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# Evaluating the cross-efficiency of information sharing in supply chains

Ming-Min Yu [a,1], Shih-Chan Ting [a,*], Mu-Chen Chen [b,2]

[a] Department of Transportation and Navigation Science, National Taiwan Ocean University, No. 2, Pei-Ning Road, Keelung 20224, Taiwan, ROC
[b] Institute of Traffic and Transportation, National Chiao Tung University, 4F, No. 118, Section 1, Chung Hsiao W. Road, Taipei 10012, Taiwan, ROC

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ABSTRACT

Supply chain management integrates the intra- and inter-corporate processes as a whole system. Through information technology, companies can efficiently manage the product flow and information related to the issues such as production capacity, customer demand and inventory at lower costs. Information sharing can significantly improve the performance of the supply chain, how the different combination of information sharing affects the performance is not yet understood. This study designs different information-sharing scenarios to analyze the supply chain performance through a simulation model. Since there are not only desirable measures but also undesirable measures in supply chains, the usual data envelopment analysis (DEA) model allows measuring performance for complete weight flexibility. In this paper, a cross-efficiency DEA approach is applied to solve this problem. We identify the most efficient scenario and estimate the each efficiency of information-sharing scenarios. Contrary to the previous findings in the literature suggesting sharing as much as information possible to increase benefits, the results of this study show that the scenario of demand information sharing is the most efficient one. In addition, sharing information on capacity and demand, and full information sharing in general are good practices. Sharing only information on capacity and/or inventory information, without sharing information on demand, interferes with production at manufacturers, and causes misunderstandings, which can magnify the bullwhip effect.



## 1. Introduction

A supply chain is a logistics network, which consists of all stages (e.g. order processing, purchasing, inventory control, manufacturing, and distribution) involved in producing and delivering a final product or service. The entire chain connects customers, retailers, distributors, manufacturers and/or suppliers, beginning with the creation of raw material or component parts by suppliers and ending with consumption of the product by customers. Supply chain management (SCM) is related to the coordination of materials, products and information flows among suppliers, manufacturers, distributors, retailers and customers (Simchi-Levi, Kaminsky, & Simchi-Levi, 2000). SCM often needs the integration of inter- and intra-organizational relationships and coordination of different types of flows within the entire chain. With sharing information between trading partners and coordinating their replenishment and production decisions under demand uncertainty, it could be possible to further reduce costs and improve customer service level. The performance of a supply chain could be influenced by many factors, among which information sharing is the crucial one. Inter-company integration and coordination via information technology play a key role in improving supply chain performance. The application of current information technology, such as electronic data interchange (EDI) and the internet has helped companies to share information and has improved supply chain order fulfillment performance. Sharing both supply and demand information substantially reduces inventory costs in make-to-stock or assemble-to-order production. Sharing supply information also substantially reduced order cycle time in an assemble-to-order environment (Strader, Lin, & Shaw, 1999).

A supply chain is fully coordinated when all decisions are aligned to approach global system objectives. Lack of coordination occurs when decision makers have incomplete information or incentives that are not compatible with system-wide objectives. Even under conditions of full information availability, the performance of the supply chain can be sub-optimal when each decision maker optimizes one's individual objective (Sahin & Robinson, 2002). One line of related research analyzes the benefits of sharing customer demand information with members of the supply chain. Bourland, Powell, and Pyke (1996) analyze the savings in inventory cost that can be realized when a manufacturer shares point-of-sale (POS) data with suppliers. Ernst and Kamrad (1997) consider a supply chain in which manufacturers and retailers share demand information and analyze the impact of information sharing on

* Corresponding author. Tel.: +886 2 24622192x7050; fax: +886 2 24633745.
*E-mail addresses:* yumm@mail.ntou.edu.tw (M.-M. Yu), ericting@mail.ntou.edu.tw (S.-C. Ting), ittchen@mail.nctu.edu.tw (M.-C. Chen).
[1] Tel.: +886 2 24622192x7017; fax: +886 2 24633745.
[2] Tel.: +886 2 2349 4967; fax: +886 2 2349 4953.

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service level. Lee, Padmanabhan, and Whang (1997) prove that demand variability can be amplified in the supply chain as the orders are passed from retailers to distributors. Therefore, accurate forecasts can significantly influence the performance of the supply chain in terms of inventory cost, backorders or loss of sales, and good will. Inaccurate forecasts can also cause low utilization of capacity and other problems in production. Cachon and Fisher (2000) and Lee et al. (2000) analyze the benefits of sharing real-time information on demand and/or inventory levels between suppliers and customers. Cachon and Fisher (2000) study the value of sharing demand and inventory data. The authors compare a traditional information policy that does not use information-sharing with a full information policy. Lee, So, and Tang (2000) analyze the benefits of demand-side information sharing with a two-echelon supply chain. They suggest that this kind of information sharing alone could provide significant inventory reduction and cost savings to the manufacturer. Thonemann (2002) derives a better understanding of the benefits of advance demand information (ADI) to identify conditions under which sharing ADI results in significant cost savings. A typical model is used to capture the basic aspects of a supply chain in which ADI is shared. This enables them to derive analytical results and to gain structural insight into the ADI-sharing problem. The results can be used by decision makers to analyze the cost savings that can be achieved by ADI and help them determine if sharing ADI is beneficial for their supply chain.

Another line of related research analyzes the impact of information sharing on the bullwhip effect and/or the performance of a supply chain. Metters (1997) studies the impact of the bullwhip effect on profitability by establishing an empirical lower bound on the cost excess of the bullwhip effect. Results indicate that the importance of the bullwhip effect to a firm differs greatly between specific business environments, and eliminating the bullwhip effect can increase product profitability by 10–30% under some conditions. Chen, Drezner, Ryan, and Simchi-Levi (2000a) Chen, Ryan, and Simchi-Levi (2000b) quantify the bullwhip effect for a simple, two-echelon supply chain consisting of a single retailer and a single manufacturer. They assume that demand follows an AR(1) process, and the retailer uses a moving-average model for demand forecast and a simple order-up-to inventory policy for replenishment. They conclude that the variance of the orders is always higher than the variance in demand. Furthermore, the magnitude of the variance is significantly influenced by the number of observations used in the moving-average, the lead time between the retailer and the manufacturer, and the correlation coefficient in the demand function. They extend the analytical model to a multiple-echelon supply chain and find that the bullwhip effect could be reduced, but not completely eliminated, by sharing demand among all parties in the supply chain. Chen et al. (2000a, 2000b) investigate the impact of forecast methods and demand patterns on the bullwhip effect. They compare an exponential- smoothing forecasting model and a moving-average model, in which the demand is correlated with a linear trend. They find that reduction in ordering lead time and using more demand information in forecasting (a smoother forecast) could decrease the bullwhip effect. Another finding is that negatively correlated demand could lead to a larger increase in order variability than positively correlated demand, and that a retailer forecasting demand with a linear trend will have more variable orders than a retailer forecasting i.i.d. demand. These two papers evaluate the magnitude of the variance amplifications in the supply chain by considering alternative demand processes and forecasting models for a simple supply chain structure. However, they do not consider the impact of the variance amplifications on the costs and service levels of the supply chain, nor do they consider the costs of either inventory, ordering or setup, or production decisions by the manufacturers. Zhao, Xie, and Leung (2002a) present the impact of information sharing and ordering coordination on the performance of a supply chain with one capacity-limited supplier and multiple retailers under demand uncertainty. Zhao, Xie, and Leung (2002b) also present the impact of forecasting model selection on the value of information sharing in a supply chain with one capacitated supplier and multiple retailers. Using a computer simulation model, this study examines demand forecasting and inventory replenishment decisions by the retailers and production decisions by the supplier under different demand patterns and capacity tightness. The simulation output indicates that the selection of the forecasting model significantly influences the performance of the supply chain and the value of information sharing. Furthermore, demand patterns faced by retailers and capacity tightness faced by the suppliers also significantly influence the value of information sharing. The results also show that substantial cost savings can be achieved through information sharing and then motivating trading partners to share information in the supply chain.

Information sharing can significantly improve the performance of a supply chain. Additionally, companies can redesign their supply chain strategies through information sharing to increase profit. Many studies demonstrate the positive impact of information sharing on a supply chain. However, few studies focus on how the different combinations of information sharing affect the performance of a supply chain. Provided that the entities of supply chain are aware about how they can benefit from the information sharing, they are more willing to share the necessary information. The purpose of this paper is to examine how the different information sharing among the entities influences the performance of the supply chain, and to address the problem of selecting the most appropriate information sharing for the supply chain partners. This study designs different information-sharing scenarios to analyze the supply chain performance. To measure the performance of each scenario, it is necessary to consider not only the desirable indices but also undesirable indices. Thus, the usual data envelopment analysis (DEA) model is applied to measure the performance for complete weight flexibility.

The remainder of the paper is organized as follows. In the next section, the information-sharing scenarios are specified. A brief introduction of cross-efficiency DEA and the analysis for evaluating performance are described in the following section. The analysis and results are demonstrated in Section 4. In the final section, some conclusions and recommendations for further research follow.

## 2. Information-sharing scenarios

We develop a supply chain simulation model (shown in Fig. 1) which considers a multi-echelon supply chain (i.e. retailers, distributors, manufacturers and suppliers) and nine information-sharing scenarios. In the first information-sharing scenario, denoted by N, no information will be shared between the entities. The second scenario is partial information sharing, which consists of six combinations: (1) C: capacity information sharing; (2) D: demand information sharing; (3) I: inventory information sharing; (4) D&C: demand and capacity information sharing; (5) D&I: demand and inventory information sharing; (6) C&I: capacity and inventory information sharing. The third scenario, denoted by F is full information sharing with capacity, demand and inventory. The fourth scenario is strategic alliance of supply chain (vendor managed inventory, VMI, is adopted herein).

To compare the performance of each information-sharing scenario, a simulation tool, Rockwell Software Arena v5.0, is utilized to analyze performance indices (shown in Table 3). Input parameters such as initial inventory level, inventory policy, lead times of production and transportation, customer demand rate, and unit production time are shown in Tables 1 and 2.