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Introduction

The accelerating evolution of technology and economic- and social-changes has impacted the operational behavior of companies and the manner they are managed to fulfill their strategic purposes. On the one hand, innovation in production technologies has led to the use of expensive and specialized resources that are economically viable only through high levels of utilization. More in more the required economies of scale cannot be obtained with exclusive dedication of these assets to a single company. Consequently, many companies turn to external suppliers that are able to provide them the competences and capabilities that, otherwise, they could not develop quickly and cheaply enough to remain competitive in the long run. On the other hand, social changes have a direct impact in the population's needs and customers' preferences, whose expectations are always increasing in relation to the product itself, as well as to its delivery and post-sale service.

Thus, the effects of the vicissitudes in the environment external to the company on the way they are managed are diverse and involve changes ranging from operational processes, such as logistics, ordering systems and inventory control, to strategic choices, such as outsourcing, merges and acquisitions. In particular, many companies outsource part of their production process with the purpose of becoming more flexible, which is key for adapting to changes such as the reduction in the products' life-cycle and their increased complexity. By means of agreements, companies can unite their competences to the partners' ones in order to act in the market with competitive advantages. This is often observed when a company is seeking shorter time-to-market, superior quality, larger variety, and lower investment risk or product cost.

However, in outsourcing processes, new managerial problems arise that require coordination among the companies involved in the production value-chain. Simple isolated optimization of each company's efficiency usually is not sufficient to guarantee efficiency of the whole chain. As vertical integration is reduced, flows of information are blocked, costs are transferred to other tiers of the chain rather than being reduced, and power to impose actions that benefit the whole at expenses of few is lost. Integrating production units of different

owners is hard to obtain. Each firm has its own interests and objectives, and holds back private necessary information to avoid opportunistic behavior from the others in the chain. If no company knows the costs of other members of the supply-chain and optimizes its profit without information from other members, then reducing some costs at the expense of increasing other members' costs may seem as good as outright cost elimination. If companies are autonomous and decide in isolation, then putting into effect actions that benefit the entire value-chain efficiency may require inducing some companies to cooperate. Hence, in a supply-chain, the effective coordination of production decisions of autonomous companies and, consequently, their collective efficiency, depend on the relations established among them.

Therefore, the segmentation of the value chain brings several advantages, among them, economies of scale, flexibility for launching new and innovative products, less risky investments in specific capital, and lesser entry and exit barriers. But segmentation also has detrimental effects, among them, the strategic supplier/buyer dependency and asymmetrically increased bargaining power. Apparently, the coordination of productive activities in a supply chain is achieved when there is a focal company, which by its singular bargaining power is able to align the entire supply chain aiming at its purposes (Rice and Hoppe, 2001, 2002; Hoppe, 2001). However, the cases where a company can effectively coordinate its supply chain and, in fact, is willing to do so are more exceptions than the rule. Therefore, the study of the possible agreements that lead the companies in a supply chain to share private information and align their individual interest in order to improve their collective performance is an increasingly relevant problem, as production becomes distributed among progressively more specialized autonomous companies.

The research originated from the companies' vertical disintegration, aims at reconciling the advantages of coordinated decisions found in central planning while retaining the gains obtained by outsourcing. Research efforts for identifying supply-chain characteristics and elements needed for effective coordination have been developed in the upstream and downstream directions from a focal company (Lambert and Cooper, 2000; Tan, 2001; Kerbache and Smith, 2004; Gunasekaran and Chung, 2004). Cooperation with upstream companies usually seeks more efficient and effective management of traditional activities associated to the procurement flows of inputs. The goal is to improve the company's performance in several dimensions, including the reduction of the cycle-time, the reduction of the input inventory and the increase of customer's satisfaction level. Cooperation with a downstream company seeks more efficient and effective management of the traditional transportation and

logistics functions of the products' physical distribution. In addition to those essentially logistics aspects, the cooperation with other companies in the supply chain addresses aspects as, for example, reducing uncertainty in demand and operations planning.

Supply Chain Management (SCM) research increased considerably since the 80's decade taking into account different approaches and stressing different aspects of the supply chain. Several frameworks were developed for mapping problems and guiding the studies in this area from the conceptual point of view (Lambert et al., 1996; Cooper et al., 1997; Lambert and Cooper, 2000; Croxton et al., 2001; Gunasekaram et al., 2001, 2004; Li and O'Brien, 1999, 2001; Hoppe, 2001; Rice and Hoppe, 2002). Despite of the significant results of this research on SCM, from the practical point of view, the application of those conceptual structures in supply chains comprised of companies that have autonomy in their decision processes is not too clear at all. An important limitation in the application of those research results is the evaluation of the supply chain's benefits, which is necessary to study the real possibility of improvement of each one of the companies and how the costs and benefits generated by each one could be distributed among them. In the literature, there is a considerable number of papers dealing with the supply chain's performance evaluation that, though not always explicitly, assume the chain to have a definite and stable structure, i.e. who are the participating companies and what are their functions and relationships in the value chain (Lambert and Pohlen, 2001; De Toni and Tonchia, 2001; Arns et al., 2002). However, in practice, it has been difficult to identify those supply chain structures, as well as to develop adequate measures to evaluate their performance.

Therefore, in spite of the abundant literature about SCM, there is not a practical orientation offered to the executives by well-defined prescriptive models to decide on the relationships that could be established with their suppliers, or customers (Araneda-Fuentes and Lustosa, 2005a, 2005b). In fact, there is a scarcity of researches facing the integration of the members' activities in supply chains that consider more than a dyad, or more than two companies in the upstream, or downstream, side of the focal company. Among the exceptions are Simpson and Erengüc (2001, apud Dudek and Stadler, 2005), who study the central coordination in a supply chain comprised by three links, and Cakravastia et al. (2002), who develop an analytical model for the suppliers selection process in the design of a supply network. Both of them consider upstream planning, that is, the companies' planning is determined link-to-link starting from the downstream-most company and continuing the upstream planning. According to Croom et al. (2000, apud Kerbache and Smith, 2004),

around 6% of the published articles treat the supply chain optimization with prescriptive purposes, while the other are mostly empirical studies that lead to descriptive results. See Ganeshan et al. (2002) for a taxonomic review of SCM research, where eighty three works from 1957 to 1998 are classified in relation to two dimensions, the problem category (competitive strategic, firm focused tactics, or operational) and the solution methodology (literature review/historical, concept, quantitative models, or case study).

The most part of SCM research assumes common planning, or coordination of plans, is always possible among autonomous companies and, also, that each company can become better off, that is, gets an acceptable part of the supply chain's benefit obtained by the coordination. The assumption is quite strong, since each company has its own interests and the coordinated plan can be in conflict with these interests. The management of a centralized system in hierarchy governance is simplified by the power on the internal decision processes granted by ownership (Hart and Moore, 1990). So, in practice, centrally coordinated plans will be effective only in the rare cases in which a company is sufficiently powerful, and is interested in using it, for acting as a chain master imposing upon its partners the supply chain's interest. Most of non-dyadic studies of coordination in supply chains derive from the logistics perspective leaving organizational issues in the background. Under that perspective, supply chain planning is considered from the point of view of a central decision maker minimizing the system's total cost. So, the supply chain is supposed to be managed in a similar way to a vertically integrated company, where all the existing information is available to management and the flows of inputs are controlled by a single decision maker, who counts on the collaboration of all the companies involved in the supply chain (Martin et al., 1993; Geoffrion and Powers, 1995; Vidal and Goetschalckx, 1997; DeCroix and Arreola-Risa, 1998; apud Schneeweiss and Zimmer, 2004).

From the difficulties faced in the development of multi-company SCM research and the limited possibilities of actually managing supply chains comprised of a group of companies forming several links, have emerged some proposals to reduce the research scope. Recent approaches deal with a reduced amount of companies and links in the supply chain grouped under the name of Supply Network Management (SNM) (see, for example, Rice and Hoppe, 2002; Dudek and Stadler, 2005). The participant companies in a network are considered autonomous entities responsible only for their own decision processes and, under given situations, such as the development of new products or the requirement of specialized inputs, could act strategically following coordinated plans, or a common planning dictated by a leader

company. In particular, the auto industry has been successful and has taken advantage from special arrangements with other companies in the context of SNM (Fandel and Stammen, 2004). For example, in Rio de Janeiro for producing trucks and buses platforms, Volkswagen *Caminhões* coordinates several supplier companies. Nevertheless, there are companies that in managing closer relationships with others never achieve the expected result getting into an unfavorable cost/benefit relation (Miles and Snow, 1992).

The SCM literature developed in the last decade reveals an increasing effort in approaching the coordination of production decisions through formal contracts among autonomous companies in a supply chain. The supply chain under study can be seen as a set of autonomous decision making units, each one of them controlling locally a part of the process required to obtain the supply chain's final product (Schneeweiss and Zimmer, 2004). Contracts treated in the management of the supply chain are usually supply contracts, since the primary focus of SCM is on the material and information flows (Anupindi and Bassok, 2002), which involve tactical decisions that constrain to the operational ones. The Operational Research area has well-developed theory and methods to give support to the quantitative study of supply contracts by the effective modeling of the supply chain, or network, in the form of stochastic optimization, simulation, heuristics, and network optimization models. In fact, modeling has assisted companies to understand and get benefits by the participation in a given supply network (Maloni and Benton, 1997; Lamming et al., 2000; Otto and Kotzab, 2003; Boer, 2003). Since the companies' decision processes are autonomous, they negotiate by anticipating undisclosed private information on the other party's costs and benefits, or by sharing information if the terms of the supply contracts reward them for that. Some studies deal explicitly with hierarchical planning schemes to coordinate decisions in decentralized systems. See Schneeweiss (1995, 1998) for a conceptual framework for hierarchical structures and planning in organizations, and Schneeweiss (2003) for a review about distributed decision making in SCM.

A supply contract can be seen as a document that describes, prior to the trade, the terms of a binding agreement that specifies the process by which the amount of trade and cash flow are determined after the trade (Tirole 1988, apud Özer and Wei, 2006). A formal supply contract is an important coordination mechanism because it makes explicit the conditions under which the companies should act and, also, establishes the incentives and/or penalties associated to rights and duties. The formalization of a contract makes it binding and each party legally accountable according to its terms. By pre-establishing patterns of behavior for the parties supply contracts, the main purpose is usually reducing

the trading risks such as price changes, idle capacity, or interruptions in supply. Supply contract parameters may be the result of some planning processes and input for other planning processes. When a contract has this clear feature of communicating information and conditioning the future decision of the parties relative to quantities to be traded or capacities to be made available it is called a coordinating supply contract, or simply coordinating-contract.

But, what does coordination mean? It is common in the literature to use the coordination concept as the ultimate purpose of supply chain management, that is, to attain the supply chain's maximum performance or, equivalently (in theory), the performance achieved by central planning. For example, Anupindi and Bassok (2002) consider that a network, or channel, is coordinated when it has the same performance obtained by a single decision maker that optimizes the network taking into account the total information held by the various decision makers. Cachon (2003) considers that a contract coordinates the companies in a supply chain if the optimal collection of actions under the contract results in Nash equilibrium, that is, no company can gain by departing from the set of optimal decisions for the chain. Assuming that the companies are free to reject the contract, a coordinating contract must also be advantageous to all parties.

In this work, the coordination among autonomous companies is understood as the establishment of conditions under which each company, acting in self interest, aligns its individual decisions with the ones of the other participating companies defining a coherent plan that improves collective efficiency. The gains derived by the coordinated decisions must be properly distributed among the companies, providing incentives that lead each one to comply voluntarily with the plans, or under some existing external power. So, a contract will be said to coordinate if it can bring about any collective improvement, no matter the coordination level achieved (improvement obtained in relation to maximum possible) in the supply chain by the contract, rather than the coordination in the strict sense of reaching the maximum performance. For practical reasons, a contract that improves the companies' performances individually and has a lower administration cost can be preferred to a fully coordinating contract, i.e. one which leads to the supply chain's maximum performance. In fact, a supply-chain coordinating-contract that allows an acceptable partitioning of benefits among the companies could be so expensive and complex to control, and thus, infeasible.

The coordination among companies seeks to align self- and collective-interests, and consequently, to articulate actions and exchange of information, to attenuate the loss of efficiency of decentralized decisions in comparison

with centralized systems. So, to achieve supply chain coordination, there are basically two difficulties that must be addressed by supply contracts among autonomous companies that hold private information. First, the difficulty of exchanging information in a credibly way, that is, to convince the other company of the absence of malicious misinformation. There are several reasons why a company could distort a demand forecast informed to another company (see, for example, Lee et al., 1997). But Özer and Wei (2006) consider that one of these reasons for distorting information arises from the definition of the contract itself, i.e. it is the design of the contract that induces this behavior. It is also likely that, for fearing opportunistic misuses, the informing party refuses to communicate private sensitive information even when necessary for coordination. Second, the lack of risk sharing among the companies, which leads the companies to make sub-optimal decisions, in the sense that their decisions are locally optimal but inefficient from the supply chain's global point of view. Among those risks are the supply risk (the cost of insufficient supply) faced by retailer (or distributor), the capacity risk (the cost of excess of capacity) faced by manufacturer companies, or the inventory risk (the cost of unsold inventory) faced by both types of companies.

Therefore, taking into account these limitations in order to approach successfully the planning of coordination by a formal supply contract, the following conditions must be considered: (i) there must exist an expectation of additional gain for each company in relation to the situation without contract, (ii) it must be possible, in practice, to exchange in a credible way the information required, and (iii) it must be possible to embed, in the contract, direct or indirect incentives or penalties so as to induce the parties to comply with the terms of the contract.

The studies dealing with the coordination of companies by contracts can be grouped in two research streams, which are referred to as Analysis of Contracts and Design of Contracts. In the literature review, it does not appear a clear definition neither delimitation between those streams and, frequently, they are used without any distinction. For example, Anupindi and Bassok (2002) consider that the analysis of contracts is primarily the analysis of a given type of contract in relation to independent action of the companies and to centralized planning, and considering other aspects as mentioned above. For them, design is the conception and development of contracts to coordinate some link of companies in a given environment.

The issues to be considered in the analysis and design of a contract, from the perspective of this work are exposed as follows: (a) the analysis of a contract seeks to determine optimal contracts, that is, contract parameter-values that

optimize the supply chain's performance with each company that accepted the contract deciding in self interest. This implies quantitative modeling to evaluate the impact that the contract has on the companies, both individually and jointly, and (b) the design of contracts intends to conceive contracts with desirable characteristics in the setting under study and are appropriate in the sense of satisfying the issues raised by Cachon (2003), namely: (i) contracts must bring a gain to the supply chain by coordinating the parties' actions, (ii) the allocation (among the parties) of the supply chain's gain derived from the contract must be flexible, and (iii) the contract must be implementable.

In the SCM literature on coordination by contracts, the supply chains studied are narrow structures formed, usually, by only two companies, a buyer company and a supplier company. In this work, those companies will be called, for short, Buyer and Supplier and referred, respectively, as male and female, according to the convention suggested by Lariviere to Cachon (2003). Indeed, several studies show that, in the current industrial practice, the dyadic relationships prevail (see, for example, the study of cases by Hoppe, 2001). Nevertheless, when the dyadic relationships are analyzed from the coordination viewpoint they turn out to be already quite complex, because they involve tactical and operational decisions that must be made in different epochs under different uncertainties. Consequently, the quantitative modeling can be very complex and, perhaps, result in intractable mathematical problems when relevant uncertainties in the decision processes are incorporated. For example, the incorporation of stochastic market demand in aggregated planning models leads to problems of stochastic programming for the single period case, or stochastic dynamic problems for the multi-period case (Anupindi and Bassok, 2002).

Several types of supply contracts have been proposed aiming to tackle the inefficiencies in the decentralized system to improve their individual performances and, consequently, the supply chain performance. These contracts involve commitments based on advance purchase, (capacity or purchase) options, sharing of revenue or cost, and/or capacity reservation commitments, through which the companies share some risks they face. Specific conditions under these commitments and the environment assumed define different contracts such as the following: advance purchase discount, push, pull, revenue-sharing, sale-rebate, buy-back, (full and partially) DR (deductible reservation), take-or-pay, pay-back and cost-sharing (see the next chapter for a brief presentation of these contracts). A detailed classification of contracts, according to the clauses that define them is given by Tsay et al. (2002). Anupindi and Bassok (2002) also review several supply contracts developed from the classical

inventory theory.

Note that, even though the studies aiming at the coordination of the companies are centered in the dyad's performance, one of the companies in its own interest can have the initiative of offering a contract. This company does not need be the more informed when it is possible to screen information from the other company by offering a menu of contracts with varying parameters (i.e. through a negotiation process). The company that offers the contract tries to get the most part of the dyad's benefits, that is, to give a minimum improvement, if any, to the other company.

On the one hand, there are cases in which it is natural that one of the parties takes the initiative. If there is uncertainty about the availability of supplies, the buyer company could be interested in offering a contract in order to ensure supply. He must make a commitment, or a set of commitments, that can be an advance purchase (firm order), an option (rights to exert "at-once" order) purchase or a capacity reservation. For that, he takes into account his belief about the demand forecast (a probability distribution). The buyer's motivation is to get potential cost reduction through early commitments, or to avoid future disruption of supply through sharing the risk of idle capacity faced by the supplier.

In a competitive supply environment, that is, when the buyer companies have an alternative source of supply, such as a spot market, the supplier company may have interest in offering a contract providing some incentives for the buyers to make advance purchase commitments thus ensuring additional demand. In some manufacturing settings, the investment in high capacity and the demand is quite uncertain, so the supplier company may take the initiative in offering a contract in order to diminish the risk of her capacity decision. If the supply capacity is scarce in the market, the buyers are willing to accept the contracts offered by the supplier assuring adequate future supply (Anupindi and Bassok, 2002; Jin and Wu, 2007), since they intent to share the supplier's capacity investment risk.

The problem to be treated in this work is the coordination of medium-term capacity decisions of a dyad of autonomous manufacturer companies who face uncertain market demands. The purpose of this coordination is to optimize the dyad's expected operational performance and, through an acceptable partition of the gain (resulting directly from the contract itself), improve the individual performance of each company. So, the motivation for the companies is to enhance their own performances so that each one will be better off than acting independently in the market. In contrast to the usual assumption in the literature, both companies are manufacturers implying finite

production capacity at each one, which need to be provided before demands are actually known.

Note that, since the medium-term capacity decision takes into account the short-term operational performance, the study involves a hierarchical planning problem in each company. Moreover, since each company is free to choose the contract or trade in the market, there may exist situations where market governance is more attractive than coordination through contract, something not admitted in some studies. It is also noteworthy that in reality most business-to-business supply contracts are between capacity constrained companies (usually manufacturers, but not excluding service providers). The medium-term capacity decision does have a profound consequence. Indeed, contrary to the uncapacitated situation, once the capacity is decided in the medium-term, sales in the short-term are limited to this medium-term capacity. This complicates the analysis, and thus, contracts between two capacity constrained companies have not extensively been studied.

The main objective in treating the problem defined above is to study, in a systematic and quantitative way, the degree of coordination that can be achieved by the supply contract under a given characterization of the environment and taking into account the randomness of the future market demand that each company faces when deciding on the medium-term production-capacity. Also, in the exploration of the contract proposed it is expected to obtain insights on relevant issues in the dyadic coordination aiming at possible extensions and applications in other settings. Therefore, the interest here is solely to assess the theoretical potential of the proposed contract. How to obtain the contract parameter values is of utmost practical interest but, similarly to other studies found in the literature, this issue will not be treated here.

The problem is studied through the analysis of a capacity reservation contract with reward-and-penalty, which is defined by the following parameters: a capacity commitment/reservation level, a fractional discount over the market price for the product traded between the companies, and a monetary penalty over the capacity units reserved but not ordered by the buyer company. The analysis of that contract is not centered in any particular company and considers the evaluation of the impact of the proposed contract on the joint performance of the companies, i.e. the sum of the individual performances as well as the possible partitioning of this total gain. So, the analysis of the contract proposed involves modeling expected profits under the contract situation, under independent decision making and under central planning. It also requires finding optimal contracts (i.e. contracts that produce maximal gain) to determine the potential improvement that the contract can produce for the

dyad, as well as its viability (i.e. attractiveness) for each company. So, two benchmarks are considered in the analysis of the contract proposed, the companies acting as units producing in a centralized system and the companies making their independent capacity decisions with no agreement between them and trading solely with the market.

This work is organized in six chapters. Chapter 2 reviews the relevant literature related to the problem treated here. A brief presentation is made of the types of contracts, addressing problems related to the one studied here. Then a taxonomy classification of them is presented in terms of the relevant issues treated in this research. In Chapter 3, the problem to be addressed in this dissertation and the manufacturing setting to be considered are discussed in detail. The proposed capacity reservation contract with reward-penalty is defined and the approach to be used for its analysis is sketched. The stochastic modeling and the general algebraic results obtained for the contract proposed are presented in Chapter 4, while the notation used and proofs for the lemmas and propositions are developed, respectively, in the appendices A, B and C. In Chapter 5, a numerical analysis is carried out for the case in which the companies' market demands are represented by instances of exponential probability density functions. The results obtained from that analysis are commented in that same chapter, while the expressions used, detailed numerical results and computational programs are shown, respectively, in the appendices D and E. Finally, general conclusions and directions for future research are presented in Chapter 6.