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# A contract for coordinating capacity decisions in a business-to-business (B2B) supply chain



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## ABSTRACT

We address the problem of coordinating the capacity decisions of two autonomous manufacturers engaged in a buyer–supplier relationship. We propose and analyze a supply contract designed to coordinate the companies' single period capacities so that both parties end up better off than they would by trading solely through the market. The setting is frequently found in supply chains, as the contract does not forbid the parties to also trade in the market. Under the proposed contract, each party decides on his own medium term capacity when demands are still only probabilistically known. When the demand is realized, the supplier must sell to the buyer at a discount contract price up to a contract reservation quantity, and the buyer will pay a contract penalty for each unit he reserved but did not order. The supplier can sell any leftover capacity on the market and if the buyer needs more than the reserved quantity, he must purchase from the supplier at market price or from the market if the supplier's capacity does not suffice. The main achievements gained through this research are (i) conditions for the companies' capacity decisions to obtain coordination under the contract, (ii) conditions for the contract to coordinate the parties' decisions and leave both better off, (iii) characterization of contract instances in which the profit can be arbitrarily distributed between the parties, and (iv) identification of two distinct kinds of gain produced by the contract. Finally, we illustrate the main properties of the contract with numerical examples.

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## 1. Introduction

This paper addresses the problem of coordinating the capacity decisions of two autonomous manufacturers engaged in a buyer–supplier relationship. Our purpose is to determine the conditions under which coordination can increase the dyad's joint expected profit and show that the companies can voluntarily agree on a supply contract that will induce them to act in such a way that both parties end up better off. We obtain insights into the effects a specific type of contract will have on the performance of each party. In particular, beyond the necessary conditions for the contract to be acceptable for both parties, we develop an original break-down of the possible win–win gain into two economically interpretable components. News-vendor-type buyer–supplier relationships are frequent in commerce, manufacturing and service industries, and, though multi-period

situations may be more common in practice, the analysis of a single period situation in the style of the newsvendor problem is more appropriate for our purpose.

The newsvendor model is a widely used tool in contract and coordination analysis (Cachon, 2003), and recent studies have used it in supply chain management (see, for example, Ryu and Yücesam, 2010; Chen, 2011; Egri and Váncza, 2012). Although, in a strict sense, it is a single-period model, it allows the high-level analysis of several strategic decision problems. In these problems, decisions such as the capacity for a future time period (for which considerable capital investment is required) need to be taken prior to the revelation of uncertainty and, after uncertainty has been resolved, short-term recourse decisions like production quantities are made. Following a general research tradition in this field, our analysis resorts to this simplification for analyzing the interaction between first-stage (capacity) decisions under uncertainty and short-term recourse (production and sales) decisions under certainty. There is some literature on optimal supplier–retailer coordination of strategic investment decisions in a multi-period time frame. Chen (2012), for example, investigates the optimal timing of strategic investment decision in

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a supplier–retailer relationship assuming stochastic demand on continuous time. However, most of these works do not delve into the problem of devising a contract capable of promoting cooperation.

We study a dyad composed of two manufacturing companies that, for grammatical ease, hereafter will be called Supplier (a feminine persona denoted by  $S$ ) and Buyer (a masculine persona denoted by  $B$ ). Both companies are considered autonomous and free to trade in the market and to engage in supply contracts. We propose and analyze a two-party contract of capacity reservation with reward-and-penalty whose mechanics is the same as the ones in Serel et al. (2001), Özer and Wei (2006), and Jin and Wu (2007). In fact, still other similar contracts have been investigated in the literature. However, as will be shown in the following section, the environment we assume, the focus of the analysis and other important details of this research allowed new relevant and original results.

The contract analyzed in this paper involves two periods of time: (a) the medium term, when each party still has only a probabilistic knowledge of his/her own demand and, later on (b) the short term, when these demands become known with certainty. Having its terms accepted by both parties, the contract establishes the following three parameters: (i) a contract capacity reservation level ( $R$ ); (ii) a contract percentage discount ( $d$ ), and (iii) a per unity penalty ( $t$ ). In short, Buyer will pay to Supplier the discount price for all units ordered up to  $R$ , and market price for all units exceeding  $R$  that she can still provide him with. If Buyer's needs exceed Supplier's capacity he will buy from the market (assumed to have unlimited capacity). Else, if Buyer orders less than  $R$ , then he will pay to Supplier the penalty  $t$  for each unit short of  $R$  (see details in Section 4).

This contract requires Buyer to inform Supplier about his (probabilistic) belief with respect to his future order, which is formalized as a probability distribution. It is reasonable that Buyer provides this information, because the terms of the contract make it useless for any opportunistic action from Supplier. It is also plausible to assume that Buyer will inform truthfully because, although he can inflict a loss to Supplier by misinforming her, he cannot profit from doing so in the assumed setting. Indeed, inducing Supplier to build excess capacity by communicating an inflated expectation will not affect the total discount or penalty because the contract parameters are established in advance.

It is also implicit that Supplier complies with the terms of the contract, i.e. to set her medium-term production capacity at no less than the contract commitment level  $R$  (legal accountability may be established because capacity is often observable). Actually, if Supplier reserves less than the committed capacity  $R$ , and if this implies a very low probability of being unable to fully honor Buyer's order, she may be better off running the risk of paying some finite penalty for not complying. However, this is likely to produce only a small effect and will not be investigated here. Beyond the quantity specified in the contract, she will build capacity to serve her (probabilistically known) market demand and the additional probabilistically revealed Buyer's order.

In this work, a contract will be said to be (fully) *coordinating* if it induces the dyad to attain maximum joint expected profit. It will be *partially coordinating* if it produces a positive gain over acting in isolation (i.e. both companies trading solely in their markets and exchanging no information), but is not (fully) coordinating. A contract will be deemed *viable* for a company if it leaves the company better off than in the scenario of making decisions independently (i.e. without a contract with the Supplier), and *dyad-viable* if it leaves both companies better off. Also, for assessing the coordinating properties and the convenience of the contract for each company, we consider two general benchmarks, namely independent planning and central planning.

It will be assumed that, without any contract, each company trades its inputs and outputs independently on its respective perfect competition markets at deterministically known market-given prices. In the medium term, each company has to decide on its capacity

while the demand is only probabilistically known. Later on, in the short term, when the demand becomes deterministically known, the decision on how much to produce will be constrained by the decided medium-term capacity. There is a cost for building capacity and, in the short term, the company loses sales if the demand exceeds its capacity; otherwise, if the demand turns out to be below capacity, any excess capacity or production will not have any residual value. This mode of trade will be referred to as *independent planning (IP)* in this paper. However, business might be better than expected under the *IP* regime. The companies may be interested in establishing a supply contract if such a contract allows each one to increase its own expected profit as a consequence of improving their joint efficiency through better coordination of their capacity decisions. In the central hierarchy mode, here called *central planning (CP)*, Buyer and Supplier can be seen as two production stages of a single company. Therefore, planning is done by a single entity with full planning information and authority for making decisions and enforcing them in order to maximize the performance of the company. Thus, *CP* is capable of achieving full coordination.

This study diverges from most of the literature in that it does not consider the parties in isolation from the market. In reality, of course, there is hardly ever a single buyer–vendor relationship within a supply chain. Mostly, both parties are embedded into different networks and environments. Our view and contribution are original by explicitly modeling the two random markets for both parties and taking this environment into consideration (admittedly, in a very aggregate way). We zoom into a single dyadic buyer–supplier relationship to illustrate the problem and benefits of bilateral coordination. We assume that the parties can legitimately trade with their markets both before and after entering into the contract. This generates two distinct improvement effects as follows.

Assuming, as we do, the markets in perfect-competition equilibrium, detaching Buyer from Supplier's market has no effect on it. Consequently, when the companies enter into the contract, Supplier has Buyer's future (probabilistic) order in addition to her own (probabilistic) market demand. We will refer to this (or to its resulting expected profit gain) as *demand effect*. The demand effect will always induce some gain and Supplier could obtain it by giving an incentive to Buyer (such as a small discount) that might be an extra motivation for earning his preference, as we are used to see in street commerce. In general, however, it is not possible to achieve full coordination by just capturing Buyer's preference. With a lower price for his input, Buyer may gain still more by increasing his capacity and Supplier may also find it worthwhile to follow expanding hers in order to profit from the increased demand, thus eliminating double marginalization (for this concept see, for instance, Spengler, 1950). We will refer to these capacity readjustments (and to the gain associated) as *alignment effect*. Under our assumptions, to obtain full coordination, a contract more elaborate than the discount-only contract is necessary. This is because some exchange of capacity information must occur (in the form of quantity or in the form of price) between the parties, we propose as in the contract.

The above discussion exposes the need to isolate the demand effect in the analysis of the proposed contract in order to observe when the alignment effect comes into play. This can be done conveniently by defining an artificial regime that we here will call *modified independent planning (IP')*. Though similar to the *IP* regime, *IP'* considers Buyer's probabilistic future order added to Supplier's own original market demand. It is the extra profit that Supplier can obtain from this increased demand that we call “demand effect”. That is, in *IP'* it is assumed that, even without a contract, Buyer reveals to Supplier his true belief (probability distribution) about the future order he will place to her under *IP*, and she uses it for deciding about her capacity. Since we use *IP'* regime only as an artifice of analysis, its realism is not an issue.