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Supplier selection under production learning and process improvements

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ABSTRACT

We study a buyer's sourcing strategy when suppliers can reduce their unit costs through production learning coupled with investments in process improvements. The buyer sources her requirement from these suppliers over two periods. In the first period, guaranteed allocations by the buyer to the suppliers decrease their unit cost due to production learning. In the second period, she procures a certain amount through a competitive bidding process. In order to win this bid amount, suppliers also invest in process improvements. We find that if the supply base is learning efficient, then the buyer should follow *dual sourcing-single sourcing strategy* (sourcing from both the suppliers in the first period and the balance from the winner of the bidding competition in the second period). However, if the supply base is learning inefficient, then the buyer procures the entire capacity through *one-shot single sourcing strategy* (sourcing entire capacity from a single supplier through a bidding competition). We link our model insights to examples from business practice.

1. Introduction

Firms often rely on suppliers to reduce manufacturing costs by exerting process improvement efforts (Nelson et al. (2001)). Such savings due to process improvements efforts by the suppliers can be substantial as evident from many cases. Chrysler, for instance, through its Supplier Cost Reduction Effort (SCORE) program identified $27 million in cost savings for its 1997 Dodge Dakota model. In this example, one of Chrysler's suppliers, Becker Manufacturing, through process improvements, was able to save $2.5 million over the life of the 1997 Dodge Dakota model (Allpar.com, 2014). In another example, General Motors (GM) significantly benefited from process improvement investments in the door-hinge production process by one of its suppliers (Andersson (2006)). In this specific case, GM experienced 13% reduction in procurement cost of the part assembly due to process improvement investments by the supplier. In another example, similar cost reduction was achieved by Pratt & Whitney (one of the engine suppliers to Airbus) through process improvement efforts for the Airbus's A320neo engine (Wall and Jon (2016)). Pratt & Whitney invested in process improvement efforts to meet the cost reduction target of 2%.

According to *resource-based view*, a firm achieves a competitive edge over other competing firms by accumulating resources and capabilities over time (Rumelt (1984) and Wernerfelt (1984)). Production through learning-by-doing helps firms gain the ability to manufacture products at lower cost. Such cost reduction due to the learning-by-doing occurs when a new product or process is introduced with high initial per unit cost at plant level; yet, with time, as the cumulative output increases, the per unit cost decreases in an orderly way (Hall and Howell (1985)). The learning curve is a way of quantifying the effect of familiarity and experience gained from the completion of a product on the efficiency and cost effectiveness in production. Empirical evidence on the existence of learning curves in the aerospace industry has been documented in a report by RAND Corporation (Lorell et al. (2000)). Further, existence of learning curves in small firms operating in traditional manufacturing industries such as garments, leather and footwear industries as well as in large, scale-intensive firms such as bulk materials (steel, glass) and automobiles is documented in a World Bank brief (Bell and Pavitt (1993)). The impact of the learning curve on production system is also well-documented in literature (see Yelle (1979) for details). Often such cost reductions due to the production learning are most significant during the initial production phases. To continue with the Airbus example (described earlier), for engine manufacturing for its A320neo model, capacity was initially allocated to the engine supplier Pratt & Whitney. By doing so, Airbus makes this supplier muddle through the inevitable learning curve for the engine production of the new model. Firms such as Airbus take maximum leverage of the learning curve at the suppliers' end during the allocation of the initial production lot (Wall (2016)).

In this paper, we investigate a sourcing strategy where cost reduction can take place due to production learning (which does not require

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costly investments) and process improvements (that require specific investments). The concept of production learning as used in this paper is best defined as automatic cost reduction that is the result of sustained production (Levy (1965)). However, process improvement is induced learning that requires investments and perhaps induction of new resources (Dutton and Thomas (1984)). In many production systems, both these cost reduction mechanisms are simultaneously present. For example, in ITT Automotive, the production costs are high in the initial phases of a project. However, over time, due to high learning effect, the company is able to standardize its assembly operations. Due to this standardization, the unit production cost gradually decreases. Another cost reduction philosophy followed by ITT Automotive is Kaizen, a continuous process improvement program. By forming Kaizen teams in one of the plants, ITT Automotive was able to improve the operating performance and hence reduce the unit production costs (Pisano and Rossi, 2001). In this research, we consider a supply base where both the above-described sources of cost reduction are present. We characterize the buyer's optimal sourcing strategy to leverage both these cost reduction phenomena.

Buyer firms follow various sourcing strategies to maintain competitive supply base while sourcing capacity over long horizons. One such strategy is where the buyer firms give some initial business to all the suppliers in the supply base and later, they shift the entire business to one of the suppliers selected though a bidding competition. In an example related to the US Navy warships procurement, US government in the initial period awarded the contract to two players: Austal USA and Lockheed Martin Corp. Subsequently, the US government sourced only from one supplier selected through bidding competition. According to a press release by US DoD: "*This award is a unique opportunity to maximize the buying power on the LCS Program by leveraging the highly effective competition between the bidders …. . Each contractor's bids reflect mature designs, investments made to improve performance, stable production, and continuous labor learning at their respective shipyards … …allowing the government a wide range of viable alternatives for effective future competition*" (US DoD press release (2010)). This press release indicates that by following such a sourcing strategy, the US government (buyer) motivates the suppliers to invest in process improvement that would lower their operating costs and hence, would lower their bid to win the second-period bidding competition. In another example, the US Department of Defense decided to dual source their requirements between General Electric and Pratt and Whitney in the initial period followed by the bidding competition in the later period. This strategy was explained by Air Force Chief of Staff: *"as the best way to generate competition in order to provide motivation and incentive for a supplier to further improve their production processes*" (Drewes, 1987). This example also indicates that the suppliers invest in process improvements in the first period to win the second-period sourcing contract. In our paper, we also consider process improvement investments by suppliers' in the first period. Similarly, in the US Pentagon's awards of tankers that can refill aircraft in mid-air, US lawmakers suggested a sourcing strategy of equally splitting the capacity in the initial procurement stage (i.e. dual sourcing of 12 tankers to each of the two contractors: Boeing and Airbus). This was followed by awarding the full share of the business in the second period to the supplier who offered better price (i.e. single sourcing). Similar to the above examples, such a sourcing strategy was followed by the US government to motivate suppliers to invest high in process improvements before the second-period bidding competition (Drew (2009) and Gansler and Lucyshyn (2006)). Motivated by such examples, we try to characterize buyer's sourcing strategies when the suppliers compete by reducing their production costs due to learning and process improvements.

In such an environment, often when a supplier improves the manufacturing processes due to process improvements or production learning, assessing the final unit production cost upfront is difficult. Hence, when upfront investments to improve the production process by new suppliers need to be made, due to variations in the internal and external environments, there is uncertainty in the final production cost per unit. In other words, the suppliers' production costs are realized after the process improvement and production learning phases are over. Uncertainties in the outcome of process improvement efforts have also been discussed by Choi and Krause (2006) and Carrillo and Gaimon (2004). Further, the uncertainties in cost reduction due to production learning have been discussed by (Mazzola and McCardle, 1996, 1997).

Motivated by the above context, we consider a situation where a buyer ("she") is sourcing a component from two suppliers ("he") over two periods. Before the start of the first period, the buyer guarantees a fixed quantity to each supplier to be sourced in the first period. The balance amount is awarded, in the second period, to the winner of a price bidding competition between the two suppliers (henceforth, we call this amount as the "bid quantity"). In the second period, both the suppliers will have a lower unit production cost. This is achieved through production learning curve (which is a function of quantity allocated to him in the first period) and through process improvements (which is dependent on the amount of investments the supplier makes in the initial period to reduce costs). There are inherent uncertainties in production learning and process improvement stages; therefore, the final production costs are privately realized after the suppliers have finished both these tasks. Next, we state our main research questions along with a brief summary of our research findings related to each of the questions.

We first ask and answer the following question: *How much investment are competing suppliers willing to make towards process improvements that will result in unit cost reduction*? We characterize the process improvement investments by the competing supplier. We find that the process improvement investments by the suppliers act as substitutes: the higher one player invests, the lower the other one will invest. We further find that as the second period bid quantity increases, the process improvement investments by the suppliers increase. Moreover, we also find that when the supply base is efficient in process improvement, then the suppliers invest more. We also study the impact of uncertainties on the investment strategies by the suppliers.

Next, we analyze the following important question: *What is the optimal sourcing strategy in the presence of production learning and process improvements over two periods by the buyer towards these competing suppliers?* We characterize the optimal sourcing strategy of the buyer under the presence of the production learning and process improvements. Our analysis reveals that if suppliers are efficient in production learning, it is optimal for the buyer to follow dual sourcing-single sourcing strategy. Under this strategy, she sources some quantity from both suppliers in the first period and the balance from the winner of the bidding competition in the second period. However, when the suppliers are not efficient in production learning, we find that the buyer always follows a one-shot single sourcing strategy where she procures the entire capacity from one of the suppliers though the bidding competition. We also provide examples from business practice for such a buyer's strategy.

The rest of the paper is organized as follows. In Section 2, we cover the relevant literature related to our problem, with the description of the problem in Section 3. The details of the model are analyzed in Section 4. Section 5 presents various model extensions. We conclude the paper in Section 6.

2. Literature review

There are two streams of literature which are relevant to our study. The first stream of papers deal with supplier selection though bidding competition. The second set of research focuses on competition between suppliers in the presence of production learning and process improvement investments.

2.1. Supplier selection under auctions

Elmaghraby (2000) in a comprehensive review paper on