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Int. J. Production Economics 91 (2004) 223–227
international journal of production economics
www.elsevier.com/locate/dsw

Strategic choice of flexible manufacturing technologies

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Received 5 August 2000; accepted 28 August 2003

Abstract

The question addressed is how the strategic choice of flexible manufacturing technologies intensifies and interacts with competition among firms. We focus on the manufacturing flexibility that allows a firm to produce its outputs at shorter expected delivery time. We find that increasing the number of firms will decrease firms' incentive to acquire more flexible manufacturing technologies.

Keywords: Flexible manufacturing technologies; Game-theoretic model

1. Introduction

The purpose of this study is to investigate how the choice of flexible manufacturing technology intensifies and interacts with competition among firms. Flexibility of a manufacturing system lies in its adaptability to a wide range of changing environments that it may encounter. We restrict our attention to a particular aspect of manufacturing flexibility that allows a firm to produce its outputs at shorter expected delivery time. Since a more flexible manufacturing technology is more apt to cope with uncertainty affecting production process as well as supply, our specification does have real-world implications.

Since the advent of the flexible manufacturing system (FMS), a substantial amount of literature dealing with manufacturing flexibility has accumulated. It is noticed that most recent literature has focused on the flexibility of changing product design, if not on flexibility of volume. However, an empirical study conducted by Tombak and De-Meyer (1988) indicates that manufacturing managers in Europe and North America are using FMS more for its flexibility in dealing with variations in the production system's inputs. For instance, FMS adopting firms can quickly set up to proceed other jobs if certain raw materials cannot be ready on time. Our study, characterizing manufacturing flexibility in terms of the expected delivery time, thus brings together several types of flexibility that have greater strategic importance but which are less studied in the economic literature.

We consider a two-stage game consisting of n identical firms. Each firm must decide first what kind of production technologies to use, and then how much output to produce. A more flexible production technology will allow a firm to produce with shorter expected delivery time. The firm that makes the fastest delivery can sell its products at a regular price, which, to simplify our analysis, is

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2003.08.010

assumed given. Firms who do not deliver first may still sell their products, albeit at a discount price. The solution concept used in our study is subgame-perfect (Nash) equilibrium. Meanwhile, only pure-strategy equilibria are considered.

We find that increasing the number of firms will decrease firms' incentive to acquire more flexible manufacturing technologies. And in a highly concentrated market, increasing the costs of slow delivery will increase firms' investment in flexible technologies. However, the result is ambiguous when the market is less concentrated. The result obtained in our study, together with earlier results, indicates that there is a linkage between industry concentration and the extent of manufacturing flexibility that firms acquire.

The notion of flexibility seems to have been first introduced into the economics literature by Stigler (1939). However, the analysis of flexibility as a strategic variable in oligopolistic contexts does not have a long history. Vives (1986) considers a two-stage oligopoly game where at the first stage firms choose the *scale* of production (through its capacity choice) for the market clearing stage that follows. In contrast, the aspect of flexibility studied in Röller and Tombak (1990) is about *scope*, that is the ability to change product design and thus produce different products. They investigate the strategic implications of the production technology choice, between an FMS and an inflexible technology referred to as dedicated equipment (DE), in a duopolistic market with differentiated products. Kim et al. (1992) and Röller and Tombak (1993) provide further extensions. Waller and Christy (1992) also analyze firms' strategic incentives to acquire product flexibility. In analyzing the strategic choice of flexible production technology, issues involving entry deterrence are investigated in Chang (1993) and Norman and Thisse (1999). Kim et al. (1994) is another relative study, which examines the decision when to switch from a DE technology to an FMS technology. The relationship between the internal structure of a firm and the extent of its technological flexibility was investigated by Gal-Or (2002).

This paper proceeds as follows. In Section 2, we develop a simple game-theoretic model of oligopolistic competition and discuss the implications of the equilibrium. We offer some concluding remarks in Section 3.

2. The model

Consider a two-stage game involving n identical firms. In the first stage, each firm simultaneously commits which production technology to use. The technological choices are assumed to be irreversible. Different technologies are characterized by different flexibilities in the sense that a more flexible manufacturing technology allows a firm to produce with shorter expected delivery time. We assume that delivery time has an exponential distribution. The probability that the λ_i technology will deliver before time t is $1 - \exp(-\lambda_i t)$, and the expected delivery time is $T_i = 1/\lambda_i$.

Let k denote the unit acquisition cost for the flexibility. Namely, the firm incurs a fixed cost $k\lambda_i$ for acquiring λ_i technology. Without loss of generality we also assume that unit cost of production is the same for all technologies. This assumption, as pointed out in Fine and Freund (1990), has been empirically supported. We denote by $cq^2/2$ the production cost for producing q units.

Regarding stage two of the game, we assume that the firm which delivers first can sell its products at a price p, and for those who cannot deliver first can only sell the product at a discount price $(1 - s)p$.[1] The parameter s, which is assumed with value $0 < s \leqslant 1$, characterizes the uncertainly in consumer preferences. If consumer preferences move away from a product's characteristics, the firm must lower its price to sell the product. Some restrictions must be placed upon the upper bound of s to ensure that a firm's profits are concave in technologies. For this purpose, $s < 2/3$ is sufficient. We therefore assume $0 < s < 2/3$.

In order to focus just on subgame-perfect equilibrium, we start by considering the second stage of the game. At this stage, firms select the quantities of output to maximize their expected profits. Since the probability for ith firm to deliver

[1] We could have considered more sophisticated demand. Nevertheless, it merely complicates the algebra and does not add additional insights.