Cooperation in Supply Chain Networks: Motives, Outcomes, and Barriers

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***Abstract*— This paper analyzes the phenomenon of cooperation in modern supply chains in the light of Cooperative Game Theory. The author provides a detailed discussion on the meaning of cooperation in supply chains, its motives, outcomes and barriers. A review of recent studies that analyze the cooperation in supply chains by means of cooperative game theory is provided with a special emphasis on inventory centralizations games. Gaps in the literature are identified to clarify and to suggest future research opportunities.**

***Keywords*—** *Cooperation, Supply Chains, Cooperative game theory, Alliance, Inventory games*

1. Introduction

Nowadays, the competitive, fast-moving business environment has permanently transformed the supply chain and the management of its functions. The main idea of the supply chain has been described as "*something that consists of elements that are linked to each of their two immediate neighbors and which jointly provide a strong but flexible connection*" [1]. However, this traditional view of a "chain" where different functions/firms are linked in a linear and simple manner is no longer a reality given the complex and global structure of business [2]. Thus, the paradigm of the modern supply chain has metamorphosed into a nonlinear complex network that allows efficient interactions among thousands of suppliers and partners, regardless of their size, location, or number of products. We now talk about the "supply chain network" rather than the "supply chain."

Previous studies such as [3, 4, 5, 6, 7, 8] have emphasized the network character of support chain management. Various new terminologies have also been proposed in this growing field. [4] and [9] introduced the "supply network," [7] proposed the term "netchain," while [8] discussed "supply chain networks".

The key word in these definitions is the term "network," which was defined by [10] as a lateral and horizontal exchange of resources and communication between independent partners. As mentioned by [11] the definitions of networks are grouped around two key concepts: (1) a model of an interaction based on exchange and relationships, and (2) a flow of resources between independent units. The network character of supply chains has been the subject of several previous studies. Many of these studies have considered supply chain networks from strategic and social viewpoints [5, 7]. Others have focused on highlighting the changes in various industries. For instance, [12] studied aspects of vertical coordination in the US food industry. [13] presented insights into the evolution of partnerships in meat industry networks. [11, 14] focused on the network character of the agri-food industry. [8] provide many useful examples that clearly illustrate the typical challenges faced by the automotive, aerospace, and defense industries, where an emphasis on academic research into supply chain networks was stressed. An early research framework was described by [3].

Given the current economic climate and the complexity of supply chain networks, companies need to enhance their competitive advantage in the marketplace by developing and maintaining close relationships. Thus, the trend in modern supply chain networks is to seek partnerships that improve efficiency in the face of increasing globalization and outsourcing. For example, in recent years, but particularly in the last decade, the terms "supply chain cooperation" and "supply chain coordination" have been used increasingly. The usage of these terms has been growing because of changes in the business landscape. Indeed, in current supply chain networks, organizations are considering cooperation and the coordination of their business processes more strategically, as well as searching for more refined and closer relationships with other supply chain network participants. These strategies appear to be a key factor that affects competitiveness. However, although this is a controversial topic in both academia and industry, a definition of supply chain cooperation/supply chain coordination continues to elude many. For example, there have been many recent studies of this topic and a growing number of companies choose these strategies to manage their supply chains, but a great deal of confusion still remains. After evaluating previous research in this area, we failed to identify a single consistent definition of these concepts. Indeed, various terms such as "cooperation" are often used interchangeably with "coordination" and sometimes with "collaboration." However, these terms actually describe different levels of supply chain relationships. In the following, based on organizational studies and research related to supply chain networks, we aim to clarify the boundaries between each of these terms.

1.1 Coordination

In a supply chain network, companies have individual (private) goals and objectives that they can achieve by themselves. In this case, they can control and execute their plans independently. However, all companies are linked by the integrated nature of the supply chain business in which they participate and thus they operate in the same environment. However, conflicts may arise in this environment. Therefore, companies need to synchronize their activities in order to avoid harmful interactions. This process is called coordination. In other words, coordination within a supply chain is a strategic response to the problems caused by inter-organizational dependencies within the chain. Coordination occurs between two or more firms, where tight control requires a coordination mechanism that synchronizes two or more specific functions [15]. In current supply chain networks, because information technology is becoming cheaper to deploy, the information systems of firms are more strongly linked and they engage in more coordination mechanisms, such as collaborative planning, forecasting, and vendor-managed inventories, to obtain a clearer appreciation of demand information [16]. In general, the term "coordination" has been used quite often in previous studies to qualify buyer-supplier (or bilateral) relationships.

1.2 Cooperation

Cooperation originates from the Latin words *co*, meaning "together," and *operari*, meaning "to work." Thus, cooperation refers to situations where multiple participants work together to achieve mutual goals. Cooperation has been defined as joint striving toward a common object or goal [17]. According to [18], cooperation is an activity where potential collaborators are viewed as providing the means by which a divisible goal or object desired by the parties may be obtained and shared. In summary, cooperation is conceptualized as "a set of joint actions of firms in close relationship to accomplish a common set of goals that bring mutual benefits" [15]. By working together and coordinating their actions, the supply chain participants become partners in an alliance [19]. The term "alliance" is often used to describe cooperative behaviors in an interfirm context. [20] defined an alliance as a collaborative relationship among firms to achieve a common goal that each firm could not easily accomplish alone. Similarly, [21] defined an alliance as a broad term that refers to collaborative arrangements in which participants explicitly agree to work together in the belief that, by doing so, they are more likely to succeed than by working alone. [22] suggest that alliances encompass a variety of agreements that allow two or more firms to pool their resources to pursue specific market opportunities.

The present study focuses on cooperation and strategic alliances as keys to business success and competitiveness in supply chain networks.

2. Research Methodology

Cooperation and alliance formation appear to be successful strategies and they comprise an interesting trend in supply chain networks, but this raises various challenging questions, as follows.

- Why cooperate?
- How is cooperation achieved?
- What are the outcomes of cooperation?
- What factors can hinder the achievement of cooperation?

The answers to these questions are summarized in Appendix 1 and they are discussed in the following sections.

2.1 Why Cooperate?

The business world is a rapidly changing landscape, which is characterized by unprecedented complexity. The increase in global trade means that supply chains are now even longer and more dynamic. The profound impact of globalization on traditional supply chains requires that many companies must exceed the borders of individual actions to achieve collective actions/strategies that can handle the geographical distribution of supply chain entities, different laws, and customs. These cooperative strategies are also reinforced by the creation of new supply chain concepts such as third party logistics providers [23, 24].

Recent advances in information and communication technology have also played a key role in changing the way that business is conducted. Thus, distinct supply chain entities that can access high quality information have emerged in supply chains, thereby generating new challenges and trends. The proliferation of the Internet and e-commerce means that time requirements have been reduced. Indeed, the flow of information and orders is almost instantaneous, especially when procurement systems are electronically integrated with the sales and production systems of thei suppliers. These new technological advances include radio frequency identification technology and electronic data interchange. For a detailed description of new trends in supply chain design and management with an emphasis on technologies and methodologies we refer the reader to [25].

2.2 How is Cooperation Achieved?

Companies may use several forms of cooperation to compete successfully, such as mergers, joint ventures, joint investment in specific assets, joint replenishment, and shipment consolidation. Detailed descriptions of these mechanisms are outside the scope of this study, but the main aim of cooperation in supply chain networks is to ensure that independent firms share their holding infrastructures and ordering channels. Therefore, when an alliance forms between firms, each firm works with the best holding technology and ordering channels in the coalition. Thus, the coalition members manage their cost components (purchasing, holding inventory, etc.) at the minimum cost to the coalition members [26]. In this context, cooperation refers to situations where the activities and/or the resources of some independent firms are pooled and joint problems are solved. Clearly, information sharing is a key determinant of the success and achievement of supply chain partnerships [27, 28, 29]. For example, in order to obtain joint solutions to their problems, supply chain actors must agree to sharing information to address these problems [30].

2.3 What are the Outcomes of Cooperation?

If they cooperate, companies can win new business, achieve market penetration, improve their performance, and increase their profitability. Thus, cooperative strategies allow firms to maintain lower costs, but while improving their levels of service to meet the growing expectations of customers. In general, cooperation brings three main benefits to supply chain networks: reduced costs, risk pooling, and enhanced negotiation power. The first main advantage of cooperation is cost reduction by sharing resources and economies of scale. Indeed, depending on the form of cooperation, the inventory levels and/or transportation costs are often reduced. Moreover, with joint orders, many economies of scale can be achieved and significant savings can be obtained when joint investments in specific assets occur. The second issue is better risk management. Indeed, within a supply chain, an actor no longer needs to address the internal and external disturbances that affect them on their own. In a given alliance, risk management becomes a collective activity, rather than individual. The last issue is negotiation power. When several actors are willing to cooperate, they create an entity that shares and pools their forces. Therefore, these actors benefit from greater power during negotiations in their environment. For example, several actors may decide to collaborate to impose lower prices on their supplier.

2.4 What Factors Can Hinder the Success of Cooperation?

Many studies in industry and academia have emphasized the importance of cooperation in supply chains given the current economic climate. However, many cooperative supply chain structures have failed to achieve the expected benefits [31]. Similar to previous studies that focused on the contributions and impacts of cooperation on the effectiveness of logistic networks, the barriers that can hinder the success of cooperative supply chain network structures have been the subject of a separate research area (for example, [31, 32, 33]). Some of these studies have suggested that conceptualizing strategic alliances as social dilemmas helps to understand how cooperation can be achieved in strategic alliances and sustained over time [21]. It has been shown that the success of supply chain alliances is not related simply to the intention to cooperate. For example, the fact that supply chain partners willingly choose to cooperate does not necessarily ensure that they will do so successfully. Several factors can hinder the development and success of partnership in supply chain networks, including trust between partners, compromise, interdependency or mutual dependency between partners, organizational compatibility (i.e., goals, objectives, shared operational philosophy, and corporate culture), shared vision, and key processes [34]. In addition, "inter-firm rivalry" [32] or misalignments may occur when allying the efforts of firms to cooperate, including a reluctance to share information, skills, and processes, as well as opportunistic behavior [5, 35].

In addition to the aforementioned elements that may cause the failure of a partnership even before its formation, another type of barrier is particularly relevant to the success of supply chain alliances. This barrier does not affect the creation of value, but instead it comprises attempts to claim an unfair share of the value that is created [36]. Indeed, ensuring that cooperating agents agree about how to share the costs or divide the benefits that they jointly create has been identified as a major obstacle that hinders the formation of collaborative structures [37].

Therefore, obtaining an unfair share of the value created may give rise to defecting actors. Defection is a general term that refers to any form of non-cooperative behavior by participants in a social dilemma [33]. In supply chain a network, defection is often used to refer to the fact that one (or more) participant leaves their alliance (network) to work on their own or join another existing alliance. Cooperative game theory is used to study these problems in social networks such as supply chain networks. In particular, one of the main contributions of cooperative game theory is to provide methods that allow all cooperating agents to agree about how to allocate the costs or to share benefits to ensure that each party feels that participating in a coalition is worthwhile for its own sake [38].

2.5 The Challenges of Cooperation

The questions rose above regarding coalitional behavior and cooperative strategies may be classified into two major problems (see Figure 1): (1) alliance formation and (2) profit/cost allocation.

Alliance Formation: This problem concerns the formation of alliances/coalitions by supply chain agents, i.e., the partitioning of cooperating actors into exhaustive and disjoint alliances to form the so-called coalition structure (partition). For each coalition, an associated optimization problem needs to be solved, which involves pooling the activities and/or resources of the agents in the coalition and solving this joint problem. For example, the optimal reorder policy of each coalition has to be determined in a joint replenishment system.

Profit/Cost Allocation: After solving the questions of alliance formation and joint problem optimization, the problem of how to divide the overall value created among the cooperating actors needs to be addressed, where each actor is associated with a portion of the savings generated by their involvement in the coalition. This problem is as important as alliance formation because each actor is usually interested in what they will gain individually from the cooperation. Moreover, any cases of "unfair" allocation will immediately lead to the end of the alliance. Thus, cooperative game theory using so-called core allocations is often employed to address the payoff division question.

Obviously, the problems of alliance formation and profit allocation are mutually dependent. Indeed, [39] emphasized that these two aspects of coalitional behavior are closely related. First, the final allocation of payoffs to the players depends on the coalitions that form. Second, the coalitions that are finally formed depend on the payoffs available to each player in each of the coalitions. The coalition that an actor wants to join depends on the portion of savings that this actor will gain from each potential coalition. Thus, the payoffs influence the coalition structure and vice versa. A more detailed discussion on the potential of cooperative game theory for supply chain management is provided in [40].

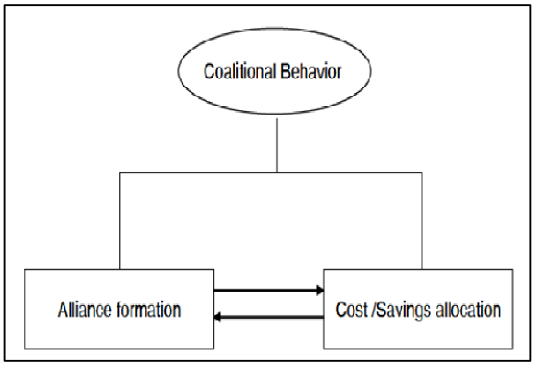

Figure 1. Challenges of coalitional behavior

3 Literature Review

The discussion above clearly emphasizes the revolutionary move from simple supply chains to supply chain networks, where firms may compete and/or cooperate to achieve sustainable advantages.

Previous studies of supply chain management have reacted to these changes and advances by providing analytical and theoretical support, as well as methodologies, for the areas of *competition*, *cooperation*, and *coordination* in supply chain networks. The cooperative and non-cooperative branches of game theory have played important roles in the analysis and understanding of cooperative and competitive interactions among supply chain participants. For example, [41] provided many examples of competition and cooperation in business environments.

In the following, we give a brief description of competition and coordination in supply chains. Subsequently, we focus on providing a detailed overview of the study of cooperation in supply chain networks based on cooperative game theory.

3.1 Buyer-Supplier Coordination

Many previous studies have aimed to understand bilateral buyer-supplier relationships, thereby identifying operational plans that align the objectives of the buyer and the supplier in order to ensure better performance and cost minimization in the chain. In this context, coordination mechanisms may be defined as a joint policy achieved by both parties, which is characterized by an agreement or contract, such as a quantity discount, credit option, buy back/return policies, quantity flexibility, or a commitment to a purchase quantity (see [42, 43]). In general, previous studies in this area may be characterized as analyses of competitive and cooperative inventory policies in the vendor-buyer system, including [44, 45, 46]. We should mention that many coordination mechanisms have been extended to systems with multiple retailers (e.g., [47, 48]). Non-cooperative game theory has been used often to understand buyer-supplier interactions. Indeed, the buyer and supplier inventories can be modeled as two-person games (competitive games), where the main aim is to find an equilibrium strategy (e.g., Pareto, Nash, and Stackelberg equilibria). Detailed surveys of this topic have been made by [49] and [50].

3.2 Inventory Centralization Games

For a long time, cooperative game theory did not attract the same level of attention in economics research as non-cooperative game theory. Therefore, few studies addressed supply chain management based on cooperative game theory compared with non-cooperative games. However, in the last few years, many studies have focused on the great potential of cooperative game theory for understanding business and supply chain applications. Thus, the analysis of operations re-search problems using cooperative game theory is now a major trend and a focus of modern sup-ply chain management research.

Cooperative game theory focuses mainly on the outcomes of games in terms of the value created by cooperation among many actors (players). Thus, its main contribution to supply chain management is in facilitating the modeling of outcomes of complex business process and supply chains with centralized decisions and actions. However, the effect of cooperation and centralization (in terms of created value and outcomes) is not a new topic in supply chain management re-search. For example, inventory management centralization and multi-retailer inventory joint replenishment systems have been investigated extensively since the 1980s (e.g., [51, 52, 53, 54, 55, 56]). Using inventory management centralization and joint replenishment frameworks, totally centralized chains were shown to be more efficient than decentralized chains and solutions have been found that minimize the total system-wide costs and that maximize the total system-wide profits. However, in most of these studies, the supply chains were assumed to belong to one actor. As a consequence, the study of the interactions and relationships between supply chain participants, as well as the question of how to divide the created value, were ignored completely for many years. In cooperative game theory settings, these situations and new ones can be modeled differently, but the main focus concerns questions of stability and dividing savings.

In a supply chain, the participants may maintain total decentralized strategies, which mean that each will maintain their standalone situation and aim to optimize their own system based on specific economic parameters and objectives. By moving away from decentralized strategies, the supply chain participants may adopt cooperative strategies to centralize their decisions and operate jointly (e.g., they may share/mutualize some physical resources such as warehouses or vehicle fleets, or perform projects jointly such as shipment consolidation and joint replenishment). Thus, each of them will receive a portion of the savings achieved. Inventory centralization games refer to the study of cooperative behavior in centralized supply chains in terms of alliance formation and savings allocation. Each centralized model is associated with a cooperative game where the supply chain participants are the players. The value of a coalition to players comprises the savings/value that the players obtain jointly, which they divide among themselves. Of course, the allocation of the value created should satisfy many properties. For example, the maintenance of stability is satisfied by the so-called core allocations, i.e., the allocation of the created value among the cooperating actors to ensure that no group of actors wants to behave independently.

Recently, inventory centralization games have been studied in various multi-retailer inventory systems (reviewed by [49, 50]). [57] provided a fascinating and detailed survey of exclusive cooperative game theory use in supply chain management. In the following, we consider some inventory centralization games that are closely related to the present study. We classify these games in terms of the inventory models that they employ. Thus, we distinguish two main environmental classes: stochastic and deterministic. In general, we identify newsvendor games in stochastic inventory environments. In deterministic environment, we identify economic lot-sizing games and inventory games. Finally, we focus on games with coalition structures. The proposed classification is presented in Appendix 2.

3.3 Newsvendor games

The newsvendor game problem refers to a situation where a store (newsvendor) addresses a random demand for newspapers by ordering a specific amount of newspapers at the beginning of each day (period). Given their nature, the newspapers can be sold only on the day when they are ordered. Therefore, at the end of the day (period), the unsold newspapers are lost or discounted. [58] provides a detailed review of newsvendor models. Newsvendor games are concerned with situations that involve multiple newsvendors who make joint orders to satisfy the total demand they must meet. The savings achieved are then allocated in a manner that is advantageous to all the newsvendors. [59] was probably the first reported study of this area, which considered a three-player newsvendor game in both cooperative and noncooperative settings. Later, [60] studied a multi-retailer cooperative game, where each was faced by a newsvendor problem. They conditioned the non-emptiness of the core of the game based on some assumptions regarding the demand distribution. This result was generalized by [61] who showed that the cores of newsvendor games are non-empty irrespective of the demand distribution. [62] considered a multiple newsvendors game with multiple warehouses, which assumed that the amount of goods ordered became available after a non-null lead time. They showed that the retailers could increase their expected joint profits by coordinating their orders and making allocations after realizing the demand. They also proved that the associated game has a non-empty core. A similar model was developed based on an assumption that the reallocation of inventories occurs after a demand signal observation [26], which updates the information related to the demand distribution.

The impacts of two classic contracting mechanisms (the wholesale price contract and the buyback contract) were discussed in three different scenarios: non-cooperating retailers, cooperating retailers, and manufacture resale of the returned items. [63] studied the cooperation between multiple newsvendors, by including non-identical selling and purchasing prices and transshipment. This study mainly showed that cooperative newsvendor games with transshipment have a nonempty core. Transshipment was also considered later in another game [64]. [65] focused on profit sharing mechanisms, where they studied a cooperative game between several retailers with normally distributed and correlated individual demands. They showed that when the holding and penalty shortage costs are identical for all subsets of stores, a game based on optimal expected costs (or the corresponding benefits) is subadditive and the core is never empty for normally distributed demands, irrespective of the correlations. When the holding and penalty costs of stores differ, the corresponding game may have an empty core. A similar result was given by [66], who showed that multiple newsvendors cooperative games with non-identical holding and penalty costs may have an empty core.

3.4 Economic Lot-sizing Games

The economic lot-sizing model is one of the best known models in inventory theory, where it involves meeting the demand for an identical (possibly different) product during each phase of consecutive time periods. The demand during a given time period can be fulfilled by orders in that period or in previous periods. The objective is to decide the order quantity (lot) during each time period that satisfies the total demand at a minimum total cost [67]. Detailed surveys of lotsizing models were provided by [67, 68, 69, 70]. Next, we consider a situation where several retailers operate in a lot-sizing environment. In the decentralized case, each retailer solves a classic economic lot-sizing problem to determine their optimal ordering policy. In the centralized case, the retailers may reduce their ordering costs by making joint orders. In a cooperative game theory setting, this situation is called the economic lot-sizing game. The standard form of this game was studied in [71], which considered a set of retailers who sell the same item purchased from the same supplier. The demand for the item is known over a multi-period time horizon. When an order is placed, the manufacturer charges the ordering cost and production cost according to a linear relationship with the amount of items ordered. In addition to these costs, the retailers are assumed to incur an inventory holding cost whenever a specific amount of the item is kept in stock from one period to the next. [71] showed that it is always profitable for a collective of retailers to cooperate, i.e., making joint orders yields some savings. When dealing with the problem of sharing savings, [71] showed that the economic lot-sizing game has a nonempty core. [72] considered a cooperative game between multiple retailers who face an economic lot-sizing problem with a general concave ordering cost (the ordering cost is assumed to be a concave function of the order quantity). When they cooperate, the retailers form a coalition and place joint orders to a single supplier in order to re-duce their ordering costs. The demand in a given period can be backlogged and fulfilled by orders in later periods. The unfulfilled demand incurs a penalty cost to the retailer. [72] showed that the core of the economic lot-sizing game with backlogging costs is nonempty. Moreover, using a method based on linear programming duality, a core allocation may be computed in polynomial time.

3.5 Inventory Games

The class of inventory games refers to inventory cooperative situations, which are similar to those described above but they include continuous-time model assumptions. The economic order quantity is often used as a reorder policy in this class of inventory centralization games. The economic order quantity model has many uses and it is influential in production and inventory research. It was proposed in [73] and its basic form concerns inventory situations with an infinite time horizon and constant demand rate [67]. [74] studied the so-called holding game where a collective of retailers may cooperate by sharing a storage capacity for their inventories. This holding game involves many agents, one of which has a capacitated storage facility. The available goods of other agents can be stored partially in the facility, thereby generating a certain benefit. The main questions addressed by this game aim to find an optimal holding plan and to distribute the benefit obtained. [75] consider a replenishment function based on the economic production quantity model where the order arrives gradually. In addition to making joint orders, the retailers share their holding facilities. This allows the firms to make their orders jointly and to store their items in the cheapest warehouse. It was shown that this inventory-production game is totally balanced and it has a nonempty core. [76] discussed a similar class of inventory-production games, where they considered a situation that allows a collective of retailers to share their production and inventory facilities. Thus, the required items are produced, stored, and backlogged by the player with the lowest production, holding, and backlogging costs. This production-inventory game was shown to satisfy the property of total balancedness, and thus the game has at least one core allocation. [77] considered a set of retailers, each of whom uses the economic order quantity model as a reorder policy to meet a deterministic demand rate. Each retailer has a linear holding cost and a fixed ordering cost. The retailers may reduce part of the fixed ordering cost by making joint orders. In this case, the sum of the ordering costs is reduced to only one cost, which is supported by the coalition of retailers. This form of inventory centralization is called an inventory game. [77] focused on the allocation of joint profits among different retailers. They showed that the game has a non-empty core and they proved that proportional allocation rules belong to the core. [78] extended the model of [77], where a major setup cost was incurred for each order in their cost structure, which was independent of the set of retailers who placed the order. In addition, a minor setup cost was incurred by each retailer included in the joint order. A necessary and sufficient condition was characterized, which was a threshold value for the shared ordering cost, below which it was optimal for all the retailers to order together and to have a non-empty core for the game. [38] studied the same model as [78], but they focused mainly on a class of easy to implement policies called power-of-two policies. They showed that under the optimal power-of-two policy, the cooperative game associated with the joint replenishment model with a first-order interaction is concave and thus it has a non-empty core. [79] extended the model of [38] to a more general cooperative game associated with the joint replenishment model, where the joint setup cost was a submodular function of the set of retailers who placed the order together. Similar to [38], the game was defined under an optimal power-of-two policy. [79] used the strong duality theorem to prove that the game has a non-empty core. In the aforementioned studies, the cooperative games only involve the set of firms/retailers in the system, whereas other supply chain parties such as suppliers are not formally included in the cooperative game. Indeed, we identified only one previous study ([80]) where the supplier participated explicitly in the cooperative process. In this study, [80] considered the coordination of actions and the allocation of profits in a supply chain where the supplier offers wholesale prices to induce the retailers to make large orders. Two types of cooperative situations were compared: the supplier was not considered to be a cooperating agent or the supplier could cooperate with the retailers. It was shown that it is preferable to include the supplier as a player in the cooperative game because the profit was higher in this case compared with a situation that exclusively considered cooperation among retailers.

3.6 Inventory Games with Coalition Structures

Alliance formation and games with coalition structures have received very little attention in supply chain management research. Furthermore, few studies (approximately 10) have used cooperative game theory to investigate the formation of alliances and the interactions among them in supply chains. To the best of our knowledge, no previous studies have used the coalition structure core to analyze a game with a coalition structure in supply chain management research. However, several have analyzed the farsighted satiability of coalition structures in some supply chain games, including [81,82,83,84,85]. Most of these studies dealt with coalition stability in assembly models, although [85] considered the stability of group buying organizations. The authors in [82] were probably the first to deal with farsighted stability in supply chain management. They focused mainly on the coalition structures with farsighted stability outcomes in a three-retailer cooperative game. [81] analyzed two contracting systems between an assembler and their suppliers. The push system allows the suppliers to set their price first before the assembler orders. In contrast to the push system, the assembler offers a price to each of the supplier first in the pull system, before the suppliers then determine the quantity. A grand coalition was shown to be the farsighted coalition structure with the push system, whereas any coalition structure could have farsighted stability under the pull system. For the assembly supply chain, [84] considered an assembler who purchases *n* components from *n* suppliers to build and sell the final product. First, they considered the same cases as [81]: in one case, the suppliers were the Stackelberg leaders; and in the second case, the assembler was the Stackelberg leader. Moreover, they considered a case where the assembler and the suppliers made their decisions simultaneously. In this case, the authors characterized the farsighted coalition structures formed by the suppliers. [83] studied dynamic alliance formation among agents in competitive markets. They considered the problem of price competition in an n-agents game. The different agents sold substitutable products and they faced deterministic and stochastic demands. The farsighted agents could form alliances in order to determine a common price and compete against each other. [85] analyzed the farsighted stability of group purchasing organizations. Group purchasing, also known as group buying, refers to group of many firms (buyers) that pool their purchasing requirements and buy large quantities of a particular product from a seller. This allows them to take advantage of significant quantity discounts from the seller. [85] mainly considered three well known allocations, i.e., proportional allocations, equal allocations, and shapely value allocations, and investigated the farsighted stability of several group purchasing models.

4 Discussion

Analysing cooperation in supply chain networks using cooperative game theory is a fairly new research area in supply chain management. Thus, several questions have not been investigated fully or addressed. After analysing previous studies, we can conclude that most of the studies were only interested in the stability of one set of agents. For example, early studies (see Figure (2)) assumed that games are superadditive in the sense that it is beneficial for all supply chain agents to cooperate. Therefore, the non-emptiness of the core and the distribution of the savings available to the grand coalition of individuals have been investigated most frequently. The non-emptiness of the core and the superadditivity of games are interesting questions from a theoretical viewpoint. We should mention that superadditive games have been studied extensively, even in the theory of games, because they have nice theoretical properties. However, we consider that these issues are not sufficient to model the cooperation in supply chain networks. Thus, deeper and more detailed analyses are required to understand the interactions among firms in supply chain networks.

In many situations, it is not sufficient to declare that the game admits a non-empty core, but we need to identify one such core allocation. Even if a core allocation is found, it is not sufficient to declare that the supply chain participants will use this allocation. This is because core allocations only guarantee immunity to group deviations (stability). However, some core allocations might be costly or complex to put into practice (e.g., they may require a third party to manage the money’s transfer between the partners). Moreover, core allocations often fail to consider the comparative payoffs attributed to each actor and they do not guarantee that the actors who contribute most to the alliance will be paid more. In these situations, it is easy to expect the disbanding of an alliance.

We believe that these questions and many others should be investigated in supply chain networks where cooperation does not mean the elimination of rivalry among firms. We also mentioned that most of the previously investigated cooperative supply chain games are superadditive. In the following, we explain how this assumption restricts supply chain models. In supply chain net-works, as well as in general social networks, many situations are not superadditive in nature. Thus, in the absence of superadditivity, forming a grand coalition is not necessarily efficient be-cause a higher aggregate payoff can be obtained with a different coalition structure. Furthermore, the superadditivity itself can be called into question. There are many reasons for doubting the formation of a grand coalition. For example, as explained by Aumann and Dreze in [86], “acting together may be difficult, costly, or illegal, or the players may, for various personal reasons, not wish to do so.” Indeed, the formation and management of an alliance might incur costs such as coordination overheads, e.g., communication costs and third party logistic costs (when such a party is used). Alliance formation/management process costs have not been considered in cooperative games, but we believe that these cost components will be relevant and important in practice. If we consider these costs, a grand coalition might not be more attractive compared with a smaller coalition. Moreover, in many cases, acting together is difficult or even impossible for practical reasons (such as the geographic locations of the supply chain members) or due to some constraints on the supply chain. For example, in inventory games, the supplier (or the external warehouse) is assumed to have an infinite production capacity, thereby satisfying the large quantities ordered by the grand coalition. However, we expect that this assumption is very different from the actual economic situation. Finally, a grand coalition might not be formed due to rivalry and competition among firms. Some “competitors” might not want to cooperate with each other, even if it is beneficial for them to do so.

Before ending this section, we would like to emphasize that in addition to the focus on the core and superadditivity, most previous cooperative supply chain games have dealt with cooperation exclusively using inventory-cost models. However, we consider that it is important to incorporate transportation decisions in supply chain cooperative models. Indeed, transportation costs may be as important as the inventory costs, and thus including such costs could model more realistic situations and highlight modern supply chain trends, such as green supply chains (e.g., by considering greenhouse gas emissions).

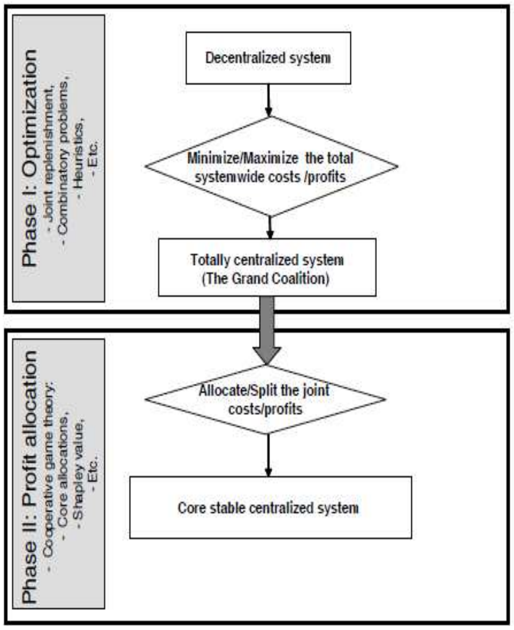

Figure 2: Traditional approaches in modelling supply chain games

5 Conclusion

This paper presents an analysis of the cooperation in supply chains in the light of cooperative game theory. We discussed the potential of cooperation and alliance formation for modern supply chains and highlighted the related challenges and barriers. The paper also presents a comprehensive literature review of recent and state-of-the-art papers in modelling the cooperation in supply chains by means of cooperative game theory. Several supply chain games were reviewed, categorized, and analysed to find the future directions and opportunities of research in this field.

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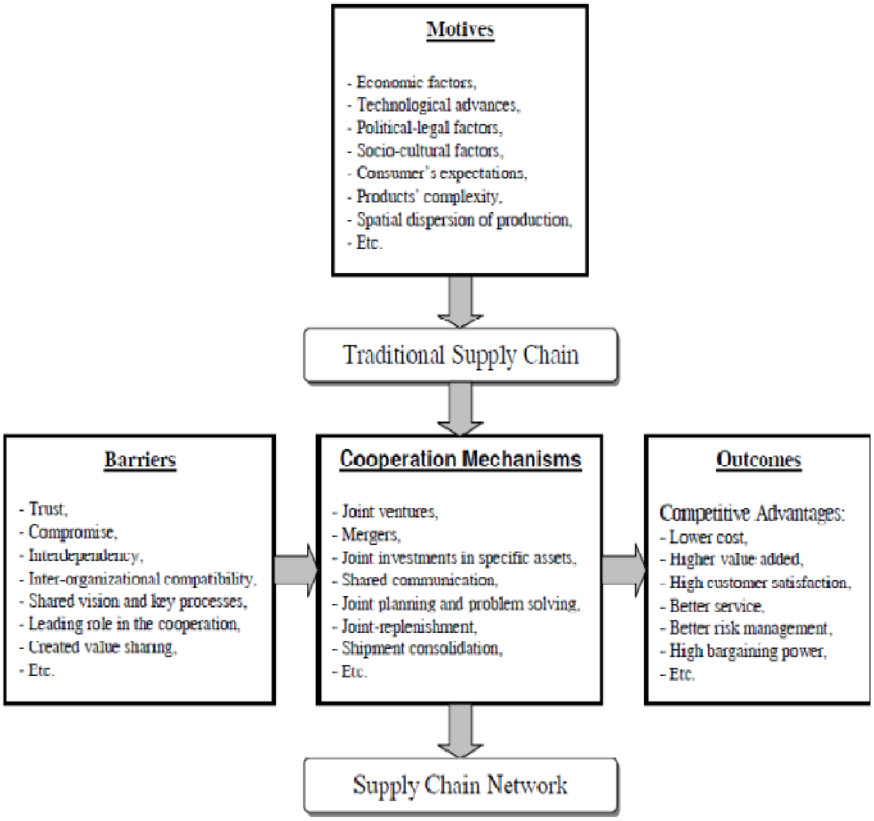
Appendix1: Cooperation in supply chain networks



Appendix 2: Classification of supply chain games