



Capacity reservation under spot market price uncertainty

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ABSTRACT

Capacity reservation contracts and spot markets are two alternative purchasing practices. We focus on the cost-effective management of the combined use of these two procurement sources. Due to the variability of the spot market prices and demand uncertainty, the flexibility of combined sourcing can be advantageous. Spot market purchasing is a benefit in case of low spot market prices or insufficient reserved capacity, and the capacity reservation contract is an operational risk hedging for high spot market price incidents. The structure of the optimal combined purchasing policy is complex. In this paper we consider a simple and easy-to-implement capacity reservation—base stock policy and compare it to single sourcing options. We examine the joint effect of demand and spot market price uncertainty. Our analysis shows that in the case of large spot market price variability the combined sourcing is superior over spot market sourcing even in the case of low average spot price. The combined sourcing is also superior over long-term sourcing even in the case of high average spot price if there is large spot market price variability. Analytical and simulation results are presented to show the effect of the different price, cost, and uncertainty parameters on the optimal capacity reservation—base stock policy and on the expected percentage gain over single sourcing.

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1. Introduction

With the increase of component production outsourcing, the share of purchasing cost increased up to 50–90% of the total revenue of manufacturing companies (de Boer et al., 2001), becoming a critical element of competitiveness. Further globalization of trade and the Internet extended the procurement sources, making decisions about purchasing more complex. The simple price contract has been extended to several contract forms including the *capacity reservation contract* extensively used for purchasing chemicals, commodity metals, semiconductors, and electric power (Kleindorfer and Wu, 2003). In electric power generation the so-called “tolling agreement” (see Woo et al., 2006) offered by a generator gives the local electricity distribution companies the right, but not the obligation, to dispatch a generation unit specified by the agreement. Some contracts entail any desired portion of a reserved capacity for a fixed unit price in exchange for a reservation price paid by the buyer. This is a form of real option since the buyer has the right to exercise the purchase in the future for a contracted price up to a contracted quantity. Long-term procurement price is, on average, lower than the price of short-term supply. Long-term contracts provide price stability but much less flexibility even with the option that the reserved quantity is not required to be exercised.

Spot market sourcing has a large flexibility but also a high risk of price increase. It is a common method for purchasing commodities such as steel, oil, and chemicals. Around 30% of the memory chips are bought on spot markets according to the Gartner Group estimates (see Andren, 2000 and Seifert et al., 2004). With the growing importance of electronic commerce and global sourcing, the spot market is competing with contract based procurement. A 2002 survey shows that 57% of industrial buyers ranging from automotive to electronics increased “just-in-time” purchases and reduced buying based on long term contracts (Ansberry, 2002). In this environment of multiple procurement options with differences in costs and flexibility, the process of coordinating the procurement activities has become more difficult including the decision about the alternatives of long-term procurement contracts versus short-term procurement or if a combination of both alternatives should be used.

Capacity reservation contracts and spot markets are two alternative purchasing practices. This contribution focuses on the cost-effective management of the *combined use of these two procurement options*: the short-term option is given by a spot market with a random spot-market price, whereas the long-term alternative is characterized by a wholesale price contract with a capacity reservation level. The planning situation we consider is made more complex by the fact that in addition to the stochastic spot-market price also the randomness of demand at the time of the procurement is taken into account. Under these conditions, the managerial decision is to fix a long-term capacity reservation level and to decide period-by-period on how to combine the two

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supply options in order to profit from the cost savings of long-term procurement while still remaining flexible using the spot procurement option. Spot purchasing is a benefit in case of low spot price or insufficient reserved capacity and the capacity reservation contract is an operational risk hedging for high spot market price incidents.

Next we review the *relevant literature*. Several papers consider only one of our purchasing sources: capacity reservation contracts or spot market purchase. We summarize briefly these two areas first. A number of papers have been published lately on combined sourcing using contracts and spot markets. These papers are summarized thereafter, emphasizing the differences among these approaches and our research problem.

Various types of supply contracts involving *advance capacity reservations* have been investigated, generally based on a single-period framework. The pricing of option contracts has been investigated by *Ritchken and Tapiero (1986)* first and has been extended in several papers, like in *Wu et al. (2001)* where the price of real option depending on capacity availability is investigated from a financial point of view. *Jin and Wu (2001)* analyzed capacity reservation contracts between a single supplier and multiple buyers with reservation fees deductible from the purchase price paid at delivery. *Deng and Yano (2002)* studied the contracts between a component supplier and a manufacturer involving a fixed wholesale price for advance purchases, and a spot price determined and charged for purchases after the demand is realized. Other papers dealing with the use of real options in supply chains include *Kamrad and Siddique (2004)*. *Erkoc and Wu (2005)* model the negotiations between a manufacturer and a supplier when the supplier has to make a costly investment in additional production capacity. *Burnetas and Ritchken (2005)* considered the impact of option contracts on the wholesale and retail prices under price-dependent demand in a manufacturer–retailer chain.

Some early contributions reveal that *purchasing on the spot market* with changing prices is much more than inventory replenishment. *Morris (1959)* develops a policy for spot buying depending on the daily changes of price. *Fabian et al. (1959)* apply dynamic programming to develop an optimal purchasing strategy for a known demand pattern. *Kingsman (1969)* deals with tactical commodity buying, using safety stock and treating demand as deterministic, acknowledging though, that for different buying opportunities at different prices it is not feasible to ignore the stochastic nature of the future prices. In our research the random price characteristic of the spot market is the focal point and the alternative purchasing option using a capacity reservation contract is also included. Purchasing and price connections are widely examined in the finance literature as connections of operations and finance. *Tapiero (2008)* combined price and purchasing policy when both the demand and the price are uncertain, explaining the reason behind the practice of purchasing materials traded in speculative financial markets.

The closest to our research problem is the stream of recent papers on procurement strategies *combining spot market purchases with purchases based on reservations* made in advance from a specific long-term supplier. *Henig et al. (1997)* derived a three-parameter optimal policy but without the consideration of uncertainty that is a critical factor in practice. *Bonser and Wu (2001)* studied the fuel procurement problem for electric utilities in which the buyer can use a mix of long-term and spot purchases. Our problem of combined purchase from spot market and capacity reservation was first defined and studied in the supply chain literature by *Serel et al. (2001)*. They considered a simple capacity reservation—order up policy but they disregarded the spot market price uncertainty. *Wu et al. (2001)* considered uncertainty in spot market prices and analyzed the contracts for non-storable goods involving options executable at a predeter-

mined price. Using a similar single-period model, *Spinler and Huchzermeier (2006)* show that, mainly due to the decrease in the supplier's production costs when an options contract is used, the combination of an options contract and a spot market is Pareto improving with respect to the other alternative market structures. *Seifert et al. (2004)* also analyzed a single-period problem from the buyer's standpoint with changing levels of buyer's risk preferences. *Kleindorfer and Wu (2003)* linked this literature to evolving B2B exchanges on the Internet. In *Sethi et al. (2004)* a situation with both demand and price uncertainty is taken into consideration and a quantity flexibility contract is employed, but no capacity reservation takes place. The model described in *Serel (2007)* is the closest to our research; we also use a similar notation. Spot market capacity uncertainty is considered by *Serel (2007)*, but the paper does not deal with price uncertainty. We concentrate on the spot price uncertainty which we believe is a more typical problem than capacity uncertainty under the current extended spot market opportunities. The recent publication of *Serel (2008)* deals with the negotiation between a newsvendor (retailer) and a manufacturer when there is competition from a second supplier.

In our paper, we consider both demand and spot market price uncertainty in a multi-period framework. The optimal combined purchasing policy structure is a complex three-parameter decision policy with a price-dependent order-up-to level for short-term procurement. In this paper we consider a simple and easy-to-implement capacity reservation—base stock policy and compare it to single sourcing options, examining the joint effect of demand and spot price uncertainty. In Section 2, the optimal parameters of the capacity reservation—base stock policy are derived. In Section 3, analytical and simulation results are presented to show the effect of the different price, cost, and uncertainty parameters on the optimal sourcing policy. In Section 4, we compare the optimal base stock policy, combining capacity reservation and spot market procurement, with the optimal single sourcing policy of using only short-term spot market and also with the optimal single sourcing strategy using only capacity reservation. We discuss under which conditions it is better to use the combination of both alternatives and what is the expected monetary gain compared to the single sourcing options. We close the paper with a summary of the results and future extension plans.

2. Simple base stock policy combining capacity reservation and spot market procurement

In this section we derive the optimal combined capacity reservation—base stock policy parameters. As it is common in the relevant literature, we consider independent and identically distributed (i.i.d.) random product demand, ξ , and random component spot market price, π , per period. For a large spot market we can assume that our purchase and demand does not influence the spot market price, so we consider no correlation between demand and spot price. We use the following notation:

$F(x), f(x), \mu_x, \sigma_x$ distribution, density function, expected value and standard deviation of *demand* and

$G(p), g(x), \mu_p, \sigma_p$ the same distribution characteristics for the *spot market price*.

We consider a periodic decision process involving different level of knowledge in time. The *first decision* is on

R the capacity reservation quantity that must be *fixed for a longer time horizon* based on the random demand and

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