Information Sharing and Information Rents in a Two-level Supply Chain

Suresh Radhakrishnan\textsuperscript{a} and Bin Srinidhi\textsuperscript{b}\textsuperscript{*}

\textsuperscript{a}University of Texas at Dallas
\textsuperscript{b}Hong Kong Polytechnic University

Abstract

Advances in information technology have greatly facilitated information exchange in value-chains, and the resulting efficiencies from resource coordination have led to higher profits. However, in spite of the well-established advantages, not all value-chains have implemented such information exchanges. In this paper, we show that this lack of implementation could arise due to strategic behavior of value-chain partners. Specifically, allowing for strategic behavior, we examine the conditions under which information exchanges might or might not be implemented. The value-chain partners’ trade off their share of increased value-chain profits from information exchange against the loss of their information rent. We develop the model of a two-partner value-chain with a manufacturer and a privately informed retailer. We show that the value-chain partners will agree to move from the traditional (no information exchange) to the information exchange regime only if (a) the retailer is sufficiently large, (b) the demand variability is sufficiently high, and (c) the cost of manufacturing is sufficiently low. This provides a rationale for why information exchange is not prevalent with small retailers.

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\textit{Keywords}: Supply-chain, Value-chain, Information exchange, adverse selection, information rent

1. Introduction

Advances in information technology have enabled the value-chain partners to share information and increase value-chain profits by coordinating resource deployment decisions. As a case in point, Kurt Salmon Associates (1993) estimate the benefits from information exchange to be $14 billion for the food industry. Recent research has shown that sharing information on demand and inventory levels among value-chain partners helps in (a) mitigating the bullwhip effect, i.e., the amplification of demand

\textsuperscript{*}Corresponding author: email: sradhakr@utdallas.edu.

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variability as order information is communicated from downstream to upstream players in the value-chain (see Lee et al., 1997a and 1997b), (b) increasing the efficiency of resource utilization (see Bourland et al., 1996; Cachon and Fisher, 1997; Gavirneni et al., 1999), and (c) increasing the value-chain profits, when demands are correlated over time (see Lee et al., 2000). Collaborative forecasting models examine the benefits of resource coordination arising from sharing information to each value-chain partner (see Aviv, 2001). These studies argue that information sharing among value-chain partners increases their overall benefits. However, in spite of these established benefits, several value-chains have not implemented such information exchanges. In this paper, we show that this puzzling lack of implementation could be attributed to strategic behavior of the value-chain partners.

We develop the model of a two-level value-chain with one manufacturer and one retailer. The retailer has superior private information on demand that can be used by the manufacturer for efficient resource deployment. Two information regimes are considered: in the traditional (TR) regime the retailer’s superior demand information is not shared with the manufacturer; and, in the information exchange (IE) regime, while the retailer shares his superior demand information with the manufacturer, the retailer can strategically misrepresent the information when he finds it beneficial to do so. Our model incorporates the following elements of a value-chain: resource (capacity) costs; bargaining powers of the value-chain partners; and the variability of product demand. We compare the value-chain partners’ profits in the TR and IE regimes to provide insights into the key drivers of moving from the TR to the IE regime.

We find that the total value-chain profit is higher in the IE regime than in the TR regime because of improved resource deployment, which we call the profitability effect. However, compared to the TR regime the retailer gets lower information rents in the IE regime, which we call the information rent effect. It follows that the manufacturer always finds it beneficial to move from the TR to the IE regime, because of increased profits from resource deployment and savings in information rent. On the other hand, the retailer will find the move from TR to IE beneficial only when his share of the increased value-chain profit is greater than the resulting decrease in his information rent. As such, both the value-chain partners will agree to move from the TR to the IE regime if the retailer’s profit in the IE regime is greater than that in the TR regime.

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1 For a discussion on information sharing and information systems models, see Lee and Whang, 1998.
2 A case in point is Tyco International’s undersea repeater factory’s information sharing and pricing agreements, which include the main elements considered in this model. The model also captures information transfer regimes, where the retailer can potentially alter the actual sales to influence the manufacturer’s decisions by providing price promotions or in-store advertising (see Lal and Villas-Boas, 1998).
Even though IE regimes that include sales forecasts are typically collaborative in nature, in our model the retailer has better information than the manufacturer. The roles would be reversed if the manufacturer had superior information on demand. This can occur with pharmaceutical firms, where companies such as Warner Lambert have superior demand forecast than retailers, based on the weather-related and demographic information. The insights and the tradeoff between the benefit from resource deployment and information rent are qualitatively unchanged.

3 This is consistent with research findings based on survey responses of grocery stores. Specifically, retailers perceived that manufacturers reaped more benefits from information sharing (see Nakayama, 1998).
We find that compared to the TR regime the retailer’s profit is higher in the IE regime when (a) the retailer is a large volume retailer (such as Wal-Mart), (b) the variability of demand is high, and (c) the cost of manufacturer’s activity adjustment (resources) is low. We discuss the intuition behind each of these factors. First, retailers with high bargaining power, typically large retailers, get a higher proportion of the value-chain profit. As such, compared to the TR regime, the large retailer gets a high proportion of the incremental profits in the IE regime, arising from better resource deployment in the IE regime. In effect, the profitability effect dominates the information rent effect when the retailer has a high bargaining power. Second, high demand variability makes the demand information more valuable in terms of improved resource deployment. The increased share of retailer’s profit from improved resource deployment compensates for the loss of information rent in the IE regime. Third, if the cost of activity adjustment is high, resource deployment changes become less likely even in the presence of demand information. As such, the profitability effect is not high if the activity cost adjustment is high, and vice versa. Thus, if the activity adjustment cost is high, the loss of information rent is less likely to be adequately compensated by the profitability effect.

Baiman and Sivaramakrishnan (1991) and Penno (1984) examine the value of pre-decision information using a principal/agent model. They compare two regimes: one where pre-decision information can be used; and one where no such information is available. In general, they find that allowing for pre-decision information leads to higher profits because of improved decisions and incentives. Baiman and Sivaramakrishnan (1991) also show the existence of settings in which welfare decreases when more information becomes available. Our results are consistent in that the IE regime leads to improved resource coordination and hence improved decisions. However, this study differs from the above-mentioned studies in three aspects. First, we examine the move from the no communication regime to the IE regime when the retailers have different bargaining strengths. Second, we consider a setting that requires coordination between unobserved actions by both the manufacturer and the retailer. Third, we focus on studying the implications for pricing and profitability that arise from the shift in regimes.

Other studies have examined value-chain relationships. Desai and Srinivasan (1996) study the signaling problem when the retailer is subject to moral hazard and the manufacturer has private information. They examine the effects of the two-part pricing scheme and find that a non-linear pricing scheme (a quadratic scheme) is first best optimal. Narayanan and Raman (1996) study the impact of inventory levels in a value-chain. They consider only hidden-action effects and offer branding and EDI (Electronic Data Interchange) as alternative mechanisms to mitigate the information asymmetry effects. In contrast to these studies, we focus on the retailer’s private information on demand and let the manufacturer use wholesale prices to mitigate the problem of adverse selection and moral hazard. By examining how information exchange alters the sharing of value-chain profits and setting the wholesale prices, we provide insights about the costs/benefits of moving to the IE regime.

The rest of the paper is organized as follows: section 2 outlines the model, section 3 contains the analysis and a discussion of the managerial insights, and section 4 provides concluding remarks.
2. The Model

We consider a single-product value-chain with a manufacturer who transfers the products to a retailer. We describe the retailer’s side and the manufacturer’s side of the value-chain.

2.1 Retail Price and Demand

We consider two types of retailers: a small “boutique” retailer; and a large retailer, indexed \( j = L, S \). The retailer charges a price \( a_j \) per unit. The demand (sales quantity) \( x_j \in [0, x_j^{MAX}] \) for retailer \( j = L, S \) is uncertain with an expected value of \( X_j \). The expected demand can take on one of the values \( X_j \in \{X_{ij}, \ldots, X_{nj}\} \) with \( X_{ij} < X_{ij} < \ldots < X_{nj} \) for \( j = L, S \). The retailer obtains a forecast \( X_j^i \) on expected demand based on his superior information about the local condition. The retailer’s forecast on expected demand is perfect, i.e., \( X_j^i = X_j \) when the expected demand is \( X_j \). Henceforth, we will refer to the retailer’s forecast as \( X_j \). The manufacturer’s prior belief on \( X_j \) is given by \( \phi_{ij} \) for \( i = 1, \ldots, N \). We assume a symmetric distribution for \( X_j \), i.e., \( X_{(i+1)j} - X_j = X_{(k+1)j} - X_j \) and \( \phi_{ij} = \phi_{i(N-k+1)j} \) for any \( i, k = 1, \ldots, N \). We denote the expected value of \( X_{ij} \) as \( \mu_j = \Sigma \phi_{ij} X_{ij} \), the variance of \( X_{ij} \) as \( \sigma_j^2 = \Sigma \phi_{ij}(X_{ij} - \mu_j)^2 \) and let \( \Delta_j = X_{nj} - \mu_j = \mu_j - X_{ij} \).

The retailer incurs a cost of \( B_j(X_{ij}) = 0.5 b_j X_{ij}^2 \) to satisfy the consumer demand. The cost is increasing and convex in expected demand.

We characterize the small and large retailers by the expected demand profiles, the variance in demand, the retail price and the cost of servicing demand. The large retailers are characterized by a higher expected demand profile than the small retailers, i.e., \( X_{NS} < X_{IL} \) where \( X_{NS} \) denotes the highest expected demand profile of the small retailer and \( X_{IL} \) denotes the lowest expected demand profile of the large retailer. In this case, it is clear that the expected demand of the large retailer is higher than the expected demand for the small retailer, i.e., \( \mu_S < \mu_L \). We also allow the variance in demand to be lower for the large retailer than the small retailer, i.e., \( \sigma_S^2 > \sigma_L^2 \). We assume that \( \alpha_S > \alpha_L \) because the small retailer provides better service and is closer location-wise to the consumer. We assume that the average cost for the lowest expected demand for the small retailer is higher than the average cost for the highest expected demand for the large retailer, i.e., \( b_S X_{IS} > b_L X_{IL} \). The rationale behind this assumption is that large retailers can use their bargaining power and economies of scope (spread fixed costs over a larger offering) to decrease their average costs of each offering. Overall, these characteristics represent the difference between large retailers such as Wal-Mart and small boutique retailers. We assume that the demands of the large and small retailers are not correlated.

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4 Denoting the conditional distribution of demand for any given \( X \) by \( f(x|X) \) it follows that the unconditional distribution of \( x, f(x) = \Sigma_i f(x|X_i) \phi_i \). The demand variance faced by the manufacturer can be decomposed as \( \sigma^2 + \Sigma_i \int (x - X_{ij})^2 f(x|X_i) \phi_i dx \). The first term (\( \sigma^2 \)) is the portion of demand variability that is resolved by the retailer’s information and is referred to in this paper as variability in demand. The second term is the residual uncertainty that the informed retailer faces.

A non-shifting support for the demand distribution is implicitly assumed, i.e., \( f(x|X) \neq 0 \) for all \( i, x \). In other words, for any realization of demand (\( x \)) the manufacturer cannot perfectly infer the retailer’s forecast.
2.2 Manufacturer’s Resources and Costs

The manufacturing effort \( M_j \) includes production activities that result in a fixed cost of \( V(M_j) = [M_j^2/2v] \) and a variable cost of \( C(x_j,M_j) = [(c - M_j)x_j] \) for \( j = L,S \). The manufacturing effort includes activities that are customized to retailer type \( j \). For instance, to handle larger volumes required by \( L \), the manufacturer can dedicate automated processes, which result in lower direct costs. The fixed manufacturing cost is increasing and convex in manufacturing effort, while the variable manufacturing cost is decreasing in manufacturing effort. The variable manufacturing cost includes the direct material and manufacturing overheads, while the \( M \) represents the order taking and support staff requirements that vary with the type of retailer.\(^5\) Note that for a given manufacturing effort, the fixed cost is invariant to volume changes, while the variable cost changes linearly with volume.

2.3 Wholesale Pricing and Profits

The manufacturer’s wholesale price schedule is given by \( \alpha_j + \delta_j x_j \) for retailer type \( j = L,S \). The constant portion (\( \alpha \)) of the wholesale charge represents the minimum order quantity and fixed commitment charges imposed on the retailer as part of franchise and exclusive supply arrangements. The unit wholesale price (\( \delta \)) is the volume-based charge. The expected profits for the manufacturer (\( U \)), the retailer (\( T \)) and the value-chain (\( \pi \)) for any given expected demand profile \( X_{ij} \) are:

\[
U_j = \alpha_j + \delta_j x_j - C(X_{ij}, M_j) - V(M_j),
\]

\[
T_j = a_j X_{ij} - B_j(X_{ij}) - \alpha_j - \delta_j x_j,
\]

\[
\pi = \sum_j \pi_j = \sum_j [(a_j X_{ij} - B_j(X_{ij}) - C(X_{ij}, M_j) - V(M_j)]
\]

2.4 Information Regimes and Sequence of Events

Traditional Regime (TR): In the TR regime the retailer does not communicate his expected demand information (demand forecast) to the manufacturer. Consequently, the manufacturing effort is not conditioned on the retailer’s demand forecast. This regime captures arm’s length, manufacturer-retailer relationships that were more prevalent before the advances in information technology.

Information Exchange Regime (IE): In the IE regime, the retailer communicates his demand forecast to the manufacturer. The manufacturer can change the wholesale price schedule based on the retailer’s demand forecast. However, the retailer can strategically misrepresent his demand forecast. In this interaction, if the manufacturer decreases the unit price for higher demand forecasts, then the retailer could report a higher than true demand forecast. As a rational response, the manufacturer would agree to a wholesale price schedule that prevents the possibility of such misrepresentation.

\(^5\) These relationships between batch-level (fixed) and unit-level (variable) costs are described in chapter 11 of Kaplan and Atkinson (1989).
The sequence of events for each retailer $j$ is described below.

Stage 1: The manufacturer and the retailer agree on the information regime $\Lambda_j \in (TR_j, IE_j)$.

Stage 2: The retailer observes his expected demand $\in \{X_{ij}, ..., X_{Nj}\}$.

Stage 3: If IE is chosen the retailer communicates his forecast as $X_j(m) \in \{X_{ij}, ..., X_{Nj}\}$ to the manufacturer. If TR is chosen the retailer does not provide his forecast to the manufacturer.

Stage 4: The manufacturer and retailer agree on the wholesale price schedule $\{\alpha_j, \delta_j\}$.

Stage 5: The manufacturer chooses the manufacturing effort, $M_j$.

When the demand is realized, the retailer gets the units from the manufacturer and pays the manufacturer the agreed-upon wholesale price. The retailer provides the units to the customer and collects the retail price.\footnote{We do not allow any stock outs or inventory. Allowing for inventory and an ordering decision by the retailer will make the expressions complex without adding any additional insights into the information rents.}

2.5 Negotiation Between the Manufacturer and the Retailer

The value-chain concept requires that the participating firms manage their external stakeholders proactively. That is, the manufacturer should understand and analyze the operations of the retailer, and vice versa, so that decisions are made within each organization to enhance the value that the firms add to the consumer. Strategic cost management relies upon integrating the value-chain concept with cost analysis, such that each firm in the value-chain understands the value that they add for the consumer, and also gets an idea on how much profit is parked in each part of the value-chain (see Shank and Govindarajan, 1993, chapter 4).\footnote{The second author has implemented strategic cost management techniques for medium-sized firms by estimating the value added by each firm in the value-chain, and also obtained estimates on how profits are parked across the value-chain.} Thus, a key feature of the value-chain concept is that the retailer and the manufacturer share the total value-chain profit. We incorporate this feature into our model by requiring that the wholesale price be such that the retailer gets a portion $w(\mu) \in [0, 1]$ of the value-chain’s expected profit, with $w'(\mu) > 0$. In effect, the large retailer captures a larger portion of the value-chain profits than the small retailer and $w_L > w_S$. However, to ensure the retailer’s participation, the wholesale price schedule should be such that for every expected demand $(X_{ij})$ the retailer should get at least a proportion $w_j$ of the value-chain’s expected profit, where large retailers with high sales volume command a higher proportion of the value-chain profits. Even though the share of value-chain profits is assumed to be common knowledge among the players, they actually negotiate on the wholesale price as the mechanism to share the value-chain profits. The wholesale price is typically determined based on the units transferred from
the manufacturer to the retailer. Thus, when the wholesale price is chosen in any regime, it should guarantee the retailer a proportion of the expected value-chain profits.\footnote{In essence, the value-chain model requires the retailer and the manufacturer to know each other’s cost structures. Even without the notion of the value-chain, sales persons use phrases such as, “the price that you are asking does not cover my costs”, when negotiating wholesale prices. Also, surveys of EDI effectiveness such as Nakayama (1998), capture the notion of value-chain profit sharing across the retailer and the manufacturer.

The proportion of value-chain profits that is parked with the retailer will depend on the level of competition that the manufacturer and the retailer face in their respective markets. For instance, if competition at the manufacturer’s end of the supply chain is high, then the retailer will capture a higher profit. Consider the example when a leading battery manufacturer introduced the “power check” feature. This feature increases the value of batteries for the consumer and is cost-beneficial for the entire value-chain. However, competition between cell manufacturers resulted in the increased value being captured mostly by large retailers such as Wal-Mart. Our model captures the essence of such bargaining ability that depends on the product category. We also consider the participation condition based on the product margins. See the equilibrium derivation section for details.}

In summary, our model incorporates the following important features.

1. Integration of the value-chain and information exchange issues when the value-chain partners make decisions strategically.
2. A parsimonious representation of costs, demand and partnership (bargaining power).

3. Analysis and Results

In this section, the solutions to TR and IE regimes are derived separately, by considering stages 2 through 5. The expected profits across the regimes are compared and the determinants of the differential profits are identified. We assume that \( a_i > c \), which implies that the consumer’s willingness to pay for the product is greater than its marginal cost; and \( v > b_j \), which implies that the costs of manufacturing and service efforts are low enough such that the product yields positive value-chain profits. These conditions are sufficient to ensure that expected profits, wholesale and retail prices in both TR and IE regimes are positive.

3.1 Equilibriums for Each Information Regime

3.1.1 Traditional Regime

In the TR regime, each retailer \( j \) does not provide his demand forecast to the manufacturer and hence, stage 3 does not occur. We derive the equilibrium working backwards from stage 5 to stage 2 and characterize the expected profit for the manufacturer and the retailer in stage 1.
Stage 5

For any wholesale price schedule \(\{\alpha_j, \delta_j\}\) that is chosen in stage 4 and any given \(X_{ij}\) that retailer \(j\) observes in stage 2, the expected profits for the manufacturer from retailer \(j\) are given by:

\[
E[U_{ij}] = \sum_i [\alpha_j + \delta_j X_{ij} - C(X_{ij}, M_j) - V(M_j)] \phi_{ij}.
\]

Note that the manufacturer does not have the information on the expected demand, and hence, chooses the manufacturing effort with the information set that is available to him. The optimum effort choice for each \(j\) is given by the following equations:

\[
\frac{\partial E[U_{ij}]}{\partial M_j} = -\frac{\partial E[C(X_{ij}, M_j)]}{\partial M_j} - V'(M_j) = 0,
\]

(TR-ICM)

It follows that for any given \(\{X_{ij}, \alpha_j, \delta_j\}\) the optimum service and manufacturing efforts are given by \(M_j^* = vE(X_{ij}) = v\mu_j\). The manufacturer uses the expected value based on his prior beliefs to choose manufacturing effort.

Stage 4

In this stage the wholesale prices are chosen (or agreed upon by the manufacturer and the retailer) to satisfy the following conditions. The retailer refuses to participate unless his expected profits are greater than the proportion \(w_j\) of the value-chain’s profits for each expected demand for each \(X_i\). Thus, the participation conditions for each \(i, j\) are given by:

\[
T_{ij} = a_j X_{ij} - B_j(X_{ij}) - \alpha_j - \delta_j X_{ij} \geq w_j[a_j - B_j(X_{ij}) - C(X_{ij}, M_j^*) - V(M_j^*)]
\]

(TR-PCV)

The wholesale price schedule is determined by the lowest and the highest expected demands, i.e., \(X_{ij}\) and \(X_{Nj}\). This is because the retailer’s effective expected profit before considering the wholesale price, \(\theta_{ij} = T_{ij} + \alpha_j + \delta_j X_{ij} - w_j \tau_{ij}\), is concave in \(X_{ij}\) for each \(j\). The wholesale price can be set such that the retailer gets exactly his proportion of the expected profits for the lowest and the highest expected demands. It follows that whenever the expected demand is not equal to the lowest or the highest expected demands, the retailer’s expected profit is greater than the proportion of the value-chain’s expected profit, \(w_j \tau_{ij}\). Thus, in the TR regime the retailer gets an information rent due to having private information on expected demand. The optimum \(\{\alpha_j^*, \delta_j^*\}\) are:

\[
\alpha_j^* = [(1 - w_j)b_j X_{ij} X_{Nj}/2] + w_j V(M_j^*),
\]

\[
\delta_j^* = (1 - w_j)(a_j - b_j(X_{ij} + X_{Nj})/2] + w_j(c - M_j^*).
\]

The unit wholesale price (\(\delta_j\)) is designed to get the average retail margin, i.e., the first term, \((1 - w_j)[a_j - b_j(X_{ij} + X_{Nj})/2] = [1 - w_j][a_j - b_j \mu_j]\), since \(\mu_j = (X_{ij} + X_{Nj})/2\) by the symmetry of \(X_{ij}\) assumption; and the retailer’s portion of the manufacturer’s variable cost, i.e., the second term \([w_j(c - M_j^*)]\). The constant portion of the wholesale price
(αj) is used to recover the retailer’s portion of manufacturing effort fixed costs, i.e., the second term [wjV(Mj*)].

Stages 2 and 1

In stage 2 the retailer observes his private information, and hence, no decisions are made. In stage 1, when the retailer and the manufacturer have to agree to the information regime, the respective expected profits are given by:

\[ U^*_j = E[U^*_ij] = (1 - w_j)E[\pi^*_j] - (1 - w_j)[b_j(\Delta_j^2 - \sigma_j^2)/2] \]
\[ T^*_j = E[T^*_ij] = w_jE[\pi^*_j] + (1 - w_j)[b_j(\Delta_j^2 - \sigma_j^2)/2] \]
\[ \pi^*_j = E[\pi^*_ij] = (a_j - c)\mu_j - (b_j - v)\mu_j^2/2 - b_j\sigma_j^2/2 \]

Therefore, in the TR regime the retailer \( j \) gets an information rent \( R^*_j = (1 - w_j)[b_j(\Delta_j^2 - \sigma_j^2)/2] > 0 \), where the information rent is defined as the expected profits for the retailer over and above his proportion of the value-chain profits.

3.1.2 Information Exchange Regime

In the IE regime, each retailer communicates his demand forecast to the manufacturer, and the wholesale price schedule can be made contingent upon the retailer’s reported forecast. We use the notation \( X_{ikj} \) to denote that the retailer forecasts \( X_j \) but reports \( X_k \), which could be different from \( X_{ij} \). Truthful reporting by the retailer is indicated when \( X_{ikj} = X_{ij} \). As in the TR regime, we derive the equilibrium working backwards from stage 5 through to stage 2 and characterize the expected profit in stage 1.

Stage 5

For any wholesale price \( \{\alpha_{kj}, \delta_{kj}\} \) agreed upon in stage 4 and any given \( X_{ikj} \), i.e., when retailer \( j \) observes \( X_i \) in stage 2 and reports \( X_k \) in stage 3, the expected profit for the manufacturer is given by:

\[ U_{kj} = \alpha_{kj} + \delta_{kj}X_k - C(X_k, M_{kj}) - V(M_{kj}), \]

for each \( \{X_{kj}, X_{ij}\} \). Note that the wholesale prices and the manufacturing effort choices can be conditioned on the reported expected demand as the index \( k \) reflects. The manufacturer uses the reported expected demand for making his decisions.\(^9\)

The manufacturer’s optimum effort choice for each \( X_{kj} \) that is reported is given by:

\[ \partial E[U_{kj}]/\partial M_{kj} = -\partial E[C(X_k, M_{kj})]/\partial M_{kj} - V'(M_{kj}) = 0, \text{ for each } X_{kj} \quad (IE-ICM) \]

\(^9\) In equilibrium the retailer will report truthfully and the manufacturer will rationally expect this and base his resource deployment decision on the report. If this were not true, a rational manufacturer would ignore the report of the retailer and choose the price based on his priors.
Thus, for any given \( \{X_{ij}, \alpha_{ij}, \delta_{ij}\} \), the optimum manufacturing effort is given by \( M_{ij}^{**} = vX_{ij} \). The manufacturer uses the reported information to choose the manufacturing effort. The difference between the TR and IE regime is that in the TR regime the manufacturer chooses the manufacturing effort based on his prior belief, while in the IE regime the manufacturer uses the reported expected demand information.

**Stages 3 and 4**

The wholesale price needs to ensure that the retailer does not have the incentive to misreport the expected demand. Specifically, for each retailer and expected demand \( \{X_{ij}, X_{kj}\} \), the wholesale prices should ensure that:

\[
T_{ij} = a_j - b_jX_{ij}^2 - \alpha_{ij} - \delta_{ij}X_{ij} \geq a_j - b_jX_{ij}^2 - \alpha_{ij} - \delta_{ij}X_{ij} = T_{ij} \text{ for each } \{X_{ij}, X_{kj}\} i \neq k \quad \text{(IE-TTR)}
\]

The left side of (IE-TTR) is the retailer’s expected profit when he reports \( X_{ij} \) truthfully; while the right side is the expected profit when he observes \( X_{ij} \) and reports \( X_{kj} \). The benefit from misreporting is obtained mainly by influencing the wholesale prices. In addition to the truth-telling condition, the wholesale prices should ensure that the value-chain profit sharing conditions and the participation conditions are satisfied. These participation conditions are similar to those in the TR regime and are satisfied for each \( X_{ij} \), i.e., each \( X_{ij} \) and \( X_{kj} = X_{ij} \).  

\[
\begin{align*}
T_{ij} &= a_j - b_jX_{ij}^2 - \alpha_{ij} - \delta_{ij}X_{ij} \geq w_j[a_jX_{ij} - b_jX_{ij}^2 - C(X_{ij}, M_{ij}^{**}) - V(M_{ij}^{**})] \quad \text{(IE-PCV)} \\
T_{ij} &= a_jX_{ij} - b_jX_{ij}^2 - \alpha_{ij} - \delta_{ij}X_{ij} \geq K_{ij} \quad \text{(IE-PCR)} \\
U_{ij} &= \alpha_{ij} + \delta_{ij}X_{ij} - C(X_{ij}, M_{ij}^{**}) - V(M_{ij}^{**}) \geq K_{ij}X_{ij} \quad \text{(IE-PCM)}
\end{align*}
\]

We assume \( a_j \) to be sufficiently large such that when (IE-PCV) is satisfied both (IE-PCR) and (IE-PCM) are satisfied (see footnote 10).

The wholesale price schedule is determined for each expected demand based on the marginal pricing mechanism.  

The unit wholesale price \( (\delta_{ij}) \) is set equal to the retailer’s effective marginal expected profit \( \theta_{ij} \) [given by \( T_{ij} + \alpha_{ij} + \delta_{ij}X_{ij} - w_j\pi_{ij} \)] before paying the manufacturer. The constant \( (\alpha_{ij}) \) is used to adjust the retailer’s expected profit to exactly equal the retailer’s minimum proportion of value-chain profits. When the retailer reports truthfully, the resulting unit wholesale price maximizes the retailer’s effective expected profit. Therefore, the wholesale pricing scheme induces truthful reports of the demand forecast. The optimum \( \{\alpha_{ij}^{**}, \delta_{ij}^{**}\} \) for any reported \( X_{ij} \) are:

\[
\begin{align*}
\alpha_{ij}^{**} &= (1 - w_j)b_jX_{ij}^2/2 + w_jV(M_{ij}^{**}), \\
\delta_{ij}^{**} &= (1 - w_j)[a_j - b_jX_{ij}] + w_j(c - M_{ij}^{**}).
\end{align*}
\]

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10. The participation conditions are not specified for each \( \{X_i, X_j\} \), since in equilibrium the retailer will report the truth. Truthful reporting is considered by the condition specified in (IE-TTR).

11. This is similar to the two-part Ramsey tariff (see Laffont and Tirole, 1999, chapter 2, p.137).
\( \alpha_{ij} \) is designed to get the retailer’s share of the manufacturer’s fixed costs (the second term), and \( \delta_{ij} \) is designed to get the retail margin (the first term) and the retailer’s share of the manufacturer’s variable cost (the second term).

**Stages 2 and 1**

In stage 2 the retailer observes his private information and hence no decisions are made. In stage 1, when the retailer and the manufacturer have to agree to the information regime, the respective expected profits are given by:

\[
U_j^{**} = E[U_{ij}^{**}] = (1 - w_j)E[\pi_{ij}^{*}]
\]

\[
T_j^{**} = E[T_{ij}^{**}] = w_j E[\pi_{ij}^{*}]
\]

\[
\pi_j^{**} = E[\pi_{ij}^{**}] = (a_j - c) \mu_j - (b_j - v)\mu_j^2/2 - (b_j - v)\sigma_j^2/2
\]

Thus, in the IE regime the wholesale price schedule is designed such that retailer \( j \) gets no information rent \( R_j^{**} = 0 \). This result is similar to the findings in Demski and Sappington (1984), Cremer and McLean (1988) and McAfee and Reny (1992), where it is shown that with correlated signals on the private information the information rent can be driven to zero. In this case, the realized demand \( (x_i) \) is the signal that is used in the wholesale price schedule for the unit wholesale price portion, and provides information on the retailer’s demand distribution. The use of this information allows the extraction of the information rent from the retailer.

We proceed to examine the characteristics of the retailer’s and manufacturer’s profits and the choice of the information regimes.

### 3.2 Comparison Across Retailers and Information Regimes

#### 3.2.1 Comparison of Retailers’ Information Rents

We compare the information rents that the large and small retailer commands. While the retailers do not get any information rent in the IE regime, they command a positive information rent in the TR regime. Comparing the expected information rents across the large and small retailers in the TR regime leads us to Proposition 1.\(^{12}\)

**Proposition 1:** *In the TR regime, the large retailer’s information rent is lower than the small retailer’s information rent if the large retailer’s expected demand is less dispersed than the small retailer’s expected demand. Technically, \( R_L^{*} < R_S^{*} \) if \( \{.5(\mu_{NL}^2 + \mu_{NL}^2) - (b_j - v)\mu_j^2/2\} > \{.5(\mu_{NS}^2 + \mu_{NS}^2) - (b_j - v)\mu_j^2/2\} \).*

Proposition 1 shows that large retailers obtain lower information rents than small retailers, even though their expected volume is higher. This is driven by three factors. First, since the large retailer gets a higher proportion of the value-chain profits than the small retailer, i.e., \( w_L > w_S \) the manufacturer’s portion of the value-chain profits is

\(^{12}\) The proofs of all propositions are given in the appendix.
lower, i.e., \((1 - w_L) < (1 - w_S)\). Consequently, the portion of rents that the large retailer can extract from the manufacturer is lower. Second, the wholesale price mechanism is designed such that the manufacturer shares the retailer’s costs and vice versa. The retailer extracts rents by making the manufacturer share a higher portion of the retail service cost. Thus, the retail service cost is a factor that determines extent of information rent. As argued earlier, the small retailer’s service cost parameter is higher than the large retailer’s service cost parameter, i.e. \(b_S >> b_L\), because of economies of scope. Third and most important, variance in the expected demand represented by \((\Delta_j^2 - \sigma_j^2)\) influences the information rent. Variance influences the information rent because it represents the extent of the information advantage that the retailer has over the manufacturer. If the variance increases due to an increase in \(X_N - X_1\), then \((\Delta_j^2 - \sigma_j^2)\) increases, leading to higher information rents. This occurs because the manufacturer extracts information rents in the extreme expected demand, i.e., \(\{X_{1j}, X_{Nj}\}\) alone. If the variance decreases without an increase in \(\Delta_j^2\), for instance by an increase in the probability mass around the mean of \(X_{ij}\), the information rent increases. This occurs because the retailer’s information becomes more valuable to the manufacturer and consequently the retailer is able to capture a larger portion of the information rent.

3.2.2 Comparison of Manufacturer’s Profit Across the Regimes

We examine the manufacturer’s profits across the regimes to gain insights into whether the manufacturer prefers one regime over the other. Proposition 1 indicates one benefit for the manufacturer of moving to the IE regime, i.e., the savings in information rent. The following proposition characterizes the difference in the manufacturer’s expected profits across the regimes.

**Proposition 2:** The manufacturer’s expected profit is higher in the IE regime than in the TR regime for any retailer. Technically, \(U_{j^*}^* - U_{j^*}^* = [(1 - w_j)v\sigma_j^2/2] + [(1 - w_j)b_j(\Delta_j^2 - \sigma_j^2)/2] > 0\) for each \(j\).

Proposition 2 shows that the manufacturer prefers the IE regime for both retailers. The move from TR to IE is beneficial to the manufacturer for two reasons. First, the manufacturer gets his portion of the increased value-chain profits due to improved efficiency in resource utilization, i.e., \([(1 - w_j)v\sigma_j^2/2]\). Second, the manufacturer saves the information rent that he pays the retailer in the TR regime, i.e., \([(1 - w_j)b_j(\Delta_j^2 - \sigma_j^2)/2]\). Consequently, the manufacturer always prefers the IE regime.

3.2.3 Comparison of Retailer’s Profits Across the Regimes

We examine the retailer’s profit across the regimes. From Proposition 1 we know that the retailer loses information rent in the IE regime and thus may not prefer the IE regime. On the other hand, from Proposition 2 we know that the efficiency gains that accrue to the value-chain by sharing information in the IE regime will flow through to the retailer, which could make the retailer prefer the IE regime. The following proposition characterizes the difference in the retailer’s expected profits across the regimes.
Proposition 3: Retailer j’s expected profit is higher in the IE regime than in the TR regime if and only if \( C_{1j} \geq 0 \), i.e., \( T_{j}^{**} \geq T_{j}^{*} \) iff.

\[
C_{1j} = w_{j}v_{j} \sigma_{j}^{2} - (1 - w_{j})b_{j}[\Delta_{j}^{2} - \sigma_{j}^{2}] \geq 0.
\] (1)

The value-chain’s expected profit is higher in the IE regime than in the TR regime, because the manufacturing effort is adjusted optimally to the demand environment (i.e. improved efficiency in resource utilization). The increase in the value-chain’s expected profit due to improved efficiency in resource utilization is \( v_{j} \sigma_{j}^{2}/2 \). The retailer’s share of the value-chain’s increased expected profit is thus \( w_{j}v_{j} \sigma_{j}^{2}/2 \), i.e., the first term in equation (1). On the other hand, in the TR regime the retailer gets information rent while in the IE regime there is no information rent. The information rent that the retailer loses by moving to IE is given by \((1 - w_{j})b_{j}(\Delta_{j}^{2} - \sigma_{j}^{2})/2\), i.e. the second term in equation (1) (also see Proposition 1). The retailer’s expected profit in the IE regime is higher than in the TR regime if and only if his proportion of the value-chain’s efficiency gains compensates him for the lost information rents.

The retailer’s decision to move from TR to IE trades off the benefits from the increased share of value-chain profits due to improved efficiency in resource utilization against the cost of losing the information rent in TR. Proposition 3 shows that the retailer would agree to move from TR to IE if and only if the benefit outweighs the cost.

3.3 Discussion

The TR regime is considered as the benchmark regime that existed before advances in information technology made information exchange possible. The manufacturer and the retailer will agree to move from the TR regime to the IE regime if and only if each one’s expected profit is higher in the IE regime than in the TR regime. Alternatively, if the manufacturer has a higher expected profit in the IE regime but the retailer has a higher expected profit in the TR regime, the TR regime will prevail in a non-cooperative equilibrium. Propositions 2 and 3 identify the factors that influence such an agreement. Specifically, the manufacturer is always better off in the IE regime due to increased efficiency gains and the savings with respect to information rent. What type of retailer is more likely to move from the TR to the IE regime?

3.3.1 Large and Small Retailers

The retailer will prefer the IE regime if and only if the benefit (the retailer’s portion of the efficiency gains) outweighs the cost (lost information rent). Proposition 1 indicates that the small retailer’s information rents can be higher even though his expected demand is lower if his expected demand profile is more diverse. Thus, there is also a higher potential of efficiency gains from sharing the small retailer’s demand information. This argument and finding complements the finding of Lee and Whang (1998), who show that the value of information increases with increased variability. However, the small retailer’s share of value-chain profits is small. Consequently, the small retailer will capture only a small portion of the value-chain’s efficiency gains. In addition, the information rent depends on the manufacturer’s portion of the value-chain profits, i.e. \((1 - w_{j})\), and thus his information rents will be high. Thus, in the cost-benefit
analysis of moving from the TR to the IE regime, the small retailer is likely to have lower expected profits and hence he will not agree to move to the IE regime.

On the other hand, the large retailer will capture a large portion of the value-chain’s efficiency gains moving from the TR to the IE regime, while his information rent in the TR regime is relatively lower. Thus, the large retailer is likely to have higher expected profits in the IE regime, and will agree to move to the IE regime.

This result provides an information based rationale for why large retailers such as Wal-Mart were the first to move from the TR to the IE regime. More importantly, the result provides a reason why the small boutique stores might not move from the TR to the IE regime. Specifically, the small retailers get a high information rent in the TR regime but will share little of the increased profits in the IE regime. This insight is important because there are a large number of small retailers, whose ordering patterns would cause a higher variability in the orders that the manufacturer’s get. Hence, it would appear as if it would be more beneficial to get the forecast of the large number of small retailers. However, the result provides an information-based reason for why this may not be possible.

3.3.2 Effect of variance in demand

Examining the condition specified in equation (1) we observe that if an increase in demand variability without an increase in the dispersion of the expected demand, i.e. $X_{nj} - X_{ij}$ is constant then $C_1$ is more likely to be satisfied. The increase in demand variability of this kind decreases the retailer’s information rent in the TR regime and increases the profitability due to the improvements in efficiency in the IE regime. Thus, the greater the demand variability, the more likely the retailer is to agree to move from the TR to the IE regime. This finding also complements the finding of Lee and Whang (1998), who show that the value of information increases with increased variability. Here we show that even after accounting for the information rent effect, a similar intuition prevails.

3.4 Illustration of the Effects

Both these aspects, i.e. the large versus small retailers and the impact of variability of demand, are illustrated with an example. For purposes of the example, $v = 0.02$, $c = 4.5$, $a_s = 4.5$, $b_S = 0.01$, $X_{1S} = 40$, $X_{2S} = 45$, $X_{3S} = 50$, $X_{4S} = 55$, $X_{5S} = 60$, $w_S = 0.40$, $\phi_{1S} = \phi_{5S} = 0.10$ to 0.185 in increments of .005, $\phi_{2S} = \phi_{4S} = 0.20$, $\phi_{3S} = 1 - 2(\phi_{1S} + \phi_{2S})$, $\alpha_L = 0.01$, $\alpha_L = 4.0$, $b_L = 0.01$, $X_{1L} = 100$, $X_{2L} = 150$, $X_{3L} = 200$, $X_{4L} = 250$, $X_{5L} = 300$, $w_L = 0.60$, $\phi_{1L} = \phi_{5L} = 0.01$ to 0.18 in increments of .01, $\phi_{2L} = \phi_{4L} = 0.20$, $\phi_{3L} = 1 - 2(\phi_{1L} + \phi_{2L})$. Thus, the variability of demand for the small retailer varies from 30 to 47, while the variability of the demand for the large retailer varies from 1200 to 4600. Figure 1, Panel A plots the expected

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13 We are not ruling out other reasons, such as access to and cost of capital, which might inhibit information exchange by small retailers. Even so, the loss of information rent is a powerful disincentive for pursuing this option.

14 To see this, differentiate the condition in equation (1) with respect to $\sigma^2$.

15 Note that this violates the assumption of $b_s < b_l$ and $\sigma_s^2 > \sigma_l^2$. However, those are sufficient but not necessary conditions. The example is still valid with the given parameters.
profits of the small retailer in each regime, while Figure 1, Panel B plots the expected profits of the large retailer in each regime. For each retailer, the higher the variance of demand the more benefits he obtains from moving to the IE regime. The small retailer is less likely to move to the IE regime, because his profits are higher over a larger region.

Figure 1: Comparison of Retailer’s Profits Across the Regimes

Panel A: Small Retailer’s Expected Profits

Panel B: Large Retailer’s Expected Profits

Parameter values: \( v = 0.02, c = 4.5, a_s = 4.5, b_s = 0.01, X_{1s} = 40, X_{2s} = 45, X_{3s} = 50, X_{4s} = 55, X_{5s} = 60, w_s = 0.40, \phi_{1s} = \phi_{5s} = 0.10 \) to \( 0.185 \) in increments of \( .005, \phi_{2s} = \phi_{4s} = 0.20, \phi_{3s} = 1 - 2(\phi_{1s} + \phi_{2s}), a_l = 4.0, b_l = 0.01, X_{1l} = 100, X_{2l} = 150, X_{3l} = 200, X_{4l} = 250, X_{5l} = 300, w_l = 0.60, \phi_{1l} = \phi_{3l} = 0.01 \) to \( 0.18 \) in increments of \( .01, \phi_{2l} = \phi_{4l} = 0.20, \phi_{5l} = 1 - 2(\phi_{1l} + \phi_{2l}). \)
4. Concluding Remarks

This paper examines the effect of strategic behavior by the value-chain partners on the feasibility of implementing information exchange. We model a two-level value-chain that includes a manufacturer who sells a manufactured product to a retailer, who is privately better informed about the demand for that product. We examine the tradeoff resulting from information exchange between incremental profit from more efficient resource utilization and a possible loss of information rent for the retailer.

We showed that the move from the traditional (no information exchange) to the information exchange regime is more likely to benefit a large retailer than a small one. Further, we showed that information exchange is preferred when high demand creates a high incremental value of demand information to the manufacturer. Information exchange becomes less attractive if activity adjustment cost is high. These findings come about because of strategic interplay between the manufacturer and the retailer. This paper’s primary contribution is that the incentives of value-chain partners determine whether information exchange will be implemented or not in value-chains.

While considerable attention has been devoted in the current academic and practitioner literature to the benefits of value-chains and information exchange, not much attention has been devoted to the feasibility of implementing such information exchange. This paper seeks to answer the question of feasibility of information exchange implementation in value-chains by providing a better understanding of the strategic interactions between players in the value-chain.
Appendix 1: Proof of Propositions

Proof of Proposition 1
Note that \( \Delta_j^2 = \mu_j^2 - X_{ij}X_{nj} = (X_{ij}^2 + X_{nj}^2 - 2X_{ij}X_{nj})/4 \), and \( \sigma_j^2 = E(X_j^2) - \mu_j^2 = E(X_j^2) - (X_{ij}^2 + X_{nj}^2 - 2X_{ij}X_{nj})/4 \). Using these, we have \( (\Delta_j^2 - \sigma_j^2) = [(X_{ij}^2 + X_{nj}^2)/2] - E(X_j^2) \). The inequality in the proposition follows directly using the condition along with the expression for \( (\Delta_j^2 - \sigma_j^2) \), and the assumptions \( b_L < b_S \) and \( w_L > w_S \). ♦

Proof of Proposition 2
We need to show that \( E[U_{ij}^{**}] \geq E[U_i^*] \).

\[
E[U_{ij}^{**}] - E[U_i^*] = (1 - w_j)(a_j - c)\mu_j - (1 - w_j)[(b_j - v)\mu_j^2/2] - (1 - w_j)[(b_j - v)\sigma_j^2/2] \\
- (1 - w_j)((a_j - c)\mu_j + ((b_j - v)\mu_j^2/2)] + [(1 - w_j)b_j\Delta_j^2/2] \\
= (1 - w_j)b\Delta_j^2/2 - (1 - w_j)(b_j - v)\sigma_j^2/2 \\
= (1 - w_j)b_j(\Delta_j^2 - \sigma_j^2)/2 + (1 - w_j)v\sigma_j^2/2 > 0,
\]
where the last inequality follows because of the symmetry of distribution assumption, which implies \( \Delta_j^2 > \sigma_j^2 \). ♦

Proof of Proposition 3
We need to show that \( E[T_{ij}^{**}] \geq E[T_i^*] \).

\[
E[T_{ij}^{**}] - E[T_i^*] = w_j(a_j - c)\mu_j - w_j[(b_j - v)\mu_j^2/2] - w_j[(b_j - v)\sigma_j^2/2] \\
- w_j(a_j - c)\mu_j + w_j[(b_j - v)\mu_j^2/2] - (1 - w_j)b_j\Delta_j^2/2 + b_j\sigma_j^2/2 \\
= w_j[v\sigma_j^2/2] - (1 - w_j)b_j(\Delta_j^2 - \sigma_j^2)/2 > 0,
\]
where the last inequality is obtained if and only if the condition in equation (1) is satisfied. ♦
Appendix 2: Derivation of the Solution

For brevity, we suppress the subscript \( j = L, S \). All these derivations apply for any \( j \).

**Solution for the TR Regime**

From the first-order conditions for (TR-ICM) for any given \( \{\alpha, \delta\} \) we have:

\[
\frac{\partial E[U_1]}{\partial M} = -\frac{\partial E\{C(x, M)\}}{\partial M} - V'(M) = 0,
\]

where \( E[.] \) is the expectations operator over \( X_i \). From \( E[C(x, M)] = (c - M)\mu \) and \( V(M) = [M^2/2\nu] \), we have \( \frac{\partial E\{C(x, M)\}}{\partial M} = \mu \) and \( V'(M) = M/\nu \). Substituting these in the above, we have \( M' = v\mu \).

We next show that (TR-PCV) is satisfied at equality for \( \{X_1, X_N\} \). Rewrite (TR-PCV) as \( \theta_i = (1 - w)[a X_i + B(X_i)] + w[C(X, M') + V(M')] \geq \alpha + \delta X_i \) for each \( i \). Substituting for \( M' = v\mu \) and \( V(.) \) we have:

\[
\theta_i = (1 - w)[a X_i - 0.5bX_i^2] + w[(c - v\mu)X_i + (v\mu^2/2)] \geq \alpha + \delta X_i \text{ for each } i.
\]

\( \theta_i \) is the retailer’s effective expected profit before considering the wholesale price. \( \theta \) is concave in \( X_i \), i.e., \( \frac{\partial \theta}{\partial X} = (1 - w)[a - bX_i] + w[(c - v\mu)] > 0 \), and \( \frac{\partial^2 \theta}{\partial X^2} = -(1 - w)(b - h) < 0 \). Assume that (TR-PCV) is binding for some \( \{X_i \neq X_1\} \) and \( \{X_i \neq X_N\} \) with \( X_i > X_1 \). Then we have \( \theta_i = \alpha + \delta X_i \) and \( \theta_j = \alpha + \delta X_j \). Solving for \( \{\alpha, \delta\} \) we have \( \delta = [\theta_i - \theta_j] / (X_i - X_j) \) and \( \alpha = (\theta_i X_j - \theta_j X_i) / (X_i - X_j) \). Substituting the \( \{\alpha, \delta\} \) in (TR-PCV) for \( i = 1 \), we require that \( \theta_1 - [\theta_1 X_j - \theta_j X_1] / (X_j - X_1) - [(\theta_i - \theta_j) X_i / (X_j - X_i)] \geq 0 \). Rearranging the equation we have:

\[
\theta_1 - [(\theta_i X_j - \theta_j X_i) / (X_j - X_i)] - [\theta_j - \theta_i] X_1 / (X_j - X_1) = [\theta_i X_j - \theta_j X_i - \theta_j X_1 + \theta_i X_1 - \theta_i X_j] / (X_j - X_i)
\]

\[
- \theta_i X_1 / (X_j - X_i)
\]

\[
= [\theta_i X_j - \theta_j X_i - \theta_i X_j + \theta_j X_i - \theta_j X_1 + \theta_i X_1 - \theta_i X_j] / (X_j - X_i) = [(\theta_i - \theta_j) / (X_j - X_i)] - [(\theta_i - \theta_j) / (X_j - X_i)] / (X_j - X_i) < 0,
\]

since \( (\theta_j - \theta_i) / (X_j - X_i) < (\theta_i - \theta_j) / (X_i - X_N) \) by concavity of \( \theta_i \) in \( X_j \), and hence, a contradiction with the assumption that (TR-PCV) is binding for some \( X_i \neq X_1 \) and \( X_j \neq X_N \). Thus, (TR-PCV) is binding for \( X_i = X_1 \) and \( X_j = X_N \).

Solving for \( \{\alpha, \delta\} \) with (TR-PCV) satisfied at equality for \( \{X_1, X_N\} \), we have \( \delta = [\theta_N - \theta_i] / (X_N - X_i) \) and \( \alpha = [\theta_i X_N - \theta_N X_i] / (X_N - X_i) \). This leads to:

\[
\alpha = (1 - w)bX_i X_N / 2 + w(v\mu^2/2) \text{ and } \delta = (1 - w)[a - b(X_i + X_N)/2] + w(c - v\mu).
\]

Using \( X_i = (\mu - \Delta) \) and \( X_N = (\mu + \Delta) \) we have \( X_i X_N = (\mu^2 - \Delta^2) \) and \( (X_i + X_N) = 2\mu \). Substituting in \( \{\alpha, \delta\} \) yields \( \{\alpha^*, \delta^*\} \). Substituting the optimum \( \{\alpha^*, \delta^*, M^*\} \) in \( U_i \) we have:
\[ U_i^* = (1 - w)b(\mu^2 - \Delta^2)/2 + w\mu^2/2 + (1 - w)[a - b\mu]X_i + w(c - v\mu)X_i - (c - v\mu)X_i - (v\mu^2/2) \]
\[ = [(1 - w)(b - v)\mu^2/2] - [(1 - w)b\Delta^2/2 + [(1 - w)((a - c) - (b - v)\mu)]X_i \]

Taking expectation over \( X_i \) and rearranging yields:
\[ E[U_i^*] = (1 - w)[(a - c)\mu - ((b - v)\mu^2/2)] - (1 - w)b\Delta^2/2. \]

Similarly substituting the \( \{\alpha^*, \delta^*, \theta^* \} \) in \( T_i \) and taking expectations over \( X_i \) we have:
\[ E[T_i^*] = w[(a - c)\mu - ((b - v)\mu^2/2)] + (1 - w)b\Delta^2/2 - b\sigma^2/2. \]

Substituting for \( E[\pi_i^*] = E[T_i^*] + E[U_i^*] \) yields the expressions for \( E[\pi_i^*] \), \( E[T_i^*] \) and \( E[U_i^*] \).

**Solution for the IE Regime**

From (IE-ICR) and (IE-ICM) for any \( X_i \) reported as \( X_j \) \( \{\alpha_j, \delta_j\} \) we have for each \( i \):
\[ \frac{\partial U_{ij}}{\partial M_j} = -\frac{\partial C(x, M_j)}{\partial M_j} - V(M_j) = 0. \]

Substituting for \( \frac{\partial C(x, M_j)}{\partial M_j} = X_j \) and \( V(M_j) = M_j/v \), we have \( M_j^{**} = vX_j \), which depends on the reported \( X_j \).

Denote the retailer’s effective expected profit when he observes \( X_i \) and reports \( X_j \) as:
\[ \theta_{ij} = (1 - w)[a X_j - B(X_j, S_{ij}^{**}) - H(S_{ij}^{**})] + w[C(X_j, M_j^{**}) + V(M_j^{**})] \]
for each \( j \).

In general, if \( \theta_{ij} \) is concave in \( X_i \), then the wholesale prices will satisfy (IE-TTR) and (IE-PCR) by choosing \( \{\alpha_j, \delta_j\} \) as follows:
\[ \delta_j = [\partial \theta_j/\partial X_j] = (1 - w)[a - bX_j] + w[c - M_j^{**}], \text{ and } \alpha_j = \theta_{ij} - \delta_jX_j. \]

Substituting for \( \{S_{ij}^{**}, M_j^{**}\} \) and rearranging we have:
\[ \delta_j^{**} = (1 - w)[a - bX_j] + w[c - vX_j], \text{ and } \alpha_j^{**} = (1 - w)bX_j^2/2 + vwX_j^2/2. \]

When the retailer observes \( X_i \) and reports \( X_j \), his expected profit will be:
\[ T_{ij} = aX_i - (b/2)X_i^2 - \alpha_j^{**} - \delta_j^{**}X_j. \]

Substituting for \( \{\alpha_j^{**}, \delta_j^{**}, K_j^{**}\} \) in \( T_{ij} \) we have:
\[ T_{ij} = aX_i - (1 - w)bX_j^2/2 - (1 - w)bX_j^2/2 - vwX_j^2/2 + (1 - w)[a - bX_j]X_i + w[c - vX_j]X_i \]
\[ = w(a - c)X_i - bX_j^2/2 + (1 - w)b[X_jX_i - (X_j^2/2)] + w v[X_jX_i - (X_j^2/2)]. \]
To verify that the mechanism designed induces truth-telling, we need to show that $\frac{d}{dX_j} = 0$ for $X_j = X_i$ and $\frac{d^2T_{ij}}{dX_j^2} < 0$. Differentiating $T_{ij}$ with respect to $X_j$ we have $\frac{dT_{ij}}{dX_j} = (1 - w)b + wv(X_i - X_j) = 0$, if and only if $X_j = X_i$. Differentiating again with respect to $X_j$ we have $\frac{d^2T_{ij}}{dX_j^2} = -(1 - w)b + wv < 0$, since (IE-TTR) is satisfied by the optimum $\{\alpha_j^{**}, \delta_j^{**}, M_j^{**}\}$.

Substituting $\{\alpha_j^{**}, \delta_j^{**}, M_j^{**}\}$ in $\pi_{ii}^{**}$ we have:

$$\pi_{ii}^{**} = (a - c)X_i - (b - v)X_i^2/2.$$ 

It follows that (IE-PCR) is satisfied at equality for each $X_i$, since $T_{ii} = w\pi_{ii}^{**}$. Hence,

$$E[\pi_{ii}^{**}] = (a - c)\mu - (b - v)\mu^2/2 - (b - v)\sigma^2/2].$$

With (IE-PCR) satisfied at equality we have $E[U_{ii}^{**}] = (1 - w)E[\pi_{ii}^{**}]$ and $E[T_{ii}^{**}] = wE[\pi_{ii}^{**}]$. ♦

References

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