Game Theory and Supply Chain Networks

Fei He
University at Buffalo, The State University of New York, USA

Song He
Tyson Foods Inc., USA

INTRODUCTION

Supply chain network is the collection of physical locations, transportation vehicles and supporting systems through which the products and services are managed and ultimately delivered. It connects suppliers, manufacturers, distributors and retailers with competition and collaboration. Each decision maker in the network aims to achieve profit maximization, capacity maximization, and delay minimization. Erengüç, Simpson, and Vakharia (1999) review the research progress using operations research technology on supplier selections, plants setup, resources allocation, and configuration of distribution networks in supply chains. In an increasingly integrated global economy, the research area of supply chains undergoes a remarkable change. Pure optimization that assumes each decision maker, or player acts independently, is limited. Actually, at nearly all stages of a decision process, interactions across decision makers are not negligible. On the contrary, the interactions significantly affect the decision-making. For example, each decision maker may observe or conjecture the action of other suppliers, manufacturers, distributors, retailers, and customers, based on his information of others. Game theory (Myerson, 1991; Fudenberg & Tirole, 1991) studies the mathematical models of conflict and cooperation between intelligent rational players. In this setting, each player performs his or her best response based on his knowledge of other players' actions and the game structure.

Game theory has become a vital tool to explore the strategic interactions between decision makers in supply chains. Based on different criteria we have different types of games. For example, based on the availability of common knowledge of players' payoffs and strategies, we have complete information and incomplete information games. According to players' moving sequences, we have simultaneous or sequential games. Based on the time scale of games, we have static or dynamic games. Among all supply chain operational models, two-stage games are mostly investigated. The suppliers determine the inventory competitively in the first stage and supply jointly (e.g., transshipment) to meet the customer demand in the second stage. The non-cooperative and cooperative game models are set up to analyze the tradeoff between the decision-making in those two stages.

In this article, we review the research of game theory and network methodology in supply chain management, analyze the challenges and foresee future research directions. The rest of the article is structured as follows. The first section describes a series of game models in supply chain field, in particular the centralized and decentralized models, and the experimental game theory in supply chains. The main focus section presents the key methodologies in game-theoretic networks, such as the non-cooperative and cooperative games, network equilibrium modeling and analysis. The final section concludes with implications and future research directions.

DOI: 10.4018/978-1-4666-5202-6.ch096

BACKGROUND

The body of literature regarding game theory and supply chain is huge, from both research and practical perspectives (Boone & Ganeshan, 2002; Pegels, 2005; Nagurney, 2006, and the references therein). The list we present is far from complete but can provide a flavor of game theoretic research in supply chains.

An ideal supply chain network model captures strategic interactions among decision makers subject to dynamic and stochastic information sharing, capacity, demand, production and policy across all tiers of the network. Early applications of game theory in supply chain include constructing game-theoretic frameworks of the buyer-supplier relationship (Christy & Grout, 1994), and minimizing the bullwhip effect (Lee, Padmanabhan, & Whang, 1997). Most recently, Stackelberg games (Yu, Huang, & Liang, 2009), Bayesian games (Chu & Lee, 2006), bargaining games (Sucky, 2006) and evolutionary games (Xiao & Yu, 2006) are developed to provide "policy insights;" such as to inform the decision maker the push and pull boundary for inventory management, and the make-to-stock or make-to-order production strategy.

In the global economy, a supply chain tends to be geographically decentralized and the local decision makers usually need to make decisions based on the information that is not available to the headquarter. This raises a question of coordination mechanism among all decision makers in order to maximize the performance of the whole supply chain as well as the payoffs of local suppliers, distributors or retailers. In general, each decision maker in a decentralized supply chain independently determines his or her action. Lee and Whang (1999) investigate the incentive and information asymmetry effect in the decentralized supply chain and propose a performance measure scheme to align the interests of all decision makers in a supply chain. Moreover, the decentralized supply chain with partial cooperation is also studied (Gulu, Van Houtum, Sargut, & Erkip, 2005). Hennet and Arda (2008) model a Stackelberg game between a producer and a supplier to study the equilibria of production and inventory under contracts using queuing concept. It is found that decentralized decisions are generally less efficient than a centralized mechanism and the leader in the game gets the maximal utility.

Some experimental game-theoretical studies complement the theoretical work (Croson & Donohue, 2002; Wellman, Estelle, Singh, Vorobeychik, Kiekintveld, & Soni, 2005). Parkhe (1993) investigates six hypothesis about strategic alliance between firms and testifies them using empirical data. He analyzes the endogenous and exogenous factors, such as opportunism, and payoff structures, that determine a company's decision on cooperation or deflection. Cantor and Macdonald (2009) propose and test hypothesis of comparing the high-level abstract problem-solving approach to the low-level concrete one. They find that under limited information the decision maker performs better using abstract approach than the concrete way. But the impacts of both approaches are negligible when the information is completely available. Furthermore, a few studies use network topology to investigate the supply chain performance (Nair & Vidal, 2011). Pathak, Dilts, and Biswas (2007) analyze the evolution of supply chain network structures based on historical data.

MAIN FOCUS

Non-cooperative and cooperative game theory has been proven viable to investigate the design and operational strategies in supply chain management (Simchi-Levi, Wu, & Shen (Eds.), 2004). An interesting and challenging task is to model and analyze the supply chain performance considering decision makers' information sharing and risk preferences. The analysis of supply chain network equilibrium based on variational inequality, graph theory and control theory provides valuable insights for supply chain management.