Managing Demand Uncertainty with Dual Supply Contracts

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Abstract

We consider a single product, dual supply problem under a periodically-reviewed finite planning horizon. The downstream party, manufacturer, receives supply from two upstream parties, local and global suppliers with consecutive leadtimes (i.e., the leadtime of the global supplier is one period longer than that of the local supplier). The suppliers offer complementary contracts in terms of transfer prices and leadtimes; thus, the manufacturer faces a trade-off between the responsive local supplier and the cost-efficient global supplier. We model the manufacturer’s problem in two stages: (i) she first chooses a portfolio of contracts (one from each supplier) and reserves capacity levels (at the prices specified by the contracts) for the whole planning horizon; (ii) she then orders from the suppliers according to the terms of the contracts chosen in the previous stage. In our second-stage problem, we prove that a two-level modified base-stock policy is optimal for a wide range of transfer prices. With various analytical results and numerical analysis, we illustrate how the optimal policy parameters change with respect to problem parameters. A reserve-up-to policy is shown to be optimal for the manufacturer’s capacity reservation problem. We also develop a methodology that can be used to explain diverse sourcing strategies (such as in-house vs. offshore production) practiced by many companies in various industries.

Keywords: Dual supply, demand uncertainty, consecutive leadtimes, minimum and maximum order bounds, option contracts, capacity reservation, portfolio selection.

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In today’s global economy, offshoring is a critical component of many supply chains. Increasing numbers of companies in a variety of industries now rely on global suppliers to lower costs, improve quality, and increase capacity. The Swedish retail chain IKEA, for instance, has a supply base consisting of more than 1800 suppliers in 55 different countries (Margonelli, 2002). Although IKEA’s sales are mostly in European markets (with 81% of total sales), only 66% of total purchases are made in that region. On the other hand, they acquire a significant amount of goods (31% of total purchases) from suppliers in Asian countries, whereas only a minor portion (less than 3%) of total sales are in Asia (IKEA Corporate Website, 2005).

In most cases, local and global suppliers provide complementary services in terms of prices, leadtimes, quality, etc. Hence, companies face a trade-off between the two supply alternatives. For instance, by working with a local supplier in close proximity, a company can be more responsive to uncertain customer demand. On the other hand, a global supplier usually provides a significant cost advantage by offering cheaper prices at the expense of longer leadtimes. In this case, an attractive solution is to use the two resources together in a portfolio with the flexibility to exploit the individual advantages. Choosing the right portfolio of suppliers, however, is a complicated task. Even though the increased flexibility of dual sourcing is available for most products in many industries, the implementation of the dual supply solution is seldom the same for different products. In fact, a good solution for a particular product can result in drastically different, even disastrous, outcomes for another.

According to Fisher (1997), companies should match their products with a suitable supply chain structure in order to improve their performance: an “innovative” product with a “responsive” supply chain and a “functional” product with a [cost] “efficient” supply chain. Spanish fashion group Zara is a successful example of a responsive supply chain. A significant portion of Zara’s suppliers (around 85%) are located in Europe (mostly in Spain), whereas the rest are mainly in Asian countries (Ferdows et al., 2004). On the other hand, as we discussed, IKEA, which operates an efficient supply chain, has a more diverse supplier base. The difference between the supply chain strategies of the two companies can be attributed to the characteristics of the products they provide. It is reasonable to assume that the expectations of customers shopping for a scarf at Zara and a pot at IKEA are completely different; thus, these companies
need different supply strategies to be successful.

Our main objective in this study is to investigate the trade-offs in constructing a portfolio of two (local and global) suppliers offering the same product with complementary services. We develop a framework that analyzes the benefits of dual sourcing as a tool to manage demand risk. Our results can be used to explain diverse sourcing strategies such as in-house vs. offshore production practiced in various industries. We prove that it is optimal to reserve capacity from the two suppliers according to a reserve-up-to policy. We also show the optimality of a two-level modified base-stock policy under a wide range of transfer prices for a capacitated dual supply problem with consecutive leadtimes.

1 Model Definition

In order to analyze various dual supply scenarios, we consider a single product, periodically-reviewed system under a finite planning horizon. We assume that there is a downstream party, manufacturer, who receives supply from two upstream parties, suppliers, each with limited capacity allocated to the manufacturer. The two suppliers differ from each other with their fixed leadtimes and the contracts they offer. Although the global supplier has a longer leadtime, this option provides a cost advantage over the local supply. The manufacturer has to satisfy a random customer demand for each period of the planning horizon using a portfolio of the two sources available.

We assume consecutive leadtimes, i.e., the global supplier has a leadtime one period longer than the local supplier. Even though it sounds restrictive at first, this assumption is realistic in many situations. Consider an environment where the manufacturer places orders once a month. Shipping goods from the global supplier takes around a month, while shipping from the local supplier is almost instantaneous. The total leadtime is composed of the manufacturing and transportation leadtimes. In this case, it is reasonable to assume that the manufacturing leadtimes are equal for local and global suppliers. Hence, the difference between the leadtimes is only due to the transportation of the product, which is 0 for the local supplier and 1 for the global supplier in this example.
Each supplier independently offers a menu of option contracts to the manufacturer at the beginning of the planning horizon. Option contracts are defined as an agreement between the manufacturer and the supplier, which gives the manufacturer the right but not the obligation to place an order at a specified cost within certain order bounds. In this contract structure, the manufacturer pays for both reserving capacity and executing her options (i.e., ordering within the predetermined capacity limits) from the suppliers. In addition to these transfer payments, contracts can also include exogenous order bounds, such as capacity limits or minimum order quantities.

The manufacturer’s goal is to minimize the sum of (i) the cost of contracts and (ii) the cost of operating under chosen contracts. The first term represents any upfront payment made by the manufacturer to reserve capacity from the suppliers. The second term consists of two major cost categories: ordering-related and inventory-related costs. We use ordering-related costs to denote the purchasing costs of the manufacturer (i.e., execution costs), whereas the inventory-related costs correspond to the cost of backordering excess demand or holding excess inventory. We formulate the model as a two-stage optimization problem: (going backwards) at the second stage, finding the optimal order quantities from each supplier given the contract terms; at the first stage, choosing the best contracts among the available menus of contracts.

There are various scenarios that can appropriately fit into this dual supply problem setting. Instead of two independent suppliers, we could also assume a single supplier with two different production/transportation options, where local orders correspond to expedited channel and global orders correspond to regular channel. Although the analysis is similar in both scenarios, in our discussions below we use the more interesting independent suppliers scenario.

2 Analysis of the Second-Stage Problem

In the second-stage problem, the manufacturer orders from the suppliers given the terms of the contracts chosen at the previous stage. Due to different leadtimes and transfer prices offered by the suppliers, the manufacturer faces trade-offs in ordering decisions; her goal is to minimize the sum of ordering-related and inventory-related costs. The events in any period follow the
same sequence. At the beginning of a period, the manufacturer first observes the pipeline inventory. The on-hand inventory is the only source available to satisfy the demand at the current period. This inventory can also be negative, which means there is still backordered demand from the previous periods; thus, the current demand has to be backordered as well. Knowing the current situation of the pipeline inventory, the manufacturer places first the local and then the global orders. She then satisfies the random demand of the current period (if there is available inventory). In order to facilitate cost accounting, we assume that the ordering costs are incurred at the beginning of a period, whereas the inventory holding and shortage costs are incurred at the end of the period. The last event in the period is the update of the pipeline by shifting the inventories considering the ordering decisions and the demand realized in the period.

We show that the optimal ordering policy is what we call two-level modified base-stock policy. The manufacturer first aims to increase her inventory position to constrained order-up-to level considering the restrictions imposed by her contract with the local supplier; afterwards, she places her global order in order to increase the inventory position to unconstrained order-up-to level, however, again considering the contract terms.

3 Analysis of the First-Stage Problem

We analyze the first-stage problem in two parts. In the first part, we determine the optimal reservation quantities from each supplier given a pair of contracts, i.e., one contract from each supplier. We call this part capacity reservation problem. In the second part, given menus of contracts, we select the best contract pair, which we call portfolio selection problem. We consider the previously exogenous contract parameters, such as costs and order bounds, and investigate the manufacturer’s optimal choices. To the best of our knowledge, such an analysis is the first in dual supply literature.

The sequence of events for the first-stage problem is as follows. First, each supplier offers a menu of contracts to the manufacturer. Observing these menus, the manufacturer then chooses a pair of contracts; her goal is to minimize the sum of the cost of the contracts (any upfront
payments made by the manufacturer due to the cost of reserving capacity from the suppliers) and the expected cost of operating under the chosen contracts (calculated according to the formulations of the second-stage problem discussed in Section 2).

There are many different forms of contracts used in supply chains; nevertheless, we limit our discussion to option contracts. We define an option contract as an agreement between the manufacturer and the supplier, which gives the manufacturer the right but not the obligation to place an order at a specified cost up to certain order bounds\(^2\). Thus, this contract structure provides a flexible supply opportunity to the manufacturer against the uncertain demand.

We show that the optimal policy for the capacity reservation problem is what we call reserve-up-to policy. Given a pair of contracts, there are optimal local and global capacity levels, up to which the manufacturer is interested in reserving from the suppliers. Any capacity levels reserved higher than these reserve-up-to levels imply redundant capacity; hence, the additional benefit of higher capacity is outweighed by the additional cost of reserving it. Similarly, if the manufacturer reserves less than these levels, she then operates under insufficient supply capacity; thus, increasing the capacity levels implies an overall reduction in cost.

The optimal solution of the capacity reservation problem plays an important role in the first-stage problem of supplier portfolio selection. Because the manufacturer is offered a finite set of contracts in each menu, the portfolio selection problem is merely the evaluation of all capacity reservation problems formed by the possible combinations of contracts in each menu. Therefore, we can easily solve the manufacturer’s first-stage problem.

4 Conclusion and Future Research

In this paper, we modelled a dual supply problem of a manufacturer purchasing a single product from two suppliers with consecutive leadtimes. The manufacturer’s problem consists of two stages: (i) she first chooses a portfolio of option contracts (one from each supplier) and reserves capacity levels (at the prices specified by the contracts) for a finite planning horizon; (ii) she then orders from the suppliers according to the terms of the contracts chosen in the previous

\(^2\) Because we concentrate on the option contracts in this section, the lower order bounds \(m_a^u\) and \(m_b^u\) are assumed to be zero for the whole planning horizon.
In our second-stage problem, we prove that a two-level modified base-stock policy is optimal for a wide range of transfer prices. Due to the separability property of the cost functions in the second-stage problem, we are able to characterize the optimal policy parameters in detail and use these results to evaluate the contracts of the first-stage problem. A reserve-up-to policy is shown to be optimal when the manufacturer reserves capacity from a given contract pair.

Because the suppliers offer complementary contracts in terms of transfer prices and leadtimes, the manufacturer faces a trade-off between the responsive local supplier and the cost-efficient global supplier. With numerical experiments, we show that the manufacturer's decisions can be explained in a framework, which depends on the characteristics of the product as well as the supply and demand conditions.

Our methodology can be used to explain diverse sourcing strategies (such as in-house vs. offshore production) practiced by many companies in various industries. We show that when the weight of the ordering-related expenses form a significant portion of the total cost of the product, the manufacturer seeks to reduce costs at all means; which leads her to use the cost-efficient global supplier more than the local. On the other hand, if manufacturer is producing an inventory-costs-driven product, characterized by high holding and/or penalty costs, the manufacturer has an incentive to use a responsive supplier in addition to global resources.

We plan to extend our analysis to investigate different contract structures. This paper does not explicitly consider the supplier’s problem; we are currently working on supplier’s choice of menu of contracts. An interesting, however quite involved, extension is the portfolio selection problem with nonconsecutive leadtimes: the manufacturer can choose a portfolio with different leadtimes and cost trade-offs. This would be an initial step towards leadtime-based contracts.