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THE COMBINED IMPACT OF PLACE POSTPONEMENT AND INFORMATION SHARING STRATEGIES ON REDUCING INFORMATION DISTORTION

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Abstract

Postponement strategy is one of the effective strategies to increase the supply chain's responsiveness to product variations while information sharing strategy is a type of inter-organization's coordination that the participants share useful information among them to improve the chain-wide performance. One recent finding on postponement is that it can improve the demand information quality: the quality of demand forecast is improved as the forecasting point moves closer to the production period and more information is gathered during the delayed period. Meanwhile, sharing demand information in supply chain has been shown to improve the accuracy of estimating demand parameters. Since these two types of strategies affect demand parameters in different ways, it is valuable to analyze the combined impact of these two strategies, called information shared postponement strategy, on improving the supply chain performance. This paper studies the combined impact of place postponement and various information sharing strategies on reducing information distortion and provides an illustration of how these two strategies affect the demand parameters simultaneously. The result shows that place postponement, combined with demand information sharing strategy, may perform better on reducing information distortion than that of place postponement alone, whether it is better than information-sharing alone conditionally depends on lead-times before/after postponing among the participants in the chain.

Keywords: Information sharing, place postponement, supply chain, information distortion, combined impact

Introduction

Postponement, defined as the delay of the point of product differentiation in a production process to the latest possible time (Lee, 1993), has proved to be an effective strategy to increase a supply chain's responsiveness to the increasing product variations and shortening product life cycle. Various analytical models on evaluating the benefit and costs associated with postponement have been developed. Lee and Tang (1997, 1998) studied some basic costs/benefits associated with various postponement strategies at a process level and analyzed the impact of operation reversal. Garg and Tang (1997) analyzed the situation in which the differentiation occurred at two points. After postponement in the manufacturing tier has been studied, researchers turned to its systematic performance in the production-distribution model. Aviv and Federgruen (1998) studied the benefits of capacity sharing enabled by postponement. Whang and Lee (1999) quantified how the postponement may resolve demand uncertainty to improve forecast quality for the manufacturer. Gavirneni and Tayur (1998) compared the impact of postponement and information sharing: Via a two-tier supplier-customer simulation model, the researchers evaluated how the parameters on inventory system, such as holding cost, affected the benefit of postponement strategy and analyzed the benefit of delaying product differentiation and sharing information simultaneously. Gavirneni and Tayur's research presents a good illustration of the combined value of these two strategies. However, they only considered one postponement approach: standardizing two products into one, and one information sharing approach: sharing all information about the end-customer and downstream.

Information sharing between member organizations of a supply chain is another main concern in supply chain management (SCM). Sharing information among the chain members, such as POS (point-of-sales) data from retailers, directly impacts members' production and inventory control, and is regarded as a tight collaboration approach in supply chain. With rapid development of cost-effective information technologies (IT), such information flows are now able to move through the chain accurately in a timely manner. As the result, research turns to focus on analyzing the cost-benefit trade-off of various information sharing strategies in the supply chain. On this topic, Tan (1999) evaluated the impact of demand information sharing on supply chain network structures, product structures and demand mix. Chen et al. (2000) studied centralized demand information sharing to reduce the bullwhip effect in supply chains. Lee et al. (2000) analyzed benefits of sharing demand information and identified some of the drivers behind using a two-level supply chain model. Li et al. (2000) quantified the benefit of several information sharing strategies on reducing demand uncertainty.

Whang and Lee (1999) argued that the value of postponement is the value of information: as time passes, more information about the customer demand would be acquired. Thus as the forecasting point moved closer to production period, demand forecast quality would improve and the quality of decision would be optimized (Fisher and Raman, 1996). Meanwhile information sharing helps the tiers improve the accuracy in estimating demand parameters by sharing information within the chain.

Although postponement and information sharing both influence the demand parameters and consequently affect the supply chain performance, the combined effect of these two strategies was rarely considered, except Gavirneni and Tayur (1998), or fully studied in previous studies. Therefore it is valuable to analyze various combined impacts of them on supply chain performance and find the correlations between these two strategies. Here we define the combination of these two strategies as information shared postponement. In this paper, we study the combined impact of place postponement, a representative postponement approach, and three common demand information sharing strategies on reducing information distortion. We choose the estimating demand variance, i.e. the orders the chain-member's customers place to, of each tier as the measurement because the demand variability is a main concern of analyzing information distortion. Meanwhile, the greater estimating error of demand variance requires chain members to hold excessive inventory but usually still results in poor service (Li et al. 2000).

Place Postponement vs. Information Sharing

Place Postponement

Place postponement is an approach that postpones the differentiation (production/delivery) tasks to downstream. Various studies have described the implementing of this postponement approach in the real world, such as Zinn and Bowersox (1988), Lee and Billington (1994), Lee and Tang (1997) and van Hoek (1999). In HP case, HP delayed the final assembling activities of its Deskjet printers to the distribution centers (Lee, 1993). Comparing with some other postponing approaches, such as standardization and modularization (such as Lee and Tang 1997, and Lee 1993) which are usually carried out at the operation level within an manufacturing organization, place postponement is a strategic practice that requires supply chain collaboration or chain-structure redesign since the location, both geographical position and conceptual position in the supply chain, where differentiation takes place is moved closer to the demand source. In this paper, we measure the length of operation tasks in unit times with the same unit character of delivery lead-time and assume that the production/inventory cost factors, such as unit production cost or unit holding cost, are not affected much by implementing this strategy. This assumption is quite reasonable especially in the final assembly process in which the operations usually are relatively simple with low-technology requirements. Meanwhile, this paper focuses on analyzing the distortion of demand variance, so the result will not be affected by cost factors.

Information Sharing Strategies

Information sharing strategy is a type of inter-organization's coordination that the participants share useful information among them to improve the chain-wide performance (Note here the useful information means the information that may directly benefit the information receiver). Various types of information sharing strategies have been discussed (Lee and Whang (1998), Tan (1999), and Li et al (2000)). We evaluate three typical strategies dealing with demand information as follows:

Traditional information sharing: no other information received by the supplier except orders from immediate downstream. This is the basic information flow among supply chains.

Demand information sharing: the exact sales of end consumers are made available to every tier in the SCN. Thus information distortion along the chain is greatly reduced. Examples include Wal-Mart sharing its point-of-sale data with its suppliers.

Order information sharing: the supplier knows the order quantity of which its immediate customer's customer places to its customer, i.e., the supplier knows its downstream customer's demand. Thus the information distortion from the customers to its supplier is eliminated and the supplier can make timelier production/delivery decisions. This strategy is a kind of partial information sharing (Li et al. 2000), comparing with demand information sharing, since the supplier only knows the information from its customer, not from the end market.

Combined Impact of Place Postponement and Information Sharing Strategies

It is clear that the estimate of demand parameters - mean demand, standard deviation of demand and lead time—are the crucial factors to the tiers' inventory/production's decision, and affect system performance consequently. In this paper, we consider the variance of order quantity as the measurement to study how these two strategies reduce information distortion. Our analysis is an extension of Li et al. (2000)'s analytical model (the cases of sharing traditional/order/demand information alone, without any postponing approach, have been deduced in their model, what we extend is the place postponement, i.e. postponing some of the operation task from the upstream to the successive downstream, and the combined issues. Table 1 summarizes the six situations we plan to examine.

We assume a N -tier linear supply chain managing one single type of product. At period t , customers come to the retailer, the first-tier chain member, and make their purchases for that product, with the amount of D_t . The excess market demand is backlogged and is prioritized for fulfillment in the next period. The retailer sells the goods to the customer and makes the new order to its supplier, the second-tier member, with the amount of $o_{t,1}$ (in the following, we use subscript (t, k) to denote the variable in period t at the tier k), based on its forecast of future need and its own inventory management policy - to ensure a continuous selling. The second-tier fulfills the first-tier's order and places new orders on its supplier and so on. That is how the order information passes upwards in the supply chain. We assume the very initial supplier, the last-tier supplier in the chain, has infinite capacity to fully supply what its customer orders. Suppose the transportation time, L , between each member in the chain and the production lead-time, w , are constant in this case, so they do not need to worry about the delivery time uncertainty. Also, assume that all members use smoothing-average techniques with n -period observations to forecast its customer's future demand and the "order-up-to" inventory policy.

Table 1. The Combined Situations of Place Postponement and Information Sharing

	Traditional IS	Order IS	Demand IS
No postponement	$Var_0(o_k)$	$Var_1(o_k)$	$Var_2(o_k)$
Place postponement	$Var_3(o_k)$	$Var_4(o_k)$	$Var_5(o_k)$

(IS is the short form of information sharing. $Var(o_k)$ stands for the demand variability tier- k faces. $Var_0(o_k)$, $Var_1(o_k)$ and $Var_2(o_k)$ has been analyzed by Li et al (2000), therefore section 2.3.1 to 2.3.3 is mainly a brief summary of their work. Our extension starts at section 2.3.4.)

Traditional Information Sharing

In this case, the estimate mean demand of tier k in the period t can be denoted as $\hat{u}_{t,1} = \sum_{j=1}^n D_{t-j} / n$ and

$$\hat{u}_{t,k} = \sum_{j=1}^n o_{t-j,k-1} / n \quad (k=2, \dots, N).$$

The stock level is $S_{t,k} = (L_k + w_k + SS_k) \cdot \hat{u}_{t,k} = \partial_k \cdot \hat{u}_{t,k}$ where $\partial_k = L_k + w_k + SS_k$

and $SS_k \cdot \hat{u}_{t,k}$ is the safety stock (Although Li et al (2000) mentioned that in practice many companies use the policy of this form, it is not the optimal safety stock policy. However in this paper we focus on analyzing the strategic impact on estimating demand variance, not restricting that the inventories are being managed at optimal level. Meanwhile, our latter analysis only consider the

changes of L_k and w_k , not SS_k). The order quantity for tier- k in the period t can be denoted as $o_{t,k} = S_{t,k} - (S_{t-1,k} - o_{t-1,k-1}) = (1 + \partial_k/n) \cdot o_{t-1,k-1} - (\partial_k/n) \cdot o_{t-n-1,k-1}$, therefore the variance of $o_{t,k}$ when sharing traditional information is $Var_0(o_k) = [1 + 2\partial_k/n + 2\partial_k^2/n^2] \cdot Var_0(o_{k-1}) = \prod_{t=1}^k [1 + 2\partial_k/n + 2\partial_k^2/n^2] \cdot Var(D), (k=1, \dots, N)$

Order Information Sharing

In this case (Note that Li et al (2000) named it as the inventory IS. Since this strategy in their paper only uses downstream’s order information to improve the decision, we think it is better to be named as order IS), since the tier- k knows the demand of its customer meets, i.e. the order quantity, $o_{t,k-2}$, its customer, tier- $k-1$, receives from the customer’s customer, tier- $k-2$, it uses such information, instead of the order quantity it receives, to estimate the mean demand. Therefore the estimate value of tier- k in the period t can be denoted as $\hat{u}_{t,1} = \hat{u}_{t,2} = \sum_{j=1}^n D_{t-j}/n$ and $\hat{u}_{t,k} = \sum_{j=1}^n o_{t-j,k-2}/n (k=3, \dots, N)$. The variance of its order quantity

with order information sharing is $Var_1(o_k) = \left[1 + 2 \cdot \sum_{t=1}^k \partial_k/n + 2 \cdot \sum_{t=1}^k \partial_k^2/n^2 \right] \cdot Var(D)$ when $k=1,2$, and $Var_1(o_k) = \left[1 + 2 \cdot \sum_{t=k-1}^k \partial_k/n + 2 \cdot \sum_{t=k-1}^k \partial_k^2/n^2 \right] \cdot Var_1(o_{k-2})$ when $k=3, \dots, N$.

Comparing $Var_0(o_k)$ with $Var_1(o_k)$ for the situation of $k>2$:

$$\lim_{k \rightarrow \infty} \frac{Var_0(o_k)}{Var_1(o_k)} = \lim_{k \rightarrow \infty} \left\{ \left[1 + \frac{4 \cdot \partial_k \cdot \partial_{k-1} (n^2 + n\partial_{k-1} + n\partial_k + \partial_{k-1}\partial_k)}{n^2 \left(n^2 + 2n \sum_{k-1}^k \partial_t + 2 \sum_{k-1}^k \partial_t^2 \right)} \right] \cdot \frac{Var_0(o_{k-2})}{Var_1(o_{k-2})} \right\} > \lim_{k \rightarrow \infty} \frac{Var_0(o_{k-2})}{Var_1(o_{k-2})}$$

(Note that $\frac{Var_0(o_3)}{Var_1(o_3)} > \frac{Var_0(o_2)}{Var_1(o_2)} > \frac{Var_0(o_1)}{Var_1(o_1)} = 1$, therefore we can also get $\lim_{k \rightarrow \infty} \frac{Var_0(o_{k-2})}{Var_1(o_{k-2})} > 1$ when $k>2$) This result

indicates that as one moves upstream, the variance of the order quantity, o_k , at tier- k with order information sharing is less than that with traditional information sharing, which results in less inventory holding cost than that of traditional information environment.

Demand Information Sharing

In this case, every tier in the chain is aware of the end market demand. As a result each tier uses the same estimate mean demand as $\hat{u}_t = \sum_{j=1}^n D_{t-j}/n$. Therefore the variance of the order quantity with sharing demand information is

$$Var_2(o_k) = \left[1 + 2 \cdot \sum_1^k \partial_t/n + 2 \cdot \sum_1^k \partial_t^2/n^2 \right] \cdot Var(D). \text{ It is clear that } \lim_{k \rightarrow \infty} \frac{Var_0(o_k)}{Var_2(o_k)} > \lim_{k \rightarrow \infty} \frac{Var_1(o_k)}{Var_2(o_k)} > 1 \text{ (when}$$

$k>2$) since the increasing of $Var_2(o_k)$ along the chain is additive, while $Var(o_k)$ and $Var_1(o_k)$ is multiplicative, with greater-than-one coefficients. Therefore the inventory holding cost under the situation of sharing demand information is less than that of traditional information sharing and order information sharing respectively.

Place Postponement

In this case, a m -unit-time operation/task, of a total w_k -unit-time operation/task, at tier k is delayed to the tier $k-1$ ($1 \leq m \leq w_k$), therefore the variance of the order quantity with place postponement is:

$Var_3(o_k) = \left[1 + 2 \cdot (\partial_k - m) / n + 2 \cdot (\partial_k - m)^2 / n^2\right] \cdot \left[1 + 2 \cdot (\partial_{k-1} + m) / n + 2 \cdot (\partial_{k-1} + m)^2 / n^2\right] \cdot Var_0(o_{k-2})$ Let

$\hat{\lambda}_k = 1 + 2 \cdot \partial_k / n + 2 \cdot \partial_k^2 / n^2$, (note here $w_k \geq m \geq 1$ and $L_k \geq 1$ so $\partial_k \geq m + 1$) we can get

$$\lim_{k \rightarrow \infty} \frac{Var_0(o_k)}{Var_3(o_k)} = \lim_{k \rightarrow \infty} \frac{\hat{\lambda}_k \cdot \hat{\lambda}_{k-1}}{\left[\hat{\lambda}_k - 2m \cdot (n + 2 \cdot \partial_k - m) / n^2\right] \cdot \left[\hat{\lambda}_{k-1} + 2m \cdot (n + 2 \cdot \partial_{k-1} + m) / n^2\right]} \quad (k > 2).$$

This result cannot indicate whether operation delay can improve demand accuracy since it depends on the relationship of ∂_{k-1} , ∂_k and m , in other word: the final result depends on the relationships of the lead-times among participants before postponing, i.e., ∂_k and ∂_{k-1} , and after postponing, i.e., $\partial_k - m$ and $\partial_{k-1} + m$. One thing is obvious: delaying the operation/task does affect the estimate value of demand variance.

Combination of Order Information Sharing and Place Postponement

In this case, tier- k not only uses its customer’s demand to estimate the mean demand but also delay m unit-time operation to tier- $k-1$. Therefore, we get the variance of its order quantity in the combined case as

$Var_4(o_k) = \left\{1 + 2 \cdot (\partial_{k-1} + \partial_k) / n + 2 \cdot [(\partial_{k-1} + m)^2 + (\partial_k - m)^2] / n^2\right\} \cdot Var_2(o_{k-2})$. Compared to sharing order information alone and place postponement alone respectively, we can get (when $k > 2$):

$$\lim_{k \rightarrow \infty} \frac{Var_1(o_k)}{Var_4(o_k)} = \lim_{k \rightarrow \infty} \left[1 + \frac{2m(\partial_k - \partial_{k-1} - m)}{n^2 + 2n \cdot \sum_{t=1}^k \partial_t + 2 \cdot \left(\sum_{t=1}^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k)\right)} \right] \geq 1$$

ONLY when $\partial_k \geq \partial_{k-1} + m$

$$\lim_{k \rightarrow \infty} \frac{Var_3(o_k)}{Var_4(o_k)} = \lim_{k \rightarrow \infty} \left\{ 1 + \frac{[2n(\partial_k - m) + 2(\partial_k - m)^2] \cdot [2n(\partial_{k-1} + m) + 2 \cdot (\partial_{k-1} + m)^2]}{n^2 \left[n^2 + 2n \sum_{t=1}^k \partial_t + 2 \cdot \left(\sum_{t=1}^k \partial_t^2 + 2m\partial_{k-1} + 2m^2 - 2m\partial_k\right) \right]} \right\} \cdot \frac{Var_0(o_{k-2})}{Var_1(o_{k-2})}$$

$$> \lim_{k \rightarrow \infty} \frac{Var_0(o_{k-2})}{Var_1(o_{k-2})} > 1$$

(Note that when $k < 3$, the situations of sharing order or demand information is the same)

This result shows that under the order information-sharing environment, place postponement achieves better outcome than that without such information. It is better than sharing order information alone when $\partial_k - \partial_{k-1} - m \geq 0$, in other word, whether it is the optimal depends on participants’ lead-times before/after redesign.

Combination of Demand Information Sharing and Place Postponement

In this case, tier- k not only uses end-market demand to estimate the mean demand but also delay m unit-time operation to tier- $k-1$. Therefore, we get the variance of its order quantity in this combined case as

$Var_5(o_k) = \left[1 + 2 \cdot \sum_{t=1}^k \partial_t / n + 2 \cdot \left(\sum_{t=1}^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k)\right) / n^2\right] \cdot Var(D)$. Compared to sharing demand information alone, place postponement also and last combined case respectively, we can get (when $k > 2$):

$$\lim_{k \rightarrow \infty} \frac{Var_2(o_k)}{Var_5(o_k)} = \lim_{k \rightarrow \infty} \left[1 + \frac{2m(\partial_k - \partial_{k-1} - m)}{n^2 + 2n \cdot \sum_1^k \partial_t + 2 \cdot \left(\sum_1^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k) \right)} \right] \geq 1 \text{ ONLY when } \partial_k \geq \partial_{k-1} + m$$

$$\lim_{k \rightarrow \infty} \frac{Var_3(o_k)}{Var_5(o_k)} = \lim_{k \rightarrow \infty} \left\{ \frac{\left[n^2 + 2n \cdot (\partial_k - m) + 2 \cdot (\partial_k - m)^2 \right] \cdot \left[n^2 + 2n \cdot (\partial_{k-1} + m) + 2 \cdot (\partial_{k-1} + m)^2 \right] \cdot \frac{Var_0(o_{k-2})}{Var(D)}}{n^2 \left[n^2 + 2n \cdot \sum_1^k \partial_t + 2 \cdot \left(\sum_1^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k) \right) \right]} \right\} > 1$$

and

$$\lim_{k \rightarrow \infty} \frac{Var_4(o_k)}{Var_5(o_k)} = \lim_{k \rightarrow \infty} \left\{ \frac{\left(n^2 + 2n \cdot \sum_{k-1}^k \partial_t + 2 \cdot \left(\sum_{k-1}^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k) \right) \right) \cdot \frac{Var_0(o_{k-2})}{Var(D)}}{n^2 + 2n \cdot \sum_1^k \partial_t + 2 \cdot \left(\sum_1^k \partial_t^2 + 2m(m + \partial_{k-1} - \partial_k) \right)} \right\} > 1$$

This result shows that place postponement combined with demand information sharing achieves better outcome than the place postponement alone and combined postponement with order information (when the postponement tier, k , is large enough). It is better than sharing demand information alone when $\partial_k - \partial_{k-1} - m \geq 0$, in other word, whether it is the optimal depends on participants' lead-times before/after redesign.

Numerical Examples and Conclusions

In summary, in the situation of solely information sharing strategies, demand IS may reduce the demand variability mostly, then comes the order IS. In the situation of place postponing alone, the impact of reducing demand variability depends on participants' production/delivery lead-times before/after postponing. When together with implementing place postponement, demand information combined with place postponement conditionally achieves the best reduction on demand variability, and then comes the combination of order information and place postponement. Whether the combined cases are better than the purely sharing-information cases respectively depends on participants' lead-times before/after postponing, as shown in table2.

Table 2. The Relationship of Each Situation

	Traditional IS vs. Order IS vs. Demand IS
No postponement	$Var_0(o_k) > Var_1(o_k) > Var_2(o_k)$
Place postponement	$Var_3(o_k) > Var_4(o_k) > Var_5(o_k)$
When $\partial_k > \partial_{k-1} + m$	$Var_1(o_k) > Var_4(o_k), Var_2(o_k) > Var_5(o_k)$

We can make several observations on order/demand information sharing and place postponement based on previous analysis: first, sharing order/demand information always reduce demand variability while the impact of postponing operation depends on other environment conditions among participants, the total production and delivery lead time. Second, place postponement and information sharing strategies do have some degree of correlation on reducing information distortion since the demand variance in combined situation is not the same as that of pure information-sharing or postponement strategy (Note that the changing rate of combined case to the sharing-information alone is different either, i.e. $\frac{Var_1(o_k)}{Var_4(o_k)} \neq \frac{Var_2(o_k)}{Var_5(o_k)}$). Third, sharing order/demand

information improves the performance of place postponement on demand uncertainty in the combined situation. In this case, place postponement, combined with demand information, may achieve the best performance on reducing information distortion, which conditionally depends on participants' lead-times before/after postponing. Also note that the reduction of information distortion directly affects the inventory holding cost as it reduces the excrement inventory.

To understand this combined impacts of place postponement and information sharing strategies on information distortion, some numerical examples are provided. To simplify the case, we assume that there are five tiers in a supply chain and the sequence of each tier from the very up tier to the end market is: raw supplier, manufacturer, agent, wholesaler and the retailer. The transportation times between each tier in the supply chain are the same, varied as 1, 2, 4, 8 and 16 to simulate the chain as a production channel (the production time takes a large portion in the chain-wide lead-time) or a production-delivery (both the delivery time and production time are equal-important time factor) or a delivery channel (the delivery time is the main time factor). There is only one single postponing point in the chain, i.e. an m -unit-time operation/task, of a total 4-unit-time operation/task, at the manufacturer tier is delayed to its downstream customer: the agent in this example. M varies as 1 and 2 (as in the practice, usually part of the final assembling activities are postponed). The safety stock factor, SS_k , is fixed as 1 and the window size of the moving average forecasting method is set as 30 unit times. The result is shown in table 3.

Table 3. Some Numerical Examples to Illustrate the Combined Impact of Place Postponement under Various Informative Environments on Reducing Information Distortion

(Transportation Time, Production Time)	Postponed Time (m)	Traditional IS	Order IS	Demand IS
(1,4)	1	0.2%	-0.8%	-0.7%
	2	0.3%	-1.1%	-0.9%
(2,4)	1	0.3%	-0.7%	-0.6%
	2	0.4%	-1.0%	-0.8%
(4,4)	1	0.3%	-0.6%	-0.5%
	2	0.4%	-0.8%	-0.6%
(8,4)	1	0.3%	-0.4%	-0.3%
	2	0.4%	-0.6%	-0.4%
(16,4)	1	0.3%	-0.3%	-0.2%
	2	0.4%	-0.3%	-0.2%

(Postponed Time: m -unit-time operation/task at current tier is delayed to the downstream; Percentages in the table: the centesimal change of postponement under different informative environments comparing to no-postponing case. In the "Traditional IS"

column, the result is gained following the formula of $\frac{Var_0(o_k)}{Var_3(o_k)} - 1$. Similarly, the result in "Order IS" and "Demand IS" columns

are calculated from $\frac{Var_1(o_k)}{Var_4(o_k)} - 1$ and $\frac{Var_2(o_k)}{Var_5(o_k)} - 1$, respectively. The positive number stands for an increase of information distortion, negative number stands for a decrease of information distortion)

It shows, in this particular numerical case, that place postponement increases the information distortion under traditional information sharing situation, but resolve some degree of such distortion when the chain members sharing order or demand information. This result is quite rational: delaying operations potentially increase the information uncertainty at the downstream side as its lead time, the sum of the production time and the transportation time between its supplier and itself, increases. Since this distortion has a purely multiplicative effect under traditional information environment, as we proved before, it worsens the upstream although that upstream has a shorter lead-time after postponing. This observation infers that implementing place postponement may involve two aspects: one is allowing more information gathered before making final production decision so to improve forecasting quality, and the other is increasing the difficulty of forecasting accuracy along the chain as the lead-time demand for the downstream becomes more uncertain. However, because the lead-time before postponing is always greater than the downstream's lead-time after postponing, i.e., $\partial_k > \partial_{k-1} + m$, the place postponing under order-information-sharing environment and demand-information-sharing one helps the member to reduce information distortion, as we proved before. An interesting find is that under this particular numerical setting, the place postponement strategy helps the member resolve more

percentages of distortion under order-information-sharing situation than that of demand-information-sharing one. It may suggest that considering the cost factors of sharing certain information, place postponement, combined with order-information-sharing system, may achieve a better trade-off, or provide a more economical solution to the supply chain member, than that with demand-information-sharing system, given the assumptions that the more information, the greater payoff; and that the information required for order-information is less sensitive than the end consumer information, required by demand-information sharing.

Therefore we are encouraged to extend the research in several ways: to examine several other combinations of postponement and information sharing strategies to find the better-fit of postponing under different information environment; to develop other measurement on supply chain performance need, such as inventory relevant cost; and quantify the correlations of the combined strategies (As we find such correlations are hard to identify and analyze, the simulation approach is considerable); to consider the associated lead time in setting up the information infrastructure as this situation is repeatedly occurs in the Internet context where new suppliers are identified continuously.

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