Information Sharing in Supply Chain: A Review

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ABSTRACT: *The importance of information sharing in supply chain management is a matter of consensus between practitioners and researchers. Information sharing can increase supply chain efficiency by reducing inventories and smoothing production. Studies from different and recognised authors are reviewed, compiled and analyzed in three aspects. First, the types of shared information in supply chain are summarized. After, the value of different shared information and the factors which affect its value are presented. Moreover, the methodologies used in literature are detailed. The paper concludes with some future directions for theory construction and empirical research.*

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1. Introduction

As a network whose objective it is to deliver the right product, at the right place, at the right time, and for a competitive price, supply chain widely exists in many industrial sectors. The importance of supply chain management for business is a matter of consensus between practitioners and researchers. However, supply chain practitioners have suffered from greatly from market fluctuation in niche markets. In this unstable environment, a strategy which provides robustness and resilience for the supply chain without decreasing its effectiveness is required [13]. Under this new supply chain design, information sharing which can make the supply chain more robust and resilient without undermining its efficiency plays an important role for companies' performance.

The aim of this paper is to evaluate the relationship between information sharing and supply chain management through the analysis of the existing theoretical and empirical works, and to contribute to the debate on the role of information sharing in supply chain management. [21] pointed out that efficient knowledge flows and knowledge sharing process among supply chain partners give them the following characteristics: agility, adaptability, and alignment. These characteristics allow them to be the best performers. In this paper the results of a review of information sharing literature in supply chain management are presented. The paper is organized as follows: section two presents types of shared information. Section three deals with the value of information sharing in supply chain. Sections four presents the methodology used in literature. Finally, the key findings of the research are summarized.

2. Types of shared information

The information in a supply chain can be classified in different ways e.g. strategic or tactical; logistical; or pertaining to consumers [27]. [18] sort information into six categories pertaining to product, process, resource,

inventory, order, and planning. Different information has been studied in previous literature. The types of shared information in the literature are summarized in this paper (see to Table 1) and the most common type of shared information in existing research is demand information.

Authors	Shared Information
Bourland et al. (1996)	Demand
D'Amours et al (1999)	Price,Time,Capability
Lee, So & Tang (2000)	Demand
Cachon & Lariviere (2001)	Demand, Demand Forecasts
Moinzadeh (2002)	Demand, Inventory
Simchi-Levi & Zhao (2003)	Demand
Huang & Gangopadhyay (2004)	Demand
Mitra & Chatterjee (2004)	Demand
Fiala P(2005)	Demand, Order
Shen et al (2005)	Cost
Ding, Guo, Z Liu (2011)	Inventory
Barlas, Gunduz (2011)	Demand Forecast
Wu et al (2011)	Suppliers' Product Quality
Chan & Prakash (2012)	Demand

Table1. Types of shared information in the literature

The value of information sharing depends on several conditions. Some research showed that demand sharing has no significant benefits for a manufacturer under tight capacity [34]. But at the same time, [23] found that demand information sharing has more value if demand is highly correlated over time, highly variable, or the lead-time is long. The characteristics of the product also affect the value of information sharing. It was recognized that demand variability of products may affect the value of demand forecast [1]. The relationship between the trading partners is another factor which influences the choice of the type of information sharing. For example, sharing production schedules with part suppliers can reduce their inventories. Sharing shipping information with logistics agents can improve customer service levels.

In most of the previous studies, much attention has been paid to analyses the sharing of production information, and only little attention is given to other information such as market and consumer information, although this type of information can be important [27]. [24] 's study showed that sharing market knowledge can improve promotion planning, sharing information and close coordination between retailers and manufacturers may facilitate the R&D process.

3. The value of information sharing

The bullwhip effect is an observed phenomenon in forecast-driven distribution channels. [22] analyzed four sources of the bullwhip effect: demand signal processing, rationing game, order batching, and price variations. [35] argued that an effective information exchange mechanism is the right way to improve the efficiency of the supply chain management.

3.1 The value of demand information sharing

Some researchers found that the correlation of demand information has impact on the value of information sharing. [17] analyzed the effect of autocorrelation coefficients and demand lead times on information sharing in multi-echelon supply chains. Similarly, [23] showed that in a two-level supply chain with non-stationary AR (1) end demand, the manufacturer benefits significantly when the retailer shares point-of-sale (POS) demand data. Raghunathan (2001), however, showed that the manufacturer's benefit is insignificant when the parameters of the AR (1) process are known to both parties, as in Lee, So, and Tang (LST). The key reason for the difference is that LST assume that the manufacturer also uses an AR (1) process to forecast the retailer order quantity. [32] also found that higher correlation increases (reduces) the manufacturer (retailer) surplus.

Additionaly, some research also showed that timely demand information sharing also affect the value of information sharing. [3] examine the changes brought about by the exchange of timely demand information in inventories and service levels. Research showed that timely demand information sharing can help suppliers to reduce the cost, improve the service level. [16] developed a model which quantifies the benefits to the supplier from obtaining advanced commitments from downstream customers. The results showed that the earlier demand information shared, the lower is the potentially cost.

The method and accuracy of demand forecast are key factors which affect the value of demand information sharing too. Demand forecast sharing is regarded as an effect way to reduce order fluctuations and safety stocks [22]. [5] demonstrated the fact that smoother demand forecasts reduce the bullwhip effect. They also show that for both moving average and exponential smoothing forecasts, the very inclusion and need for estimation of a linear trend parameter into the forecasting model results in increased bullwhip. [8] analyzes the relationships between demand and order forecasting and the bullwhip effect, and proposes an advanced forecasting model (GARCH) for supply chain management. [28] studied the value of demand forecast sharing in two scenarios: the make-to-order scenario and make-to-stock scenario, and acknowledged that in any scenario, the prediction accuracy has direct effect on value of demand forecast sharing.

3.2 The value of production, inventory and other information

Most of current research on information sharing focus on demands information sharing. Some researchers also

studied the information sharing of production information, inventory information, sales information and other information [18].

Different types of shared information have different potential benefits [24]. For example, sharing order information can improve the quality of customer service, reduce payment cycles, and reduce labor cost. Sharing retail sales data can mitigate the bullwhip effect. Based on the general model, 12 representative models are selected from the literature and their relationship and distinctions are compared [25] and found that information sharing in supply chains is valuable. However, the value and affecting factors are dependent on analytical methods.

[22] classified the information shared in supply chain into inventory, sales, demand forecast, order, production planning and etc.Their study confirmed that every member's efforts in supply have contributed to reduce the whole system inventory level when the supply chain is regarded as a whole.Liu and Sahinidis (1996) classified information in the supply chain into demand, inventory and shipment information, and constructed 3 information sharing models respectively. Furthermore the 3 models were integrated to propose a hybrid information sharing model, which proves the information sharing value in supply chain management.

[37] developed a simulation model with the objective of quantifying the value of sharing shipment information, which can help managers evaluate the cost-benefit trade-off during information system construction. [36 studied quality information sharing in a supply chain and showed that the buyer always benefits from quality information sharing, and sharing quality information with the buyer impacts supplier's market share.

Research on the value of supply-side information was studied too [12] [3]. [12] presented an evaluation approach specifically focusing on the supply-side collaboration on inventory decisions. Two scenarios were compared and showed that the supply-side collaboration has the ability to improve the supply chain performance. Similarly, [3] 's study showed that with more accurate demand information the supplier could reduce inventories, or improve the reliability of its deliveries to its customer, or both. The customer, in turn, could reduce its inventories if its supplier were more reliable.

3.3 The degree of information sharing

According to the degree of information sharing, there are 3 scenarios: no information sharing, partial information sharing and full information sharing. Different levels of information sharing have different effects on information sharing value.

[15] studied three patterns cases of information sharing: no information sharing, partial information sharing and full information sharing.Study of these three models revealed the relationships between capacity, inventory, and information at the supplier level, as well as how they are affected by the retailer's $(S * s)$ values and end-item demand distribution. [7] presented a modeling approach for quantifying the value of information in supply chains using Markov decision processes (MDP) in two cases: (1) the case where information sharing occurs; (2) the case where no information sharing occurs. [19] presented an investigation on the effectiveness of information sharing. The results showed that from the perspectives of end inventory and back-order quantities, distributors and wholesalers gain significantly from information sharing, while not much gain can be realized for retailers.

3.4 Information sharing strategy

To manage supply chain efficiently, supply chain members should cooperate with each other with high coordination. However, information sharing among nodes of supply chain is just the base of supply chain coordination. It is a difficult task for enterprises to choose the appropriate information sharing mode.

[14] illustrated how information flows in supply chains can be better utilized by appropriately changing the operating policies in the supply chain. The same information shared may have different value with different information sharing strategy. Similarly, in order to understand how information sharing strategy influences supply chain performance, a survey of the Taiwanese manufacturing industry was carried out [20]. Results indicated that information sharing strategy has a strong impact on reducing supply chain uncertainty and enhancing chain performance. A similar view has also been confirmed in [6].

4. Methodology used in literature

Because of its inherent dynamics and complexity, there are various methodologies employed in study on information sharing in supply chain, i.e. linear programming, probability method, system dynamics, multi-agent system simulation and game theory. A summary of research models that focus on information sharing is shown in Table 2.

4.1 System dynamics

System dynamics is an aspect of systems theory as a method for understanding the dynamic behavior of complex systems. It deals with internal feedback loops and time delays that affect the behavior of the entire system. Different from other approaches to studying complex systems, system dynamics use feedback loops and stocks and flows to catch the possible causal factors and their respective contribution to the overall dynamics.

A supply chain dynamic network model based on information sharing is proposed in [11]. The proposed modeling framework is composed from three inter-related network structures: a production net, Petri net and a neural net. The production net captures information flows among agents. The Petri net is used to coordinate asynchronous events of different units in network production systems

Author	Actors	Stages	Methodology
D'Amours et al (1999)	M actors at each stage	K-stages	Linear programming
Gavirneni et al (1999)	1 supplier to 1 retailer	2 stages	Analytical models
Lee, So and Tang (2000)	1 supplier to 1 retailer	2 stages	Analytical models
Chen et al. (2000)	1 actor at each stage	K-stages	Analytical models
Moinzadeh (2002)	1 supplier to N retailers	2 stages	Analytical models
Fiala P (2005)	multiple entities in each level	K-stages	System dynamics
Y Barlas, B Gunduz (2011)	1 Retailer 1 wholesaler and 1 producer	3 stages	System dynamics
Chan & Prakash (2012)	1 supplier to 1 retailer	2 stages	Multi-agent system
Huang & Gangopadhyay (2004)	multiple entities in each level	4 stages	Multi-agent system
Shen et al (2005)	1 supplier to N retailers	2 stages	Game theory
H Ding, B Guo, Z Liu (2011)	1 manufacturer, J distributors and I retailers	3 stages	Game theory
Raghunathan (2003)	1 manufacturer to N retailer	2 stages	Game theory
Wu et al (2011)	2 competing suppliers and 1 buyer	2 stages	Game theory

Table 2. Methodology used in literature

and to model negotiation process. The neural net serves as an instrument for inductive learning of negotiation strategies. System dynamics modeling was used as the research platform in [2] study. By using system dynamics simulation, they investigated some of the structural sources of the bullwhip effect, and explored the effectiveness of information sharing to eliminate the undesirable fluctuations.

4.2 Multi-agent System Simulation

A multi-agent system (MAS) is a system composed of multiple interacting intelligent agents within an environment. Multi-agent systems can be used to solve problems that are difficult or impossible for an individual agent or a monolithic system to solve. It provides a method of integrating the entire supply chain as a network system of independent echelons; different entities employ different decision making procedures in most cases.

A simulation study was presented to investigate the effectiveness of information sharing under 6 different information sharing strategy(no information sharing, partial information sharing and full information sharing) and demand fluctuation (low or high low volatility) scenarios [19]. The results show that from the perspectives of end inventory and back-order quantities, distributors and wholesalers gain significantly from information sharing, while not much gain can be realized for retailers. An agent-based simulation approach was also used to test several combinations of information sharing and coordination mechanism, which showed how the use of different levels of information sharing and coordination can be effective [8]. Chen J (2002) described a multi-agent framework for serial enterprise supply chain systems, giving common structure and ontology to define agents. A simulation approach has been employed to show the impact of lateral collaboration on performance measures such as the total cost [4].

4.3 Game theory

Generally, all enterprises in supply chain (upstream and downstream) should share their private information with each other. Howerver, because of cost and risk the downstream enterprises generally are unwilling to sharing their private information. There is a game process in the information sharing for upstream and downstream enterprises. As a study of mathematical models of conflict and cooperation between intelligent rational decision-makers, game theory can be conveniently applied to solver such problems in supply chain.

In a study on value of cost information sharing in a supply chain [33], results show that with Bertrand competition between the retailers, the manufacturer always gains with cost information sharing but the retailers are always worse off. [26] also used the cooperative game model to study the supply chain profit allocation and supply chain stability. By means of cooperative game approach, [9] developed a graphic model with three-dimensions to depict the possible cooperative solutions of profit allotment between partners.

5. Conclusions

This paper has presented a number of existing studies on information sharing in supply chains. Many investigations on the impacts of information sharing have been carried out under different circumstances and assumptions. From the above discussion, the following conclusion can be drawn:

• On demand information sharing, some properties of demand information such as correlation, timeliness and volatility have been considered in modeling the value of information sharing. However, only one product's demand information was modeled in most of preview research. Littler attention has been paid on the value of information sharing in a multi-product supply chain, especially when these products may also be substitutable.

• Approaches such as linear programming, probability method, system dynamics and game theory were usually taken to modeling the complex nature of supply chain; all of them are top-down modeling methods. All the rules and relationships of the system is requires to catch clearly in modeling, which however is almost impossible task. Indeed, multi-agent system simulation has been recognised as an increasingly powerful tool for planning the supply chain and computer-based models have a critical role in the study of dynamics systems.

• The network characters of supply chains network is seldom recognized as effect factor in modeling the value of information sharing. As [10] pointed out, the characters of supply chains network affects information sharing, in turn, the behavior of information sharing among nodes of supply chains network also has influence on the formulation of supply chains network. However, the mechanism of information sharing on supply chain network formation and evolution is still a critical question that needs more investigation.

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