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Single sourcing versus dual sourcing under conditions of learning

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A R T I C L E I N F O

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A B S T R A C T

This paper considers a buyer who has to decide whether to select a single or two sources of supply for a homogeneous product. The production processes of the suppliers are subject to learning effects, which reduce the production costs and increase the production capacities of the suppliers. This, in turn, enables the suppliers to reduce the sales price, which results in lower acquisition costs at the buyer. As the supplier selection decision influences the individual production quantity of a supplier, the learning effect has to be considered when deciding how many and which suppliers to select. Since the effect of learning on the supplier selection problem has not been investigated in the literature, this paper addresses this limitation and derives models for continuous learning and when learning plateaus. Numerical results indicate that the supplier selection decision can comprehensively influence the learning process for the suppliers and therewith the total costs of the system under study. The results also show that it is not necessarily optimal solely to select the supplier with the highest learning rate.

1. Introduction

In many industries, the purchasing volume, defined as the total amount of money a firm spends on acquiring parts, materials, components, and services from external sources, reaches an average of approximately 60% of the firm's revenue (see Monczka, Trent, & Handfield, 2005; van Weele, 2000). Thus, a firm has to carefully select suppliers to reduce acquisition costs and improve its competitive position. The evaluation process that precedes the supplier selection decision involves a variety of tangible and intangible factors that need to be considered (see, for example, Ellram, 1990; Swift, 1995). The supplier evaluation and selection process received considerable attention in the literature resulting in a variety of models that provide quantitative and/or qualitative support for different stages of the supplier selection process.

Prior studies on supplier selection, however, did not consider the effects of learning in the production processes of the suppliers. This is insufficient inasmuch as the supplier selection decision influences the proportion of the order quantity that is allocated to a supplier, which affects gains in experience and consequently the unit production costs. Especially in an oligopoly, where companies realize a profit margin and where reducing the sales price may lead to a higher market share (see, e.g., Scherer & Ross, 1990), lower production costs may induce the supplier to lower the sales price, which affects the cost position of the buyer by reducing acquisition costs. Such a reaction of the supplier can especially be expected in case the supplier follows a mark-up pricing strategy, where a fixed profit margin is added to the total costs of producing a product (see, e.g., Grant & Quiggin, 1994; Irmen, 1997). If, for example, a buyer orders exclusively at a single supplier, the supplier may be able to proceed quickly on the learning curve, leading to high efficiency gains and high reductions in unit production costs. Sourcing at two suppliers, on the other hand, may lead to slower efficiency gains at both suppliers. It is clear that in such a scenario, it is in the personal interest of the buyer to contract suppliers with high learning effects, and to consider in the supplier selection decision how the allocation of the order quantity to the suppliers impacts the sales price and the own cost position. Since this aspect has not been analyzed in prior research, this article develops a formal model for the single sourcing/dual sourcing-decision and analyzes the effect of learning and forgetting on the relative performance of the two sourcing approaches. Thereby, it integrates the supplier selection decision in an inventory model and focuses on the total costs of the system under study, which are assumed to consist of inventory carrying charges, ordering costs, setup costs, labor costs, and the costs of relationship management. A closer look at the literature reveals that the supplier selection decision has mostly been studied in environments where particular model parameters, such as lead time or product quality, are subject to random influences and thus provide an opportunity to take advantage of multiple suppliers as a means to reduce variability (see Thomas and Tyworth (2006) for a review of related literature). Intuitively, in the absence of risks, one might suspect that it may not be optimal from the buyer's or the system's perspective to select more than one supplier, especially if the production costs of the supplier are subject to learning effects. In this paper, we show that also in a deterministic scenario, selecting two suppliers

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may be better than sourcing from a single supplier. This is caused by the effect the total production capacity of the supplier base has on the total system inventory, as will be shown below. Our work is representative for a variety of industries, especially for those which rely on a high proportion of human work in the production process, such as the fashion industry or industries which use assembly lines.

The remainder of the paper is organized as follows: in the next two sections, the article reviews related literature and outlines the assumptions and definitions which are used in the remainder of the paper. Accordingly, two formal models for the single sourcing/dual sourcing-decision under conditions of learning are developed and a solution method for the models is proposed. Section 7 contains a numerical study and Section 8 concludes the article.

2. Literature review

The supplier selection decision and the effects of learning and forgetting on inventory systems have frequently been discussed in the literature. Weber, Current, and Benton (1991) and Assaoui, Haouari, and Hassini (2007) provided reviews on the supplier selection problem, and Jaber and Bonney (1999) reviewed works that applied learning curves to inventory management. To position our model in the existing literature, we review both research streams in the following, but restrict our discussion to those works that are important for the development of our model.

In a review of literature on the supplier selection decision, Mohebbi and Posner (1998) differentiated between (1) articles that analyze certain effects of the supplier selection decision on the inventory system without considering its impact on the total costs of the system, and (2) articles that consider the total costs of a particular sourcing strategy. In the first category, Kelle and Silver (1990) analyzed the consequences of order splitting among multiple vendors on the variability of demand during lead time in a continuous review model with lead time following a Weibull distribution. The authors showed that splitting orders leads to a high reduction of lead time demand especially if lead time variability is high, which enables the buyer either to reduce safety stock or to improve service level. Their findings were supported by Pan, Ramasesh, Hayya, and Ord (1991), who derived similar results for three other lead time distributions. The effect of order splitting among two or more vendors on the inventory level of the buyer was analyzed by Zhao and Lau (1992), who showed that the average inventory can be reduced if the buyer orders from multiple vendors. They demonstrated that it is not necessarily optimal to choose suppliers with the lowest average lead times as selecting a second supplier with a larger average lead time than the first may reduce peak and average inventory level. The impact of the sourcing strategy on the risk of supplier failure was analyzed by Berger and Zeng (2006). They accounted for operating and risk costs and used a decision tree approach to derive a solution for the resulting problem. In numerical studies, it was shown that multiple sourcing leads to lower total costs for a variety of parameter settings.

In the second category, Ramasesh, Ord, and Hayya (1991) proposed a stochastic (s,Q) inventory model wherein the buyer may either source at a single vendor or split the order quantity equally among two homogeneous suppliers. The problem was solved for uniform and exponentially distributed lead times. The results showed that dual sourcing can be cost effective, especially when lead time uncertainty is high or ordering costs are low. In a subsequent paper, Ramasesh, Ord, and Hayya (1993) extended their earlier work to include heterogeneous suppliers. Chiang and Benton (1994) considered different distributions for lead time and demand and showed that dual sourcing can be beneficial under a variety of parameter settings. An inventory model that considers supplier selection and yield randomness, i.e. a random proportion of defective items in a production lot, was proposed by Gerchak and Parlar (1990). The authors formulated two models: The first model assumed that yield randomness can be reduced through the choice of an optimal randomness level, whereas the second model assumed that yield uncertainty can be lowered by splitting an order among several suppliers. Other authors, such as Anton and Yao (1987,1989), Riordan and Sappington (1989) and Inderst (2008) modeled the supplier selection decision using game theory principles. These models will not be discussed in this paper. However, it is worth mentioning that Anton and Yao (1987) analyzed learning effects in their model. They assumed that a relationship to a particular supplier has already been established and that the incumbent supplier has collected experience prior to the upcoming decision. Thus, the new and the incumbent supplier are in an asymmetric position, since the new supplier has to start at a different point of his learning curve, which has to be considered when making a supplier selection decision.

Similar to the treatment of the supplier selection decision, learning and forgetting effects have frequently been discussed in the management literature. Learning, in this respect, refers to the fact that the performance of an individual or a group improves for a repetitive task, whereas forgetting denotes a lack of learning retention in case the repetitive task is interrupted (see Jaber & Bonney, 1999). A variety of different learning curves appear in the literature, e.g. the log-linear model (e.g. Wright, 1936), cubic learning curves (e.g. Carlson, 1973), or learning curves with a plateauing effect (e.g. Baloff, 1966; de Jong, 1957). Of the available learning curve models, the Wright learning curve remains to be the most widely accepted and used one as it is simple to use and it fits empirical data quite well (see e.g. Jaber, 2006; Jaber & Guiffrida, 2004).

Keachie and Fontana (1966) is the earliest reported work that investigates the lot sizing problem for learning and forgetting effects. They considered full, partial, and no transmission of learning from period to period, and showed that full transmission of learning does not affect the determination of the lot size. However, larger lots were observed when there is no or partial transmission of learning. Fisk and Ballou (1982) revisited Keachie and Fontana (1966) and investigated the lot size problem for a corrected form of Wright's learning curve (de Jong, 1957), which considers plateauing effects. They showed that earlier lots are larger than later lots. Modified versions of the work of Keachie and Fontana (1966) are found in Smunt and Morton (1985) and Klastorin and Moinzadeh (1989). These works modeled forgetting as a percentage of cumulative experience that is independent of the length of the production break. This assumption is unrealistic as forgetting is linked to the length of a production break.

An inventory model which explicitly considers a forgetting curve was developed by Jaber and Bonney (1998). Their model, the learn-forget-curve-model (LFCM), assumed a forgetting curve that has an exponent which is a function of the level of experience gained prior to the production break and the length of the interruption. The authors showed that the optimal production strategy under partial transmission of learning is to produce larger lots in initial periods, which helps to reduce inventory in later production cycles. Related works can be found in Jaber and Bonney (2003), Jaber, Goyal, and Imran (2008) and Jaber and Guiffrida (2007). Readers are referred to Jaber and Bonney (2011) for a review of the effects of learning and forgetting on the lot size problem.

As could be shown, both research streams presented above have thus far been treated widely independently. This is surprising, as learning effects resulting from higher production volumes are often cited as important advantages of single sourcing strategies (cf. e.g. Dobler & Burt, 1996; Ramsay & Wilson, 1990; Saunders, 1997). Thus, incorporating learning and forgetting in the supplier