Int. J. Production Economics 183 (2017) 103–115

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Dual sourcing under suppliers' capacity investments

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ARTICLE INFO

Keywords:
Supplier competition
Capacity investments
Sourcing
Game theory

ABSTRACT

Dual sourcing is used by various firms as an effective strategy to mitigate supply chain risks. In this paper, we model a supply chain, where two upstream suppliers compete by investing in capacity to fulfill a buyer's requirement, and to serve their individual alternative markets. The suppliers' capacity investment outcomes face uncertainties in terms of final production cost and final plant capacity. We formulate a simultaneous game situation where a buyer allocates its sourcing requirements among two suppliers. We find below a certain threshold value on the mean of suppliers' capacity, the suppliers increase their capacity investment as mean of production capacity increases. Above this threshold value, the suppliers decrease the capacity investments with the increase in mean production capacity. Next, we find that an increase in the variability of suppliers' capacity decreases the suppliers' investments. Our analysis also reveals that as the mean of production cost increases, the suppliers decreases their capacity investments. As the variability in the suppliers' production cost increases, we find their capacity investment decisions do not change much. We also find that under different conditions the buyer may use different sourcing structures: *symmetric dual sourcing strategy* (sourcing equal capacities from all the suppliers), *asymmetric dual sourcing strategy* (sourcing positive but unequal capacities from all the suppliers) and *single sourcing* (sourcing completely from a single supplier). Later, in the paper, we also explore the impact of scale economies due to plant size and the scale economies associated with the total output produced.

1. Introduction

Firms often rely on external suppliers for capacity requirements ranging from small parts to complex sub-assemblies (Gottfredson et al., 2005). To meet such requirements the suppliers often need to invest upfront in the capacity, which are input to these buyers' s final product offerings as the capacity installation process requires a long lead time. In many cases, suppliers, facing competition, upfront invest in the capacity to win orders from the influential buyer firms even though they do not receive any upfront order commitments from these dominant buyer. For example, Taiwan Semiconductor Manufacturing Company (TSMC) plans to invest upfront $12 billion on plants and equipments to counter Samsung's investments to win chip orders from powerful buyer like Apple (Culpan and King, 2015). According to an analyst: "*Both companies are not deterred by the higher cost, as they both hope to offset the higher cost with bigger share and larger volume.*" (Culpan, 2015). In strategy literature, Kang et al. (2009) also provide empirical evidence in context of electronics manufacturing industry where OEM suppliers make such upfront investments to win orders from the powerful/dominant OEMs. Similar investments have also been observed in the pharmaceutical manufacturing industry where contract manufacturing organizations (CMO) like CMC Biologics, Lonza, etc. invest in new technologies like mammalian cell culture and microbial fermentation capabilities to get new large clients (Downey et al., 2011).

Often when the suppliers invest in new technology due to variations in the internal and external environments, there are uncertainties in final production capacity (due to yield uncertainties) and final production costs. This means the final production capacity and net production costs are only realized when the capacity installation stage is over. For example, Sharp Corporation invested in a new plant to manufacture LCD screens in Japan with the objective of reducing manufacturing costs of these panels. Eventually, when the capacity installation stage was completed, the realized production capacity was low due to some technical issues during capacity installation phase. Moreover, the unit production costs that was realized were high as compared to other competitors in the market (Wakabayashi, 2012). Similar yield problems were also faced by other screen manufacturers like Samsung, Pioneer, LG and Matsushita when they invested in new capacity (Einhorn, 2005). Uncertain capacity issues due to low plant yield have

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http://dx.doi.org/10.1016/j.ijpe.2016.09.022
Received 1 April 2016; Received in revised form 13 June 2016; Accepted 29 August 2016
Available online 12 October 2016
0925-5273/

also been observed in chip manufacturing industry. For example, IBM faced low yields at its EastFishkill (New York) plant when they invested in capacity for Apple' s Power Mac G5 model (Hamm, 2004). In this paper, we investigate buyer's sourcing strategy when suppliers invest upfront in the capacity under production yield and cost uncertainties. Similar production cost uncertainties also occur in manufacturing environment (Manyika et al., 2012). In this paper, we consider uncertainties in yield and production cost because in our modeling context, the capacity for new technology is being installed, and these uncertain production parameters are realized only after the capacity installation phase is over.

Another important aspect that is relevant to this paper is the case when the unit production cost is dependent on the realized plant yield. In other words, the actual production cost depends on the realized capacity. In many manufacturing and service operations, such a capacity-cost correlation is common. There are different sources of this relationship between the realized yield and the unit production cost.

One such source is the economies of scale associated with the total scale of the plant. In other words, a larger capacity facility will have a lower unit production cost as compared to the smaller plant producing the same number of unit. Lieberman (1987) provides the empirical evidence of this phenomenon of plant-size related scale economies. Such cost reduction due to higher plant capacity happens because of less than a proportionate increase in the cost of energy, labor, and maintenance with the same proportion of the increase in the plant size (Besanko et al., 2010). In process engineering industries, if the linear dimensions of a chemical reactor is doubled, the net capacity of the reactor will increase eight times, whereas, the net surface area of the walls of the chemical reactor will only increase four times (Bruni, 1964). As a result of this, the total heat energy losses which are proportional to surface area of the vessel decreases more drastically as the volume of the chemical reactor increases. Overall, this results in the energy cost savings. This correlation has also been observed in bio-fuel production and Active Pharmaceutical Ingredients manufacturing firms (see Bonaquist (2013) and Kaplan and Laing (2005)). Another source of the realized capacity-cost correlation is the production output specific cost reductions. That is, the unit production cost decreases as the total volume of production output increases. The reason for this is that the total fixed costs are spread out over more units of output produced. In literature, Moore (1959) provides the early empirical evidence of the phenomenon. We also consider this source of production cost - capacity correlation in our paper.

In this paper, we contribute to the literature, by exploring the effects of both of these cost reduction phenomenon. In the first mechanism, the unit production cost reduction happens due to higher realized plant size. In the second mechanism, the unit production cost reduction are due to the higher production volume, i.e., the net production output of the plant.

Suppliers while deciding to invest in capacity to win orders from specific buyers also invest in capacity to serve other third party clients. This has been seen in practice where firms like Micron Technology and Elpida not only sell the DRAM chips capacity to Apple, but also dedicate some fraction of their capacity to third party clients in Asia (King, 2013). Further, Kang et al. (2009) also provide the empirical evidence that the supplier firms investment decisions to win contracts from the buyer firms are also influenced by other potential third party transactions. This is also realistic for CMOs in pharmaceutical manufacturing industry where they dedicate their capacity to other third party clients for other services like drug discovery services, downstream process development, formulations development, etc (gvkbio.com, 2015). Generally, operations management literature have not considered the suppliers' access to other third party clients when they are decision makers, but we incorporate the suppliers' access to third party clients in our stylized model setting.

Our problem setting is a supply chain with two upstream suppliers and a single buyer. The suppliers simultaneously make capacity investment decisions under uncertainties about the final production cost and the final production capacity (or capacity yield). The suppliers have two sources of demand. One of the sources is the buyer (with a known requirement) who allocates her capacity requirements among these two suppliers. Another source of demand is capacity requirements by third party clients, which is uncertain. Throughout this paper, we refer to capacity yield as the ratio of units of capacity realized after the capacity installation process is over to the units of capacity towards which investments were made. For example, if firm Z invests in a capacity for 100 units (per period) but after the investments, the realized capacity is only 70, then the capacity yield of firm Z is 0.7. The buyer allocates her capacity requirement among these two suppliers. As motivated above, in practice, such a model setting is realistic in highly competitive industries like electronics and semiconductor manufacturing as well as in the pharmaceutical manufacturing industries. Our main research questions accompanied by a brief summary of the related research findings are stated below:

- *How much capacity investments competing suppliers are willing to make in order to serve both the buyer's requirement and the alternate market demand?*

We characterize one threshold policy on the effect of mean capacity yield on the supplier's capacity investment strategy. Below a certain threshold of supplier's mean yield it is optimal for the suppliers to increase their capacity investment as the mean yield increases, beyond this threshold value, the suppliers decrease their capacity investments on the further increase in mean yield. We also find that as mean production cost increases, the supplier's capacity investment decreases.

- *What is the optimal capacity allocation strategy for the buyer towards these competing suppliers?*

We find in case the supply base is homogeneous (symmetric players), it is optimal for the buyer to follow *symmetric dual sourcing strategy* (sourcing equal capacities from all the suppliers). Further if the supply base is heterogeneous, i.e. asymmetric in attributes like production costs, capacity yield, etc. then the buyer follows *asymmetric dual sourcing strategy* (sourcing positive but unequal capacities from all the suppliers). Finally, if the asymmetry in above-mentioned attributes is very high, the buyer's strategy shifts towards *single sourcing*.

- *What is the impact of plant size-cost correlation and the production output-based scale economies on the supplier's capacity investment decisions?*

Our analysis reveals that the presence of either plant size-cost correlation or production output-based scale economies motivates the suppliers to invest high during the capacity installation phase.

The rest of this paper is organized as follows. We position our work against the literature in Section 2. Then we present the model in Section 3, followed by the model analysis in Section 4. Section 5 establishes the results about the structure and choice of the optimal sourcing strategy. We summarize our conclusions in Section 6.

2. Literature review

The capacity investment literature has evolved over last sixty years starting with some earlier work by Erlenkotter and Manne (1968). Van Mieghem (2003) and Wu and Kleindorfer (2005) also provide an elaborate review of the capacity investment literature. Papers on capacity investment decisions by firms in case they are strategic is relevant to our work (For example, see Loch, 1991; Lederer and Li, 1997; Bashyam, 1996; Van Mieghem and Dada, 1999). These papers on capacity investment competition focus specifically on the case when