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***Abstract*-This paper evaluates the impact of information sharing strategies on the performance of a supply chain. We consider three forms of information sharing strategies: (1) order information sharing where every stage of the supply chain only knows the orders from its immediate downstream stage; (2) demand information sharing where every stage has full information about the market demand; (3) inventory information sharing where each stage shares its inventory levels and demand information with its immediate upstream stage. Our results indicate that information sharing improves supply chain performance when demand is relatively stable. More importantly, we find that a hybrid information sharing strategy, which uses demand information sharing in the distribution network of the supply chain while using inventory information sharing in the supplier network, is the ideal strategy to improve supply chain performance when demand mix is volatile.**

I. INTRODUCTION

More and more companies have recognized that there is a direct link between the performance of supply chains and the availability and quality of timely information. It is widely known that Wal-Mart and Proctor & Gamble (P&G) share information regarding the retail sales of P&G products at Wal-Mart stores. This information enables P&G to do a better job of managing its production of these products and provides Wal-Mart with greater "in store" availabilities. Furthermore, new successful companies such as Dell and Cisco are already sharing information with suppliers and customers to reduce working capital and inventories. The flow of information through the supply chain enables them to match supply closely to consumer demand and to anticipate changes in the marketplace. The wide use of advanced information technologies (e.g., EDI and Web technologies) in supply chains also suggests that companies have come to realize the importance of information sharing.

Academic researchers have also showed a growing interest in the value of information sharing in supply chains. The value of information in inventory management is studied by, e.g., Lee, Padmanabhan and Whang [4], Chen [2], Chen, Drezner, Ryan and Simchi_Levi [1], Gavirneni, Kapuscinski and Tayur [3], and Tan [8]. Closely related to our paper is the research conducted by Tan, who tested the impact of information sharing strategies on the performance of supply chains. Her research relies on a multi-agent simulation model, whereas ours depends on analytical models.

While information is commonly described as valuable, there is little research on what kind of information supply chain members should share and how to share it in a supply chain. In this paper we attempt to achieve two main objectives. First, we study how information sharing affects supply chain performance, which consists of four dimensions: inventory, backorder, fill rate and cycle time. We develop simple analytical models to evaluate the impact of different information sharing strategies on supply chain performance. Second, we investigate the potential of a hybrid information sharing strategy, which uses demand information sharing in the distribution network and uses inventory information sharing in the supplier network, to improve the overall performance of the supply chain when demand is volatile.

The rest of the paper is organized as follows. The next section describes the bullwhip effect and information sharing in the supply chain context. Section 3 evaluates three forms of information sharing strategies: order information sharing, inventory information sharing and demand information sharing. In section 4, we propose the hybrid information sharing strategy. In section 5, we conclude and identify opportunities for future research.

II. INFORMATION SHARING IN SUPPLY CHAINS

Lack of information sharing is a common root cause for many supply-chain related problems. An important observation in supply chain management, widely known as the bullwhip effect, suggests that demand variability is magnified as it is further upstream in the supply chain. The bullwhip effect is a major concern for companies because the increased variability in the order process requires each facility to increase its safety stock in order to maintain a given service level and therefore leads to increased inventory cost. The importance of information sharing lies in reducing the bullwhip effect by synchronizing supply with demand. In this section, we discuss the bullwhip effect and information sharing in the supply chain context.

A. *The Bullwhip Effect*

In the simplest sense, the bullwhip effect refers to the phenomenon that the systematic distortion in real demand is amplified as it is passed upstream through the supply chain. The bullwhip effect has been observed in many industries. P&G observed that although the end-customer demand for diapers was fairly stable over time, the diaper orders issued by retailers to its wholesalers or distributors were quite variable. Furthermore, even larger fluctuations exist in the orders that P&G received from its wholesalers. Finally, the variability in the orders for materials to P&G's suppliers was even larger.

The bullwhip effect is a main concern in supply chain management for several reasons. First of all, the increased order variability requires each supply chain member to hold excessively high and variable inventory levels in order to meet a boom-and-bust demand pattern. Secondly, high stocks and poor service often go together. Despite the overall overstocking throughout the supply chain, the lack of synchronization between supply and demand leads to a very high inventory at certain times and complete stockout at other times. Finally, the bullwhip effect increases not only the physical inventories but also operating costs. Poor demand forecasts based on the distorted demand lead to uncertain capacity planning and missed production schedule. Hence, the bullwhip effect should be minimized or eliminated.

In order to minimize the bullwhip effect, we need to identify the root causes of the bullwhip effect. Previous research suggests that this amplification of demand is primarily caused by the problems of management intervention [4]. While it is true that the common effects in supply chains, such as large batch sizes, rationing game, and price variations, exaggerate the bullwhip effect, our study suggests that the bullwhip effect is inherent in a traditional supply chain even without these problems. Several characteristics of the supply chain that can cause the bullwhip effect include (1) lead times; (2) supply chain uncertainties; (3) information gap; and (4) supply chain structure. First, each stage of the supply chain amplifies the demand variability because of the time lag between placing an order and receiving it. We will show that lead times cause an increase in demand variability. Second, the amount of safety stock used to buffer against supply and demand uncertainties amplifies the bullwhip effect. Since the order placed by each stage of the supply chain to its supplier consists of the amount it needs to meet its demand and the safety stock, high and variable safety stock level magnifies the bullwhip effect. Third, without sharing of demand information, an upstream supplier is forced to forecast demand based on the orders from its immediate downstream stage. Such an arrangement will cause the supplier automatically to lose track of the real demand pattern. Finally, supply chain structure can contribute to the bullwhip effect, e.g., the length of the serial channel can lead to the bullwhip effect because the order variability is amplified at each stage of the supply chain.

The differences in understanding about the bullwhip effect lead to the different ways of eliminating it. Previous findings suggest that the bullwhip effect can be mitigated through modifications in behavioral practice and operational practice. Our study suggests that information sharing among supply chain members plays a critical role in countering the bullwhip effect.

B. Information Sharing Strategies in Supply Chains

A great deal of controversy exists about the impact of information on supply chain performance. While some authors have reported very beneficial impact, others have found marginal, no, or negative impact. Determining the value of information is a fundamental research problem for information system researchers. In this paper, we argue that information sharing can significantly reduce the bullwhip effect and improve supply chain performance. For this purpose, we evaluate three common information sharing strategies: order information sharing, demand information sharing and inventory information sharing. The three information sharing policies are described as follows.

Order Information Sharing: In the case of order information sharing, each stage of the supply chain does not know the status of its downstream stages and forecasts are based only on the orders from its immediate downstream stage, which, as we will see, can be significantly more variable than real demand. The beer game is probably the most famous case that demonstrates order information sharing in a traditional supply chain. Even when the end consumer demand is relatively stable, the bullwhip effect intrinsic in the chain leads to high inventories, poor forecasts, and delays which in turn cause lost customers, lost production, lost sales, and lost time.

Demand Information Sharing: On the other extreme, demand information sharing assumes total real demand visibility. Real-time demand information is transmitted from the end-consumer back through every stage of the supply chain. This means that any real change in demand can be known at all points in the supply chain. With real demand information, the bullwhip effect is minimized and channel partners can forecast future demand more accurately, reduce safety stock, and anticipate customer needs. Direct sales model, sharing of POS data, and collaborative planning and optimization belong to this type of information sharing.

Inventory information sharing: In this form of information sharing, a stage of the supply chain shares information about its inventory levels and actual demand rather than places orders with its supplier. Since the supplier knows its downstream customer's demand, this strategy eliminates at least one tier of information distortion, i.e., the downstream customer stage. Moreover, by monitoring its downstream inventory levels, the supplier can synchronize its production and delivery schedule with the downstream customer's demand and maintain a high level of availability. This policy is a kind of partial information sharing because the supplier looks at only its downstream stage. This strategy is currently common in the grocery and fashion retailing industry. Vendor managed inventory (VMI), schedule sharing window, and continuous replenishment belong to this type of information sharing.

Information sharing provides benefits in terms of reduced order variability and supply chain visibility. For example, demand information sharing allows each stage to forecast accurately based on real demand in order to reduce the overall level of safety stock compared with sales. Information sharing also affects other performance measurements, such as fill rate, backlog and cycle time.

Perhaps, some measurements may be worsened because of information sharing. For example, Chen [2] reports that high demand variability decreases the value of information. The reason is that the reduced inventory gives each stage less buffer to cope with sudden increase in its downstream demand and causes a very large backlog. As a consequence, a different information strategy may affect the performance differently. In the next section, we develop mathematical models to evaluate these information sharing strategies.

III. EVALUATING INFORMATION SHARING STRATEGIES

Consider a linear supply chain with N stages. Consumer demand arises at stage 1, stage 1 orders from stage 2, etc., and stage N orders from an outside supplier. This triggers material flow in the opposite direction. Each stage has a fixed lead time. We first assume that each stage maintains a high service level so that the supply chain can be "decoupled" into N single-stages. We also assume that the demands are independent across periods and each stage faces a normal demand. Finally, we assume that each stage replenishes its stock by following a periodic-review policy with a fixed review time, one period and that when the demand in a period exceeds the on-hand inventory, the excess is backordered. The objective is to find out how information sharing can affect the performance of the supply chain.

For each stage of the supply chain, let

S_t = order-up-to inventory level in period t,
L = lead time plus 1 (review period),
Q_t = order quantity in period t,
$\hat{m}_t$ = forecast demand in period t,
$\hat{s}_t$ = forecast standard deviation of demand in period t,
D_t = real consumer demand in period t,
$I(t)$ = average inventory level in period t,
$B(t)$ = average backorder level in period t,
a = customer service level,
$b(t)$= average fill rate in period t.

Let z be the safety-stock factor. One common form of a periodic inventory policy is to set the target inventory level in period t, S_t, is equal to [5].

$$S_t = L\hat{m}_t + z\sqrt{L}\ \hat{s}_t\ , \qquad (1)$$

where

$$z = [1/2\sqrt{(2/p)}\ ]\ln[a/(1-a)],$$

$z\sqrt{L}\ \hat{s}_t$ is an estimate of safety stock and a is the customer service level, which measures the proportion of periods in which no stockout occurs. For a given service level, we can determine the safety factor z with the above formula.

A. *Performance Measures*

For a given stage of the supply chain, we use the following four performance measurements to evaluate the supply chain performance.

Inventory: Inventory is the key driver to the supply chain cost. Inventory measured in dollars hides many problems. The amount of the inventory often accurately demonstrates the performance. The average inventory level is the sum of safety stock and average cycle stock, and is given by

$$I(t) = z\sqrt{L}\ \hat{s}_t + \hat{m}_t/2. \qquad (2)$$

For a given target service level a, we can compute the safety factor z and then the average inventory level and vice versa.

Fill rate: Fill rate measures the proportion of demands that are met from the inventory on hand. It is an important indicator of availability. The long-run relationship between the safety-stock factor and fill rate can be expressed as the approximation formula in [7]

$$b(t)= 1-[\exp(-0.92-1.19z-0.37z^2)]\sqrt{L}\ \hat{s}_t/\hat{m}_t. \qquad (3)$$

Backlog: Backorder is associated with a loss of customer goodwill. It's another driver to the supply chain cost. Expected shortage per replenishment cycle is [7]

$$B(t) = \hat{s}_t\ \sqrt{L}\ G_u(z), \qquad (4)$$

where $G_u(z)$ is the probability that a unit normal variable takes on a value of z or larger.

Cycle time: Cycle time is defined as the amount of time that elapses from the instant that an order is placed until it arrives. It is an important indicator of supply chain performance, especially when firms compete on speed of delivery. Let RT be the response time to the customer demand. A customer order is delayed with probability $(1–a)$. Hence, the overall average cycle time CT equals to

$$CT = L + (1 - a)RT. \qquad (5)$$

Several observations can be made from Equation (1) to (5). First, average inventory and backlog are increasing functions of the standard deviation of demand. Second, fill rate is a decreasing function of the standard deviation of demand. Third, cycle time is a decreasing function of a service level and an increasing function of response time. Empirical evidences demonstrate that reduction of demand uncertainty can reduce the response time through improvement in planning and scheduling, and communication. Hence, the performance of the supply chain squarely relies on demand uncertainty seen by each stage. Inventories are often used to protect the supply chain from uncertainties, but it is an expensive solution. We will quantify how information sharing can reduce demand uncertainty at each stage of the supply chain and hence improve supply chain performance.

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B. Order Information Sharing

In the case of the order information sharing, demand forecasts at each stage of the supply chain are based only on the orders from its customer. We assume that each stage uses the simple moving average forecast method with *n* observations to estimate the mean and standard deviation of demand, i.e,

$$\hat{m}_t^1 = \sum_{i=1}^{n} D_{t-i} \,/\, n, \qquad (6)$$

and

$$\hat{m}_t^k = \sum_{i=1}^{n-1} Q_{t-i}^{k-1} \,/\, n, \qquad \text{k} = 2, \ldots, N, \qquad (7)$$

where Q_{t-i}^{k-1} is the order placed by stage *k-1* in period *t-i*.

To simplify our analysis, assume that each stage, *k*, follows a period review policy where the target inventory level is of the form

$$S_t^k = (L_k + SS_k)\,\hat{m}_t^k, \qquad \text{k} = 1, \ldots, N, \qquad (8)$$

where L_k is the lead time between stages *k* and *k+1* plus 1, SS_k is the safety stock expressed in units of the average demand.

Note that (8) is just a special case of (1) with the safety stock $z\sqrt{L}\ \hat{s}_t = SS_k\ \hat{m}_t^k$. In practice, many companies use policies of this form. For instance, a retailer facing an order lead time of three week may choose to keep its target inventory level equal to four weeks of forecast demand, with the extra week of inventory representing its safety stock. The more volatile the demand, the larger SS_k becomes. At stage *k*, we can determine the variance of Q_t^k relative to the variance of its demand, Q_t^{k-1}. So we write Q_t^k as

$$Q_t^k = S_t^k - (S_{t-1}^k - Q_{t-1}^{k-1}).$$

Observe that Q_t^k may be negative, in which case we assume that the excess inventory is returned without cost. Using (7) and (8), we can write the order quantity Q_t^k as

$$Q_t^k = (L_k + SS_k)\,\hat{m}_t^k - (L_k + SS_k)\,\hat{m}_{t-1}^k + Q_{t-1}^{k-1}.$$
$$= (1 + (L_k + SS_k)/n)\ Q_{t-1}^{k-1} - ((L_k + SS_k)/n)\ Q_{t-n-1}^{k-1}.$$

Taking the variance of Q_t^k, we get

$$Var\,(Q^k) = [1+2(L_k + SS_k)/n+2(L_k + SS_k)^2/n^2]\,Var(Q^{k-1}). \qquad (9)$$

Hence we can deductively derive the following expression for the variance of the orders placed by stage *k*

$$Var(Q^k) =$$
$$\{\prod_{j=1}^{k}[1+2(L_j+SS_j)/n+2(L_j+SS_j)^2/n^2]\}\,Var(D),$$
$$k = 1, \ldots, N. \qquad (10)$$

The increase in demand variability is an increasing function of L_k, the leadtimes, and SS_k, the safety stock, and the decreasing function of *n*, the number of observations used in demand forecasting. More importantly, the variance increases multiplicatively at each stage of the supply chain. This expression shows the bullwhip effect that demand information increases quickly as one moves up a traditional supply chain. Empirical evidence also shows that the orders placed by a retailer tend to be much more variable than the end consumer demand seen by that retailer. This increase in demand variability propagates up the supply chain, distorting the orders received by upstream channel members. Based on (2) to (5), the increased demand variability not only requires each stage to increase its safety stock in order to maintain a given service level but leads to an increase in backlog and cycle time and a drop in fill rate.

C. Demand Information Sharing

On the other extreme, demand information sharing assumes that the first stage of the supply chain (i.e., the retailer) shares its real-time demand data with each of the subsequent stages. Since each stage has real demand information, each stage will use the same estimate of the mean demand.

$$\hat{m}_t = (\sum_{i=1}^{n} D_{t-i})/n,$$

When demand information is shared among stages, an echelon inventory policy is used. Consider an echelon inventory policy where the target inventory level is given by

$$S_t^k = (\sum_{i=1}^{k}(L_i + SS_i))\ \hat{m}_t, \qquad k = 1, \ldots, N. \qquad (11)$$

If we perform an analysis similar to that presented above, we have the following expression for the variance of the orders placed by stage *k*, Q^k, relative to the variance of real demand.

$$Var(Q^k)=[1+2\sum_{j=1}^{k}(L_j+SS_j)/n+2(\sum_{j=1}^{k}(L_j+SS_j))^2/n^2]\ Var(D),\quad k=1,\ldots,N. \qquad (12)$$

In comparison with (10), (12) demonstrates that the increase in demand variability at each stage of the supply chain is additive not multiplicative. So using real demand information, each stage can use real demand to create more accurate forecasts, rather than relying on the orders received from its downstream stage, which, as shown in (10), can be significantly more variable than the real demand. Hence demand information sharing can reduce the bullwhip effect and reduce the safety stock to the minimum.

Intuitively, as consumer demand becomes more volatile, it would be more beneficial for stage 1 to share its demand information with the upstream stages. But even for demand information sharing, as shown in (12), there still exists an increase in order variability at every stage of the supply chain because of the time lag and the safety stock. Therefore, if each stage plans its safety stock based on real demand, it is insufficient to meet the orders from its downstream customer. When the variance of real demand is very high, the increase in order variability can be substantial. Hence the backlog problem is aggravated as one moves upstream through the supply chain. This in turn results in low fill rates and long cycle time.

D. Inventory Information Sharing

In this type of information sharing, a stage shares its inventory status and actual demand with its immediate upstream stage. To a large extent, this strategy looks at only one supply chain link and belongs to partial information sharing. Suppose stage *k*-1 shares its actual demand and inventory status with stage *k*. Two distinct characteristics of this relationship are the following. First, because stage *k* knows the demand of stage *k*-1, it can implement the echelon-based inventory control. Both stage *k* and stage *k*-1 forecast the mean of demand based on the demand of stage *k*-1 in *n* periods. We have

$$\hat{m}_t^1=\hat{m}_t^2=\sum_{i=1}^{n}D_{t-i}/n,\quad k=1,2,$$

and

$$\hat{m}_t^k=\hat{m}_t^{k-1}=\sum_{i=1}^{n}Q_{t-i}^{k-2}/n,\quad k=3,\ldots,N,$$

where Q_{t-i}^{k-2} is the order placed by stage *k-2* and received by stage *k-1* in period *t-i*.

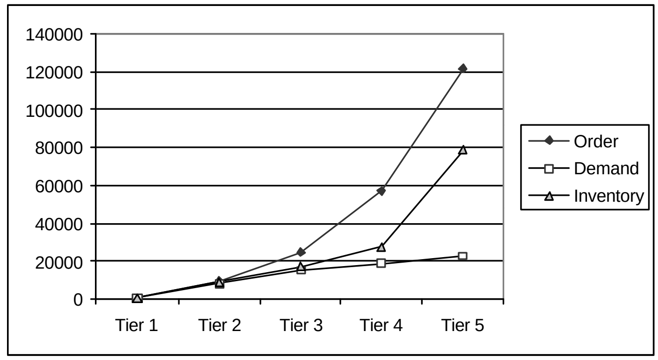

Fig. 1. Standard deviation of orders placed across a 5-tier supply chain

If we perform an analysis similar to that presented in sub-section C, we can derive the variance of the orders placed by stage *k* and stage *k*-1:

$$Var(Q^k)=[1+2\sum_{j=1}^{k}(L_j+SS_j)/n+2(\sum_{j=1}^{k}(L_j+SS_j))^2/n^2]\ Var(D),\quad k=1,2,$$

and

$$Var(Q^k)=[1+2\sum_{j=k-1}^{k}(L_j+SS_j)/n+2(\sum_{j=k-1}^{k}(L_j+SS_j))^2/n^2]\ Var(Q^{k-2}),\quad k=3,\ldots,N. \qquad (13)$$

When *k*=2, inventory information sharing performs like demand information sharing. In comparison with (10), (13) demonstrates that the increase in demand variability between stage *k* and stage *k*-1 is additive not multiplicative. Stage *k* can use the actual demand of stage *k*-1, which is less variable than the orders received from stage *k*-1, to create more accurate forecasts. Thus, inventory information sharing eliminates one stage of information distortion, i.e., stage *k*-1, and consequently reduces some degree of the bullwhip effect. Therefore, inventory information sharing can create more accurate forecasts and keep less safety stock than order information sharing. But it does not perform as well as demand information sharing in terms of inventory savings because the demand of stage *k*-1 may be distorted by the further downstream stages.

Moreover, by monitoring its downstream inventory status, stage *k* can synchronize its production and delivery schedules with the downstream demand to ensure that products are consistently available to stage *k*-1. Thus, stage *k* provides stage *k-1* with high level of availability. In other words, inventory information sharing is able to maintain a low backlog, a high fill rate, and a short cycle time.

E. Evaluation of Information Sharing Strategies

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TABLE I

% BENEFIT COMPARING INFORMATION SHARING STRATEGIES TO ORDER INFORMATION SHARING FOR RANDOM DEMAND

	Demand information sharing	Inventory information sharing
Inventory	84.19%	53.96%
Backorder	19.06%	64.48%
Fill rate	–7.54%	5.59%
Cycle time	–0.95%	16.15%

We have demonstrated that information sharing can reduce the bullwhip effect, mainly caused by the lead times and the safety stocks in the supply chain. Fig. 1 presents the simulation estimates of the standard deviation of orders across a 5-tier supply chain. It shows that information sharing reduces the order variability dramatically and thus reduce supply chain inventory. Insufficient inventory, however, causes an increase in backlog and cycle time and a drop in fill rate when demand is volatile. The following observations can be made from the results above.

Different information sharing policy gives its distinct "signature" performance. First, in the case of order information sharing, the increased demand variability requires each stage to increase its safety stock in order to keep a given service level and leads to overstocking throughout the system. This strategy also has a high backlog, a low fill rate, and a long cycle time since a boom-and-bust order pattern results in a very high inventory at some times and complete stockout at other times. Second, demand information sharing can significantly reduce the bullwhip effect and thus reduce its safety stock to the minimum. But the minimum safety stock causes an increase in backorder cost and cycle time, and a drop in fill rate under volatile demand. Finally, Although inventory information sharing does not perform as well as demand information sharing in terms of inventory, this strategy is able to maintain a low backlog, a high fill rate, and a short cycle time by maintaining sufficient inventory and efficient production and delivery planning.

Information sharing improves supply chain performance when demand is relatively stable. In the case of order information sharing, the demand variance increases multiplicatively at each stage of the supply chain. With demand information sharing, the bullwhip effect is minimized since the demand variance increases additively at each stage of the supply chain. Inventory information sharing can reduce at least one level of distortion. The reduction of the demand variance is also achieved by the reduced safety stock at each stage of the supply chain. Based on (2) to (5), lower demand variance not only reduces inventory but improves other performance measures.

Using a multi-agent simulation model, Tan simulated a generic supply chain with four stages: retailer (tier 1), distributor (tier 2), manufacturer (tier 3) and supplier (tier 4) [8]. The end-demand is generated by Uniform[8500,11500]. Table I shows the simulation estimates of the percentage

TABLE II

% BENEFIT COMPARING INFORMATION SHARING STRATEGIES TO ORDER INFORMATION SHARING FOR VOLATILE DEMAND MIX

	Demand information sharing	Inventory information sharing	Hybrid Information sharing
Inventory	88.89%	–97.78%	20%
Backorder	–463.64%	–36.36%	27.27%
Fill rate	–44.83%	2.3%	3.45%
Cycle time	–183.4%	14%	22%

benefits realized through information sharing. Demand information sharing experiences 84.19% and 19.06% in inventory and backlog respectively while there is a drop in fill rate and a slight increase in cycle time. Inventory information sharing experiences 64.48% decrease in backorder, 5.59% increase in fill rate and 16.15% decrease in cycle time while its inventory savings 53.96% is not as significant as that of demand information sharing. These results verifies that information sharing improves supply chain performance (especially inventory) when demand is relatively stable and that different information sharing policy behaves differently.

The Benefits of Information sharing are reduced when the variance of demand is very high. While demand information sharing lowers supply chain inventory, the reduced inventory gives each stage of the supply chain less buffer to cope with the increased demand uncertainty under volatile demand. The reason is that each stage of the supply chain underestimates the variability of its downstream demand by planning the safety stocks based on real demand. Inventory information sharing, on the other hand, gives the best customer service, but the bullwhip effect and the high product availability may drive the inventory up when demand is highly volatile.

Table II presents the simulation estimates of the percentage benefits realized through information sharing under volatile demand mix. This experiment considers four end products that share one common platform. Although the total demand are constant, the demand for each product changes randomly and cyclically (refer [8] for details). The results demonstrate that demand information sharing experiences 463% increase in backlog, 44.83% drop in fill rate, 183.4% increase in cycle time and that inventory information sharing experiences 97.78% increase in inventory. Therefore, information sharing is not very beneficial under demand volatile. In the next section, we will propose a hybrid information sharing strategy to cope with volatile demand mix.

IV. Hybrid Information Shahring Strategy

Another important task of this research is to devise an ideal information sharing strategy for a supply chain under volatile demand. We have already seen that the value of information sharing relies heavily on the nature of demand. Moreover, each different part of the supply chain has its own distinct characteristic and may require a different information sharing strategy. In this section, we propose a hybrid information sharing strategy, which uses demand information sharing in the distribution network of the supply chain and uses inventory information sharing in the supply network, for managing a supply chain with volatile demand mix.

Our primary motivation in developing the hybrid information sharing strategy comes from our experience at a major electronics manufacturer that manufactures radio products. One of the goals of the manufacturer is to control inventories in its distribution network through enhancing the value of information, providing insights for its global supply chain, which consists of local and offshore suppliers, factories, super distribution centers (DCs), regional DCs and dealers. These facilities are distributed all over the world. By moving to a more systems integrated environment, the company adopted schedule sharing window to schedule factories based on product usage and inventory level information supplied by their downstream stages at the supply chain. But the problem is that DCs strive to maintain a high customer service level by setting very large windows and dealers do not want carry inventories and want immediate deliveries; hence, the company carries several months of inventory at its DCs. The root cause of the problem is a mismatch between the schedule sharing strategy and its distribution network.

The radio product is a customizable product that provides more than one hundred of localized versions of a basically similar product to satisfy the requirements of different markets. Its demand changes mainly in product mix rather than volume. In this case, we find that hybrid information sharing should be an ideal strategy for the radio supply chain. The key to understanding the hybrid information sharing strategy is that it takes into account both the position on the supply chain and the nature of demand.

A. The Supplier Network and the Distribution Network

A typical supply chain can be divided into the supplier network (upstream of final assembly) and the distribution network. Each sub-network has its distinct characteristics. The supplier network, in which products are in the raw or semi-finished states that will be transformed and assembled at the manufacturer, is further away from the end consumer. Its inventories, including parts, components and sub-assemblies, have less value, greater commonality, and greater flexibility than finished products. Partnerships between suppliers and final assembly are important because a better knowledge of the supplier production schedules and part availability is of high value to the manufacturer in order to get the supplies in time for production. Another reason for such partnerships is that different input factors are complementary. Hence the objective of the supplier network is to improve its availability and responsiveness to the manufacturer.

On the other hand, the distribution network is close to the consumers. Finished products have a much higher value, greater differentiation, and less flexibility than components. High inventory cost rates and high demand uncertainty require both the manufacturer and distributors to better forecast demands based on real demand. Thus the objective of the distribution network is to signal the right demand and reduce the inventory through reducing the bullwhip effect.

Therefore, the supplier network and the distribution network may require different information sharing strategies. In a volatile market place, inventory information sharing may be a good policy for the supplier network because it offers the best customer service. Demand information sharing, on the other hand, may be a good strategy for the distribution network because it provides each stage with real demand information and minimizes the bullwhip effect. Matching the information sharing strategy with the position on the supply chain can improve the supply chain performance.

B. Demand Pattern

Life would be easy if demand was stable. But supply chains in many industries often suffer from an excess of some products and a shortage of others because of an inability to forecast demand accurately. In a volatile market, demand may change in demand volume, product mix, or both. Thus demand variability has two major dimensions: quantitative variability and qualitative variability. Quantitative variability captures changes in volume while qualitative variability captures changes both in demand mix and in the nature of the demand.

On the basis of their demand patterns, products fall into one of three categories: functional products, customizable products, or innovative products. Functional products, such as shampoo for dry, normal and oily hair, have a stable demand. Many companies have customized their products to satisfy the requirements of different market segments. The demand mix of a customizable product, such as cellular phone, may vary widely while the total demand does not change much. Demand for innovative products, such as fashion apparel, has both quantitative variability and qualitative variability.

C. Hybrid Information Sharing Strategy

In section III, we only talked about quantitative variability. When demand has a small quantitative variability, demand information sharing is the ideal strategy because it minimizes supply chain inventory by reducing the bullwhip effect. Even when demand has a certain degree of quantitative variability, inventory buffers in its distribution network can be used to absorb the variability. Actually, retailers usually have to hold more inventory than it is required to meet sales in order to show a full stock level so that the stores look like they are 'in business'. Based on our performance equations, the deployment of the inventory at retailers also enables rapid replenishment to the consumer.

When demand mix is highly volatile, however, the use of finished goods inventory (FGI) is not only very costly but also inflexible. When there are rapid changes in the nature of

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the demand owning to shifts in customer preferences and/or introduction of new, improved products, the old products already made and held in inventory would have a reduced value or simply become obsolete [6]. This is especially true for customizable products and innovative products. For the supply chains that supply such products, hybrid information sharing, which takes advantage of the strengths of both demand information sharing and inventory information sharing, is the ideal strategy.

On the one hand, the distribution network benefits from this strategy. First, demand information sharing in the distribution network can reduce qualitative variability since each stage in the distribution network can benefit from the value of centralized demand information and consequently make accurate forecasts to minimize inventories and improve customer service performance. Second, demand information helps each stage to make segment-specific forecasts and deploy FGI properly to buffer against qualitative variability. Finally, the manufacturer is the best place to decouple supply from demand because significant product differentiation often occurs in the distribution network. If the total demand does not change much even though the demand mix varies widely, the manufacturer can benefit from the risk-pooling effect and produce to accurate forecasts; otherwise, it can reactive capacity to buffer against quantitative variability.

On the other hand, the supply network also benefits from the strategy. First, component commonality is a key characteristic of customized products. Different models of a customizable product, e.g, the radio product as mentioned above, usually share a platform or other components. The suppliers of such common components can fully benefit from the risk-pooling effect. Moreover, inventory information sharing gives the best customer service, e.g., a high fill rate, a low backorder, and a short cycle time. Therefore, this policy has its obvious advantages at the supplier network, where the availability and responsiveness of suppliers will be critical for the manufacturer's production planning and scheduling. Finally, since many suppliers in the supplier network usually are smaller companies with limited financial resources and technical expertise, it is infeasible and very expensive to use real demand to drive decisions. Hence the goal of the supplier network is to improve service level and responsiveness.

Our simulation results indicate that hybrid information sharing is a powerful strategy. As shown in Table II, this policy experiences 20% decrease in inventory, 27.27% decrease in backorder, 3.45% increase in fill rate and 22% decrease in cycle time. It also offers best customer service among all the information sharing strategies while reducing the inventory significantly. The results also show that while demand information sharing lowers the supply chain inventory, the reduced inventory jeopardizes the customer service; the bullwhip effect in inventory information sharing drive the inventory up although this policy gives good performance.

V. Conclusions

Companies have long been aware of the value of information sharing in supply chains; however, there has not been much research into how information impacts on supply chain performance, what kind of information supply chain members should share and how they should share it. Our study offers the following insights into these long-standing concerns. First, information sharing improves supply chain performance when demand is relatively stable since information sharing can significantly reduce the bullwhip effect. Second, different information sharing strategies have different impacts on supply chain performance. While demand information sharing lowers supply chain inventory, the reduced inventory gives the supply chain less buffer to cope with rapid change in demand. Inventory information sharing can give the best customer service but the bullwhip effect may drive the inventory up under volatile demand. Corporations often need to trade off gains in some dimensions of performance against losses in other measures. Finally, hybrid information sharing is an ideal strategy when demand is volatile in terms of demand mix. This strategy uses demand information sharing in the distribution network to reduce demand uncertainty associated with product mix while using inventory information sharing in the supplier network to guarantee reliable supplies.

Our ongoing studies are aimed at formalizing the hybrid information sharing strategy. We are also investigating how the value of information depends on the physical characteristics of a supply chain, such as product structure, supply chain structure, demand patterns, and production and distribution process.

References

[1] F.Y. Chen, Z. Drezner, J.K. Ryan, and D. Simchi-Levi, "The bullwhip effect: managerial insights on the impact of forecasting and information on variation in a supply chain," in *Quantitative models for supply chain management*, S. Tayur, R. Ganeshan, and M. Magazine Eds. Norwell: Kluwer Academic Publishers, 1999, pp. 417-439.

[2] F. Chen, "Echelon reorder points, installation reorder points, and the value of centralized demand information," *Management Sci*., vol. 44, pp. S221-S234, December 1998.

[3] S. Gavirneni, R. Kapuscinski, and S. Tayur, "Value of information in capacitated supply chains," *Management Sci*., vol. 45, pp. 14-24, January 1999.

[4] H.L. Lee, P. Padmanabhan, and S. Whang, "Information distortion in a supply chain: The bullwhip effect," *Management Sci*., vol. 43, pp. 546-558, April 1997.

[5] H.L. Lee and C. Billington, "Material management in decentralized supply chain," *Operations Research*, vol. 41, pp. 835-847, September-October 1993.

[6] L. Li, "The role of inventory in delivery-time competition," *Management Sci*., vol. 38, pp. 182-197, February 1992.

[7] S. Nahmias, *Production and Operations Analysis*, Homewood: Richard Irwin, 1989.

[8] G.W. Tan, "The impact of demand information sharing on supply chain network," PhD thesis, Department of Business Administration, University of Illinois at Urbana-Champaign, July 1999.