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Comparing sourcing strategies in two-echelon supply chains

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ABSTRACT

We investigate four sourcing models with respect to either cooperative or non-cooperative planning strategies and either sole or dual sourcing. A two-stage supply chain is considered. It involves a single buyer and either one or two supplier(s)/vendor(s). At the buyer, the product is consumed at a constant rate and an (r, Q) inventory control policy is used for replenishments. The delivery lead time from the vendors is stochastic. The cost function comprises five elements: inventory holding costs for buyer and vendors, backorder costs and ordering costs for the buyer, and setup costs for the vendors. The objective is to minimize total system costs incurred at the buyer and the vendors. As there is no overall dominating combined sourcing strategy, a major finding is that determining the best strategy requires a detailed analysis. However, when total system costs are taken into account, dual sourcing does not appear as beneficial as sometimes claimed in the literature on order splitting.

1. Introduction

Sourcing is a fundamental element in supply chain management and organizations need to consider alternatives to traditional sourcing principles. The best sourcing strategy based on the internal and external factors at hand may be specified with respect to several different strategic attributes. Among these attributes are the number of suppliers to source from for each product and the level of coordination with the chosen suppliers. This paper analyzes the combined cost implications of these two strategic choices.

The choice of the number of suppliers is an issue that has been under much discussion in the literature on different management concepts. There are several arguments in favor of using either a single supplier or multiple suppliers. Concepts such as Just-In-Time, Lean Manufacturing, and Total Quality Management often suggest reducing the supplier base and building long-term relationships with important suppliers. However, risk exposures as well as the availability of e-commerce with opportunities for spot market replenishments emphasize advantages of multiple sourcing. As one of the focal points in this paper, we study order splitting in dual sourcing and its relation to total replenishment costs.

With regard to multiple sourcing, the order-splitting literature focuses on splitting orders simultaneously among several suppliers in order to obtain reductions in total system cost. The first paper in this stream of literature was published by Sculli and Wu [19]. They study an inventory system with two sources, where lead times are normally distributed. The numerical results indicate that the reorder level required for a given stock-out probability is lower than in the corresponding single source system. Later, Ramasesh et al. [14,15] develop analytical models with two sources, where demand is assumed to be constant and both sources have exponential lead-time distributions.

Chiang and Benton [3] investigate a model with normally distributed demand and shifted exponential lead times. Hill [9] uses a similar framework for analyzing the cycle stock under order splitting and shows that multiple sourcing reduces the average stock levels for any reasonable lead-time distribution. Ryu and Lee [16] consider dual-sourcing models assuming exponentially distributed lead times and constant demand. They use expediting cost functions and demonstrate how an investment to reduce lead times can result in significant savings. Recently, Glock [5] incorporated a learning effect in single and dual sourcing decision models. For further literature, we refer to the papers by Minner [12] and Thomas and Tyworth [20] which provide comprehensive surveys of order-splitting problems. The latter also includes a critical review of the order-splitting literature. One of the key points in this critique is the lack of analyses in a supply chain context. This issue is addressed in our paper.

Coordination of activities within a supply chain facilitated by the sharing of information allows companies to provide products and services at a reduced cost. With traditional inventory management, production and shipment in a dyadic supply chain link are managed independently by the supplier/vendor and the buyer. As a result, the optimal lot size for the buyer may not result in an

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optimal policy for the vendor and vice versa. And in general, neither of the two is optimal for the dyad as a whole. To overcome this difficulty, the integrated vendor–buyer model has been developed, where the joint total relevant costs for buyer and vendor are minimized. In the literature, one stream of research that deals with this integrated vendor–buyer problem is referred to as the Joint Economic Lot Sizing (JELS) problem. Our paper is related to this stream of research because the supply chain coordination is our second focal point.

Goyal [6] was one of the first to introduce the idea of a joint total cost for a single vendor and a single buyer scenario. The assumptions of an infinite production rate and a lot-for-lot shipment policy were relaxed by Banerjee [1] and Goyal [7], respectively. Goyal [8] develops a model where the shipment size increases by a factor equal to the ratio of the production rate to the demand rate. Hill [10] generalizes the model of Goyal [8] by including the geometric growth factor as a decision variable. Hill [11] relaxes the assumptions of the shipment policy and develops an optimal solution for the problem. He shows that the structure of the optimal policy includes shipments initially increasing in size according to a geometric series followed by equal-sized shipments.

The existing literature on JELS encompasses a number of different problem sub-categories (see, e.g., [13,18,21,22,23]). We refer further to Ben-Daya et al. [2] and Glock [4] for comprehensive reviews of JELS problems.

The main contribution of our paper is the integration of the two above mentioned streams of literature into models which can be used to analyze four different sourcing scenarios (see Fig. 1). On the one hand, these models can be regarded as JELS models in which more than one supplier/vendor provides the product. On the other hand, they can be regarded as order-splitting models in which the joint costs of the buyer and the suppliers/vendors are optimized. Thus, we analyze the combination of sourcing and coordination decisions in order to find the optimal strategy and its associated costs.

The best overall sourcing strategy generally depends on a number of factors such as vendor capabilities, demand stability, the level of trust among the supply chain parties, etc. In this paper we focus on the operational costs of setups, ordering, inventory holding, and shortages to determine the best sourcing strategy. When comparing the supply-chain wide operational costs in the four different sourcing scenarios, there is no completely dominating strategy. However, our results suggest that companies should focus primarily on the strategy of coordinating with a single vendor. For a relatively broad range of parameter values, dual sourcing is not found to be advantageous. This is in contrast to conclusions often found in the order-splitting literature.

The rest of the paper is organized as follows. In Section 2, the problems and the strategy scenarios are defined. Notation and assumptions are also introduced. Section 3 provides a specification of each of the sourcing models. The solution approaches are also specified in this section. Section 4 presents numerical examples and an extensive sensitivity analysis. The main findings and further research directions are summarized in Section 5.

2. Problem definition and notation

Consider a single product supply chain dyad consisting of a single vendor and a single buyer. The final demand for the product is assumed to be deterministic and constant. The lead time on the other hand is stochastic. The lots delivered from the vendor to the buyer are equally sized batches. As soon as the inventory position at the buyer drops to r, an order of size Q is issued by the buyer. The vendor manufactures the product at production rate P and

Sourcing / ***Coordination***	Sole sourcing	Dual sourcing
Non-cooperative	*Scenario SN*	*Scenario DN*
Cooperative	*Scenario SC*	*Scenario DC*

Fig. 1. Four sourcing scenarios obtained from the combination of sourcing and coordination strategies.

in lot sizes which are a multiple n of Q. The cost of the system includes setup, ordering, holding, and shortage costs. The objective is to determine the number of lot shipments n, the reorder point r, as well as the order lot size Q so that the total expected long-run average costs of vendor and buyer are minimized.

Considering sole and dual-sourcing strategies as well as cooperative and non-cooperative strategies, there is a total of four possible sourcing scenarios. In the cooperative strategy, the total expected costs are optimized jointly, whereas in the non-cooperative strategy, they are optimized individually. As can be seen in Fig. 1, Scenario *SN* represents the setting in which the buyer sources the product from a single vendor, and there is no cooperation between them regarding coordination of replenishment policies. Scenario *DN* also represents the non-cooperative case, but under a dual sourcing strategy. If the supply chain members decide to coordinate replenishments with each other, then Scenarios *SN* and *DN* transform into Scenarios *SC* and *DC*, respectively.

Scenarios *SN* and *SC* have been studied before by Sajadieh et al. [17]. On the one hand, this paper can be considered an extension of their JELS model into the dual-sourcing context. But as noted above, it can also be viewed as an extension of the order-splitting models into an integrated model in which the total costs of the buyer and the vendors are optimized jointly. This contrasts with several previous studies of order splitting in the literature.

The following assumptions are common to all four strategy scenarios:

1. The model deals with a single buyer for a single product.
2. The final customer demand rate D is deterministic and constant.
3. Inventory is continuously reviewed and infinitely divisible. The buyer orders a lot of size Q when the inventory position reaches the reorder point r.
4. Lead-time to replenish the buyer's order is a stochastic variable L that follows an exponential distribution, i.e., $L \sim \exp(\lambda)$ with $E(L) = 1/\lambda$.
5. Replenishment orders do not cross in time. This is approximated by requiring that the probability of order crossover is small.
6. Shortages are allowed and completely backordered.
7. The vendor (manufacturer) has a finite production rate P which is greater than the demand rate D.
8. The vendor manufactures a batch nQ, where n is an integer, at each setup, and each batch is delivered to the buyer in n equal sized shipments.
9. The time horizon is infinite.

The cost parameters are

A_V Setup cost for the vendor(s)
A_B Ordering cost for the buyer
h_V Inventory holding cost for the vendor(s) per unit per unit time