Abstract

We assess the benefits of sharing demand forecast information in a manufacturer–retailer supply chain, consisting of a traditional retail channel and a direct channel. The demand is a linear function of price with a Gaussian primary demand (i.e., zero-price market potential). Both the manufacturer and the retailer set their price based on their forecast of the primary demand. In this setting, we investigate the value of sharing demand forecasts. We analyze the make-to-order scenario, in which prices are set before and production takes place after the primary demand is known, and the make-to-stock scenario, in which production takes place and prices are set before the primary demand is known. We also compare the supply chain performance with and without the direct channel under some assumptions (production cost is zero, and each demand function has the same slope of price). We find that the direct channel has a negative impact on the retailer’s performance, and, under some conditions, the manufacturer and the whole supply chain are better off. Our research extends and complements prior research that has investigated only the inventory and replenishment-related benefits of information sharing.

Keywords: Supply chain management; Information sharing; Direct channel; Uncertainty modeling

1. Introduction

Information technology has significantly reshaped supply chain behavior in the last two decades. Particularly, the commercial blossoming of the Internet has introduced tremendous opportunities and has underscored the importance of effective supply management. Companies such as Dell use direct sales, primarily through the Internet, to bring products to market faster than competitors, thus enjoying a huge early-to-market advantage. Moreover, direct sales allow the manufacturer to eliminate distributor and retailer
margins, thus increasing its own profit margin. According to one survey reported in the New York Times, about 42% of top suppliers in a variety of industries have begun to sell directly to consumers over the Internet.

One significant benefit of information technology is to allow firms to share information (i.e., point-of-sale data, inventory, forecast data, and sales trends) quickly and inexpensively. Information sharing helps the supply chain in two fundamental ways. First, it enables the manufacturer to respond to consumer demand more quickly by appropriately scheduling production and replenishing retailer inventory. Innovations such as CRP and Vendor Managed Inventory (VMI) are efforts in this direction. Second, information sharing improves the accuracy of demand forecasts. As we know, forecasts are essential to the supply chain’s decision making and planning processes. Better forecasting can contribute to better price structuring and better inventory management. Recently, schemes such as Collaborative Planning, Forecasting, and Replenishment (CPFR) facilitate sharing of demand forecasts among the supply chain players in this direction. Conventional wisdom suggests that sharing of forecasts within a supply chain improves the forecast accuracy and leads to higher profitability.

One objective of this paper is not only to analyze the value of demand forecast sharing in a supply chain with direct channel but also to understand how to share information, e.g. under what conditions is information sharing mutually beneficial to both the manufacturer and the retailer and under what conditions is one player better off and the other is worse off with information sharing, as one player may use the shared information against the other.

So far, most research on information sharing has focused solely on inventory and replenishment related savings (i.e. Bourland et al., 1996; Gavirneni et al., 1999; Lee et al., 2000; Cachon and Fisher, 2000). In their models, price and demand are considered exogenous. By focusing on inventory and replenishment decisions alone, these models underestimate the benefit of information sharing, and also do not address the strategic role forecasts play in pricing. Our paper contributes to existing literature by addressing information sharing’s impacts on two components: pricing and inventory.

Another objective of this paper is to analyze the direct channel’s impact on supply chain performance. Intuitively, a direct channel enables the manufacturer to be the upstream product provider for the retailer and also enables the manufacturer to become the competitor of the retailer. Thus, questions may arise naturally, such as is the retailer the loser due to the resulting channel conflict (competition)? What about the manufacturer’s performance? We know that the direct channel simultaneously brings opportunity and threats to the manufacturer. Specifically, a direct channel is able to attract a new customer segment and increase the manufacturer’s profit margin, but on the other hand, a direct channel could lead to conflict with the existing retailer channel. Therefore, what is the overall effect of direct channel on the manufacturer’s performance? We will quantify these effects in this study.

Information sharing has been a major issue in supply chain literature. This literature discusses how a manufacturer can elicit information from retailers through inventory, lead time, and shortage allocation policies (Bourland et al., 1996; Gavirneni et al., 1999; Gallego et al., 2000; Cachon and Fisher, 2000). Bourland et al. (1996) show that information sharing offers significant benefits to the manufacturer and retailer when their ordering cycles are significantly out of phase. Gavirneni et al. (1999) study the holding and penalty cost of a finite capacity supplier facing demands from a single retailer following a (s, S) policy. By considering various types of demand distributions in their numerical experiments, Gavirneni et al. examine the conditions under which gaining information about the retailer’s inventory level is beneficial. Lee et al. (2000) study the benefit of demand information sharing when the underlying demand process faced by the retailer is an AR (1) process. They assume that the manufacturer and the retailer incur linear holding and backlogging costs, experience constant lead times, and follow base-stock policies. Chen et al. (2000) quantify the bullwhip effect for a simple two-stage supply chain and demonstrate that centralizing demand information can significantly reduce the increase in variability. Cachon and Fisher (2000) study the value of sharing data in a model with one supplier, N identical retailers, and stationary stochastic consumer
demand. They conclude that implementing information technology to accelerate and smooth the physical flow of goods through a supply chain is significantly more valuable than using information technology to expand the flow of information. Gallego et al. (2000) show that delay base-stock policies can capture a significant portion of the benefits of demand information sharing. They compare the costs under fixed and random delay base-stock policies against the cost under demand information sharing. Aviv (2001) investigates the value of collaborative forecasting and integrating the retailer into the manufacturer’s replenishment process. Cachon and Lariviere (2001) study forecast sharing in a two-stage supply chain between a manufacturer and a supplier, where the manufacturer provides an initial forecast and a contract to the supplier. They find that it is always in the interest of the manufacturer to truthfully share the forecast with supplier, particularly when the demand forecast is high. Li (2002) considers a supply chain model with a manufacturer and multiple symmetric retailers. He shows that vertical information sharing has two effects: a direct effect and an indirect effect (leakage effect). He identifies conditions under which information can be traded and examines the impact of information sharing on the total supply chain profits.

The impact of forecasting on pricing has been studied in marketing and economics literature. This literature typically considers the competition in a duopoly that uses different forecasts of the market demand. Vives (1984) identifies conditions under which the sharing of private information between competitors is profitable. Raju and Roy (2000) analyze the impact of firm size, product substitutability, and intensity and mode of competition on the value of forecast information. Researchers have also looked at how to combine information from different sources (Winkler, 1981). Sarvary and Parker (1997) show that information from different sources can be substitutes or complements depending on characteristics such as variance and correlation. Mishra et al. (2001) examine the value of demand forecast sharing in a simple supply chain consisting of a manufacturer and a retailer. They find that demand forecast sharing is beneficial to the manufacturer under any condition and beneficiary to the retailer under some conditions.

Another stream of research related to this work is about direct channel: Balasubramanian (1998) models the competition in the multiple-channel environment with direct marketers and obtains the price equilibrium; Chiang et al. (2003) study the dual channel supply chain design for goods that do not provide a large service (value). Their results show the manufacturer can mitigate the profit loss by adding a direct channel. Geyskens et al. (2002) find that powerful firms with a few direct channels achieve better financial performance than less powerful firms with broader direct channel offerings. Yao and Liu (2003) study the customer diffusion between an e-tail channel and a retailer channel. They find that demands on both channels are stable under certain conditions.

In this paper, we consider a manufacturer–retailer supply chain, which consists of a mix of the traditional retail channel and a direct channel. Customers can purchase products from either the retailer channel or the direct channel. The demand is a linear function of price. The retailer and the manufacturer forecast the primary demand, which is unknown. When forecasts are not shared, the manufacturer and the retailer set the wholesale price and retail price respectively, using their own forecasts. In the information sharing case, the forecasts are shared prior to setting the prices. In order to focus on the pricing aspect of the supply chain as opposed to the inventory aspect considered in prior literature, we first assume that the retailer places an order and the manufacturer makes production after demand is known. We show that the manufacturer and the retailer benefit from information sharing when the manufacturer is optimistic about the demand, i.e., the manufacturer’s forecast is sufficiently larger than the retailer’s. Under this situation, the manufacturer would like to give a price discount to the retailer for sharing the forecast information. This represents a win–win situation for the manufacturer and the retailer. Alternatively, when the manufacturer’s forecast is sufficiently lower (pessimistic) than the retailer’s, information sharing increases the manufacturer’s profit but decreases the retailer’s profit due to double marginalization. In this case, it is not in the interest of the retailer to share forecast information. If the supplier and the retailer jointly maximize their profits, the misalignment of incentives for information sharing caused by double marginalization can be alleviated.
We also compare the manufacturer and the retailer’s profits between the cases with and without the direct channel under some assumptions (production cost is zero, and each demand function has the same slope of price). We find that the direct channel has a negative impact on the retailer’s performance, and the manufacturer and the whole supply chain are better off under some conditions.

We extend our model to consider the case when production takes place before demand is known. In such cases, we find that the manufacturer can offer an appropriate price discount or side payment, such as buying the information from the retailer, to obtain the information from the retailer when the retailer has no incentive to share the information voluntarily. Through a simulation example, we illustrate information sharing’s impact on the supply chain performance.

The rest of the paper is organized as follows: we discuss the model framework in Section 2. In Section 3, we analyze the value of information sharing when production and sale takes place after the demand is known (prices are set before the demand is known). In Section 4, we analyze the value of information sharing when both price and production decisions are made before the demand is known. We present our simulation result in Section 5 and conclude the paper in Section 6.

2. Model framework

We consider a simple supply chain made up of one manufacturer and one retailer (see Fig. 1). Customers can purchase items either through the retail channel or through the manufacturer’s direct channel. We assume that both the manufacturer and the retailer choose their own decision variables to maximize their respective profits. We also assume that the manufacturer is the Stackelberg leader and the retailer is the follower. To derive the optimal decisions, we use the Bayesian Nash Equilibrium (Harsanyi, 1967) concept, a pair of strategies and conjectures such that (a) each firm’s strategy is a best response to his conjecture about the behavior of the rival, and (b) the conjectures are right in the equilibrium.

In the Stackelberg model, the manufacturer will act as the leader by announcing its decision first. The retailer then announces its own decision, knowing the leader firm’s already declared strategy. It is assumed that the firms are rational.

Thus, the manufacturer sets the uniform wholesale price \(w\), the direct channel price \(p_d\), and (or) the production quantity \(Q\) first. The retailer follows by setting the retail price \(p_r\) in response to the

---

**Fig. 1.** A mixed retail and direct channels of distribution system.
manufacturer’s wholesale price \((w)\). The demand of each side (manufacturer or retailer) depends on its own price and the price of the other player. The demand is uncertain. Each player (the retailer or manufacturer) obtains a forecast of the base level of demand (the demand intercept), and uses this forecast in its pricing decision. In this context, we examine the value of forecast information sharing.

We assume that the demand functions are linear in self and cross-price effects, but with different parameters for each channel (see Raju and Roy, 2000; McGuire and Staelin, 1983). Specifically, the demand function is assumed to be

\[
\begin{align*}
D_d &= \theta a - b_1 p_d + c_1 p_r, \\
D_r &= (1 - \theta) a - b_2 p_r + c_2 p_d,
\end{align*}
\]

where \(D_d\) is the manufacturer’s direct channel demand and \(D_r\) is the retailer’s demand. \(a\) is the primary demand (i.e., potential demand if free of charge), \(\theta\) is the percentage share of the demand going to the manufacturer’s direct channel when \(p_d\) and \(p_r\) are zero, and \((1 - \theta)\) goes to the retailer when \(p_d\) and \(p_r\) are zero. \(\theta\) reflects the customer’s preference for the direct channel (the higher \(\theta\) is, the more customers prefer to use the direct channel). \(p_d\) is the price of the manufacturer’s direct channel, \(p_r\) is the retailer’s price, \(b_1\) is the slope of \(D_d\), and \(b_2\) is the slope of \(D_r\). Cross-price sensitivities \(c_1\) and \(c_2\) reflect the degree to which the products of the two channels are substitutes. We assume that \(c_i \leq b_i\) for \(i = 1, 2\), so that own price effects are greater than or equal to cross-price effects.

All parameters are positive. To capture uncertainty in market demand resulting from changes in economic and business conditions, we assume that \(a\) is a random variable. We assume that

\[
a = \bar{a} + \epsilon,
\]

where \(\epsilon\) is assumed to be normally distributed with mean zero and variance \(\sigma_\epsilon^2\). We allow each player to obtain a forecast about the unknown demand using the market-information-gathering techniques at its disposal. Denote the manufacturer’s and retailer’s forecast of the base level of demand \(a\), as \(f_m\) and \(f_r\) respectively. We assume that

\[
\begin{align*}
f_m &= a + \epsilon_m, \\
f_r &= a + \epsilon_r,
\end{align*}
\]

where \(\epsilon_m\) and \(\epsilon_r\) are normally distributed, independent of the base level of demand \(a\), with mean zero and variance \(\sigma_m^2\) and \(\sigma_r^2\) respectively. A higher (lower) variance implies a less (more) precise forecast. The forecast errors \(\epsilon_m\) and \(\epsilon_r\) can be correlated. The extent of correlation depends on the data and methodology used by the retailer and the manufacturer in their forecasting process. Similar data and methodology will result in higher correlation between forecasts. The covariance matrix of forecast errors is represented by

\[
\Sigma = \begin{bmatrix} \sigma_\epsilon^2 & \rho \sigma_\epsilon \sigma_m \\ \rho \sigma_\epsilon \sigma_m & \sigma_m^2 \end{bmatrix}.
\]

We assume that the covariance is not greater than the variance, i.e., \(\rho \sigma_\epsilon \sigma_m \leq \sigma_m^2\), and \(\rho \sigma_\epsilon \sigma_m \leq \sigma_\epsilon^2\). One can interpret these conditions as if the magnitudes of the variances of the two forecasts are quite different than the data are likely to be from independent sources (small \(\rho\)), and if the magnitudes of variances are similar, then they are likely to be highly correlated (\(\rho\) close to 1). We assume that the forecasts are obtained without incurring any cost. All parameters of the model, except the forecasts, are common knowledge to the manufacturer and the retailer.

The normality assumption has limitations because it allows for negative values of industry demand. However, the normality assumption has been used extensively in the past literature (Raju and Roy, 2000; Padmanabhan and Png, 1997; Lee et al., 2000) because it simplifies the analysis considerably.
We can mitigate this negative effect by allowing a large \( a \) value relative to \( \sigma^2_0 \). Our analysis will refer to the conditional expectations and variances of Winkler (1981)\(^1\) (shown in Appendix A).

In order to focus on information sharing’s effect on pricing decision and its impact on profit, we first assume that the retailer places an order and the manufacturer makes the product after the demand is known. We refer to this as the ‘make-to-order’ scenario, in which neither the manufacturer nor the retailer keeps any inventory. Next we assume that the manufacturer makes the product and the pricing decision before the demand is known. We refer to this as the ‘make-to-stock’ scenario, in which the manufacturer is involved in inventory disposal and shortage cost (the retailer still places an order after the demand is known). We analyze the value of information sharing in these two cases. In the first case (make-to-order), we can solely assess the impact of information sharing on price setting; in the other case (make-to-stock), we can see information sharing’s impact on both pricing and inventory cost.

3. Analysis of the make-to-order scenario

The sequence of manufacturer and retailer actions in the make-to-order scenario is depicted in Fig. 2. We derive the optimal price and profits for (a) no information sharing and (b) information sharing cases. We compare these results to derive the value of information sharing.

3.1. No information sharing case

In this scenario, the retailer and the manufacturer maximize their own anticipated profit (shown as below) respectively, as shown below:

\[
\pi_{\text{rNI}} = E[(p_r - w)((1 - 0)a - b_2p_r + c_2p_d)/\sigma^2_0],
\]

\[
\pi_{\text{mNI}} = E[((w - c)((1 - 0)a - b_2p_r + c_2p_d) + (p_d - c)(0a - b_1p_d + c_1p_r))/\sigma^2_0],
\]

where \( c \) is the production unit cost, and \( w \) is the manufacturer’s price. Since the manufacturer is the Stackelberg leader and the retailer is the follower, we derive the optimal solution by deriving optimal \( p_r \) followed by optimal \( w \) and \( p_d \). We show that the following result holds (proofs are in Appendix A).

**Observation 1.** Retailer can infer \( f_m \) from \( w \) in the no information sharing case (proof is in Appendix A).

Observation 1 shows that in the no information sharing case, the manufacturer uses its forecast in setting prices. In doing so, it reveals \( f_m \) through \( w \). In other words, though there is no explicit arrangement to share information, the manufacturer implicitly shares its information with the retailer when setting prices. The retailer thus has the manufacturer’s information before it sets the retail price, but the manufacturer does not enjoy a similar advantage. Given that the retailer can infer \( f_m \) prior to setting \( p_r \), it will determine \( p_r \) based on both \( f_r \) and \( f_m \). Result 1 summarizes the results for the no information-sharing case.

Next, we will derive the optimum strategies for both supply chain players. These strategies are for a case of Bayesian Stackelberg game for maximizing each player’s expected profits.

To maintain analytical tractability, we assume that \( c_1 = c_2 = e \). In other words, we assume that cross-price effects are symmetric.

**Result 1.** Table 1 shows the Bayesian Stackelberg expected equilibrium prices and the corresponding expected profits for both the manufacturer and retailer with no information sharing in the make-to-order scenario.

---

\(^1\) Vives (1984), Gal-Or (1985), and Raju and Roy (2000) use special cases of the more general results of Winkler.
Table 1
Optimal values for the no information sharing case

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w^*$</td>
<td>$\frac{a_M b_1 (1 - \theta) + a_M e \theta + b_1 b_2 c - c e^2}{2 b_1 b_2 - 2 e^2}$</td>
</tr>
<tr>
<td>$p_d^*$</td>
<td>$\frac{a_M e (1 - \theta) + a_M b_2 \theta + b_1 b_2 c - c e^2}{2 b_1 b_2 - 2 e^2}$</td>
</tr>
<tr>
<td>$p_r^*$</td>
<td>$\frac{a_M (b_1 b_2 + e^2 - (b_1 b_2 - 2 b_2 e + e^2) \theta) + (b_1 b_2 - e^2)(c(b_2 + e) + 2 a_1 (1 - \theta))}{4 b_2 (b_1 b_2 - e^2)}$</td>
</tr>
<tr>
<td>$\pi_{mNI}^*$</td>
<td>$\frac{(a_M (1 - \theta) - 2 a_1 (1 - \theta) + b_2 c - c e^2)^2}{16 b_2}$</td>
</tr>
<tr>
<td>$\pi_{mNI}^*$</td>
<td>$\frac{(b_1 b_2 - e^2)(c^2 (2 b_1 b_2 + b_2^2 - 2 b_2 e - e^2) + (a_M - a_{mNI}) (b_1 b_2 - e^2)^2 - 4 b_2 e (1 - \theta) \theta - 2 b_2^2 \theta^2) + 2 a_1 (c(b_1 b_2 - e^2)(b_2 (1 + \theta) + \theta (1 - \theta))}{4 b_2 (b_1 b_2 - e^2)}$</td>
</tr>
</tbody>
</table>

Note: $\pi_{NI}$ and $\pi_{mNI}$ are retailer’s profit and manufacturer’s profit respectively with no information sharing,

$a_1 = I \tilde{a} + J f_m + K f_r, \quad a_M = I \tilde{a} + J f_m + K ((1 - d_m) \tilde{a} + d_m f_m)$.

$J = \frac{(1 - \rho^2) \sigma_{I m}^2 \sigma_{I r}^2}{(1 - \rho^2) \sigma_{I m}^2 + \sigma_{I r}^2 (\sigma_{m}^2 + \sigma_{m}^2 - 2 \rho \sigma_{m} \sigma_{I})}, \quad J = \frac{(\sigma_{I m}^2 - \rho \sigma_{I m} \sigma_{I r}) \sigma_{I r}^2}{(1 - \rho^2) \sigma_{I m}^2 + \sigma_{I r}^2 (\sigma_{m}^2 + \sigma_{m}^2 - 2 \rho \sigma_{m} \sigma_{I})},$ 

$K = \frac{(\sigma_{m}^2 - \rho \sigma_{m} \sigma_{I}) \sigma_{I r}^2}{(1 - \rho^2) \sigma_{I m}^2 + \sigma_{I r}^2 (\sigma_{m}^2 + \sigma_{m}^2 - 2 \rho \sigma_{m} \sigma_{I})}.$

Note that as given in Result 1, the optimum price for the manufacturer is obtainable by using only the market reaction parameters and the manufacturer’s forecast. The retailer, on the other hand, has the
privilege of using the manufacturer’s forecasts as well as its own to obtain an optimum price. We also observe that both \( w^* \) and \( p_d^* \) are increasing function of \( f_m \), respectively, and \( p_r^* \) is an increasing function of \( f_m \) and \( f_t \). This implies that the more optimistic the manufacturer or the retailer feels about the primary demand, the higher price it would set. We will now contrast these optimum strategies with those using another case where the players actually share forecast information with each other.

3.2. Information sharing case

In this case, the manufacturer and the retailer share their forecasts with each other before making decisions.

The retailer and the manufacturer maximize their own anticipated profit, respectively:

\[
\pi_{r1} = E[(p_t - w)((1 - \theta)a - b_2p_t + c_2p_d)|f_t, f_m],
\]

\[
\pi_{m1} = E[((w - c)((1 - \theta)a - b_2p_t + c_2p_d) + (p_d - c)(\theta a - b_1p_d + c_1p_t))|f_m, f_t].
\]

Result 2. Table 2 shows the Bayesian Stackelberg expected equilibrium prices and the corresponding expected profits for both the manufacturer and retailer with information sharing in the make-to-order scenario.

The structure of the price expressions for the no information sharing and information sharing cases are similar. While the former uses \( a_{1M} \) (expected value of \( a \) given \( f_m \)), the later uses \( a_I \) (expected value of \( a \) given \( f_m \) and \( f_t \) both).

3.3. Value of information sharing

Now we would like to assess the impact of information sharing on each player’s performance. The value of information sharing to the manufacturer and the retailer is easily determined from the profit expressions given in Tables 1 and 2. The value to the manufacturer is

\[
\pi_m^* = \frac{a(b_1(1 - \theta) + c(e^2 - 2b_1b_2 - 2e^2))}{2b_1b_2 - 2e^2}
\]

\[
\pi_r = \frac{a(3b_1b_2(1 - \theta) + e(e(-1 + 0) + 2b_2e)) + c(b_2 + e)(b_1b_2 - e^2)}{4b_2(b_1b_2 - e^2)}
\]

\[
\pi_{rd} = \frac{(aI(-1 + 0) + b_2c - ce)^2}{16b_2}
\]

\[
\pi_{rd} = \frac{(b_1b_2 - e^2)(e^2(2b_1b_2 + b_1^2 - 2b_2e - e^2) + a^2(1 - \theta)^2 + e^2(1 - \theta)^2 + 4b_2e(1 - \theta)0 + 2b_2^2e^2) - 2a_0c(b_1b_2 - e^2)(b_1(1 + 0) + e(1 - 0)))}{8b_2(b_1b_2 - e^2)}
\]

Note: \( \pi_{rd} \) and \( \pi_{rt} \) are retailer’s profit and manufacturer’s profit respectively for the information sharing case.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w^* )</td>
<td>( \frac{a(b_1(1 - \theta) + c(e^2 - 2b_1b_2 - 2e^2))}{2b_1b_2 - 2e^2} )</td>
</tr>
<tr>
<td>( p_d^* )</td>
<td>( \frac{a(3b_1b_2(1 - \theta) + e(e(-1 + 0) + 2b_2e)) + c(b_2 + e)(b_1b_2 - e^2)}{4b_2(b_1b_2 - e^2)} )</td>
</tr>
<tr>
<td>( p_r^* )</td>
<td>( \frac{(aI(-1 + 0) + b_2c - ce)^2}{16b_2} )</td>
</tr>
<tr>
<td>( \pi_{rt} )</td>
<td>( \frac{(b_1b_2 - e^2)(e^2(2b_1b_2 + b_1^2 - 2b_2e - e^2) + a^2(1 - \theta)^2 + e^2(1 - \theta)^2 + 4b_2e(1 - \theta)0 + 2b_2^2e^2) - 2a_0c(b_1b_2 - e^2)(b_1(1 + 0) + e(1 - 0)))}{8b_2(b_1b_2 - e^2)} )</td>
</tr>
</tbody>
</table>

---

and the retailer are
and direct channel price shares its higher demand forecast with the manufacturer, the manufacturer will increase the wholesale price /C213 whole price contract with the manufacturer if and only if condition (3.3) is satisfied. Assuming that the retailer and
mates the retailer of information sharing on retailer profit is as follows. Under condition (3.3), the manufacturer overesti-
high retailer price /C213 in the retailer absence of information sharing. The retailer, in turn, sets a high retail price (p)
This leads to smaller manufacturer and retailer profits. When the retailer shares information in this case,
To the manufacturer is non-negative. The value of information sharing to the retailer is non-negative if and only if
Result 3. The value of information sharing to the manufacturer is non-negative. The value of information sharing to the retailer is non-negative if and only if
(a1 - aIM)((aIM - 3a1)(1 - ) + 2c(b2 - e)] > 0. (3.3)
Result 3 reveals some important findings. The positive value of information sharing to the manufacturer is intuitive because under information sharing, the manufacturer sets prices knowing the retailer’s forecast, and this additional information helps the manufacturer make a better pricing decision. The managerial guideline learned here is that the manufacturer should actively pursue the retailer to share forecast information. The amount of profit increase can give the manufacturer an idea how much, if any, it would be willing to pay the retailer as incentive for the sharing of information. This is consistent with results of prior studies.
However, as our model shows, the retailer’s profit might decrease from information sharing. This is be-
cause the manufacturer uses the information strategically to maximize its own profit at the expense of the retailer. Condition (3.3) implies that aIM must be greater than a1 (or E[fI|m] > f, which means that the manufacturer’s expectation of the retailer’s forecast is higher than the retailer’s actual forecast). The impact of information sharing on retailer profit is as follows. Under condition (3.3), the manufacturer overestimates the retailer’s forecast and would set a high wholesale price (w) and direct channel price (pD) in the absence of information sharing. The retailer, in turn, sets a high retail price (p), which leads to a decrease in the retailer’s demand (although a high direct channel pD helps increase the retailer’s demand, the effect of high retailer price p (which is resulted from the high wholesale price w) dominates the effect of high pD). This leads to smaller manufacturer and retailer profits. When the retailer shares information in this case, the manufacturer reduces its anticipated demand because of the smaller forecast from the retailer. The man-
ufacturer thus reduces the wholesale price and direct channel price pD. A lower wholesale price always in-
creases the retailer profit, although a lower pD contributes to decreasing the retailer’s demand (the lower whole price’s effect dominates the lower pD’s effect for the retailer). Thus, under condition (3.3), the retailer would be motivated to share its forecast information with the manufacturer without any monetary incentive from the manufacturer.
When the manufacturer is pessimistic about the demand (i.e., E[fI|m] < fI), the manufacturer sets a low wholesale price (w) and a direct channel price (pD) in the absence of information sharing. If the retailer shares its higher demand forecast with the manufacturer, the manufacturer will increase the wholesale price and direct channel price pD, which in turn leads to hurt the retailer’s profitability.
An implication of Result 3 is that the retailer would like to enter into an ex ante information-sharing contract with the manufacturer if and only if condition (3.3) is satisfied. Assuming that the retailer and the manufacturer enter into such a contract, the value of the information sharing to the manufacturer and the retailer are
Vm = πm* - πmNI = (a1 - aIM)e[(b1b2 + e2)(1 - )2 + 4b2e(1 - ) + 2b2] > 0. (3.1)

The value to the retailer is
Vr = πr* - πrNI = (a1 - aIM)((aIM - 3a1)(1 - ) + 2c(b2 - e)] > 0. (3.2)

Now we can prove the following result.

Result 3. The value of information sharing to the manufacturer is non-negative. The value of information sharing to the retailer is non-negative if and only if
\[ V_r = \int_0^\infty \int_{f_c}^{\infty} \frac{(a_1 - a_{IM})(1 - \theta) [(a_{IM} - 3a_1)(1 - \theta) + 2c(b_2 - e)]}{16b_2} g(f_r, f_m) \, df_m \, df_r, \]  
respectively, where \( f_c \) is the threshold value so that condition (3.3) is satisfied, and \( g(f_r, f_m) \) is the density of the bi-variate normal probability distribution of \( f_r \) and \( f_m \). We can observe easily that the value of information sharing is non-negative for both the manufacturer and the retailer under this contract.

If the manufacturer and the retailer agree to integrate into a single organization with the two channels, the integrated supply chain profit is

\[ \pi_{\text{INT}} = E[(p_r - c)((1 - \theta)a - b_2p_r + ep_d) + (p_d - c)(\theta a - b_1p_d + ep_r)|f_r, f_m]. \]

We obtain

\[ p_d^* = \frac{b_1b_2c + a_1e + a_1b_2\theta - e(c + a_2\theta)}{2b_1b_2 - 2e^2}, \]
\[ p_r^* = \frac{b_1b_2c + a_1b_1 - a_1b_1\theta - a_2e\theta}{2b_1b_2 - 2e^2}, \]

\[ \pi_{\text{INT}}^* = \frac{(b_1b_2 - e^2)(c^2(b_1 + b_2 - 2e) + 2a_1c(-b_1b_2 + e^2) + a_1^2(b_1(1 + \theta)^2 + \theta(2e + b_2\theta - 2e\theta)))}{4(b_1b_2 - e^2)}. \]  

3.4. Comparison of the supply chains with and without the direct channel

If we consider a simple manufacturer–retailer supply chain without the direct channel, and we assume that the demand function is \( D = a - bp \). Based on the similar model development shown in the supply chain with direct channel, we can come up with the following results:

\[ \pi_{\text{ND}}^{\text{rNI}} = \frac{(2a_1 - a_{IM} - bc)^2}{16b}, \]
\[ \pi_{\text{ND}}^{\text{mNI}} = \frac{(a_{IM} - bc)(2a_1 - a_{IM} - bc)}{8b}, \]
\[ \pi_{\text{ND}}^{\text{rI}} = \frac{(a_1 - bc)^2}{16b}, \]
\[ \pi_{\text{ND}}^{\text{mI}} = \frac{(a_1 - bc)^2}{8b}, \]

where \( \pi_{\text{ND}}^{\text{rI}} \) is the retailer or manufacturer’s profit for the case of without the direct channel.

To simplify the computation and make the result comparable, we assume that all the price sensitivity parameters are equal and the same before and after the direct channel is introduced \( (b_1 = b_2 = b) \), production cost is zero \( (c = 0) \), and the direct channel does not have impact on the primary demand \( (a) \) is the same with/without the direct channel.

We have the following result:

**Proposition 1**

1. The direct channel always has a negative impact on the retailer’s profit.
2. The direct channel has a positive impact on the manufacturer’s profit if and only if

\[ 4be(1 - \theta)\theta + b^2\theta(-2 + 3\theta) + e^2(1 - \theta)^2 + e^2 > 0. \]
(3) If information is shared between the retailer and the manufacturer, the direct channel has a positive impact on the total supply chain profit if and only if

\[ 8be(1 - \theta)\theta + b^2\theta(-6 + 7\theta) + e^2(1 - \theta)^2 + 3e^2 > 0. \]

(4) If information is not shared between the retailer and manufacturer, the direct channel is guaranteed to have a positive impact on the total supply chain profit if

\[ 8be(1 - \theta)\theta + 2b^2\theta(-2 + 3\theta) + 2e^2(2 - (2 - \theta)\theta) > 0. \]

Proof. By comparing the expected profits when a direct channel exists with the profits when no direct channel exists under different scenarios for each supply chain player, we can prove the proposition.

Proposition 1 justifies our prior concern, that is, that a direct channel would hurt the retailer. The reason is evident: channel conflict causes a detrimental effect. Proposition 1 also indicates conditions in which the direct channel is beneficiary to the manufacturer and the whole supply chain. This implies that within these conditions, the direct channel’s merits (i.e., increasing the manufacturer’s profit margin, etc.) dominates its downsides (i.e., channel conflict), and, outside these conditions, the downsides outweigh the merits. Apparently, the manufacturer and the whole supply chain could decide on when to open a direct channel, based these results.

4. Analysis of the make-to-stock scenario

The sequence of manufacturer and retailer actions in the make-to-stock scenario is depicted in Fig. 3. We assume here that the manufacturer schedules production level \( Q \) before the demand is known, and the retailer places the order after the demand is known. Thus, the burden of inventory disposal and shortage cost is borne only by the manufacturer. If the demand is less than \( Q \), the manufacturer incurs a disposal cost of \( h \) per unit of inventory. If the demand exceeds \( Q \), we assume that the manufacturer can obtain additional
units from an external source at the cost of $s$ per unit. Several earlier studies in the supply chain information sharing literature have made similar assumptions (Bourland et al., 1996; Gavirneni et al., 1999; Lee et al., 2000). Note that the make-to-order (MTO) scenario can be regarded as a special case of the make-to-stock (MTS) scenario when $s = c$. It is apparent that, in the situation of MTS when $s = c$, the manufacturer has no incentive to make any production as the manufacturer can obtain the product from external sources at the price of $s = c$ to satisfy the retailer’s demand after the demand uncertainty is resolved. Again, we derive the optimal price and profits for two cases: (i) no information sharing (ii) information sharing. We compare these results to derive the value of information sharing. We also compare the value of information sharing in the make-to-order and make-to-stock scenarios.

4.1. No information sharing case

The retailer and the manufacturer maximize their own anticipated profit:

$$\pi_{rNI} = (p_r - w)[(1 - \theta)a - b_2p_r + c_2p_d]/f_r,f_m],$$

$$\pi_{mNI} = \int_0^\infty [(w - c)((1 - \theta)a - b_2p_r + c_2p_d) + (p_d - c)(\theta a - b_1p_d + c_1p_r)]f(a) da$$

$$- \int_0^{Q+(b_2-c_1)p_r+(b_1-c_2)p_d} h[Q - ((1 - \theta)a - b_2p_r + c_2p_d + \theta a - b_1p_d + c_1p_r)]f(a) da$$

$$- \int_0^{\infty} s[(1 - \theta)a - b_2p_r + c_2p_d + \theta a - b_1p_d + c_1p_r] - Q]f(a) da,$$

respectively. Note that the manufacturer’s model is a variation of the newsboy model. Even in the make-to-stock scenario, we can show that Observation 1 holds. Thus, the retailer’s optimal price as a function of $w$ and $p_d$ remains the same as in the make-to-order scenario. That is, $p_r^* = E(a|f_r,f_m)(1-\theta)c_1p_r + b_1w$. Therefore, we only need to consider the manufacturer’s side.

Result 4. **Table 3 shows the Bayesian Stackelberg expected equilibrium prices, production quantity, and the corresponding expected profits for both the manufacturer and retailer with no information sharing in the make-to-stock scenario.**

We can see, from Tables 1 and 3, that $w$ and $p_d$ are the same in the make-to-order and make-to-stock scenarios. This is driven by our assumption that the manufacturer can obtain additional units from another source in case of a shortage.

4.2. Information sharing case

Result 5. **Table 4 shows the Bayesian Stackelberg expected equilibrium prices, production quantity, and the corresponding expected profits for both the manufacturer and retailer with information sharing in make-to-stock scenario.**

As shown, $\sigma_{N1} \geq \sigma_1$. Again, $w_1^*$ and $p_d^*$ are same in the make-to-order and make-to-stock scenarios.

4.3. Value of information sharing

The value of information sharing for the manufacturer and the retailer is determined from the profit expressions given in Tables 3 and 4. The value for the manufacturer is
Table 3
Optimal values for the no information sharing case

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w^*$</td>
<td>$\frac{aM b_1(1 - \theta) + aMe \theta + b_1 b_2 c - ce^2}{2b_1 b_2 - 2e^2}$</td>
</tr>
<tr>
<td>$p_0^*$</td>
<td>$\frac{aM e(1 - \theta) + aM b_2 \theta + b_1 b_2 c - ce^2}{2b_1 b_2 - 2e^2}$</td>
</tr>
<tr>
<td>$p_i^*$</td>
<td>$\frac{aM (b_1 b_2 + e^2 - (b_1 b_2 - 2b_2 e + e^2)\theta) + (b_1 b_2 - e^2)(c(b_2 + e) + 2a_1(1 - \theta))}{4b_2(b_1 b_2 - e^2)}$</td>
</tr>
<tr>
<td>$Q^*$</td>
<td>$\frac{aM (e + b_2(-3 + \theta) - e\theta) - 2b_1 b_2 c - b_2^2 c + 2b_2 e c + ce^2 + a_1 + \sigma_N \Phi^{-1}\left(\frac{s}{s + h}\right)}{4b_2}$</td>
</tr>
<tr>
<td>$\pi_{NI}^*$</td>
<td>$\frac{(aM(1 - \theta) - 2a_1(1 - \theta) + b_2 c - ce^2)}{16b_2}$</td>
</tr>
<tr>
<td>$\pi_{mNI}^*$</td>
<td>$\frac{(b_1 b_2 - e^2)(c^2(2b_1 b_2 + b_2^2 - 2b_2 c - e^2) + aM(aM - aM)((-b_1 b_2 - e^2)(1 - \theta)^2 - 4b_2 e(1 - \theta) - 2b_2^2 e^2\theta^2) + 2a_1(-c(b_1 b_2 - e^2)(b_2(1 + \theta) + e(1 - \theta))}{8b_2(b_1 b_2 - e^2)}$</td>
</tr>
</tbody>
</table>

Note:

$\sigma_N^2 = \frac{\sigma_n^2 + \sigma_m^2}{\sigma_n^2}$,  $r = \Phi^{-1}\left(\frac{s}{s + h}\right)$,  $L(x) = \int_{s}^{\infty} (z - x) d\Phi(z)$,  
and $\Phi$ is the density function of the standard normal probability distribution.

Table 4
Optimal values for the information sharing case

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w^*$</td>
<td>$\frac{a_1 b_1(1 - \theta) + a_1 e \theta + b_1 b_2 c - ce^2}{2b_1 b_2 - 2e^2}$</td>
</tr>
<tr>
<td>$p_0^*$</td>
<td>$\frac{a_1 e(1 - \theta) + a_1 b_2 \theta + b_1 b_2 c - ce^2}{2b_1 b_2 - 2e^2}$</td>
</tr>
<tr>
<td>$p_i^*$</td>
<td>$\frac{a_1 (3b_1 b_2(1 - \theta) + e(e(-1 + \theta) + 2b_2 \theta)) + (b_1 b_2 - e^2)c(b_2 + e)}{4b_2(b_1 b_2 - e^2)}$</td>
</tr>
<tr>
<td>$Q^*$</td>
<td>$\frac{a_1 (e + b_2(-3 + \theta) - e\theta) - 2b_1 b_2 c - b_2^2 c + 2b_2 e c + ce^2 + a_1 + \sigma_i \Phi^{-1}\left(\frac{s}{s + h}\right)}{4b_2}$</td>
</tr>
<tr>
<td>$\pi_{NI}^*$</td>
<td>$\frac{(a_1(-1 + \theta) + b_2 c - ce^2)}{16b_2}$</td>
</tr>
<tr>
<td>$\pi_{mNI}^*$</td>
<td>$\frac{(b_1 b_2 - e^2)(c^2(2b_1 b_2 + b_2^2 - 2b_2 c - e^2) + a_1^2(a_1 b_1(1 - \theta)^2 + e^2(1 - \theta)^2 + 4b_2 e(1 - \theta) + 2b_2^2 e^2\theta^2) - 2a_1 c(b_1 b_2 - e^2)(b_2(1 + \theta) + e(1 - \theta))}{8b_2(b_1 b_2 - e^2)}$</td>
</tr>
</tbody>
</table>

Note:

$\sigma_i^2 = \frac{(1 - \rho^2)\sigma_n^2 + \sigma_m^2 - 2p\sigma_m\sigma_i}{(1 - \rho^2)\sigma_m^2 + \sigma_n^2 - 2p\sigma_m\sigma_i}$.
\[ V_m = \pi_{mI} - \pi_{mNI} \]
\[ = \frac{(a_1 - a_{IM})^2[(b_1b_2 + e^2)(1 - \theta)^2 + 4b_2e(1 - \theta)\theta + 2b_2^2\theta^2]}{8b_2(b_1b_2 - e^2)} + (\sigma_{NI} - \sigma_I)((s + h)L(r) + hr) > 0, \]
\[ V_r = \pi_{rI} - \pi_{rNI} = \frac{(a_1 - a_{IM})(1 - \theta)[(a_{IM} - 3a_1)(1 - \theta) + 2c(b_2 - e)]}{16b_2}. \] (4.1)

Note that the first term of \( V_m \) in Eq. (4.1) is identical to \( V_m \) in Eq. (3.1). The second term in (4.1) is the manufacturer’s savings in inventory and shortage costs because of information sharing. The value for the retailer remains the same as that in the make-to-order scenario.

We can readily see that Result 3 applies in the make-to-stock scenario also. Thus the retailer will not voluntarily share information unless condition (3.3) holds. However, contrary to the make-to-order scenario, in which the manufacturer can neither provide a discount nor a side payment to induce the retailer to share information, the manufacturer can indeed provide incentives to the retailer to get its forecast information in the make-to-stock scenario even when condition (3.3) does not hold. Since the manufacturer realizes the inventory and shortage cost savings for all values of \( f_m \), the manufacturer can use this savings to either give a price discount or a side payment when condition (3.3) does not hold. The exact division of the surplus due to inventory-related savings between the retailer and the manufacturer will depend on their respective bargaining powers. Thus, the region of information sharing expands in the make-to-stock scenario. In fact, information sharing can take place for all values of \( f_m \) in the make-to-stock scenario.

Thus, we have Result 6.

**Result 6.** In the make-to-stock scenario, both the manufacturer and the retailer can benefit from information sharing.

If the manufacturer and the retailer agree to integrate into a single organization with the two channels, the highest supply chain profit, the optimal prices, and optimal production quantity are obtained as below.

\[
p_d^* = \frac{b_1b_2c + a_1e + a_1b_2\theta - e(ce + a_1\theta)}{2b_1b_2 - 2e^2},
\]
\[
p_r^* = \frac{b_1b_2c + a_1b_1 - a_1b_2\theta - ce^2 + a_1e\theta}{2b_1b_2 - 2e^2},
\]
\[
Q^* = \frac{-a_1 - b_1e - b_2c + 2ce}{2} + a_1 + \sigma_I \Phi^{-1} \left( \frac{s}{s + h} \right),
\]
\[
\pi_{INT}^* = \frac{(b_1b_2 - e^2)(c^2(b_1 + b_2 - 2e) + 2a_1c(-b_1b_2 + e^2) + a_1^2(b_1(1 + \theta)^2 + \theta(2e + b_2\theta - 2e\theta)))}{4(b_1b_2 - e^2)} - \frac{\sigma_I[(s + h)L(r) + hr]}{b_1b_2 - e^2}. \] (4.3)

A quick comparison of Eq. (4.3) and (3.6) shows that an integrated supply chain’s profit is lower in the make-to-stock scenario than in the make-to-order scenario by an amount equal to the expected inventory disposal and shortage cost of \( \frac{\sigma_I[(s + h)L(r) + hr]}{b_1b_2 - e^2} \). This difference also represents the value of postponing production until demand uncertainty is resolved in the integrated channel.
5. An illustrative simulation example

We now present a simulation example to illustrate the magnitude of manufacturer and retailer profits under different scenarios, and the impact of model parameters, namely, $\sigma_r$, $\sigma_m$, $\theta$, and $\rho$, on profits as well as on the value of information sharing. While the impact of some of these parameters can be derived analytically, the analytical expressions are too complex to provide meaningful insights. Note from Eqs. (3.4) and (3.5) that we can compute the expected profits for the manufacturer and retailer using numerical analysis for double integrals. However, we find it more convenient to simulate the actual demands and forecasts and to calculate the expected profits under various scenarios.

For our simulation, we use the following parameter values: $\bar{a} = 250$, $b_1 = b_2 = 1$, $e = 0.5$, $c = 10$, $h = 1$, $s = 20$. We vary $\sigma_r$, $\sigma_m$, $\rho$, and $\theta$ using the following data ranges.

$\sigma_r \in \{5, 10, 15, 20, 25, 30, 35, 40, 45, 50\}$,
$\sigma_m \in \{5, 10, 15, 20, 25, 30, 35, 40, 45, 50\}$,
$\rho \in \{0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9\}$,
$\theta \in \{0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0\}$.

For every value of the specific parameter analyzed, we average the profits over all other parameters' various combinations.

For each set of parameters analyzed, we analyze the scenarios of make-to-stock and make-to-order. For each scenario, we determine the expected manufacturer and retailer profits for the non-integrated channel with information sharing and without information sharing. We assume that information sharing occurs only when condition (3.3) is satisfied. Since the manufacturer can buy information from the retailer in the make-to-stock scenario when condition (3.3) does not hold, we thus underestimated (overestimated) the retailer’s (manufacturer’s) profit in the make-to-stock scenario.

5.1. Effect of varying retailer forecasting errors ($\sigma_r$)

The impacts of the retailer’s forecasting accuracy on profits under various scenarios are shown in Figs. 4 and 5. The manufacturer’s profit is higher than that of the retailer for all values of $\sigma_r$, the standard deviation of retailer’s forecast error. This is because the manufacturer is the Stackelberg leader in the supply chain.

The profits as well as the value of information sharing (the difference between profits in the information sharing case and no information sharing case) decrease for the manufacturer and retailer as the retailer’s
forecast accuracy decreases in both the make-to-stock and make-to-order scenarios. This is to be expected because a loss of accuracy would penalize the retailer and even the manufacturer. The value of information sharing is found in the gap between the information sharing curve and the no information sharing curve. In Fig. 5, we observe that as $r_r$ goes up, the value of information sharing to the manufacturer decreases. This is because sharing the retailer’s forecast becomes less valuable to the manufacturer when the retailer’s forecast becomes inaccurate. Also as shown in Fig. 5, the manufacturer benefits more from information sharing in the make-to-stock scenario than in the make-to-order scenario. This is because the manufacturer realizes additional inventory-related saving in addition to pricing-related saving from information sharing.

5.2. Effect of varying manufacturer forecasting errors ($\sigma_m$)

Figs. 6 and 7 summarize the impacts of $\sigma_m$, the standard deviation of the manufacturer’s forecast error. While the manufacturer’s profit decreases, the retailer’s profit increases, and the value of information sharing increases for both the manufacturer and the retailer when $\sigma_m$ increases. The decline in manufacturer profit when $\sigma_m$ increases is to be expected because a higher $\sigma_m$ reduces the manufacturer’s forecast accuracy. A higher $\sigma_m$ also contributes to a higher value of information sharing for the manufacturer. This is because sharing the retailer’s forecast becomes more valuable to the manufacturer when the manufacturer’s forecast accuracy decreases. On the other hand, the retailer’s profit and value of information sharing are higher when $\sigma_m$ is higher. This is because the manufacturer’s ability to control the retailer’s price and demand declines when the forecast accuracy decreases. Consequently, the retailer is better able to exploit the demand to its own benefit. Again, using the same reasoning as we explained in Fig. 5, the manufacturer
realizes a higher value from information sharing in the make-to-stock scenario than in the make-to-order scenario.

5.3. Effect of varying $\theta$

Fig. 8 shows that the retailer’s profits decrease when $\theta$ increases. This is because the retail channel demand decreases with $\theta$. However, the manufacturer’s profits for all scenarios fall initially and then increase afterward (Fig. 9). The possible explanation for this effect is that, when $\theta$ is small, the retail channel dominates the direct channel, so that the manufacturer achieves its major profit from the retailer channel, which, however, is decaying when $\theta$ increases. As $\theta$ goes over some certain value, the direct channel starts to dominate the retail channel for the manufacturer. Thus, the manufacturer realizes its major profit via the direct channel (note that the manufacturer obtains a higher profit margin through the direct channel). Apparently, the higher $\theta$, the more profit the manufacturer can obtain.

5.4. Effects of varying forecasting correlation ($\rho$)

Figs. 10 and 11 show the impact of $\rho$, the manufacturer and the retailer’s forecast correlation, on each supply chain player’s performance. An increase in $\rho$ reduces the retailer’s absolute profit as well as the value of information sharing. The reason is straightforward. A higher correlation between manufacturer and retailer forecasts makes the forecast information more substitutes instead of complements, making the infor-

![Fig. 10. Forecast correlation's impact on retailer's profit.](image1)

![Fig. 11. Forecast correlation's impact on manufacturer's profit.](image2)

![Fig. 12. $h$'s impact on retailer's profit.](image3)

![Fig. 13. $h$'s impact on manufacturer's profit.](image4)
information sharing less valuable. The retailer uses both forecasts in the no information sharing and the information sharing cases. Consequently, its profit declines with an increase in $q$ in both cases. $q$ has a similar impact on the value of information sharing to the manufacturer.

5.5. Effect of varying inventory-related parameters ($h$ and $s$)

In this section, we vary $h$ (from 0 to 10) and $s$ (from 10 to 40), analyzing their impact on supply chain performance, respectively. From Fig. 12–15, we observe that the retailer’s profits (for both the information sharing and non-information sharing scenarios) and the manufacturer’s profits (under the make-to-order scenario) stay unchanged when $h$ or $s$ varies. This is expected as there is no inventory-related cost in these cases. However, under the make-to-stock scenario, the manufacturer’s profits (for both the information sharing and non-information sharing cases) decrease when $h$ or $s$ increases. This is because the inventory-related cost increases when $h$ or $s$ increases, thereby leading to decreased manufacturer’s profits.

6. Conclusions

The literature on information sharing in supply chains has focused primarily on the savings in inventory and replenishment costs when a retailer shares its point-of-sale data with the manufacturer. In this research, we investigate the value of demand forecast sharing within a simple supply chain with direct channel. We study pricing as well as inventory aspects of information sharing. We show that in the make-to-order scenario while the manufacturer always benefits from information sharing, the retailer and the supply chain will be better off only when the manufacturer’s forecast is sufficiently high. Thus, information sharing occurs only in limited settings. However, in the make-to-stock scenario, since the manufacturer realizes inventory related savings, the manufacturer is able to provide incentives to induce the retailer to share information even when the retailer does not voluntarily do so. Thus, both the manufacturer and the retailer can benefit from the information sharing. We also prove that, under some assumptions ($c = 0$, and $b_1 = b_2 = b$), while a direct channel always has negative impact on the retailer’s profit, it has positive impact on the manufacturer’s profit and the total supply chain profit if some conditions are satisfied.

Our simulation example shows that information sharing can be very valuable to both the manufacture and the retailer, especially in situations where the accuracy of the retailer forecast is low, the accuracy of the manufacturer forecast is high, and the correlation between forecasts is low. The retailer’s benefit from information sharing is derived from a more effective coordination of wholesale and retail prices to manage the consumer demand. The manufacturer’s benefit from information sharing is derived from better inventory management (in the make-to-stock scenario) in addition to better demand management.
Appendix A

Some conditional expectations and variances of Winkler (1981), which are used in this study, are shown below:

\[ \begin{align*}
E[a \cdot f_m] &= (1 - t_m)\bar{a} + t_m f_m, \\
E[a \cdot f_t] &= (1 - t_t)\bar{a} + t_t f_t, \\
E[f_t \cdot f_m] &= (1 - d_m)\bar{a} + d_m f_m, \\
E[a \cdot f_t, f_m] &= I\bar{a} + Jf_m + Kf_t, \\
\text{Var}[a \cdot f_m] &= t_m\sigma_m^2, \\
\text{Var}[a \cdot f_t, f_m] &= I\sigma_m^2,
\end{align*} \]

where

\[ t_m = \frac{\sigma_0^2}{(\sigma_0^2 + \sigma_m^2)}, \quad t_t = \frac{\sigma_0^2}{(\sigma_0^2 + \sigma_t^2)}, \quad d_m = \frac{\sigma_0^2 + \rho \sigma_m \sigma_m}{(\sigma_0^2 + \sigma_m^2)}, \]

\[ I = \frac{(1 - \rho^2)\sigma_t^2\sigma_m^2}{(1 - \rho^2)\sigma_t^2\sigma_m^2 + \sigma_0^2(\sigma_t^2 + \sigma_m^2 - 2\rho \sigma_m \sigma_t)}, \quad J = \frac{(\sigma_m^2 - \rho \sigma_m \sigma_m)\sigma_0^2}{(1 - \rho^2)\sigma_t^2\sigma_m^2 + \sigma_0^2(\sigma_t^2 + \sigma_m^2 - 2\rho \sigma_m \sigma_t)}, \]

\[ K = \frac{(\sigma_m^2 - \rho \sigma_m \sigma_m)\sigma_0^2}{(1 - \rho^2)\sigma_t^2\sigma_m^2 + \sigma_0^2(\sigma_t^2 + \sigma_m^2 - 2\rho \sigma_m \sigma_t)}. \]

Proof for Observation 1. We first solve the retailer’s profit function, and find the optimal \( p_t^* \).

\[ \pi_{\text{NI}} = E[(p_t - w)((1 - \theta)a - b_2 p_t + c_2 p_d)/f_t], \]

\[ \frac{\partial \pi_{\text{NI}}}{\partial p_t} = 0, \]

\[ p_t^* = \frac{E(a \cdot f_t)(1 - \theta) + c_2 p_d + b_2 w}{2b_2}. \]

Then, plugging the \( p_t^* \) into the manufacturer’s profit function,

\[ \pi_{\text{NI}} = [(w - c)((1 - \theta)a - b_2 p_t + c_2 p_d) + (p_d - c)(a - b_1 p_d + c_1 p_t)/f_m], \]

\[ \frac{\partial \pi_{\text{NI}}}{\partial w} = 0, \]

\[ \frac{\partial \pi_{\text{NI}}}{\partial p_d} = 0. \]

We obtain:

\[ w^* = \frac{-((c(2b_2 + 2b_2 - c_1 + c_2) + c_2(-3b_2 + c_1) - (b_2 + c_1)c_2)) - a_{M}(4b_1 b_2 - c_1(1 + 3c_2))(1 - \theta) + a_{M}(-4c_1 c_2 + 8b_1 b_2(1 - \theta) + 2(2c_1 c_2 + b_1(1 + c_1)\theta))}{8b_1 b_2 + c_1^2 + 6c_1 c_2 + c_2^2}, \]

\[ p_d^* = \frac{-(4b_1 b_2 c + (a_{RM} + b_2 c)(c_1 - c_2) + 2a_{M} (c_1 + c_2) - c(c_1 + 3c_2) c_1 + (a_{RM}(-c_1 + c_2) + a_{M}(4b_2 - 2(c_1 + c_2))\theta)}{8b_1 b_2 + c_1^2 + 6c_1 c_2 + c_2^2}. \]
where

\[ a_M = (1 - t_m)a + t_m f_m, \quad a_{RM} = (1 - t_r)a + t_r((1 - d_m)a + d_m f_m). \]

The above results are the consequence of \( w \) and \( p_d \) being a linear function of \( f_m \). Therefore, the retailer actually determines \( p_r \) based on not only \( f_r \) but also on \( f_m \) even when information is not shared between the manufacturer and the retailer. Consequently, we need to consider only the sharing of retailer’s forecast with the manufacturer in the information sharing case. □

**Proof for Result 1.** Based on Observation 1, the retailer’s profit is

\[ \pi_{rNI} = E[(p_r - w)((1 - \theta)a - b_2 p_r + c_2 p_d)]f_{r}, f_m]. \]

Taking the first order condition (FOC) and setting it to zero, we get the retailer’s best response function:

\[ p^*_r = \frac{E[a(f_r, f_m)(1 - \theta) + c_2 p_d + b_2 w]}{2b_2}. \]

Substituting \( p^*_r \) into the manufacturer’s expected profit function, which is

\[ \pi_{mNI} = E[((w - c)((1 - \theta)a - b_2 p_r + c_2 p_d) + (p_d - c)(\theta a - b_1 p_d + c_1 p_t))]f_{m}, f_r]. \]

Next taking the FOC and setting it to zero, we get the equilibrium prices and the corresponding expected profits. □

**Proof for Result 2.** In this case,

\[ \pi_{rI} = E[(p_r - w)((1 - \theta)a - b_2 p_r + c_2 p_d)]f_{r}, f_m], \]

\[ \pi_{mI} = E[((w - c)((1 - \theta)a - b_2 p_r + c_2 p_d) + (p_d - c)(\theta a - b_1 p_d + c_1 p_t))]f_{m}, f_r]. \]

Following the same procedure as what is done in the proof of Result 1, we have the result. □

**Proof for Result 3**

\[ \pi^*_{mI} - \pi^*_{mNI} = \frac{(a_1 - a_{IM})^2[(b_1 b_2 + e^2)(1 - \theta)^2 + 4b_2 e(1 - \theta)\theta + 2b_2^2 \theta^2]}{8b_2^2(b_1 b_2 - e^2)} > 0, \]

\[ \pi^*_{rI} - \pi^*_{rNI} = \frac{(a_1 (-1 + \theta) + b_2 e - e^2)^2 - (a_{IM}(1 - \theta) - 2a_1(1 - \theta) + b_2 e - e^2)^2}{16b_2} - \frac{(a_1 - a_{IM})(1 - \theta)[(a_{IM} - 3a_1)(1 - \theta) + 2c(b_2 - e)]}{16b_2}. \]

Thus, \( \pi^*_{rI} - \pi^*_{rNI} \geq 0 \) if and only if \( (a_1 - a_{IM})[(a_{IM} - 3a_1)(1 - \theta) + 2c(b_2 - e)] > 0 \). □

**Proof for Result 4.** In this case, the same as what is done in the proof of Result 1, we have the retailer’s best response function

\[ p^*_r = \frac{E[a(f_r, f_m)(1 - \theta) + c_2 p_d + b_2 w]}{2b_2}. \]

Let \( Q \) be the manufacturer’s stocking level (production quantity).
\[
\pi_{mNI} = \int_0^\infty \left[ (w-c)((1-\theta)a-b_2p_t+c_2p_d) + (p_d-c)(\theta a - b_1p_d + c_1p_t) \right] f(a) da \\
- \int_0^{Q+(b_2-c_1)p_t+(b_2-c_2)p_d} h[Q - ((1-\theta)a - b_2p_t + c_2p_d + \theta a - b_1p_d + c_1p_t)] f(a) da \\
- \int_0^\infty s[(1-\theta)a - b_2p_t + c_2p_d + \theta a - b_1p_d + c_1p_t] - Q] f(a) da,
\]

where

\[F_{NI}(x) = \int_0^x f(a/f_m) da, \quad \bar{F}_{NI}(x) = 1 - F_{NI}(x).\]

Note that \(a\) is normally distributed with mean \(\bar{a} + \hat{f}_m + K[(1-d_m)\bar{a} + d_m\hat{f}_m]\), and variance \(\sigma_{NI}^2 = \frac{\sigma^2}{\sigma^2 + \sigma_0^2}\).

Solving the following three equations simultaneously

\[
\frac{\partial \pi_{mNI}}{\partial w} = 0, \\
\frac{\partial \pi_{mNI}}{\partial p_d} = 0, \\
\frac{\partial \pi_{mNI}}{\partial Q} = 0.
\]

We obtain the optimal results. \(\Box\)

**Proof for Result 5.** The proof is similar to that of Result 5 except that \(f(a/f_m)\) is replaced with \(f(a/f_{m,f_t})\). \(\Box\)

**References**


