Information Asymmetry in Supply Chain Coordination: State of the Art

Mohammadali Vosooghidizaji, Atour Taghipour, and B éatrice Canel-Depitre Universit éLe Havre Normandie, Le Havre, France

 $Email:\ mohammadali.vosooghidizaji@univ-lehavre.fr, \{atour.taghipour, beatrice.canel\}@univ-lehavre.fr \\$

Abstract—Supply chains consist of several actors from supplier, manufacturer, distributer, wholesaler and retailers connected to each other by financial, material and informational flows. Optimal performance of supply chains requires set of actions that coordinate the members' decisions [1], [2]. In many cases, members are trying to optimize their own objectives which can lead to asymmetric information by keeping some strategic information private. Although, this information asymmetry is a challenge affecting the coordination of supply chain, but it is achievable if proper set of coordinating mechanism executed. This paper presents a comprehensive literature review of supply chain coordination under asymmetric information and tries to analyze the trend in the context and address the evolution and gaps in existing literature.

Index Terms—Information asymmetry, Supply chain coordination

I. INTRODUCTION

Supply chain is 'network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer' [1]. Supply chain planning involves synchronizing multiple activities from different functions such as purchase of equipment, production, delivery of finished products or services to the final consumer or even the provision of services after the sale. In order to improve the performance of the entire supply chain as a system, these different functions need to be coordinated, which can increase profit, decrease cost or improves other performance measures.

Despite the increasing number of studies, there is no unique definition of supply chain coordination. Albrecht [3] divides the literature on supply chain coordination into three streams. In the first one, a mechanism is coordinating if and only if it leads to the optimum of the supply chain. In the second flow, the mechanism coordinates if it improves the performance of the supply chain compared to the default solution i.e. the solution without coordination. In the last stream, the coordination mechanism can lead to a feasible solution.

Based on decision-making authority, supply chains fall into two categories: centralized and decentralized. The

centralized term refers to a system in which a single decision maker optimizes the overall performance of the system by having access to all the required information. On the other hand, in a decentralized system with multiple actors, instead of a single planner, members, who may have conflicting goals, decide according to their own interests. Recently, due to many developments and changes in competitive environments, most supply chains are decentralized. As a result, some researchers have recently moved from a centralized approach to a decentralized approach in favor of more realistic systems with independent economic entities.

Information sharing is an important issue of decentralized approaches where members have different level of knowledge or information, which complicates interactions among them. According to [4], "it is very difficult to find a supply chain, if any, of which all members have the same amount of information". Some may have private demand information, cost information [5], quality information, disruption information that cannot be observed by the others, but may affect system performance.

This article examines the literature on supply chain coordination under asymmetric information. It considers different aspects of supply chain coordination, including: types of supply chains, performance indicators or objectives, coordination issues, coordination mechanisms, types of asymmetric information. Our contributions are threefold: Development of a classification by providing a framework for analysis of supply chain types, methodology, mechanisms and asymmetric information; Report and consider various perspectives on information asymmetry in the context of supply chain coordination; and Identification of existing gaps and research for future research.

II. REVIEW METHODOLOGY

In this review, we focus on the supply chain management literature that addresses the supply chain coordination with asymmetric information. The objective is to identify and analyze the existing literature which considers the existence of information asymmetry among parties which may affect the planning and performance of members or whole supply chain. We use a systematic literature review approach adopted from [6], which consists of 6 steps.

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Step 1. Research question: We develop a framework specifying units of analysis. The framework includes three criteria and some sub-criteria.

Step 2. Properties of studies: We systematically search the academic articles written in English language focusing on supply chain coordination under asymmetrical information. For this purpose, following inclusion and exclusion criteria are applied: Inclusion criteria: (1) The papers propose coordinating mechanisms for decentralized supply chains, (2) The papers consider chains with information asymmetry.

Exclusion criteria: (1) The papers study only centralized supply chain coordination, (2) The papers study decentralized supply chains with symmetric information and full share of information.

Step 3. First sample: By applying related keywords including: "Supply Chain" "Asymmetric with Information", Information", "Private "Incomplete Information", and "Information Asymmetry", we searched in the main databases covering the academic (peer-reviewed) journals articles in management science, supply chain management and operations management such as sciencedirect.com, tandfonline.com, link.springer.com, pubsonline.informs.org, and onlinelibrary.wiley.com. The initial search resulted in more than 350 papers.

Step 4. Pertinent literature: In order to get the final sample, all the papers in initial sample were analyzed based on title and abstract. After applying inclusion-exclusion criteria and detailed reading we reached to 130 papers.

Step 5. Synthesis: We aim to refine the initial analysis framework using evidence from the synthesis sample.

Step 6. Report: This step presents the results of the review, through different analysis involving main observations and improvements alongside the gaps in the supply chain coordination under asymmetric information.

III. FRAMEWORK OF ANALYSIS

To analyze the shortlisted papers in detail, we prepared a framework of analysis consisting of three main features; supply chain structure, supply chain planning and supply chain information-coordination.

A. Supply Chain Feature (Configuration)

Supply chain structure presents a general picture of the supply chain based on the actors and products. There are three sub-criteria related to this feature:

(1) Number of products: The complexity of supply chains changes due to number of products considered. In supply chain studies, in many cases, models with one product is considered and very rarely multiple products are used in the models.

(2) Supply chain actors: The most commonly considered structure is dyadic structure i.e. an upstream actor and a downstream actor.

(3) Demand characteristics: Considering different types of demand is very often and an important factor discussed in the literature and usually is stated as deterministic or stochastic.

B. Supply Chain Planning Feature

This criterion shows elements related to planning and methodologies applied to analyze the performance measure considered in the model.

(1) Planning period: this sub-criterion shows the number of periods the supply chain under study has been analyzed.

(2) General methodology: this element shows the general methodology applied in order to model and solve the problem under study. Using analytic approaches through optimization techniques such as cost minimization and profit maximization are quite common in the literature.

(3) Performance measure: different performance metrics are used to measure or improve supply chain performance. Cost and profit are two most common metrics in the context, but there are other measures such as inventory level and bullwhip effect.

C. Supply Chain Information-coordination

This criterion includes elements related to coordination and types of information asymmetry between supply chain actors.

(1) Asymmetric information: when a supply chain member possesses more or better information, it may lead The to information asymmetry. terms 'private information'. 'incomplete information'. 'partial information', 'imprecise information' and 'asymmetric information' are used in the literature, and carry the same meaning in our paper. This sub-criterion shows which information is asymmetric between actors. Besides cost and demand, quality, inventory, capacity and price information asymmetry have been also considered in some studies.

(2) Coordination mechanism: scholars propose different forms of mechanisms to coordinate the supply chains. Majority of them are contract based mechanisms such as wholesale price, quantity discount and revenue sharing contracts. There are also some other types based on negotiations or proposal generations.

IV. OBSERVATION AND ANALYSIS

In this section we analyse the supply chain features which describe the general configuration of the supply chains that we are studying. Then, the classified literature is analysed according to the planning elements. Finally, different asymmetric information types and coordination policies will be presented. Summary of the three criteria are presented in Tables I, II and III.¹

A. Supply Chain Features

The results show that more than 85% of papers studied one product in their models, and about 15% more than one product.

¹ Due to a long list of reviewed studies, only 20 papers of 2018 and 2017 are presented in the tables.

Author	Product	Structure	Demand
	number		
[7]	1	Dyadic	Stochastic
[8]	1	Dyadic	Stochastic
[9]	1	Dyadic	Deterministic
[10]	1	Dyadic	Stochastic
[11]	1	Convergent	Stochastic
[12]	1	Dyadic	Deterministic
[13]	1	Dyadic	Stochastic
[14]	1	Convergent	Stochastic
[15]	1	Dyadic	Stochastic
[16]	1	Dyadic	Stochastic
[17]	1	Dyadic	Stochastic
[18]	1	Dyadic	Deterministic
[19]	1	Dyadic	Stochastic
[20]	1	Convergent	Deterministic
[21]	1	Dyadic	Stochastic
[22]	1	Dyadic	Deterministic
[23]	1	Dyadic	Stochastic
[24]	multiple	Dyadic	Deterministic
[25]	1	Divergent	Stochastic
[26]	1	Dyadic	Stochastic

TABLE I. SUPPLY CHAIN FEATURE

The supply chain structure column shows that the simple dyadic form, with two actors, is the most frequent setting with almost 65% followed by divergent, convergent, and serial structures by 11%, 10% and 7 % respectively. Looking further at dyadic structures indicated that Supplier-Buyer, Supplier-Retailer and Manufacturer-Retailer pairs are the most common settings considered in modelling the actors. In a few cases, two competing supply chains, each one with two players, are modelled rather than one supply chain. In some papers two different structures are presented. Notably, no network structure was observed in this context. Analyzing demand characteristics reveals that nearly 55% of studies assumed stochastic demand, 35% deterministic and a few papers (four cases) Fuzzy demand. There are some cases comparing stochastic and deterministic demand.

B. Planning Features

It is observed that almost 75% of papers studied oneperiod planning models and the remaining 25% considered more than one period whereas in other cases it is two periods or multi periods. It is very common practice to analyze the trade-off between parties by mathematical models such as linear programming or other methods. In certain papers, the joint decision is achieved after separate objective function calculations, and in other cases different scenarios are analyzed simultaneously. Since we are not analyzing the solution techniques and procedures in this paper we only considered the general methodology.

TABLE II. SUPPLY CHAIN PLANNING

Author	period	general methodology	Performance
[7]	two	analytical-numerical	Profit
[8]	one	analytical-numerical	Profit
[9]	one	analytical-numerical	Profit
[10]	one	Experimental and Analytical	Profit
[11]	one	analytical-numerical	Profit
[12]	one	analytical-numerical	Cost
[13]	multi	analytical-numerical	Profit

[14]	one	Analytical	Profit
[15]	one	Analytical- numerical -	Profit
		Optimization	
[16]	one	analytical-numerical Profit	
[17]	one	analytical-numerical example profit	
[18]	one	analytical-numerical profit	
[19]	one	analytical-numerical profit	
[20]	one	Analytical	Profit
[21]	one	analytical-numerical	Profit
[22]	one	analytical	Profit
[23]	one	analytical-numerical	Profit
[24]	multi	Analytical- numerical - Cost	
		Optimization	
[25]	one	Analytical- numerical - Profit	
		Optimization	
[26]	one	analytical-numerical	Profit

It is quite frequent the analytical models with numerical examples by more than 70% following by less than 20% analytical models without numerical examples. There are also some limited cases presenting laboratory hypothesis experiment. simulation and based methodologies. Profit maximization and cost minimization are two regular objective functions used in the literature, which also clearly observed in our review. Beside optimization techniques, heuristics and statistical techniques make up almost 7% in the literature. In addition to above mentioned approaches, in three papers fuzzy optimization is applied to present the parties' objective functions. The performance metric column shows that the bullwhip effect, inventory level and inventory accuracy level are considered as a performance metric scarcely in comparison with cost and profit measures with almost 95%.

C. Coordination Features

In regard to coordination features, the most studied coordination issue, with almost 50% of all papers, refers to procurement-distribution through which an upstream player (e.g. supplier) sells the product to downstream player (e.g. retailer) in order to deliver the product to the final customer.

Main decisions are related to order quantity, pricing and time. The second most studied issue is procurementproduction, with more than 15%, where besides the above mentioned decisions, production plan is also considered in the models. Other coordination issues in descending order are production distribution, procurementproduction-distribution, capacity allocation, supplier selection, quality management and outsourcing.

TABLE III. SUPPLY CHAIN FEATURE

Author	Asymmetric information	Coordination Mechanism
[7]	Demand information	Two part tariff contract
[8]	Production cost	Menu of contracts
[9]	Supplier's cost	Quantity discount
[10]	Demand	Wholesale price contract
[11]	Production cost	Emergency sourcing
[12]	Holding cost	Side payment
[13]	Transport time	Profit sharing
[14]	Green degree	Auction and menu of contract
[15]	Cost	Menu of Reservation Contracts
[16]	Effort level	Buyback-wholesale price
		contract

[17]	Demand	Side payment
[18]	Manufacturer's cost	Two part Tariff
[19]	Manufacturer's cost	Transfer Payment
[20]	Investment cost	Delegation, outsourcing
		contract
[21]	Supplier's Cost	Option contract
[22]	Cost	Two part tariff Contract
[23]	Disruption	Wholesale, menu of contracts
[24]	Cost Parameters	Negotiation
[25]	Demand	Advance Sale/ Regular Sale
[26]	Cost	Menu of contracts

The asymmetric information column presents the type of information being asymmetric in each study. It shows some scholars have considered only one type of information and some more than one. Throughout the papers, only 15% analyse models with more than one type of information being asymmetric and the rest studied models with one piece of information. Among papers, with only one type of information asymmetry, cost and demand are in the first and second place with 40% and 28% respectively. Following these two common types of information, other types are parameters and objective functions, quality information, capacity information, effort and service level information, disruption information, inventory level information, fairness and customers' attribute information. concerns Coordination mechanisms utilized are presented in the final column. The most widespread mechanism is the wholesale price contract being used in many instances with more than 17%, followed by quantity discount contract, profit sharing contract, negotiation based mechanisms and auction, with each being no more than 8%.

V. DISCUSSION

Information is one of the central topics in supply chain coordination literature which has been analysed from different perspectives, especially the benefits and ways to share the information which is suitable for centralized supply chains. Although the members in decentralized supply chains may keep some information private, in order to coordinate their activities, actors need to exchange some information through or minimum information. Therefore, information in this context can be discussed from two points: asymmetric information and exchanged information.

A. Asymmetric Information

A common way to classify information asymmetry is dividing it into unilateral and bilateral information asymmetry. The following is a list of asymmetric information types which are recognized in the literature:

Cost information asymmetry, Demand information asymmetry, Capacity information asymmetry, Quality information asymmetry, Disruption information asymmetry, Attribute information asymmetry, Inventory information asymmetry, Price information asymmetry, Effort level information asymmetry, Objective function information asymmetry.

B. Treatment with Unknown Information

When an information is not possessed or not known, supply chain actors may take different actions regarding that piece of information which is considered in the literature, through different models. In other words, we show how the actors cope with asymmetric information. *Information Sharing*: one scenario considered about asymmetric information is coordination through sharing

that information. Assessment by probability (discrete and continuous): a common assumption in dealing with asymmetric information is that an uninformed actor who does not know the real information about the other party but knows there are various different types of probabilities.

Estimation: one assumption about unknown information is that uninformed actors estimate the information.

No disclosure of information: different from above treatments, there is a direction in supply chain coordination literature that instead of sharing or estimating the unknown information of other actors, it acts based on local information.

C. Information Exchanged

Despite the existence of incomplete information or asymmetric information, supply chain coordination is impossible without exchange of some information. The level and type of information is not always the same but there exists at least a minimum exchanging of information in all of them.

In a broad classification, information exchanged falls into three main categories; Money based information (M), Quantity based Information (Q), Operations based (O).

VI. CONCLUSION

This paper presents a comprehensive review of information asymmetry in supply chain coordination. Although different supply chain types have been analysed and several coordination mechanisms have been proposed, there are some important issues which have not yet been covered or studied less. Fig. 1 shows the summary of studied criteria following the research framework.

Studying real world supply chains might be useful for both practitioners and scholars. In reality, majority of supply chains are more complicated than a supply chain consisting of simply two actors dealing one product, instead, they can be composed of several members and products. Moreover, supply chains may face actors possessing several private information rather than one only type of information. Besides, usually real supply chain planning is done not only for one period. However, based on our review, there are few papers studying the coordination of real world supply chains.

Various coordination issues and mechanisms need to be addressed. Though procurement, production and distribution are quite important issues which are generally studied in the literature by calculating optimal or near optimal values of quantity, price, and time, other issues such as quality improvement, sustainability, and environmental considerations are becoming very critical in supply chain management.

More information asymmetry types consideration can give better view of supply chains. The assumption of unilateral information asymmetry with only one type of asymmetric information, e.g. demand information, may not present the real supply chains. So, bilateral and multilateral information asymmetry and variety of information asymmetry consideration such as disruption information and quality information in addition to cost and demand information asymmetry, are important and interesting future research directions.



Figure 1. Summary of studied criteria.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Mohammadali Vosooghidizaji collected the data and drafted the article. Mohammadali Vosooghidizaji, Atour Taghipour and B átrice Canel-Depitre contributed to the design of the research, to the analysis of the results and to the writing of the manuscript.

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Mohammadali Vosooghidizaji is PhD candidate at University of Le Havre, NIMEC laboratory in Management Science. He obtained his master's degree in Industrial Management from IKIU and bachelor's degree in Insurance Management from ECO college of insurance.

He is temporary research and teaching member (ATER) at Faculty of International Affairs in Le Havre. His research area is supply chain management and has publications in Operational Research

and American Journal of Scientific Research.



Atour Taghipour holds an HDR in management from Normandy University and a PhD in Industrial Engineering from the Polytechnic School of Montreal in Canada. He received two masters' degrees, one in Management, Logistics & Strategy and other in Industrial Engineering.

He is a professor and the head of two international management master programs at the University of Le Havre in France. He has more than ten years of experiences as a

manager in automobile industries. He has published different books and many research papers in international journals. His areas of research are supply chain and operations management.



B éatrice Canel-Depitre obtained her PhD at the University of Rouen in 1997 and her HDR at the University of Le Havre in 2007 in France.

She has been senior lecturer at the University of Le Havre since 1999 with several publications. In 2019 she has published a book entitled "Homme/Animal: destins liés" and articles in European Journal of Operational Research and Journal of Advanced

Management Science. Her research area is on a logistics approach from the beginning of the supply chain, which takes into account ethical concerns without penalizing profitability.