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Decision Support

Side-payment contracts in two-person nonzero-sum supply chain games: Review, discussion and applications

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ABSTRACT

This paper investigates supply chain coordination with side-payment contracts. We first summarize specific side-payment contracts and present our review on the literature that developed general side-payment schemes to coordinate supply chains. Following our review, we discuss two criteria that a proper side-payment contract must satisfy, and accordingly introduce a decision-dependent transfer payment function and a constant transfer term. We present the condition that the transfer function must satisfy, and use Nash arbitration scheme and Shapley value to compute the constant transfer term and derive its closed-form solution. Next, we provide a five-step procedure for the development of side-payment contract, and apply it to four supply chain games: Cournot and Bertrand games, a two-retailer supply chain game with substitutable products and a one-supplier, one-retailer supply chain. More specifically, for the Cournot game, we construct a linear transfer function and a constant side-payment to coordinate two producers. For the Bertrand game, we build a nonlinear transfer function which is equivalent to a revenue-sharing contract, and show that the constant term is zero and two firms in the game equally share the system-wide profit. For a supply chain with substitutable products, we present a side-payment contract to coordinate two retailers. For a two-echelon supply chain, we develop a proper side-payment scheme that can coordinate the supply chain and also help reduce the impact of forward buying on supply chain performance.

1. Introduction

The theory of games extensively applies to the analyses of multi-player decision problems, where the players behave, in a conflicting or cooperative situation, to seek their optimal solutions; see, for example, Benz et al. [4] and Gibbons [29]. In recent years, the management of supply chains has been an important and interesting research field. A supply chain is the sequence of organizations—their facilities, functions, and activities—that are involved in producing and delivering a product or service (see [55, Chapter 11]). As this definition implies, each supply chain member's decision may impact the benefits of other members; thus, game theory has become a primary methodological tool in supply chain analysis. For the applications of game theory in supply chain management, see two recent literature reviews: Cachon and Netessine [13] and Leng and Parlar [37]. Furthermore, many academics and practitioners now have increasing interests in the applications of game theory to the coordination of the members in supply chain games, because the management of a supply chain is mainly concerned with the *integration* of business processes across the supply chain. That is, the channel members of a supply chain should cooperate to reduce total amount of resources required to provide the necessary level of customer service to a specific segment, as Cooper et al. [19] discussed. In contrast, independent operations of the facilities in a supply chain would be of no help in improving chainwide performance. As a senior director of strategic sourcing and supply at Gap Inc., Wilkerson[1] recognized that managing a supply chain through tight relationships with the suppliers affects the success of each member in the supply chain. This reflects the significant role of coordination of the members in supply chain improvement. From the academic perspective, Thomas and Griffin [59] demonstrated the importance of supply chain coordination.

Under supply chain coordination, a decentralized channel (where each member is an independent decision maker) should perform as if it is operating in a "centralized" pattern (where the decisions are made by a single agent). To reach the goal, we should consider the

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[1] http://www.americanexecutive.com/content/view/5546/. (Last accessed March 2008.)

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following two natural questions: (i) What contractual mechanism should we develop so that these members' decisions are identical to the globally-optimal solutions that maximize the chainwide payoff? This question is important because of the following fact: All firms in a decentralized supply chain primarily aim at optimizing their own individual objectives rather than the chainwide objective; as a consequence, their self-serving focus may result in a deterioration of the chainwide performance. For the purpose of supply chain improvement, one could develop a proper contractual mechanism to coordinate all channel members, so that these members' individually-optimal decisions that optimize their own objectives also result in the optimal chainwide performance. (ii) How should the maximum chainwide payoff be fairly divided so that no supply chain member would have an incentive to leave the coalition? The importance of this question is justified as follows: Since the total profit (cost) of all channel members can reach its maximum (minimum) under supply chain coordination, a profit surplus (cost savings) can be generated if these channel members implement a proper contractual mechanism. A proper allocation of the surplus (savings) among these members is needed to make them better off compared to the situation without the supply chain coordination. Otherwise, the supply chain members who are worse off could lose their incentives for supply chain coordination.

As Cachon [11] discussed, we could develop an appropriate side-payment contract to coordinate the members in a supply chain. There are two publications that presented the definition of side-payment in supply chain management. In Rubin and Carter [51], a side-payment is defined as "an additional monetary transfer between supplier (buyer) and buyer (supplier) that is used as an incentive for deviating from the individual optimal policy". For a supply chain involving a seller, a buyer and a carrier, Carter and Ferrin [17] defined the transfer (side) payment as "an additional monetary transfer between any two of these three members (e.g., price reduction or surcharge, rebate, retainer fee, etc.), which is used as an incentive for a particular contract concession". According to the above two definitions, we find that the side-payment in supply chains should be a *monetary* transfer that two channel members make so as to improve the chainwide performance; so, it is also known as transfer payment, compensation, reimbursement, etc. In our paper, we assume that, for a supply chain, only pure monetary value is used to measure the objective of each member and the side-payment amount transferred between any two members. We don't consider any other measurements (e.g., the utility of each decision maker) because all supply chain members are business organizations rather than individual consumers, as indicated by Stevenson's definition [55, Chapter 11] of "supply chain".

We find some practical examples in which business organizations in supply chains transfer side-payments for supply chain coordination. In [53], Shapiro reported a real story in which the Hollywood studios and Blockbuster (which is a video store in the United States) signed a side-payment contract to coordinate the two-echelon video supply chain. Specifically, in order to entice the Hollywood studios to reduce their wholesale prices, the video store Blockbuster agreed to transfer a part of her sale revenue to those Hollywood studios who decrease their prices. This side-payment contract is well known as "revenue-sharing" contract. As another real example, Rombatch[2], a vice president of the damage research team at Genco Supply Chain Solutions, noticed a major increase in cooperation between trading partners to prevent damages within a supply chain in the last two years. In some supply chains (e.g., food supply chains), manufacturers perform their analyses to quantify the levels of damages, and determine the reimbursement rate for their retailers. This has forced the manufacturers and the retailers to work together to achieve supply chain coordination. The above two examples exhibit the real applications of side-payment contracts to supply chain improvement; but, one may note that some side-payment contracts could be illegal and be thus prohibited in practice. We assume that all side-payment contracts in our discussion are legally possible. Under this assumption, we shall perform our analysis only from the perspective of each supply chain's monetary benefit.

The last decade has witnessed a rapidly increasing number of publications related to supply chain coordination with side-payment contracts. In [11], Cachon reviewed the literature that applied *specific* side-payment contracts to coordinate two-echelon supply chains. Those specific side-payment contracts include constant wholesale pricing scheme, revenue-sharing, buyback, price-discount, sales-rebate contract, etc. In addition, many publications developed *general* side-payment contracts for supply chain coordination; later, in Section 2, we shall provide a survey on the literature with general side-payment contracts. According to our review, we find that the majority of publications concerned the development of contractual mechanism, but explicitly or implicitly assuming an *arbitrary* allocation of profit surplus or cost savings; some other publications only focused on the allocation problem, but assuming that all supply chain members *voluntarily* cooperate for supply chain coordination. To the best of our knowledge, no publication has provided a particular discussion on how a proper side-payment contract is obtained to ensure that the chainwide performance is improved and all supply chain members are also better off than in the non-cooperative case. We are thus motivated to, in this paper, present our discussion on supply chain coordination with side-payment contracts. To illustrate our discussion, we shall also consider four existing supply chain games, and develop proper side-payment contracts to coordinate these supply chains.

The remaining sections are organized as follows: Section 2 summarizes major specific side-payment contracts for supply chain coordination, and then provides a literature review on the applications of general side-payment contracts. Section 3, discusses the side-payment contract that satisfies two criteria as follows: the globally optimal solutions are identical to the equilibrium solutions of the players in two-person nonzero-sum games; and each player is better off than in a non-cooperative situation. A transfer function $L(x_1, x_2)$ and a constant transfer term γ are introduced to assure the above two criteria. We compute the constant transfer term γ, by utilizing Nash arbitration scheme and Shapley value. In Section 4, we use our analytical results (obtained in Section 3) to construct side-payment contracts for four existing supply chain games: Cournot and Bertrand games that are two classical ones in economics; and two recent supply chain games. More specifically, a linear transfer function and a constant side-payment are derived to coordinate two producers in the Cournot game. For the Bertrand game, we develop a side-payment contract consisting of a nonlinear transfer function and zero constant term, and show that the overall profit is equally divided between two players. Using a recent supply chain game by Parlar [44], we present a linear side-payment contract to coordinate a horizontal supply chain in which two retailers' products are substitutable. Using Cachon's game model [11] for a two-echelon supply chain, we develop a so-called "price-margin compensation" side-payment scheme to induce supply chain coordination and also solve the forward buying problem. In Section 5, we summarize our analysis and applications, and discuss the potential applications of side-payment contracts.

[2] http://www.foodlogistics.com/print/Food-Logistics/Cracking-Down-On-Unsealables/1$839. (Last accessed March 2008.)