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Dedicated vs product flexible production technology: Strategic capacity investment choice

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ABSTRACT

This paper studies the optimal investment strategies of an incumbent and a potential entrant that can both choose between a product flexible and dedicated technology, in a two-product market characterized by uncertain demand. The product flexible production technology has certain advantages, especially when the economic environment is uncertain. On the other hand, the dedicated production technology allows a firm to commit to production quantities. This gives strategic advantages, which can outweigh the 'value of flexibility'.

It turns out that both firms prefer, for some scenarios, the dedicated production technology. However, we find that in a game with sequential technology choices, *both* firms investing dedicated, will not be an equilibrium. Especially when the economic environment is more uncertain, the incumbent overinvests in product flexible capacity to force the entrant to choose the dedicated technology. Then, the incumbent is the only firm with the product flexible production technology, which results in a high payoff.

1. Introduction

Just two decades ago it was standard in the American and European automotive industries to install separate production lines for each vehicle type that was produced. Nowadays, most automotive manufacturers have started to invest in Flexible Manufacturing Systems (FMS) that allow production of multiple car types on a single production line. Flexible manufacturing systems were first introduced by Japanese car manufacturers that developed this new way of manufacturing when they entered the car industry. It is believed that their increased market share in the automotive market is partly due to FMS (Goyal, Netessine, & Randall, 2006). The response of the American car industry was to also start investing in flexibility. When demand of a vehicle type drops, the firm can easily decide to shift a bigger part of the production capacity to another type of car that is produced on the same production line. This type of flexibility is in general referred to as product flexibility. The most important reason that induces manufacturers to invest in FMS is that it is a good hedge against uncertainty. In addition FMS is a way to respond to changes in competition. Goyal et al. (2006) find that "automotive manufacturers use flexibility as a 'competitive weapon'; flexibility is deployed in market segments in which there are a larger number of flexible competitors".

However, there are many other industries in which product flexibility can evoke several efficiencies in production. Think for example about bikes or television sets. Within these industries, the manufactured products are quite similar. Therefore, it is possible to produce them on the same production line. The products in these industries are furthermore characterized by strongly fluctuating sales. In the television industry for example, innovations occur on a regular base. Within a very short time frame the sales of a certain type of television sets can drop enormously, if an improved model is introduced. Therefore, it is very desirable for a firm to be able to easily adapt the corresponding production line for the production of a different television set.

This paper proposes a three stage game, where in the first stage an incumbent invests in the optimal capacity amount of either a product flexible or a dedicated production technology. The product flexible production technology allows a firm to produce both products on a single machine or production line. An entrant has the option to enter the market in the second stage. Given that the entrant invests, it will choose its optimal production technology and capacity amount. These capacity decisions are made before demand uncertainty is resolved (see Van Mieghem (2003) for a review of capacity management). After the investment decision of the entrant, the market can go 'up' or 'down' with equal probability. In the final stage, the demand curve is revealed, and a production game will be played.

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Research on various types of flexibility is among others surveyed in Kroll and Wasden (1990) and Karwowski and Rahimi (1990). This paper considers product flexibility. Most of the literature on product flexibility primarily focuses on monopoly cases. Firms have to determine the optimal investment type (flexible/dedicated), the optimal (lumpy/incremental) capacity to invest in, and/or the utilization rate of the capacity. Papers that discuss the value of flexibility of a monopolist are Fine and Freud (1990), Van Mieghem (1998), Bish and Wang (2004), Chod and Rudi (2005), Tomlin and Wang (2005) and Ceryan, Sahin, and Duenyas (2012). Fine and Freud (1990) consider a n-product firm that assembles an optimal mix of flexible and dedicated capacities, where uncertainty is modeled through a revenue function with a discrete set of possible scenarios. They find that optimal capacity and expected profit is increasing in demand variance, which is consistent with our results. Bish and Wang (2004) and Chod and Rudi (2005) confirm the result of Van Mieghem (1998) that in a two-product market flexible capacity can be preferred due to financial reasons when products are perfectly positively correlated.

All these contributions consider monopolies, where the strategic effect is not taken into account when determining the choice between investing in flexible or dedicated manufacturing systems. Van Mieghem and Dada (1999) extend their monopoly model to a competition model where each firm makes three decisions about capacity investment, production quantity and price. A firm is flexible in deciding which decision is postponed until after uncertainty is resolved. Patel, Terjesen, and Li (2012) empirically investigate how some firms are able to develop more effective responses to environmental uncertainty using manufacturing flexibility. Their findings show that environmental uncertainty affects firms' performance directly and indirectly through manufacturing flexibility and that operational absorptive capacity (the extend to which a firm's operational units can acquire, assimilate, and transform external information) and operational ambidexterity (pursuing both exploration and exploitation) positively moderate these mediated relationships. Considering product flexibility, Goyal and Netessine (2007) find that also under competition each firm is willing to pay more for flexibility under high demand uncertainty. For low levels of uncertainty, none of the firms will invest in flexibility, while for inbetween levels of uncertainty, the firms decide to invest in opposing production technologies. Goyal et al. (2006) explain that when there is a high demand correlation between products, the value of flexibility will be limited. Also Roller and Tombak (1990), and He, Ding, and Hua (2011) consider the strategic value of product flexibility. However, in those papers it is assumed that firms decide about their technology choice simultaneously. Therefore they cannot analyze the concept of 'entry deterrence'. We extend this approach by considering an incumbent–entrant situation.

Tseng (2004), Dewit and Leahy (2003) and Chang (1993) discuss flexibility in an incumbent–entrant setting. However, they do not consider product flexibility. Chang (1993) models an incumbent–entrant situation and shows that an incumbent can use product design flexibility to deter entry. The incumbent has an extra incentive to be flexible compared to a situation without a potential entrant. Contrary to Chang (1993), we consider product flexibility. We show that producing flexible makes it more difficult for the incumbent to deter entry in comparison to producing dedicated. This is due to the fact that a dedicated incumbent can commit to a certain production quantity.

The paper most closely related to our analysis is Anand and Girotra (2007). They consider two firms that have the opportunity to produce in a monopoly market and a competitive market. By employing early differentiation, a firm chooses the quantities for the monopoly market and the competitive market, before demand uncertainty is resolved. Delayed differentiation gives the firm the opportunity to initially produce an intermediate version of the product. Once demand uncertainty is resolved, the product will be differentiated for sale in either the monopoly market or the competitive market. They find that, when an incumbent faces a potential entrant in one of its markets, early differentiation is a better entry deterrence strategy than delayed differentiation. However, this result is found under the assumption of only one competitive market, while we assume that there are two competitive markets for the two firms. In an extension of Anand and Girotra (2007), they consider the issue of two competitive markets, where they find that early differentiation is, for a range of parameter values, the dominant strategy. This is however not shown under the assumption of sequential investments. Another important difference to Anand and Girotra (2007) is that, in our heterogeneous product market, the product quantity in one market influences the price of the other product. Anand and Girotra (2007) consider a different type of heterogeneity: they introduce correlation in the demand intercept, between the monopoly market and the competitive market.

Similar to Anand and Girotra (2007), we show that investing in dedicated production capacity could give the incumbent a higher (expected) profit than investing in flexible production capacity. The ability to commit oneself to production quantities gives strategic advantages. In particular, we find that the incumbent chooses the dedicated technology when demand uncertainty is low, products are equally profitable and not too competitive. The 'value of commitment', indicating that it can give value to a firm in a competitive setting to make credible commitments, has long been advocated in the literature (Caves & Porter, 1977). This could e.g. be in the form of a contract (Rey & Salanie, 1990) or investments in a large capacity. Most important is that competitors believe that the commitment is credible and it will become very difficult to refrain from it. This gives the committed firm value or makes it able to deter possible entrants.

Besides this form of commitment, which is known in the literature, we find that in some scenarios also the entrant can benefit from being committed. In particular, when uncertainty is sufficiently low, products are equally profitable and product substitutability is low, an entrant that faces a flexible incumbent prefers investment in dedicated capacity. In such a situation, the incumbent cannot influence the entrant's production choice in the last stage, which results in a relatively high profit for the entrant. In a similar situation (low substitutability and equally profitable products), but a more uncertain economic environment, the entrant also prefers the dedicated production choice. A higher uncertainty leads to a larger value of flexibility, i.e. high enough for the incumbent to prefer to be the only firm benefiting from the advantages of flexibility in the market. Therefore, the incumbent makes a sufficiently large capacity investment so that the entrant prefers to invest in the dedicated capacity.

Furthermore, we show that two dedicated firms cannot occur in an equilibrium, in a sequential game. This is contrary to Goyal and Netessine (2007) that make the assumption of a simultaneous technology choice. An entrant that observes a dedicated incumbent has no incentive to commit to its production quantities.

The paper is organized as follows. The general model is presented in Section 2. In Section 3 the game is solved under appropriate assumptions. Results are discussed in Section 4. Section 5 concludes.

2. The model

We consider a three stage game with two firms, an incumbent (I) and a potential entrant (E). The profit maximizing firms are assumed to be risk neutral, have full information and compete in a Cournot fashion. Demand of the two products in the market, i.e. product 1 and product 2, is uncertain. At time $t = 0$, the incumbent has to choose between a dedicated and a flexible production technology. With the dedicated technology it has to produce each product on a separate production line. The flexible production technology allows to produce two products with a single production capacity. The incumbent will also make its capacity decision at time $t = 0$. At time $t = 1$, the entrant

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