A review on supply chain coordination: a classification of coordination mechanisms and problems

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ABSTRACT

Supply chain relationships have an important impact on the global supply chain performance and the way supply chain actors design their business strategy. Traditionally based on arm’s length agreements, the last decades witnessed the emergence of new kind of supply relationships based on collaboration and trust. This trend can be explained by the growing complexity of dependencies between supply chain actors due to the globalization of the economy and the rapid development of outsourcing and information technology. This situation has brought more uncertainty and risks to supply chain environment. To overcome these challenges, supply chain actors needs to coordinate their efforts to mitigate supply chain risks and maximize their benefits as well as the global performance of the overall supply chain. In this paper, a taxonomy of supply chain coordination problems is presented. Coordination mechanisms are classified along the main classes of parameters identified in literature, and are examined with regard to the state of the art in research on coordination. Research gaps are identified and perspectives for future research are proposed.

Keywords: Supply Chain Management, Coordination, Collaboration, Contracts, Relationship

1. Introduction

Coordination as a topic has been addressed by researchers in many disciplines (Computer science, organization theory, operations research, economics, linguistics, and psychology). Even if the term ‘Coordination’ seems very intuitive, the diversity of its definitions confirms the difficulty of defining coordination and the multiplicity of the contexts for its application. Coordination as the achievement of concerted action in situations of task interdependence- - has captured the attention of organizational scholars since the very beginning of organization science. The most used definition for coordination, considers it as ‘managing dependencies between activities and the joint effort of entities working together towards mutually defined goals’. Coordination becomes essential when actors performing interdependent activities, have different objectives, and act in way that leads to an underperformance of the global system they are part of. Managing dependencies between the systems’ actors is then critical for the overall performance of the global system. Supply chain coordination has been approached from many angles in the literature and most research efforts have been oriented towards particular coordination cases. An extensive global literature review is then necessary to develop a better understanding of supply chain coordination, explore the different coordination mechanisms, and identify the research gaps in the literature.
In his research work, Arshinder presented various perspectives and a classification for coordinating supply chain. Hezarkhani focused on coordination contracts and provided an a classification scheme for this type of coordination mechanism.

The aim of this paper is to provide a general overview of supply chain coordination through presenting the state-of-the-art research in this field, developing a new taxonomy of supply chain coordination problems and mechanisms, and proposing future research directions.

2. A classification of supply chain coordination problems

A coordinated supply chain means that two actors or more of the supply chain are making joint efforts to plan and execute supply chain operations with the aim of reaching higher performance than in the case where they act in isolation. Literature is rich of contributions on supply chain coordination that approaches this subject from many perspectives, but few papers aim to give a broad view and classify supply chain coordination mechanism. In this sense, we develop, in this work, a supply chain coordination classification with the aim of taking a further step into understanding coordination, its motives and comprehending the multiples facets of supply chain coordination.

Four dimensions are considered in this work. The first dimension distinguishes between coordination within the same organization and with other organizations. The second dimension addresses coordination from a functional point of view. The third dimension approaches coordination form a customer-supplier perspective and a peer to peer perspective. The last dimension distinguishes between coordination mechanisms based on the scope and the horizon of collaboration.

![Classification of supply chain parameter](image)

**Figure 1: Classification of supply chain parameter**

### 2.1 Internal vs external Coordination

We refer to internal coordination when the internal entities of an organization (departments, subsidiaries, branches…) are operated according to a global and integrated business strategy that covers all the supply chain processes (product design, forecasting, procurement, production, inventory control, distribution and sales…). The actions of the internal actors are structured and focused to ensure that the strategic, tactical and operations plans in all of the business functions and geographies are aligned and in support of the company’s strategy and
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financial goals. It is clear that if the organization lacks a comprehensive sales and operation planning process that doesn’t included partner capabilities in the demand and supply plans that feed into SandOP process, supply chain coordination can be crippled. Internal Coordination consists mainly of integrating the functional activities of the internal entities. External coordination takes place when many interdependent supply chain entities with multiple decision makers make joint decision or share information in order to improve their performance and mitigate supply chain risks.

2.2 Inter-functional coordination

Traditionally Supply chain processes such as procurement, production, inventory and distribution have been optimized sequentially. This mode of functioning in silos leads to large inventory buffers at the frontiers of each process, generates large costs and doesn’t guarantee the expected Customer service level. The integration of all this processes into one optimization model can help improving significantly the supply chain performances by providing goods and services to the customer at low costs and high service levels [1]. The main coordination problems related to inter-functional coordination can be classified as follow:

2.3 Procurement and production coordination

Classically, Economic Order policies for procurement and production systems have been defined separately. In fact, the Economic Order Quantity of the raw material is dependent of the batch size of manufactured goods and their production scheduling. Considering the procurement and production subsystem as an integrated system can help design more coherent procurement and production strategies and end improving the global performance of the supply chain. Goyal proposes a review of integrated procurement and production systems. The different models of IPP were classified into the categories based on number of products/Stages, planning horizon, solution method employed, joint replenishment orders, and algorithmic issues. Approaches integrating procurement and production policies are developed by Agrawal and Chatterjee, using Joint Economic Lots Size model.

2.4 Production and distribution coordination

The issue of integration of production and distribution systems is of particular importance for make to order or time sensitive products (perishable, seasonal…). For this type of products, excess inventory and delivery delays in the supply chain can have detrimental effect on the quality of service and the global cost of the supply chain. By optimizing the transportation and production costs simultaneously a better global production and transportation plan can be devised and better service can be provided. Integration of the two functions allows exploiting scale economies of production and transportation, balancing production lots and vehicle loads, and reducing total inventory and stock-out Zhidevelop a comprehensive classification of production distribution problems based on three different dimensions: (A) decision level, (B) integration structure, and (C) problem parameters

Park investigates the effectiveness of integration of production and distribution planning in a context of in a multi-plant, multi-retailer, multi-item, and multi-period logistic and confirms the substantial advantage of the integrated planning approach over the decoupled one on some problem tests.
2.5 Inventory and distribution Coordination

Multi echelon inventory coordination was the first area to be addressed by researcher in view of the increasing requirements of the final customer regarding service level and price and the intensification of competition in many economic sectors. Pyke considers a two stage supply chain composed of a warehouse and retailer proposes an integrated policy that balances between inventory costs for the warehouse and the retailer as well as the transportation costs. In a later paper, Kang considers a two-level supply chain in which a supplier serves a group of retailers that share their information on demands and inventory levels with this supplier. A heuristic is proposed to minimize the total supply chain cost composed of fixed vehicle cost, retailer-dependent setup cost, and inventory holding cost of the whole supply chain.

2.6 Horizontal vs vertical coordination

Supply chains coordination can be differentiated on the basis of the structure of the Supply Chain: vertical, horizontal and lateral. Vertical coordination takes place when the supply chain actors are in a producer/consumer relationship and share responsibilities, resources and information to satisfy common customers. Quick response, Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR) are among the main initiatives that fit in this category.

Horizontal Coordination has not received due attention from researchers. This can be partly explained by the nature of the relationship between supply chain actors at the same level of the supply chain that suggests more competition than Coordination between them. Same level actors are less willing to share information on their demand and cost structure as they consider a potential source of competitive advantage against their competitors. Many initiatives reported regarding centralization of procurement functions between external entities. Horizontal coordination and collaboration in the supply chain enabled by quantity discounts is studied by Gurnani in a context of a single supplier and two buyers setting. Griffin studied the interaction between multiple buyers and multiple suppliers, where horizontal Coordination is enabled by a central mechanism or an intermediary.

2.7 Decision level

Supply management and logistics have been traditionally addressed at the operational level. The early research efforts were mainly oriented toward purchasing and distribution issues. With the globalization of world economies, the emergence of strategic alliances, the acceleration of technological changes, the compression of product life cycles and the increasing competitive environment, supply chain management is becoming a strategic lever for the firms to build a sustainable competitive advantage in this global challenging environment. Once supply chain actors has confirmed the strategic need for collaboration and found the right partners with the right capabilities, they need to decide on collaboration areas and decisions levels. Collaboration agreements between supply chain partners can apply to many functional areas: Joint Product design and development, joint procurement, joint production, Joint Distribution and logistics, Joint marketing.

Three levels of Collaboration can be distinguished for Supply chain partners based on the decision level:
2.8 Strategic level

There is a relative paucity of research work on supply chain collaboration at this level. Khaji devise a generic system dynamics simulation model for strategic partnering in supply networks to guide stakeholders in efficient decision making and increase the profitability of the entire chain. The key areas for collaboration at the strategic level can be described as follows:

Joint Marketing: The supply chain partners decide and share information on the customer segment to target and the product and service offerings mix for each segment. Joint Product Design and Development: Decisions are made regarding the sharing of capabilities between partners to conduct joint development research, enhance existing products and develop new products. Joint Production: At the strategic level, manufacturing decisions define the manufacturing infrastructure and technology that is required. Based on long term forecasting and sales estimates, the company management has to make strategic decisions on how products will be manufactured including the location of the manufacturing plant, service centers and their capacity.

Joint Procurement: Supply chain partners decide on the procurement strategy invariants and the strategic suppliers Joint Distribution and logistics: Decisions are made by supply chain partners regarding distribution centers, warehouses, transportation modes and transportation partners.

2.9 Tactical level

The key areas for collaboration at this level are summarized as follows:

Joint product design and development: Supply chain partner conjointly decide on the detailed specifications of the product they intend to produce with regard to the targeted customers segment, markets and the expected margins.

Joint production: Decisions are made regarding the best allocation of production between plants, the manufacturing process and production planning methodologies to adopt.

Joint procurement: At a tactical level, supply chain partners aims to negotiate the terms that will realize the greatest cost benefit for all of them.

Joint distribution and logistics: At this level, decisions are made concerning the medium term dimensions of the transportation resources and their allocation.

2.10 Operational level

The key areas for collaboration at this level are summarized as follows

Joint product production: Supply chain partners coordinate the day to day operations including issuing of manufacturing orders, scheduling of job-shop operations, controlling product conformity and managing inventory.

Joint procurement: At an operational level, supply chain members coordinate the generation of purchasing order and monitor their processing from generation to final receipt.
Joint distribution and logistics: At this level, supply chain partners coordinate the transportation of goods to the warehouses and customers through routing transportation resources, managing inventory at their stocking areas and managing their logistics contractors.

3. Review of supply chain coordination mechanism

A large variety of coordination mechanisms are addressed in literature and used by industrials to manage the dependencies between supply chain actors and improve the performance of the individual partners and the global supply chain. Three classes of coordination mechanisms can be identified.

3.1 Supply chain contracts

Contracts have been studied in law, economics, and marketing disciplines, but their study in SCM is undertaken differently. “What distinguishes SCM contract analysis may be its focus on operational details, requiring more explicit modeling of materials flows and complicating factors such as uncertainty in the supply or demand of products, forecasting and the possibility of revising those forecasts, constrained production capacity, and penalties for overtime and expediting” . Most coordination contracts models are based on the Single Period Newsvendor Problem where coordination is reached through setting the optimal order quantity that maximizes the overall profit of the supply chain.

3.2 Coordination contract parameters

Many extensions to this model have been explored by researcher and usually consider some of the following classes of parameters:

3.2.1 Decision-Making Process : Two aspects are mainly considered in literature :

1. Distribution of decision among supply chain actors (ex: Centralized vs Decentralized SC). A centralized control involves the existence of a unique decision-maker in the SC, who should possess all the information and the contractual power to have such decisions implemented. However, both conditions are difficult to be verified, which often make the hypothesis of a centralized control not realistic. In such cases, the hypothesis a decentralized control of the SC is more appropriate.

2. Compliance regime: This issue is related to the right of the SC actors to comply partially or totally with coordination contract terms. Accordingly, there are two classes of compliance regimes . If the contract gives the supplier the right to decide the fraction of manufacturers order to deliver, then the system would be under voluntary compliance regimen. On the other hand, under the forced compliance regime, an agent is obligated to fulfill the requests it receives. If a contract can coordinate a specific supply chain setting under a voluntary-compliance regime, it could coordinate under the forced-compliance regime as well. The opposite might not be the case.

3.2.2 Supply chain structure

(Number of tiers and SC network nodes). Supply chain can be represented as network of entities that are subject to many flows between them (Physical, Financial, information). Real
world supply chains involve usually tremendous number of entities that can be numbered in thousands. Most supply chain topologies addressed in literature are two-tier SC (bilateral monopoly) composed of a single supplier and a single retailer serving a final demand. Some research papers study one tier supply chain structures with several entities (resp one) at the upstream level, serving several (resppone) node at the downstream level. Bernstein and All investigate the equilibrium behavior of decentralized supply chains with competing retailers and design contractual arrangements between the parties that allow the decentralized chain to perform as well as a centralized one in a context of two-echelon supply chains with a single supplier servicing a network of (competing) retailers and facing uncertain demand. Other research papers addressed coordination issues of three levels supply chain with single actors at each level.

3.2.3 Environment certainty/Uncertainty

The uncertainty of supply chain environment refers generally to market demand. The two broad categories are deterministic and probabilistic market demands. Cachon and all studies revenue-sharing contracts in a general supply chain model where demand can be deterministic or stochastic and revenue is generated either from rentals or outright sales. Other sources of uncertainty have been considered by contracting literature such as uncertain lead time and uncertain quantity delivered.

3.2.5 Supply chain decision affecting the external environment

Market demand is usually sensitive to product selling price and marketing efforts. In this case, Coordination between supply chain actors is considered with regard to these internal supply chain parameters that impact the market demand. He and all [23] investigate the issue of channel coordination for a supply chain facing stochastic demand that is sensitive to both sales effort and retail price. They find that a properly designed returns policy with sales rebate and penalty (SRP) contract is able to achieve channel coordination and lead to a Pareto improving win–win situation for supply chain members. Wangac and all [24] discuss, in their article, production and order as well as advertising coordination a in context where demand depends on advertising expenditure and selling price.

3.2.5 Contract period

The contract period is the duration of time that the contracting agents are assumed to uphold the contract. Distinction can be made between single and multiple replenishment periods. Single period models are appropriate when products are perishable and replenishment time are long. Khouja [25] proposes an extensive review of the Single Period Problem literature and delineates the contribution of the different SPP extensions. Another variation of this problem was addressed by Chena who developed a two-period game model of a one-manufacturer and one-retailer supply chain and show that both the price-protection mid-life and end-of-life returns (PME) scheme and the only mid-life and end-of-life returns (ME) scheme may achieve channel coordination and allocate supply chain profit between actors under some conditions.

3.2.6 Risk Aversion

The Supply chain agent can be risk neutral or show an aversion to risk. In uncertain environments, the analysis of agents’ decision making process requires the knowledge about
their attitudes toward risk. For a risk-neutral agent, a certain payoff is equally preferred as an uncertain payoff with the same value, while a risk-averse agent prefers the certain payoff. The objective of a risk-neutral agent is to maximize its expected profit (or equivalently to minimize its expected cost). While there only one measure for risk-neutrality, risk-averseness can be reflected by many measures such as variance of profits and the mean-variance difference. In their paper, Gan and All address the issue of coordination in supply chains involving risk-averse agents, define coordinating contracts that results in pareto optimal solution and experiment them for some specific cases.

3.2.7 Information structure

It pertains to the agents’ knowledge in comparison to the collective knowledge of agents in the supply chain. When all the information about supply chain is simultaneously known by every agent, the information structure is said to be complete or symmetric. On the other hand, if some agents have some information that the other agents do not, the information structure is incomplete or asymmetric.

3.4. Overview of coordination contracts

Supply chain members use supply chain contracts to improve their profits, reduce supply chain costs (good will costs, salvage costs…) and mitigate internal supply chain risks (operational, technical, financial, labor…) and external risks (Demand, supply, reputation, regulatory…). Coordination contracts define the terms and conditions that must be observed by both buyers and Suppliers. The most common types of contracts are as follow:

3.5 Quantity discount Contracts

Distinction can be made between incremental and All Unit Discount. The Quantity Discount is a coordination mechanism that consists of offering a price discount to the buyer so that he orders the global optimal quantity, and improve the profit of both supplier and buyer. This contract has mainly been studied in contexts of deterministic demands. Jianli and all explore how to use an all unit discount coordination mechanism to achieve coordination within a multi-period supplier– buyer system selling one type of product and facing a probabilistic customer demand. Quantity Discount contract are addressed from another perspective by Huang where he proposes a quantity discount scheme that allows to deter from bringing back false returns, and to allocate of supply chain profit between upstream and downstream actors. OD. Palsule addresses a variant of revenue sharing contracts where sharing factor is dependent of the revenue. It is shown that supply chain can be perfectly coordinated using both types of revenue sharing contracts however, there exist situations in which revenue-dependent contracts outperform revenue-independent contracts.

3.6 Revenue Sharing Contract

Under this agreement, the downstream agent (Distributor, retailer) commits to share its revenue with the upstream agent (manufacturer, Distributor) in exchange of a smaller wholesale price. The application of this type of contracts has first been reported in the American Video rental industry. In a later work, Ryu, adopted a fuzzy Newsvendor approach to assess the impact of various coordination initiatives including Revenue Sharing, quantity discounts and Buy Back Contracts. Several fuzzy parameters are used in its model for the demand, the wholesale price, and the market sales price.
3.7 Buy back contracts

Under this type of contracts, a manufacturer, or an upstream agent sets the wholesale price and commits to refund a downstream channel member for excess inventory return at the end of the season. The most generous policy promises to refund the full wholesale price for all returned products; Pasternak shows that a policy allowing for unlimited returns at partial credit will be system optimal for appropriately chosen wholesale price and refund value. In a recent paper, Xiao and all investigates coordination of a supply chain consisting of one manufacturer and one retailer facing consumer return and conclude that the supply chain is better off using full refund policy if the risk is very small; otherwise no returns policy is preferred. Chena and all develop a Buy back agreement based on two buyback prices, one for unsold inventory and a second for customer returns, and show that this agreement are easy to implement and can achieve perfect supply chain coordination and be a win–win for both manufacturer and retailer when a complementary profit-sharing agreement is included.

3.8 Quantity flexibility

This coordination mechanism allows downstream actor to change his order quantity within a predefined range as he gains more insight of market demand. On the other side the upstream commits to guaranty product availability within the same range. Tsay shows that under certain conditions quantity flexibility contracts can be considered to share risk of market uncertainty between supply chain actors and achieve system wide optimal outcome.

3.9 Sales rebate contracts

Under this type of contracts, a manufacturer offer a payment to a retailer based on retailer sales to end consumers. Two common forms of channel rebates are linear rebates, in which the rebate is paid for each unit sold, and target rebates, in which the rebate is paid for each unit sold beyond a specified target level. Taylor showed, for a two stage supply chain composed of a manufacturer and retailer, that while, a properly designed target rebate achieves channel coordination and a win–win outcome independently of sales effort, Linear rebate contract can achieve coordination only when a sales effort is made. Wong demonstrates that, in a context of a supplier serving competing retailers, sales rebate contract helps achieve supply chain coordination and stimulate demand.

3.10 Information sharing mechanisms

There have been many articles that quantify the value and benefits of information sharing for supply chain actors. Cachon and all show analytically how the manufacturer can benefit from using information about the retailer’s inventory levels when the retailers use a batch ordering policy. Gaviern and all, consider the case in which the manufacturer has limited capacity is under different situations of information sharing, and examine the conditions under which gaining information about the retailer’s inventory level is beneficial. Lee et al., developed a model of a two-stage supply chain that consists of a retailer and a manufacturer, and show that under an information sharing scheme the manufacturer would experience great savings when the demand correlation over time is high, the demand variance within each time period is high and the lead times are long. Kharazi and all shed the light on the role of Vertical Cost Information Sharing in Optimizing Supply Chain Performance. They consider a two stage supply chain composed of a supplier serving multiple competing retailers and show that when both independent retailers share cost information vertically with the supplier, it leads to a
situation of common benefit for up and downstream actors. Data and all investigate the effectiveness of information sharing and coordination mechanisms in reducing uncertainty. They propose several combinations of information sharing and coordination mechanism for reducing the uncertainty in supply chains and conclude that Central coordination of material flows with supply chain wide information sharing across different members is essential in managing supply chains effectively under uncertainty.

3.11 Joint decision mechanisms

Collaborative approaches based on joint decision mechanisms have received much attention from researchers and many real cases return on experience confirm the opportunity of implementing this coordination scheme in practice

Quick Response: In this strategy, retailers share with the suppliers Point-Of-Sales (POS), inventory levels and forecast data, as well as information on promotional events. With the visibility of current demand and inventory levels, suppliers can better forecast and schedule their production-inventory activities, and provide better service to their customers. Indeed, information sharing can reduce the demand uncertainty to such an extent that suppliers can build inventory well in advance of receiving a promotional order. On the other hand, the ability of suppliers to prepare in advance of an incoming order implies that they can reduce lead-times to the retailers. This, together with an improved fill rate, allows retailers to reduce inventory levels and the Bullwhip Effect.

Vendor Managed Inventory (VMI): In a VMI partnership, the supplier, usually the manufacturer but sometimes a reseller or distributor, makes the main inventory replenishment decisions for the consuming organization. It was applied in the late 1980’s by Wal-Mart and Procter and Gamble then by other companies in the United States, such as Johnson and Johnson and by European firms such as Barilla, the pasta manufacturer. The advantages of this collaboration mechanism are exposed in many articles. M.Waller and all examine how each partner in a VMI relationship reduces cost and improves service and how the operational benefits of VMI are very compelling. Yao and all [43] expose, in later paper, an analytical model that explores how important supply chain parameters, namely the order costs of the supplier to the buyer and the ratio of the carrying charges of the supplier, affect the cost savings to be realized from collaborative initiatives such as vendor-managed inventory (VMI).

3.12 Collaborative planning, forecasting and replenishment (CPFR)

CPFR is a nine-step approach which provides volunteer standards, protocols, guidelines, etc. required to exchange sales and order forecasts (on a web-based platform) between trading partners (conventionally identified as the buyer and seller) belonging to the same supply chain. Under CPFR, both buyer and seller collaborate by correcting, adjusting, proposing prices and quantities to reach an agreement on a unique forecast, so that the buyer's purchases forecast and the seller's sales forecast coincide. The first CPFR project was begun by Wal-Mart and Warner-Lambert in the United States. By exchanging their forecast and adapting the order timing, Warner-Lambert was able to construct a smoother production plan, Wal-Mart in turn saw that its in-stock position improved and the retailer also saw that sales increased while inventories dropped over the course of the pilot.

CPFR Implementation issues were examined by Danese who investigates differences in CPFR implementation as to the type of inter-company collaboration put into practice, and the
information and Communication Technologies (ICTs) and coordination mechanisms adopted to perform CPFR. They identify six types of collaboration that can be performed to implement CPFR. Then, using this taxonomy as a starting point, they account for differences in the adoption of the ICTs and coordination mechanisms necessary to support CPFR.

4. Conclusion and future research directions

Coordination is a compelling concept that has been extensively addressed in research and many cases of successful implementation of coordination mechanisms have been reported in literature. In spite of an abundant literature and many success stories, coordination mechanisms are only implemented at small scale in the industry. Further research effort need to be undertaken to facilitate the adoption of these approaches by more supply chain actors:

1. Most of the coordination mechanisms are studied with assumptions that oversimplify the real complexity of coordination problem issues:
2. The coordination context is supposed to be mono period while the multi period case is more representative of the real issues.
3. The topology of the supply chain is usually supposed to be two level with two actors and at most one actor dealing with many competing actors at the other level. In many industries, the supply chain is multi-level with many competing actors at each level.
4. There is little research effort to quantify risk and uncertainty when supply chain coordination mechanisms are implemented.
5. Most of research works studies separately the coordination mechanisms. A further research direction could be to consider the joint implementation of many collaboration mechanisms.
6. Horizontal collaboration is rarely considered in literature in view of the competitive nature of the relationships between supply chain actors operating at the same level of the supply chain. A potential direction of research would be to experiment coordination mechanism between competing supply chain actors and assess the impact on the performance of the different parties and the global supply chain.
7. The performance measures that are used to assess coordination mechanisms are usually limited to the profit of supply chain actors. Other performance measures such the robustness of the coordination mechanism could allow the analysis of the behavior of supply chain when uncertainty and risks are major considerations in supply chain actors’ decisions.

5. References


