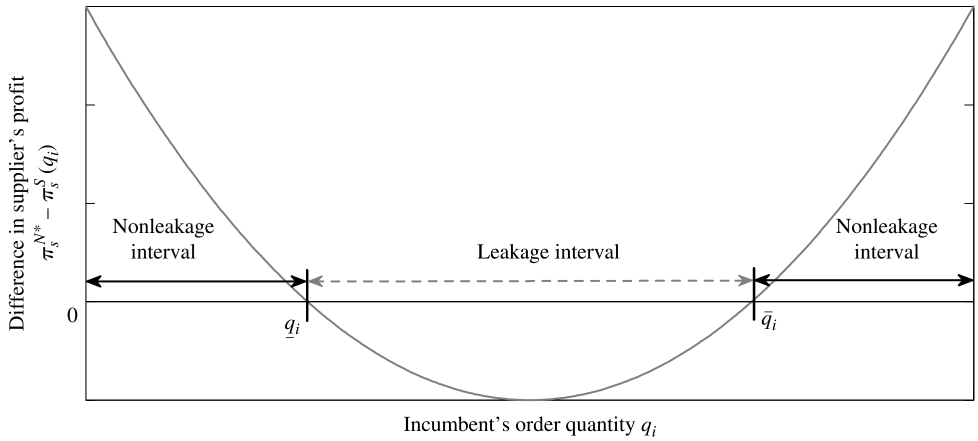
5.1. Existence of the Nonleakage Equilibrium

We first consider the supplier's incentive compatibility with nonleakage and then the incumbent's, from which we establish the existence of the nonleakage equilibrium under a given (α, w). Finally, we present a numerical example to demonstrate how a revenue-sharing contract can prevent information leakage.

5.1.1. Supplier's Incentive Compatibility with Nonleakage. In contrast to the benchmark cases considered in §4, the supplier's leakage choice is now her endogenous decision. For the nonleakage option to prevail, the supplier must make a higher profit in both demand states under nonleakage. If, say, the supplier only benefits from nonleakage when the demand is low and hence she only leaks the information when the demand is high, the entrant can still infer the demand state (low) when the information is concealed by the supplier. Thus, the supplier would like (and is able) to commit not to leak the incumbent's order information if the following conditions hold, given the incumbent's order quantities q_{iH} and q_{iL}:

$$\pi_{sH}^S(q_{iH}) \leq \pi_{sH}^{N^*} \quad \text{and} \quad \pi_{sL}^S(q_{iL}) \leq \pi_{sL}^{N^*}, \tag{4}$$

Figure 1 Supplier's Relative Profit Gain from the Nonleakage Equilibrium, in Either Demand State



where $\pi_{sH}^{N^*}$ and $\pi_{sL}^{N^*}$ are the supplier's profits in the nonleakage equilibrium in the high- and low-demand states, respectively, and $\pi_{sH}^S(q_{iH})$ and $\pi_{sL}^S(q_{iL})$ are the supplier's profits under leakage.[2] More specifically, $\pi_{sH}^{N^*}$ and $\pi_{sL}^{N^*}$ can be derived from Proposition 1 and Equation (1), and

$$\begin{aligned}\pi_{sH}^S(q_{iH}) &= w(q_{iH} + q_e^*(q_{iH})) \\ &\quad + \alpha(q_{iH} + q_e^*(q_{iH}))(A_H - q_{iH} - q_e^*(q_{iH})), \\ \pi_{sL}^S(q_{iL}) &= w(q_{iL} + q_e^*(q_{iL})) \\ &\quad + \alpha(q_{iL} + q_e^*(q_{iL}))(A_L - q_{iL} - q_e^*(q_{iL})),\end{aligned}$$

for $q_e^*(q_i)$

$$= \arg\max_{q_e} \begin{cases} (1-\alpha)q_e(A_L - q_i - q_e) - wq_e & \text{if } q_i \le q_{iL}^{S*}, \\ (1-\alpha)q_e(A_H - q_i - q_e) - wq_e & \text{if } q_i > q_{iL}^{S*}. \end{cases}$$

The constraints in (4) ensure that the supplier makes more profits under nonleakage in both demand scenarios, depending on the contract (α, w) and the incumbent's order quantity. The next result provides conditions for the supplier not to leak in terms of these variables.

Proposition 4. *Suppose the incumbent orders no more than q_{iL}^{S*} when the demand is low and more than q_{iL}^{S*} when the demand is high. In either demand state, the supplier prefers leaking the incumbent's order quantity q_i to playing the nonleakage equilibrium if and only if $q_i \in (\underline{q}_i, \bar{q}_i)$, where $\underline{q}_i = w/\alpha + w/(1-\alpha) - (1/3)|\mu - 3w/\alpha - 4w/(1-\alpha)|$, and $\bar{q}_i = w/\alpha + w/(1-\alpha) + (1/3)|\mu - 3w/\alpha - 4w/(1-\alpha)|$.*

The first assumption in the proposition guarantees that the entrant's belief is consistent with the incumbent's strategy should the incumbent's order quantity be leaked. We call $(\underline{q}_i, \bar{q}_i)$ the supplier's *leakage interval* and $[0, \underline{q}_i]$ and $[\bar{q}_i, \infty)$ the *nonleakage intervals*. The supplier's profit gains from nonleakage, $\pi_{sH}^{N^*} - \pi_{sH}^S(q_{iH})$ when the demand is high and $\pi_{sL}^{N^*} - \pi_{sL}^S(q_{iL})$ when it is low, happen to have the same functional form, illustrated by $\pi_s^{N^*} - \pi_s^S(q_i)$ in Figure 1. Thus, the leakage and nonleakage intervals depend solely on the contract (α, w) and the mean demand μ, not on the actual demand state. The function $\pi_s^{N^*} - \pi_s^S(q_i)$ always intersects the horizonal axis and its quadratic form leads to the thresholds $\underline{q}_i$ and $\bar{q}_i$. Notice that $\underline{q}_i$ and $\bar{q}_i$ can be rewritten as $\underline{q}_i = \min\{(1/3)(\mu - w/(1-\alpha)), 2w/\alpha + (7/3)w/(1-\alpha) - (1/3)\mu\}$ and $\bar{q}_i = \max\{(1/3)(\mu - w/(1-\alpha)), 2w/\alpha + (7/3)w/(1-\alpha) - (1/3)\mu\}$ and that $2w/\alpha + (7/3)w/(1-\alpha) - (1/3)\mu \le (1/3)(\mu - w/(1-\alpha))$ if and only if $w/\mu \le \alpha(1-\alpha)/(3+\alpha)$. In the special case $w/\mu = \alpha(1-\alpha)/(3+\alpha)$, we have $\underline{q}_i = \bar{q}_i$, and the leakage interval $(\underline{q}_i, \bar{q}_i)$ is empty, which confirms the result of Proposition 3(ii) that the channel quantity under nonleakage is first-best to the supplier in this situation. In all other cases, $\underline{q}_i < \bar{q}_i$.

5.1.2. Incumbent's Incentive Compatibility with Nonleakage. To support the nonleakage equilibrium, the incumbent's order quantities in the equilibrium in both demand states must lie in the supplier's nonleakage intervals, i.e., $q_{iH}^{N^*}, q_{iL}^{N^*} \in [0, \underline{q}_i] \cup [\bar{q}_i, \infty)$. There are four cases regarding the intervals in which $q_{iH}^{N^*}$ and $q_{iL}^{N^*}$ may fall. To reduce the number of cases and identify conditions that deter the incumbent's

[2] If the supplier does not leak the incumbent's order information, she can induce the nonleakage equilibrium and garner the profit $\pi_{sL}^{N^*}$ or $\pi_{sH}^{N^*}$. The incumbent's order quantity q_{iL} (or q_{iH}) other than $q_{iL}^{N^*}$ (or $q_{iH}^{N^*}$) will be off the Nash equilibrium path. Therefore, we compare the supplier's profit from leaking q_{iL} (or q_{iH}) with $\pi_{sL}^{N^*}$ (or $\pi_{sH}^{N^*}$). There are multiple ways for the supplier to make her nonleakage commitment credible. For example, if low demand is inferred, she can cap the incumbent's order quantity at $q_{iL}^{N^*}$ and make the profit $\pi_{sL}^{N^*}$. If the supplier cannot make a credible commitment, we may have to compare the supplier's profits from leaking and not leaking q_i directly. It can be shown that the nonleakage region characterized in Theorem 2 would shrink, but the main insights of the paper would be unchanged.

deviation into the supplier's leakage interval, we compare the incumbent's order quantities and profits under leakage and nonleakage.

Proposition 5. *The incumbent's order quantities and profits in the nonleakage and leakage (separating) equilibria satisfy* (i) $q_{iH}^{N^*} \le q_{iH}^{S^*}$ *and* $q_{iL}^{N^*} \le q_{iL}^{S^*}$, (ii) $q_{iH}^{N^*} \ge \underline{q}_i$ *and* $q_{iL}^{N^*} \le \bar{q}_i$, *and* (iii) $\pi_{iH}^{N^*} \ge \pi_{iH}^{S^*}$ *if and only if* $\theta \ge (1-p)/(3(1-\sqrt{2}/2)-p) \ge 0$.

According to part (i), the incumbent's order quantity is larger in the separating equilibrium in both demand scenarios because the incumbent has the first-mover advantage in a Stackelberg game. Part (ii) asserts that the incumbent's order quantity in the nonleakage equilibrium cannot be too low if the demand is high or too high if the demand is low, compared with the supplier's leakage thresholds. It leaves only one possible nonleakage case, i.e., $q_{iH}^{N^*} \ge \bar{q}_i$ and $q_{iL}^{N^*} \le \underline{q}_i$. Part (iii) shows that under a mild condition, when the demand is high, the incumbent's profit is higher in the nonleakage case, even though his order quantity is actually lower according to part (i). This is because when the demand is high the entrant's order quantity is much lower under nonleakage.

5.1.3. Existence of the Nonleakage Equilibrium. The following theorem presents a set of sufficient conditions and necessary ones for the existence of the nonleakage equilibrium.

Theorem 1. *Assume that*

$$\theta \ge \frac{1-p}{3(1-\sqrt{2}/2)-p} \ge 0$$

and

$$\frac{w}{\mu} \le \frac{1}{2}\left(\frac{3A_L}{\mu}-1\right)(1-\alpha).$$

A nonleakage equilibrium exists if $q_{iH}^{N^*} \ge \bar{q}_i$ *and* $q_{iL}^{S^*} \le \underline{q}_i$ *and only if*

$$\frac{w}{\mu} \le \left(\frac{3A_H}{\mu}+2\right)\frac{\alpha(1-\alpha)}{12+5\alpha}$$

and $q_{iL}^{S^*} \le \underline{q}_i$.[3]

The assumption $\theta \ge (1-p)/(3(1-\sqrt{2}/2)) - p$ ensures that the high-type incumbent prefers nonleakage to leakage and $w/\mu \le (1/2)(3A_L/\mu - 1)(1-\alpha)$ ensures $q_{iL}^{N^*} \ge 0$ and $q_{iH}^{N^*} \ge 0$.[4] The conditions $q_{iH}^{N^*} \ge \bar{q}_i$ and $q_{iL}^{S^*} \le \underline{q}_i$ are sufficient to ensure that the incumbent actually chooses $q_{iH}^{N^*}$ or $q_{iL}^{N^*}$ in the corresponding demand state and does not deviate into the supplier's leakage interval $(\underline{q}_i, \bar{q}_i)$. The low-type incumbent would not deviate if $(q_{iL}^{N^*} \le) q_{iL}^{S^*} \le \underline{q}_i$ because the entrant would then believe that the demand is high and place an order too large for the incumbent's liking. A necessary condition for nonleakage is that the channel quantity distortion (from the supplier's point of view) is milder under nonleakage than under leakage, which amounts to $q_{iL}^{S^*} \le \underline{q}_i$ in the low-demand scenario and $w/\mu \le (3A_H/\mu + 2) \cdot (\alpha(1-\alpha)/(12+5\alpha))$ in the high-demand one.

The above sufficient conditions and necessary ones differ by only one condition, $q_{iH}^{N^*} \ge \bar{q}_i$ versus $w/\mu \le (3A_H/\mu + 2)(\alpha(1-\alpha)/(12+5\alpha))$. The former condition is more restrictive than the latter is but the difference is small, as evident from the example illustrated in Figure 2(a). No revenue-sharing contract violating the necessary conditions can support a nonleakage equilibrium: when $w/\mu > (3A_H/\mu+2) \cdot (\alpha(1-\alpha)/(12+5\alpha))$, the supplier has the incentive to leak the high-demand information; when $q_{iL}^{S^*} > \underline{q}_i$, the supplier is tempted to leak the low-demand information. For robustness of the results, we will consider the sufficient conditions in the remainder of this paper.[5] Next, we illustrate with an example the nonleakage equilibrium under a given revenue-sharing contract.

Example 1. Assume that $A_H = 600$, $A_L = 300$, and $p = 0.3$. Thus, the inverse demand function is $P(Q) = 600 - Q$ with probability 0.3 or $300 - Q$ with probability 0.7, and the mean demand is $\mu = pA_H + (1-p)A_L = 390$. Consider a revenue-sharing contract $(\alpha, w) = (0.5, 27.3)$, under which the relative demand variation $\theta = (A_H - w/(1-\alpha))/(A_L - w/(1-\alpha)) = 2.22 < 3$. The players' order quantities and profits in the nonleakage and separating (leakage) equilibria are provided in Table 1.

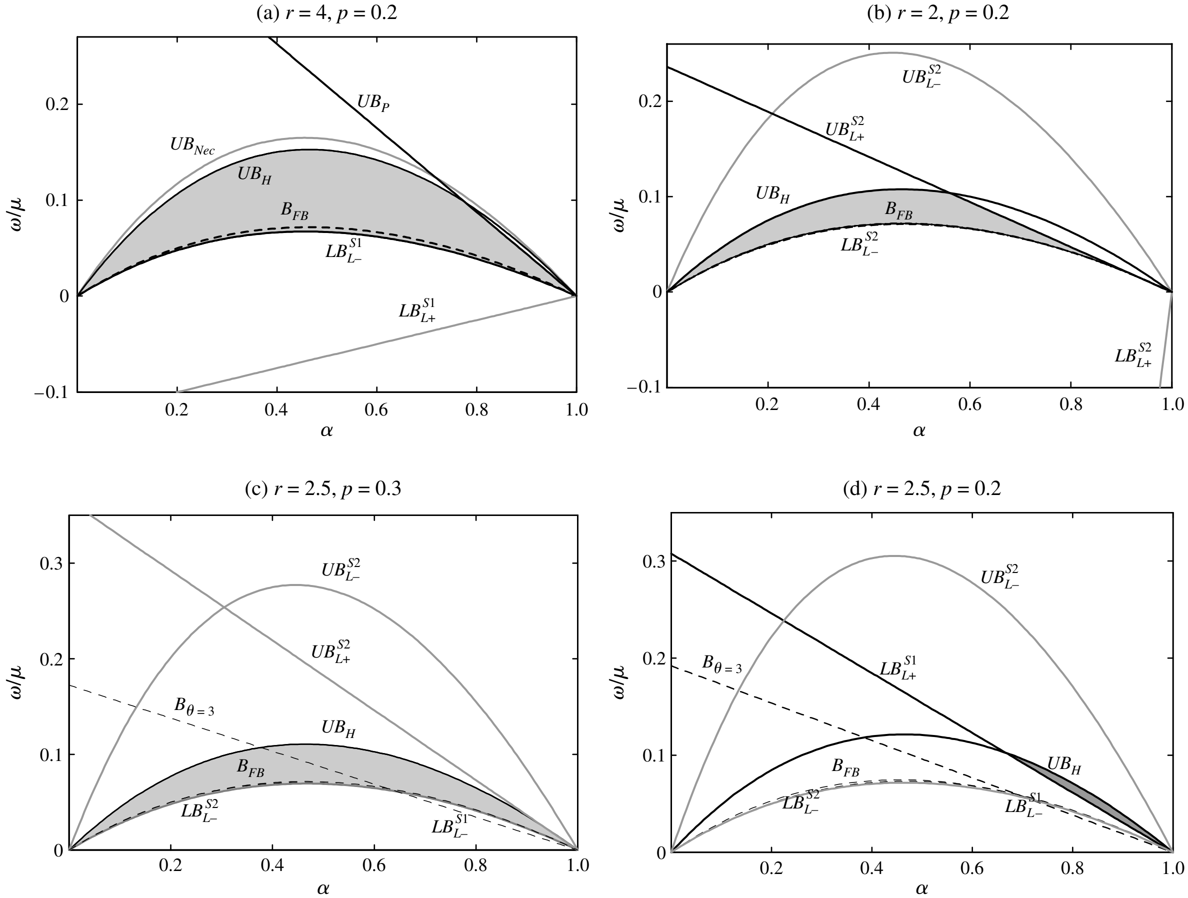
According to the table, if the supplier protects the incumbent's order information, her profits will be 53,562 and 15,717 in the two demand scenarios, respectively; if she leaks the information, her profits will drop to 50,221 and 15,706. Thus, the supplier prefers nonleakage in both demand states. The first-best channel quantities for the supplier are $Q_H^{FB} = 327.3$ and $Q_L^{FB} = 177.3$. Thus, in the separating

[3] By Proposition 2, $q_{iL}^{S^*}$ takes the value $q_{iL}^{S1^*}$ when $\theta \ge 3$ and $q_{iL}^{S2^*}$ when $\theta < 3$. In addition, it can be shown that $q_{iL}^{S2^*} <$ (= or >) $q_{iL}^{S1^*}$ when $\theta <$ (= or >)3.

[4] The range of θ and p satisfying the first assumption is illustrated in Figure B1 in Online Appendix B. The assumption is equivalent to $\pi_{iH}^{N^*} \ge \pi_{iH}^{S^*}$. It is not entirely necessary when $q_{iH}^{S^*}$ lies in the supplier's (upper) nonleakage interval, i.e., $q_{iH}^{S^*} \ge \bar{q}_i$, because the incumbent cannot realize the profit $\pi_{iH}^{S^*}$ by ordering $q_{iH}^{S^*}$, which will not be leaked by the supplier. Nevertheless, because this condition is not restrictive and is satisfied by all examples in this paper, we take it as given for convenience.

[5] The nonleakage equilibrium may exist if $w/\mu \le (3A_H/\mu + 2) \cdot (\alpha(1-\alpha)/(12+5\alpha))$ and $q_{iH}^{N^*} < \bar{q}_i$ because the incumbent may benefit from ordering some $q_{iH} \ge \bar{q}_i (> q_{iH}^{N^*})$ and persuading the supplier not to leak. Unfortunately, such a deviation (from $q_{iH}^{N^*}$) would alter the supplier's nonleakage interval and complicate the analysis, as evident from a related analysis in §7.1. Thus, for the ease of exposition, we do not derive necessary *and* sufficient conditions for nonleakage in the paper.

Figure 2 **Nonleakage Region for (a)** $r \geq 3$; **(b)** $1 < r < (23+p)/(11+p)$; **(c)** $(23+p)/(11+p) \leq r < 3$, $p \geq 0.25$; **and (d)** $(23+p)/(11+p) \leq r < 3$, $p < 0.25$



equilibrium, the two retailers overorder (underorder) when the demand is high (low); under nonleakage, the entrant orders an intermediate amount $111.8 \in (72.8, 136.4)$, bringing the total order quantities closer to the supplier's first-best. The supplier's leakage interval is given by $(\underline{q}_i, \bar{q}_i) = (106.6, 111.8)$. Hence, the incumbent would not deviate from the nonleakage equilibrium because (i) when the demand is high, he makes more profit under nonleakage; (ii) when the demand is low, if he deviates to $\underline{q}_i (> q_{iL}^{S*} = 99.7)$, the entrant will believe that the demand is high and make the incumbent worse off. Therefore, the nonleakage equilibrium is sustained under the revenue-sharing contract $(\alpha, w) = (0.5, 27.3)$.

Interestingly, Table 1 shows that the entrant's profits in the two demand states increase from 9,296 and 2,652 to 12,119 and 3,734, respectively, and the expected profits for all players are higher under nonleakage. This is not always the case, however. From the entrant's point of view, there is a trade-off: On one hand, he benefits from nonleakage because he has more leverage in a simultaneous-move game than being the follower in a sequential-move game; on the other hand, he benefits from leakage because he can

Table 1 **A Leakage-Proof Contract**

	High demand		Low demand		Expected value	
	Nonleakage	Separating	Nonleakage	Separating	Nonleakage	Separating
q_i	216.8	272.7	66.8	99.7	—	—
q_e	111.8	136.4	111.8	72.8	—	—
$Q = q_i + q_e$	328.6	409.1	178.6	172.5	—	—
π_i	23,501	18,591	2,231	3,632	8,612	8,120
π_e	12,119	9,296	3,734	2,652	6,250	4,645
π_s	53,562	50,221	15,717	15,706	27,070	26,061
$\pi_{\text{Total}} = \pi_i + \pi_e + \pi_s$	89,182	78,108	21,682	21,991	41,932	38,826

Table 2 Nonleakage Region

r	Subregions	Lower bounds	Upper bounds	Illustration
(a) $r \geq 3$		$\max(LB^{S1}_{L-}, LB^{S1}_{L+})$	$\min(UB_H, UB_P)$	Figure 2(a)
(b) $1 < r < \dfrac{23+p}{11+p}$	i	LB^{S2}_{L-}	$\min(UB^{S2}_{L-}, B_{FB})$	Figure 2(b)
	ii	$\max(LB^{S2}_{L+}, B_{FB})$	$\min(UB^{S2}_{L+}, UB_H)$	
(c) $\dfrac{23+p}{11+p} \leq r < 3$	i	$\max(LB^{S1}_{L-}, LB^{S1}_{L+}, B_{\theta=3})$	$\min(UB_H, UB_P)$	
	ii	LB^{S2}_{L-}	$\min(UB^{S2}_{L-}, B_{FB}, B_{\theta=3})$	Figures 2(c)
	iii	$\max(LB^{S2}_{L+}, B_{FB})$	$\min(UB^{S2}_{L+}, UB_H, B_{\theta=3})$	and 2(d)

adjust his order quantity according to the demand information. Interested readers can refer to §7.2 for a comparison of the entrant's expected profits under leakage and nonleakage.

5.2. The Nonleakage Region

We now characterize the set of revenue-sharing contracts under which nonleakage can be sustained for given model parameters A_H, A_L, and p. For convenience in exposition, we scale the wholesale price by the mean demand and refer to w/μ as the wholesale price henceforth. Our goal is to identify the set of $(\alpha, w/\mu)$ pairs supporting nonleakage, namely the *nonleakage region*. (This section is somewhat technical; the reader may skim it to grasp the main results.)

Define $r = A_H/A_L$, which measures the relative variation in demand, regardless of the contract. Recall that the other relative demand variation measure $\theta = (A_H - w/(1-\alpha))/(A_L - w/(1-\alpha))$ depends on the contract. The latter can be expressed more precisely as $\theta(\alpha, w/\mu) = (A_H/\mu - (1/(1-\alpha))(w/\mu))/(A_L/\mu - (1/(1-\alpha))(w/\mu))$, but for brevity we will keep using the simple notation θ. Notice that $A_H/\mu = A_H/(pA_H + (1-p)A_L) = r/(pr+1-p)$, $A_L/\mu = A_L/(pA_H+(1-p)A_L) = 1/(pr+1-p)$, and the horizontal axis of the $\alpha, (w/\mu)$ plane satisfies $\theta = r$.

The next theorem describes the nonleakage region in the cases $r \geq 3$, $(23+p)/(11+p) \leq r < 3$, and $1 < r < (23+p)/(11+p)$, corresponding to high-, medium-, and low-demand variations, respectively.

Theorem 2. *Given the demand variation r, the nonleakage equilibrium exists if w/μ lies in one of the subregions defined in Table* 2. *Each subregion is determined by a set of lower and upper bounds on w/μ defined in Table* 3.

The bound B_{FB} specifies the $\alpha, w/\mu$ pairs under which the total quantity Q ordered by the retailers is first-best for the supplier, as discussed in Proposition 3, and the bound $B_{\theta=3}$ specifies those $(\alpha, w/\mu)$ that satisfy $\theta = 3$. The upper bound UB_P corresponds to the participation constraint $w/\mu \leq (1/2)\cdot(3A_L/\mu - 1)(1-\alpha)$, and UB_H corresponds to the condition $q^{N*}_{iH} \geq \bar{q}_i$ in Theorem 1.[6] The lower bound LB^{S1}_{L-} is derived from the condition $q^{S1*}_{iL} \leq \underline{q}_i$ in Theorem 1 when $\theta \geq 3$, and the lower bound LB^{S2}_{L-} and upper bound UB^{S2}_{L-} are both obtained from the condition $q^{S2*}_{iL} \leq \underline{q}_i$ when $\theta < 3$; the "$-$" sign in the subscript of a bound indicates that the bound is only applicable when it lies *below* B_{FB}. The bounds LB^{S1}_{L+}, LB^{S2}_{L+}, and UB^{S2}_{L+} have similar interpretations, except that they are only applicable *above* B_{FB}. As discussed after Proposition 4, $\underline{q}_i$ has different expressions for $w/\mu \leq B_{FB}$ and $w/\mu > \bar{B}_{FB}$.

In case (a), where r is relatively large, we have $\theta \geq 3$ in the entire region of $(\alpha, w/\mu)$, and hence the condition $q^{S1*}_{iL} \leq \underline{q}_i$ applies. Notice that the bound LB^{S1}_{L+} lies below the horizontal axis (and hence the bound B_{FB}) if $p > 1/(2(r-1))$, as in Figure 2(a). The upper bound UB_{Nec} corresponds to the necessary condition $w/\mu \leq (3A_H/\mu + 2)(\alpha(1-\alpha)/(12+5\alpha))$ in Theorem 1. In case (b), when r is small, we have $\theta < 3$ and hence the condition $q^{S2*}_{iL} \leq \underline{q}_i$ is in effect. Subregions (i) and (ii) correspond to the scenarios $w/\mu \leq B_{FB}$ and $w/\mu \geq B_{FB}$, respectively. In the example illustrated in Figure 2(b), $UB^{S2}_{L-} > B_{FB} > LB^{S2}_{L+}$ for all $\alpha \in [0,1]$ and hence the nonleakage region is given by $LB^{S2}_{L-} \leq w/\mu \leq \min\{UB^{S2}_{L+}, UB_H\}$. In case (c), for medium r, the region is obtained from those defined in cases (a) and (b) by imposing the conditions $\theta \geq 3$ and $\theta < 3$, respectively. Note that in subregion (i), when $p < 0.25$ (as in Figure 2(d)), LB^{S1}_{L+} dominates $B_{\theta=3}$ and the nonleakage region may consist of two disjoint pieces: $LB^{S1}_{L+} \leq w/\mu \leq UB_H$ and $LB^{S2}_{L-} \leq w/\mu \leq B_{FB}$ (the subregion (iii) does not exist in this example because the upper bound UB^{S2}_{L+} lies below the horizontal axis).

It is clear from the figures that the nonleakage region (i.e., the range of wholesale prices that support nonleakage) is relatively wide when α lies in the middle of the interval $[0,1]$ and it shrinks as α

[6] The upper bound (line) UB_P has no impact on the nonleakage region if it is steeper than the upper bound (curve) UB_H at $\alpha = 1$; i.e., $-(1/2)(3/(pr+1-p)-1) \leq [(3r/(pr+1-p)+1)\cdot((1-\alpha)\alpha/(12+4\alpha))]'|_{\alpha=1}$, or $r \leq (5+3p)/(1+3p)$, which is implied by $r \leq (23+p)/(11+p)$ in case (b). Also, UB_P has no impact in cases (c.ii) and (c.iii) because $(r-1)(1-p) \geq 0$ implies $UB_P \geq B_{\theta=3}$.

Table 3 Definition of the Bounds

LB_{L-}^{S1}: $\left(\dfrac{3}{pr+1-p}+2\right)\dfrac{\alpha(1-\alpha)}{12+5\alpha}$	LB_{L+}^{S1}: $\left(\dfrac{3}{pr+1-p}-2\right)(1-\alpha)$
LB_{L-}^{S2}: $\dfrac{(72r-24p+4\alpha+24pr-10p\alpha+21r\alpha+10pr\alpha-12)-6\sqrt{\delta}}{pr+1-p}\dfrac{\alpha(1-\alpha)}{(12+5\alpha)^2}$	LB_{L+}^{S2}: $\dfrac{\underline{\theta}-r}{\underline{\theta}-1}\dfrac{1-\alpha}{pr+1-p}$
UB_{L-}^{S2}: $\dfrac{(72r-24p+4\alpha+24pr-10p\alpha+21r\alpha+10pr\alpha-12)+6\sqrt{\delta}}{pr+1-p}\dfrac{\alpha(1-\alpha)}{(12+5\alpha)^2}$	UB_{L+}^{S2}: $\dfrac{\bar{\theta}-r}{\bar{\theta}-1}\dfrac{1-\alpha}{pr+1-p}$
UB_H: $\left(\dfrac{3r}{pr+1-p}+1\right)\dfrac{\alpha(1-\alpha)}{12+4\alpha}$	UB_P: $\dfrac{1}{2}\left(\dfrac{3}{pr+1-p}-1\right)(1-\alpha)$
B_{FB}: $\dfrac{\alpha(1-\alpha)}{3+\alpha}$	$B_{\theta=3}$: $\dfrac{3-r}{2}\dfrac{1-\alpha}{pr+1-p}$
δ: $(24\alpha-108r-12p\alpha-54r\alpha+12pr\alpha+6\alpha^2-5p\alpha^2-6r\alpha^2+5pr\alpha^2+36)(1-r)$	
$\underline{\theta}$: $\dfrac{2(6-3\sqrt{p}-11p+2p^2)}{9-24p+4p^2}$, if $p\in[0,0.4019]$; 1, if $p\in[0.4019,1]$	
$\bar{\theta}$: $\dfrac{2(6+3\sqrt{p}-11p+2p^2)}{9-24p+4p^2}$, if $p\in[0,0.4019]$; $\dfrac{2(6-3\sqrt{p}-11p+2p^2)}{9-24p+4p^2}$, if $p\in[0.4019,1]$	

moves toward 0 or 1. Intuitively, when α is close to 0, the supplier's profit comes mainly from selling to the retailers, and hence a larger-order quantity is better for the supplier. As a result, the supplier is tempted to leak the high-demand information. In the extreme case $\alpha=0$, there is no nontrivial revenue-sharing contract (with $w>0$) that can prevent the supplier from leaking the high-demand information. This is consistent with the result in Anand and Goyal (2009) that the supplier always leaks under a wholesale-price contract (with $\alpha=0$). When α increases, the supplier's profit is more in line with the supply chain profit and she is more willing to control the total quantity in the channel by hiding the demand information from the entrant (recall the discussion at the beginning of §5). However, as α approaches 1, the feasible range of w that induces the retailers' participation diminishes, resulting in a narrow nonleakage band near $\alpha=1$.

The nonleakage region depends on two parameters, r and p. Their impacts are investigated in detail in Online Appendix C and a brief discussion is given here. According to Theorem 1, the nonleakage region is determined by the relationships $q_{iH}^{N^*}\geq\bar{q}_i$ and $q_{iL}^{S^*}\leq\underline{q}_i$. As r increases, A_H/μ increases and A_L/μ decreases. Thus, the incumbent's order quantity $q_{iH}^{N^*}$ increases while $q_{iL}^{S^*}$ decreases, and both are more likely to fall into the supplier's nonleakage intervals, causing the nonleakage region to expand. Intuitively, when the demand variation increases, the incumbent's information advantage exacerbates the quantity distortion from the supplier's perspective (Proposition 3 (iii)) and prompts the supplier to prevent information leakage. As p increases, both A_H/μ and A_L/μ decrease, which relaxes the condition $q_{iL}^{S^*}\leq\underline{q}_i$ for the lower boundary yet tightens the condition $q_{iH}^{N^*}\geq\bar{q}_i$ for the upper boundary. Thus, both boundaries shift downward, and the net impact is not transparent, depending on whether $p\geq 1/(2(r-1))$ or $p<1/(2(r-1))$.

6. Optimal Wholesale Price for the Supplier

In the previous section, we characterized the range of revenue-sharing contracts that sustain nonleakage. Because contract parameters are provided by the supplier, we now explore whether the supplier has an incentive to offer a leakage-proof contract. We allow the supplier to optimally choose the wholesale price w given a revenue-sharing rate α; i.e., w becomes an endogenous decision variable for the supplier.[7] We demonstrate through examples that when α is large enough the wholesale price that maximizes the supplier's profit induces nonleakage. This suggests that nonleakage is a robust outcome under certain revenue-sharing contracts because the supplier cannot do better by altering the contract (the wholesale price, more specifically). First, we identify the supplier's optimal wholesale prices in the leakage and nonleakage regions for a given α.

Theorem 3. *Assume that $r\geq(7+2p)/(3+2p)$. Given the revenue-sharing rate α,* (i) *if the supplier does not leak information, her optimal wholesale price is $(w/\mu)^{N^*}=(1-\alpha)(3-2\alpha)/(6-2\alpha)$; and* (ii) *if the supplier leaks information and $\theta\geq 3$, her optimal wholesale price is $(w/\mu)^{S^*}=(\alpha-2)(\alpha-1)/(4-\alpha)$. If the w/μ defined in*

[7] If the contract parameters α and w are both endogenized, our results show that $\alpha=1$ and $w=0$ is the unique optimal revenue-sharing contract for the supplier (see Figures 3 and 4). This specific result does not provide any substantial managerial insights because it suggests that the supplier should effectively control the entire channel.

case (i) *or* (ii) *above does not belong to the interior of the corresponding nonleakage or leakage region, the optimal wholesale price in that region, given* α, *lies on the boundary of the region.*

According to Lemma A1 (in the proof of Theorem 3), under leakage, the supplier's profit is larger when $\theta \geq 3$ than when $\theta < 3$. Thus, to show that the supplier's profit is larger under nonleakage than under leakage, it is sufficient to focus on the simpler leakage case $\theta \geq 3$.

It can be shown that, if unrestricted, $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$ decrease with α. The example below demonstrates that there exists a threshold α above which the supplier's optimal wholesale price w/μ lies in the nonleakage region.

Example 2. Assume that $r = 4$ and $p = 0.2$. Let α^{N^*} and α^{S^*} be the revenue-sharing rates at which the (locally) optimal wholesale prices $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$ intersect the upper boundary of the nonleakage region. Then,

$$\frac{(1-\alpha)(3-2\alpha)}{6-2\alpha} = \left(\frac{3r}{pr+1-p}+1\right)\frac{\alpha(1-\alpha)}{12+4\alpha}$$

implies $\alpha^{N^*} = 0.623$, and

$$\frac{(\alpha-2)(\alpha-1)}{4-\alpha} = \left(\frac{3r}{pr+1-p}+1\right)\frac{\alpha(1-\alpha)}{12+4\alpha}$$

implies $\alpha^{S^*} = 0.688$. It can be shown that $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$ do not intersect the lower boundary of the nonleakage region. The (locally) optimal wholesale prices $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$ are illustrated in Figure 3. The shaded area in the figure represents the nonleakage region depicted in Figure 2(a).

The monotonicity of $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$ imply that $(w/\mu)^{N^*}$ lies within the nonleakage region when $\alpha \geq 0.623$ and $(w/\mu)^{S^*}$ lies within the leakage region when $0 \leq \alpha \leq 0.688$; for other ranges of α, the optimal prices lie on the upper boundary of the nonleakage region $(3r/(pr+1-p) + 1)(\alpha(1-\alpha)/(12+4\alpha))$. Given the optimal prices, the supplier's corresponding expected profits $\pi_s^{N^*}$ and $\pi_s^{S^*}$ can be determined, as in the proof of Theorem 3. The supplier's maximum expected profits $\tilde{\pi}_s^{N^*} = \pi_s^{N^*}/\mu^2$ and $\tilde{\pi}_s^{S^*} = \pi_s^{S^*}/\mu^2$ (normalized by μ^2) in the leakage and nonleakage regions are depicted in Figure 4(a) as functions of α. Because $\tilde{\pi}_s^{N^*} \geq \tilde{\pi}_s^{S^*}$ when $\alpha \geq 0.51$, the optimal revenue-sharing contract $(\alpha, w^*/\mu)$, given α, resides in the nonleakage region when $\alpha \geq 0.51$. Figure 4(b) shows that the incumbent is always better off under a leakage-proof revenue-sharing contract with the wholesale price optimally chosen, whereas the entrant may or may not be better off, depending on the revenue-sharing rate.

To compare the revenue-sharing contracts with the wholesale-price contract studied by Anand and Goyal (2009), we list the order quantities and all parties' profits under various α in Table 4. To reveal the impact of the wholesale price w, we consider two w/μ under each α, i.e., $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$, the optimal w/μ in the "N"onleakage and "S"eparating (leakage) regions, respectively.

As can be seen, the first-best channel quantity decreases with α, under both $(w/\mu)^{N^*}$ and $(w/\mu)^{S^*}$, in both demand states. The retailers always underorder under $(w/\mu)^{N^*}$, and they underorder under $(w/\mu)^{S^*}$ except in the high-demand case with $\alpha = 0.6$ or 0.9. Under nonleakage, the quantity distortion (weakly) decreases with α in both demand states. Under leakage, this is not the case in the high-demand case. The quantity distortion is smaller under nonleakage than under leakage except in the high-demand case with $\alpha = 0$ or 0.6.

Figure 3 **Optimal Wholesale Prices in the Leakage and Nonleakage Regions Given α for $r = 4$ and $p = 0.2$**

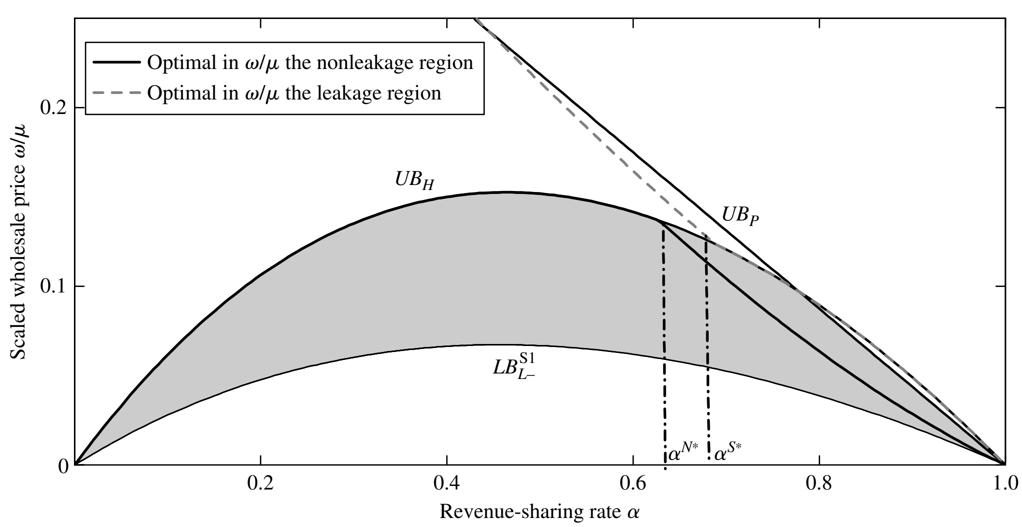
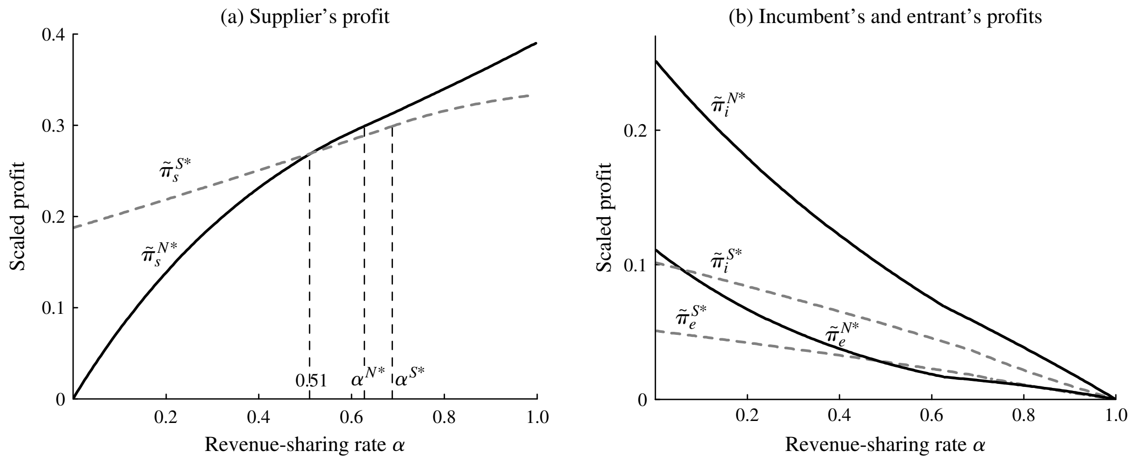


Figure 4 **Firm Profits Under Optimal Wholesale Prices in the Leakage and Nonleakage Cases for $r = 4$ and $p = 0.2$**



The supplier's benefit from nonleakage steadily increases with the revenue-sharing rate α, as the difference between her profits under nonleakage and leakage varies from -0.750 to -0.295, then -0.034, and finally 0.020 when the demand is high and from -0.047 to 0.017, 0.019, and 0.043 when the demand is low. The supply chain always benefits from nonleakage in both demand scenarios, and the incumbent and the entrant are better off under nonleakage in most scenarios.

As another example, when $r = 2.5$ and $p = 0.3$, we find that $\alpha^{N^*} = 0.789$, $\alpha^{S^*} = 0.898$, and $\tilde{\pi}_s^{N^*} \geq \tilde{\pi}_s^{S^*}$ if $\alpha \geq 0.72$, and interestingly, both the incumbent and the entrant are better off under a leakage-proof revenue-sharing contract. Comparing the two examples, we see that the threshold α at which the supplier starts to prefer nonleakage moves to the left as r increases. That is, as r increases, the demand states are more distinguishable, and a smaller share of revenue is needed to persuade the supplier not to leak (especially in the high-demand case). This is consistent with the sensitivity analysis of the nonleakage region with respect to r (Online Appendix C).

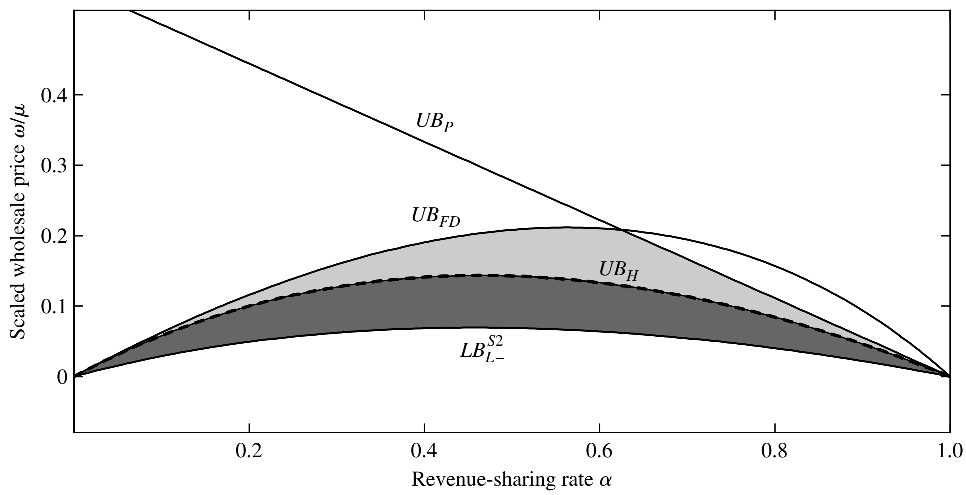
7. Extensions

In this section, we extend our results by altering some assumptions in the model. We find that these extensions do not change the main results of the paper but may alter the nonleakage region in different ways. We summarize the main findings here; the details of the analyses and examples are provided in Online Appendix D.

Table 4 **Quantities and Profits Under Various $(\alpha, w/\mu)$ for $r = 4$ and $p = 0.2$**

α	0 (benchmark)		0.3		0.6		0.9	
w/μ	0	0.500	0.135	0.322	0.142	0.165	0.029	0.049
Equilibrium	N	S	N	S	N	S	N	S
q_{iH}/μ	1.083	1.000	1.019	1.020	0.965	1.044	0.988	1.005
q_{eH}/μ	0.333	0.500	0.269	0.510	0.215	0.522	0.238	0.502
Q_H/μ	1.417	1.500	1.288	1.530	1.181	1.566	1.226	1.507
Q_H^{FB}/μ	∞	∞	1.475	1.786	1.368	1.387	1.266	1.277
π_{iH}/μ^2	1.174	0.500	0.727	0.364	0.373	0.218	0.098	0.050
π_{eH}/μ^2	0.361	0.250	0.192	0.182	0.083	0.109	0.024	0.025
π_{sH}/μ^2	0	0.750	0.642	0.937	1.102	1.135	1.441	1.421
$\pi_H^{\text{Total}}/\mu^2$	1.535	1.500	1.561	1.484	1.558	1.463	1.562	1.496
q_{iL}/μ	0.146	0.063	0.081	0.083	0.028	0.107	0.051	0.067
q_{eL}/μ	0.333	0.031	0.269	0.041	0.215	0.053	0.238	0.034
Q_L/μ	0.479	0.094	0.350	0.124	0.243	0.160	0.289	0.101
Q_L^{FB}/μ	∞	∞	0.538	0.849	0.431	0.450	0.328	0.340
π_{iL}/μ^2	0.021	0.002	0.005	0.002	0.0003	0.002	0.0003	0.0002
π_{eL}/μ^2	0.049	0.001	0.015	0.001	0.002	0.001	0.001	0.0001
π_{sL}/μ^2	0	0.047	0.076	0.059	0.090	0.071	0.096	0.053
$\pi_L^{\text{Total}}/\mu^2$	0.070	0.050	0.096	0.062	0.093	0.074	0.097	0.053

Figure 5 Nonleakage Region with Free Disposal for $r = 3.5$ and $p = 0.2$



Notes. The darkly shaded area represents the original nonleakage region without free disposal. The lightly shaded area represents the region in which nonleakage is enabled by the incumbent's free disposal option in the high-demand case. The bound UB_{FD} is given by $w/\mu = (3r/(pr - p + 1) + 1) \cdot (\alpha(1-\alpha)/(12 + ((p-5)\alpha)))$.

7.1. Free Disposal by the Incumbent

In previous analysis, we implicitly assumed that the incumbent sells all units ordered from the supplier and does not withhold any units from the market. Now we relax this assumption and explore how it impacts the nonleakage region.

Free disposal cannot benefit the incumbent if the type of equilibrium is unchanged. If a leakage game is played, the supplier and entrant know the incumbent's order quantity and can calculate his selling quantity in equilibrium if it differs from his order. Thus the incumbent has no reason to purchase more than his actual selling amount. Similarly, if a nonleakage game is played, the incumbent's order quantity is unknown to the entrant, and the two retailers' selling quantities are fully determined by the equilibrium; again, the incumbent cannot gain from free disposal.

The free disposal option can affect the type of equilibrium in two ways. (1) If $\underline{q}_i < q_{iH}^{N*} < \bar{q}_i$, the incumbent may persuade (or "bribe") the supplier not to leak the high-demand information by ordering $\bar{q}_i$ (but selling less later), which may enable a nonleakage equilibrium that is nonsustainable without free disposal. (2) If $q_{iL}^{S*} < \underline{q}_i$, the incumbent may stimulate the supplier to leak the low-demand information by ordering $\underline{q}_i$ (but selling less), which would topple an original nonleakage equilibrium; when free disposal is possible, a deviation to leakage may become more attractive to the incumbent.

The first effect enlarges the nonleakage region by pushing its upper boundary upward (because $q_{iH}^{N*} \geq \bar{q}_i$ is no longer required), whereas the second effect reduces the region by raising its lower boundary (because $q_{iL}^{S*} \leq \underline{q}_i$ may not be sufficient any more). In Online Appendix D.1, we conduct an analysis similar to the case without free disposal analyzed in previous sections.[8] The main finding is that the first effect is more prominent and, as a result, the nonleakage region expands under typical model parameters; the second effect has no impact when $\theta < 3$ and limited impact when $\theta \geq 3$. An example is shown in Figure 5.

7.2. Active Entrant Who Can Reject Information

In the basic model, the entrant plays a passive role and always accepts the incumbent's order information leaked by the supplier. Because the nonleakage game may benefit the entrant, he may want to reject the information and drag the incumbent into a nonleakage game (given that the entrant will ignore the incumbent's order information, the best order quantity for the incumbent is the one in the nonleakage equilibrium). Thus, an active entrant can turn a leakage game into a nonleakage one, whereas an original nonleakage game is unaffected because there is no information in the first place. As a result, allowing an active entrant would strictly enlarge the nonleakage region. More details can be found in Online Appendix D.2.

7.3. Simultaneous Ordering

In our original model, the incumbent enjoys two potential advantages that are intertwined: an information advantage due to his private demand information and a first-mover advantage in the leakage game. In this extension, we disentangle these two

[8] The nonleakage and leakage equilibria under free disposal differ from those without free disposal because the incumbent's order cost is sunk after ordering when free disposal is possible, whereas it is linked to the incumbent's selling quantity (which is also his order quantity) when free disposal is disregarded.

effects by studying the following game: first, the incumbent decides whether to share the demand information (high or low) with the supplier, then the supplier decides whether to leak it to the entrant, and finally the incumbent and entrant place orders *simultaneously*. This new game takes away any potential first-mover advantage enjoyed by the incumbent and allows us to focus on his informational advantage.

We assume that the incumbent cannot lie if he should decide to disclose the demand information (otherwise the incumbent would always report low demand and there would not be an interesting game). Because he would always like the entrant to learn the information when the demand is low to restrain the entrant's order quantity, the demand information is effectively always revealed to the supplier, and it is up to the supplier whether or not to leak it to the entrant. If the supplier does not leak, the game will be the same as the original nonleakage game, and the equilibrium order quantities are given in Proposition 1. If the supplier leaks the information, the incumbent and entrant will play a simultaneous Cournot game under perfect information. For a nonleakage equilibrium to exist, the supplier should prefer nonleakage in both demand scenarios. As shown in Online Appendix D.3, nonleakage is sustainable in the region $(\alpha(1-\alpha)/(3+\alpha))((A_L+\mu)/(2\mu)) \le w/\mu \le (\alpha(1-\alpha)/(3+\alpha))((A_H+\mu)/(2\mu))$, in which the channel quantity distortion from the supplier's point of view is less severe under nonleakage than under leakage in both demand states.

This new nonleakage region is qualitatively similar to the nonleakage region found under the basic model. Both contain the first-best curve B_{FB}: $w/\mu = \alpha(1-\alpha)/(3+\alpha)$ and thus overlap around that curve. We conclude that asking the incumbent to share information first and the two retailers to order simultaneously does not alter the key findings from the basic model.

7.4. Entrant Ordering First

We have shown in the paper that a properly designed revenue-sharing contract can discourage the supplier from leaking the incumbent's order information to the entrant. Alternatively, the supplier can commit not to leak the incumbent's private information by taking the entrant's order first. In this extension, we consider a new game in which steps 3 to 5 in the original sequence of events (§3) are replaced by the following: the entrant places an order q_e, the supplier decides whether or not to leak it to the incumbent, and the incumbent places an order q_i. Because the entrant has no private information, his order quantity can be inferred by the incumbent in any equilibrium. Thus, leaking the entrant's order quantity provides no extra information to the incumbent but it makes the entrant the Stackelberg leader in the retailers' game. If the supplier does not leak the entrant's order quantity, the two retailers play the same nonleakage game as under the basic model when the incumbent orders first.

A thorough analysis of the new game is provided in Online Appendix D.4. The equilibrium of the game, under a given revenue-sharing contract (α, w), can be summarized as follows: if $w/\mu < \alpha(1-\alpha)/(3+\alpha)$, the supplier would not leak the entrant's order information and the two retailers effectively play a simultaneous game; if $\alpha(1-\alpha)/(3+\alpha) \le w/\mu \le 5\alpha(1-\alpha)/(12+5\alpha)$, the supplier would be indifferent between leaking and not leaking the entrant's order quantity; and if $w/\mu > 5\alpha(1-\alpha)/(12+5\alpha)$, the supplier would leak the entrant's order information and appoint him as the Stackelberg leader. Comparing the new game with the original one, we find that the supplier weakly prefers the entrant to be the first mover in all the above regions. In the intersection of the region $w/\mu \le 5\alpha(1-\alpha)/(12+5\alpha)$ and the original nonleakage region, the supplier would be indifferent to who orders first.

The above result seems to suggest that the supplier would be better off taking the order from the uninformed retailer first. However, there are potential issues with this sequence of events. First, by holding back the informed retailer, the supplier forfeits all potential benefits from advance information about the market discussed in the introduction and literature review (which are not included in our model). Recall that the motivation of this paper was to enable information sharing between the incumbent and the supplier by preventing leakage to the entrant. Second, whether the supplier can actually dictate the order sequence and force the incumbent to order second is an open question. The incumbent can voluntarily share the demand information with the supplier or even go ahead and place an order, and it may be difficult in practice for the supplier to ignore this action and force the incumbent to react to the entrant's order.

8. Conclusion

Information sharing between parties in a supply chain has many benefits and thus we have witnessed many efforts to do so in the past decade. But many firms are reluctant to share information because of the negative effects on their revenues and profits from potential leakage of sensitive information.

In this work, we explore the potential of revenue-sharing contracts in preventing leakage of demand information in a supply chain and making the supply chain better off. We modeled the interactions between the supplier and its two clients as a dynamic game with incomplete information. Several key insights were obtained from our analysis. The incumbent reveals the demand information to the supplier through his order quantity. To prevent the supplier from choosing to leak the information, the incumbent should order a quantity that would actually lead to an underorder or overorder situation if the information gets leaked. As a result, information sharing between vertical partners is enabled, yet information leakage to horizontal competitors is prevented. Our examples show that preventing leakage may make the incumbent, supplier, and sometimes even the entrant better off. Our results also suggest that a revenue-share percentage that is relatively high is more capable of preventing leakage. This is consistent with studios' revenue-share percentages (40%–60%) in the video rental industry as well as their share of revenues with movie theaters (Dana and Spier 2001). In this scenario, the supplier may even be able to choose a wholesale price that maximizes her profits while preferring not to leak information. Furthermore, we have established that a revenue-sharing contract can be robust in its ability to prevent information leakage under various extensions.

There are many interesting avenues for future research on this issue. A natural extension of our paper is to study leakage-proof contracts under Bertrand competition, or when the products provided by the downstream retailers are imperfect substitutes or complements. Next, in this paper, we assume that the supplier can choose whether or not to leak the incumbent's order quantity, but cannot lie about it. It would be interesting to study the situation in which the supplier may distort such information and design contracts that still prevent information leakage.

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