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An Analysis upon Concepts and Approaches of Game Theory in SCM: Competitiveness among Suppliers

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Abstract – Supply chain networks that experience today a dynamic evolution with intensive competition due to globalization are exposed to several risk sources that increased their vulnerability. The quest for increased resilience of global supply chain networks against risks such as disruptions, conflicts of interests, myopic optimization decisions and economic policies emerges now more than ever. Several research efforts have been conducted the last years to increase our understanding on supply chain risk management and the relative decision making on the strategic, tactical and operational level.

Game theory provides a solid mathematical background for system modeling a well as analytical solutions in decision making, thus making it suitable to analyze these interactions, coordination needs and risk mitigation actions. The purpose of this study is to review the game theoretical approaches to supply chain risk management and apply game theory to a supply chain consisting of a supplier and a retailer with stochastic exogenous demand and risk sharing policies. The model combines inventory control and game theory in order to produce effective supply chain risk management decisions.

Effectively selecting and evaluating suppliers and managing their involvement in critical supply chain activities play vital roles in building competitive supply chain. This study proposes an integrated approach for optimal supplier selection, pricing and inventory decisions in a multi-level supply chain. A cooperative game approach is used to evaluate the marginal contribution of the supply chain members, especially the suppliers.

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INTRODUCTION:-

Supply chain management (SCM) is an area received great attention in business community. To implement SCM, the coordination and integration of the activities within organization and across the supply chain is necessary. Many firms identify and qualify adequate suppliers to provide the materials and service needed by them. Effectively selecting and evaluating these qualified suppliers and managing their involvement in critical supply chain activities enable manufacturers to achieve the four dimensions of customer satisfaction: competitive pricing, product quality, and product variety and delivery service. This study coordinates supplier selection, pricing and inventory decisions and proposes a cooperative game theory approach to evaluate the suppliers for an integrated multi-level supply chain.

There is huge literature in industrial field on the vertical integrated supply chain. The literature shows that to maximize overall system profit and integrate operations among various entities through coordination are of best interest. For example, Alchian and Demsetz and Jensen and mackling point that vertical integration would exploit synergies between different divisions appeared as economies of scope. Williamson looks at the long-term relationship between a seller and buyer and finds the advantage of integration, for example, saving transaction cost. The integration of supply chain mainly focuses on the pricing model, distribution inventory model. Boyaci and Gallego analyze the problem of integrating pricing and inventory replenishment policies in a supply chain consisting of a wholesaler, one or more geographically dispersed retailers.

This study considers a three-level supply chain composing of multiple suppliers, one manufacturer and multiple retailers. The manufacturer obtains components from the potential qualified suppliers and produces final products for retailers in different markets. In this study, we formulate a mixed-integer programming model to integrate the optimal supplier selection, pricing and inventory decisions. We put forward a cooperative game theoretic approach and use the Shapley value to evaluate the marginal contributions of the supply chain members, especially the suppliers, for the above supply chain in integrated process.

In this study we shall introduce the game-theoretic notions in simplest terms. Our goal will be later on to study and formalize mathematically various game problems, by which we understand problems of conflict with common strategic features.

While initially developed to analyze competitions in which one individual does better at another's expense (zero-sum games), it has been expanded to treat a wide class of interactions, which are classified according to several criteria, one of these being cooperative versus no cooperative interactions. Typical classical games are used to model and predict the outcome of a wide variety of scenarios involving a finite number of players (or agents) that seek to optimize some individual objective.

REVIEW OF LITERATURE

In the current competitive scenario supply chain management assumes a significant importance and calls for serious research attention, as companies are challenged with finding ways to meet ever-rising customer expectations at a manageable cost. To do so, businesses must search out which parts of their supply-chain process are not competitive, understand which customer needs are not being met, establish improvement goals, and rapidly implement necessary improvements. Previously manufacturers were the drivers of the supply chain - managing the pace at which products were manufactured and distributed. Today, customers are calling the shots, and manufacturers are scrambling to meet customer demands for options/styles/ features, quick order fulfillment, and fast delivery.

In practice, supply chain based companies have used different performance management tools to support their supply chain strategies. Monitoring and improvement of performance of a supply chain has become an increasingly complex task. A complex performance management system includes many management processes, such as identifying measures, defining targets, planning, communication, monitoring, reporting and feedback.

During the last decade, game theoretic applications on inter-organizational relationships have become popular. For example, Wolters and Schuller (1997) develop a dynamic game theory model in order to study how trust can be forged in a supplier-client relationship.

The supply chain approach to studying competitiveness reflects that competition increasingly is not between individual firms but complete value chains. As a result the nature of supply chain relations can be a source of competitive advantage or disadvantage (Simatupang & Sridharan, 2002). For researchers in the agri-food sector, this implies that one should not look at agricultural competitiveness in isolation, as efficiency at the farm level may be curtailed by downstream problems. For example, in the mid-1990s, while farm-gate wheat and oilseed prices in Ukraine were significantly below international levels, exports were modest. Weak export performance derived from downstream inefficiencies, namely the excessive cost and poor reliability of transport and storage (Striewe, 1999). Weaknesses in one part of the supply chain thus adversely affected the international competitiveness of the whole.

Huang and Li (2001) investigated manufacturer–retailer coordination as a cooperative advertising in supply chain problem. They highlighted the impact of investment in brand name, local advertising and sharing policy in three models under a cooperative regime in which the seller agrees to share a fraction of the total local advertising expenditure with the buyer.

Kelle et al. (2003) investigate two scenarios for shipment quantity, fixed by the supplier or buyer in a Just in Time (JIT) supply chain system.

Boyaci and Gallego (2004) have considered one market with two competitive supply chains; each one includes a retailer and a wholesaler. Costumer service is the considered competitive item.

Yue et al. (2006) proposed a similar model under the assumption that seller offers a price reduction to customers. The profit function in a typical supply chain model contains a logistic cost component. However, in order to avoid the confounding effect of logistic cost, these studies assume that lot size is equal to demand.

Ketchen et al. (2007) noted that as a relatively new concept, the notion of best value supply chains can become clearer and richer if examined from a variety of important theoretical perspectives. Authors showed implications for the best value supply chain concept offered by nine prominent theoretical perspectives: transaction cost economics, agency theory, resource dependence theory, institutional theory, game theory, network theory, social capital theory, strategic choice, and the resource-based view/knowledge based view.

Esmaeili, and Zeephongsekul (2010) in their paper entitled "Seller buyer models of supply chain management with an asymmetric information structure" have determined the relation between seller and buyer in supply chain with non-collaborating Stackelberg game, while the buyer is leader and the seller is follower and conclude that some factors including: organizational structure of sellers, purchase price, unknown and unpredictable factors related to buyers and unknown information have meaningful difference with market demand. Since this competition has been investigated both by confirming the desirability of lost Pareto of each company and by confirming desirability of lost Pareto of all companies.

GAME THEORY CONCEPT

Nash equilibrium concept-

Nash equilibrium is a fundamental concept in the theory of games and the most widely used method of predicting the outcome of a strategic interaction in the social sciences. A game (in strategic or normal form) consists of the following three elements: a set of players, a set of actions (or pure-strategies) available to each player, and a payoff (or utility) function for each player. The payoff functions represent each player's preferences over action profiles, where an action profile is simply a list of actions, one for each player. Pure-strategy *Nash equilibrium* is an action profile with the property that no single player can obtain a higher pay off by deviating unilaterally from this profile.

Nash equilibrium, introduced by Nash, is a fundamental solution concept in the theory of non-cooperative game and the most widely applied game theoretical method in economics. The theory is used to predict player's behavior in static game when players simultaneously chosen their strategies and do not communicate with each other. For the convenance of describing this concept, we will use the following notations. Suppose that for any player $i \in N$, where $N = \{1, 2, \cdots, n\}$ is the set of players, let S_i be the set of strategies available for player z, and denote the Cartesian product set $\prod_{j \in N, j \neq i} S_j$ Thus, S_{-i} is the set of all possible combinations of strategies for all players except player i. Using s_i denote a typical member of S_{-i}, then, a member s of, $S = \prod_{j \in N} S_j$ can be represented by $s = (s_i, s_{-i})$, where s_i is a strategy in S_i.

Stackelberg equilibrium concept-

Another commonly used solution concept in non-cooperative game is the Stackelberg equilibrium due to von Stackelberg, where for a nonzero-sum two-person game; one of the players is more dominant than the other player. Such game can be modeled as two- stage hierarchical game known as a Stackelberg game, where the dominant player, the *leader,* is allowed to make the first move; the weaker player, the *follower*, who retaliates by playing the best move consistent with available information initiated by the leader's move. The leader then responds by selecting the best decision based on the follower s decision.

The classical two-player version of Stackelberg game is described as following: Let $S_i\,(i = 1, 2)$ be the admissible strategy set of player 1 (PI) and player 2 (P2) with corresponding utility function $u_i(s_1, s_2)$ respectively. Each player desires to maximize their own utility function whose value depends on both players' strategies. The two- stage of Stackelberg game proceeds as follows: (i) the leader announces his strategy, the follower then responds rationally by choosing a strategy that results in maximizing his utility function; and (ii) the leader then selects a strategy that results in maximizing his own utility function.

Bayesian-Nash equilibrium concept-

The games like matching pennies and prisoner's dilemma that form the core of most undergrad game theory courses arc games in which players know each other's preferences. Notions like iterated deletion of dominated strategies, and rationalize-ability actually go further in that they exploit the idea that each player puts him or herself in the shoes of other players and imagines that the others do the same thing. Games and reasoning like this apply to situations in which the preferences of the players are *common knowledge.* When we want to refer to situations like this, we usually say that we are interested in games of *complete information.*

GAME STRATEGY

Game theory or competitive strategy is a theory which relates to competitive situations where two or more organizations with different goals are going to make decision. The basis of game theory is on min-max principle, based on which each competitor acts in a way that minimizes his maximum loss.

The considered game in this research is dynamic game; in this study balanced solutions for supply chain are calculated and compared based on three main hypothesis of bargaining power. When the retailer has more bargaining power, it can purchase the product with lower price from manufacturer and deliver it to customer with higher price. So in this situation, the profit of manufacturer decreases and predicted profit of retailer increases.

The field of game theory may be divided roughly in two parts, namely non-cooperative game theory and cooperative game theory. Models in non-cooperative game theory assume that each player in the game (e.g. a firm in a supply chain) optimizes its own objective and does not care for the effect of its decisions on others. The focus is on finding optimal strategies for each player. Binding agreements among the players are not allowed. One of the main concerns when applying non-cooperative game theory to supply chains is whether some proposed coordination mechanism, or strategy, coordinates the supply chain, that is, maximizes the total joint profit of the firms in the supply chain. In contrast, cooperative game theory assumes that players can make binding agreements. Here the focus is on which coalition of players will form and which allocation of the joint worth will be used. One of the main questions when applying cooperative game theory to supply chains is whether cooperation is stable, that is, whether there exists an allocation of the joint profit among all the parties in the supply chain such that no group of them can do better on its own. Up to date, many researchers use non-cooperative game theory to analyses supply chain problems.

A GAME THEORY APPROACH IN SELLER–BUYER SUPPLY CHAIN

A seller–buyer supply chain represents a manufacturer which wholesales a product to a retailer, who, in turn retails it to a consumer (Yang and Zhou, 2006).

In the literature, the terms vendor, supplier, and manufacturer have been used interchangeably to represent the seller. Likewise, the word retailer has been used to represent the buyer. In this study, for the sake of simplicity, we will use the nomenclature buyer and seller. The related literature on finding optimal seller and buyer's policy of production and ordering can be broadly categorized into three groups based on the following assumptions: seller–buyer interaction is seen in light of constant demand, seller and buyer are independently studied where demand varies, and seller and buyer interaction is considered without logistic cost including setup/ordering and holding/carrying costs. We briefly summarize these models in order to compare with our proposed approach.

There are many possible interactive coordination mechanisms that can occur between the two members of a seller–buyer supply chain. Various types of mechanisms have been discussed in the literature on supply chain coordination such as quantity discount, credit option, buy back or return policies, quantity flexibility and commitment of purchase quantity. Quantity discount, a popular tool of coordination mechanism. Abad (1994) proposed a model of seller–buyer relationship, where demand is price sensitive and provided procedure of finding the optimal policy for both seller and buyer under a cooperative scenario. A similar model was presented in Abad and Jaggi (2003) where the main assumption is that the seller offers trade credit to the buyer. Several works have addressed the problem of determining the optimal order quantity (lot size) or order (production) cycles in a cooperative structure in order to achieve maximum savings or enhance profit for the whole supply chain where demand rate is considered fixed.

In contrast, fixed demand is avoided in some research where joint lot sizing and pricing decisions are used to determine the optimal price and order quantity for maximization of the firm's profit. In such cases, price would depend on demand over a planning horizon. Similar approaches have also been used in cases where both marketing expenditure and price influence demand. A significant shortcoming of all these models is that they only regard seller or buyer supply chain management problem without considering any interaction between buyer and seller.

THE SUPPLY CHAIN NETWORK GAME THEORY MODEL

In this Section, we develop the supply chain network game theory model with product differentiation, possible outsourcing, price and quality competition among the contractors, and quantity and quality competition among the original firms. We consider a finite number of I original firms, with a typical firm denoted by i, who compete no cooperatively. The products of the I firms are not homogeneous but, rather, are differentiated by brands. Firm $i; i = 1, \dots, I$, is involved in the processes of in-house manufacturing and distribution of its brand name product, and may subcontract its manufacturing and distribution activities to contractors who may be located overseas. We seek to determine the optimal product flows from each firm to its demand markets, along with the prices the contractors charge the firms, and the quality levels of the in-house manufactured products and the outsourced products.

For clarity and definiteness, we consider the supply chain network topology of the I firms depicted in Figure 1. Each firm $i;\ i = 1, \dots, I$, is considering in-house and outsourcing manufacturing facilities and serves the same n_R demand markets. A link from each top- tiered node i, representing original firm i, is connected to its in-house manufacturing facility node M^i. The in-house distribution activities of firm i, in turn, are represented by links connecting M^i to the demand nodes: $R_1, \dots, R_{n_R}$ In this model, we capture the possible outsourcing of the products from the I firms in terms of their production and delivery. As depicted in Figure 1, there are no contractors available to each of the I firms. Each firm may potentially contract to any of these contractors who then produce and distribute the product to the same n_R demand markets. In Figure 1, hence, there are additional links from each top-most node $i;\ i = 1, \ldots, I$, to the *tiq* contractor nodes, $O_1, \ldots, O_{n_O}$, each of which corresponds to the transaction activity of firm i with contractor j. The next set of links, which emanates from the contractor nodes to the demand markets, reflects the production and delivery of the outsourced products to the n_R demand markets.

COMPETITIVE PRICING IN SCM

Nowadays, the competition between firms is shifting towards the competition between supply chains. Because of different objectives of supply chain members, conflicts occur within a supply chain and hence, behavior that is locally rational for a member, can be inefficient for the overall supply chain performance. In the supply chain management (SCM) literature, it is well known that coordination among supply chain members will improve the overall supply chain performance but the majority of this literature ignores the competition from other external supply chains and hence, there is no guaranty for improving the supply chain performance in the existence of other coordinated supply chains (Boyaci and Gallego,2004). Hence, we investigate the equilibrium behavior of a new supply chain that tends to entering in the stochastic market consisting of some competing supply chains. This new supply chain consists of one risk-neutral manufacturer and one risk-averse retailer in which, the retailer is a leader and the manufacturer is a follower. We suppose that the manufacturer should pay a fraction of the risk cost of retailer. Today, risk sensitivity has potential effects on performance of supply chain members and can cause inefficiency across the entire supply chain. The risk sensitivity of a retailer towards demand uncertainty has a considerable impact on its decisions.

Because of the important role of pricing in business behavior, here we suppose that the competition occurs on the basis of product price under a stochastic price-depended demand. To focus on the effects of competition, we consider all model parameters as a common knowledge for supply chain members. How will this supply chain compete in the market? What are the optimal wholesale and retail prices? And, how does the risk sensitivity affect the supply chain members' decisions? Our concern here is to answer these questions.

At first, it is worth mentioning the work by McGuire and Staelin (1983). They investigate equilibrium supply chain structures for duopoly market, in which two competing manufacturers sell their products through an exclusive retailer. They develop a deterministic model with price competition and product substitutability and no inventory considerations and show that the wholesaler's equilibrium distribution structure (i.e., vertical integration versus decentralized distribution) depends on the degree of product substitutability, which determines the intensity of retail price competition.

CONCLUSION

In this study, we have investigated the interactive relationship between one manufacturer and one retailer in a distributed two-echelon supply chain for a single deteriorating item. Several contributions have been made to research literature with respect to the optimal competitive pricing and replenishment policies.

Foremost, we have identified the competitive pricing and replenishment policies in a distributed channel as an important area for rigorous and systematic research. And a competitive market structure, in which the retailer and the manufacturer are independent and neither player dominates the other, is considered in our study.

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