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STRATEGIC CHOICE OF MANUFACTURING FLEXIBILITY IN INTERMEDIATE GOODS MARKETS

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This paper examines the strategic choice of flexible versus dedicated manufacturing technologies in intermediate goods markets. We show that it may not be profitable for upstream firms to choose flexible technologies in a simple successive duopoly model. The reason is that the choice of flexible technologies reduces the profits from downstream captive firms. We find that downstream competition is an important factor affecting the choice of production technologies in the upstream market.

JEL Classification: D4, L1, L2
Keywords: Flexible Manufacturing Systems, Intermediate Goods Markets

I. INTRODUCTION

This paper examines the strategic choice of manufacturing flexibility in intermediate goods markets. We focus on two types of production technologies: flexible manufacturing systems (FMS) and dedicated technologies. According to the United States (US) Office of Technology Assessment (1984), a flexible manufacturing system is defined as "a production unit capable of producing a range of discrete products with a minimum of manual intervention." An advantage of flexible technologies

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is that they provide a broader scope of products than dedicated technologies.

Several articles have analyzed the strategic choice of flexible manufacturing technologies (Chang, 1993; Eaton and Schmitt, 1994; Norman, 2000; Norman and Thisse, 1999; Röller and Tombak, 1990, 1993; and Tseng, 2004). However, few have considered this issue in the context of the upstream-downstream structure. We construct a simple successive duopoly model to examine the choice of flexible versus dedicated technologies in intermediate goods markets. In our simple model, flexible technologies allow upstream firms to produce two types of inputs for both downstream firms. However, if upstream firms choose dedicated technologies, they can provide inputs to only one downstream firm. We show that it may not be profitable for upstream firms to choose flexible technologies because the choice of flexible technologies reduces the profits from downstream captive firms.

This paper closely relates to the work of Röller and Tombak (1990). They developed a duopoly model to examine the choice of flexible versus dedicated technologies.[1] Their model incorporates two differentiated products. If a firm chooses a flexible technology, it can produce both products; however, if it chooses a dedicated technology, it can produce only one of the two products. They showed that the strategic choice of manufacturing flexibility could be affected by three factors: market size, product differentiation, and the difference in fixed investment costs between technologies. In contrast to Röller and Tombak, we focus on downstream competition as a factor affecting the choice of flexible versus dedicated technologies in the upstream market. We show that downstream competition may have negative effects on the choice of flexible manufacturing technologies.

The remainder of this paper is organized as follows. Section 2 sets up the basic model. Section 3 analyzes the strategic choice of technologies. Section 4 introduces upstream cost uncertainty as an extension of the basic model. Section 5 concludes.

[1] Röller and Tombak (1993) have extended this to the *n*th firm case.

II. THE BASIC MODEL

We construct a simple successive duopoly model based on the framework developed by Choi and Yi (2000). There are two upstream firms, $U1$ and $U2$, which provide inputs to the downstream firms $D1$ and $D2$. There exist two types of inputs; one is for the downstream firm $D1$, and the other is for $D2$. In order to simplify the model, we assume that the two types of inputs are not substitutable.

We consider a situation in which there are three kinds of technologies: a flexible technology (T_F), a dedicated technology for $D1$ (T_{D1}), and a dedicated technology for $D2$ (T_{D2}). If upstream firms make an investment in flexible technologies, they can produce two types of input at constant marginal cost of zero. However, if they make an investment in a dedicated technology, they can produce only one type of input at zero. We assume that investment costs are the same for both flexible and dedicated technologies. This assumption eliminates the effects of differences in fixed investment costs on the choice of technologies.[2] For simplicity, we assume that investment costs are zero. We also assume that inferior technologies exist. In the absence of investment in new technologies, they can produce two types of input at c, which is greater than zero.

Two upstream firms engage in Bertrand competition. We do not make any assumption about the nature of downstream competition. Downstream firms could play either a pricing or an output game.

Downstream firms transform one unit of an intermediate good into one unit of the final good, incurring no costs other than the input prices. Then, the downstream equilibrium output and profit can simply be expressed as functions of the input prices paid to the upstream firms. We need only the equilibrium output and profit for one representative downstream firm because the two downstream firms are symmetric. As an exposition, let us denote $q(x,y)$ and $\pi(x,y)$ the equilibrium output and profit, respectively, where the first component (x) refers to the firm's own input costs and the second component (y) refers to the rival firm's input

[2] Röller and Tombak (1990) have assumed that fixed investment costs for a flexible technology are greater than those for a dedicated technology.

costs. We assume that

$$\frac{\partial \pi(x,y)}{\partial x} < 0, \quad \frac{\partial \pi(x,y)}{\partial y} > 0, \quad \frac{\partial q(x,y)}{\partial x} < 0, \text{ and } \frac{\partial q(x,y)}{\partial y} > 0.$$

For virtually all oligopoly models with suitable stability conditions, this assumption is satisfied.

For simplicity, we further assume that c is not too large in order to avoid complexities in the upstream firm's optimal pricing strategy. Under this assumption, the optimal input price will always be c.

The timing of the basic model is as follows. Upstream firms choose between flexible and dedicated technologies in the first stage. We assume that if $U1$ chooses a dedicated technology, it is for $D1$. Similarly, if $U2$ chooses a dedicated technology, it is for $D2$. Input prices are determined in the second stage. Finally, downstream equilibrium is determined in the third stage.

III. THE CHOICE OF TECHNOLOGY

Suppose that both $U1$ and $U2$ choose flexible technologies. In this case, both upstream firms produce two kinds of input and engage in Bertrand competition in both upstream markets. Thus, the equilibrium input prices for $D1$ and $D2$ will be zero and both upstream firms will obtain zero profits.

We next consider the case in which $U1$ chooses a flexible technology but $U2$ chooses a dedicated technology for $D2$. First, consider the input market for $D1$. There is only one supplier in this market, $U1$, which charges the monopoly input price of c. In contrast, the equilibrium input price for $D2$ will be equal to zero because both $U1$ and $U2$ engage in Bertrand competition. If the unit input cost for $D1$ is c and the unit input cost for $D2$ is zero, the downstream equilibrium quantity for $D1$ is equal to $q(c,0)$ and $U1$ obtains profits of $\underline{\phi} = c \times q(c,0)$ from $D1$. Meanwhile, both upstream firms obtain zero profits in the input market for $D2$ because the input price for $D2$ is equal to zero.

Finally, consider the case in which $U1$ chooses a dedicated technology for $D1$ and $U2$ chooses a dedicated technology for $D2$. There is then only one input supplier in each separate input market. Consequently, $U1$ and $U2$ can charge the monopoly price c to $D1$ and $D2$, respectively. Thus, both upstream firms obtain the profits of $\bar{\phi} = c \times q(c,c)$ from each downstream firm.

The above results are summarized in Table 1. The notation T_F represents a flexible technology. T_{D1} and T_{D2} represent dedicated technologies for $D1$ and $D2$, respectively.

[Table 1] Technology Choices, Input Prices, and Profits

Technology Choices		Input Prices		Profits			
$U1$	$U2$	$D1$	$D2$	$U1$	$U2$	$D1$	$D2$
T_F	T_F	0	0	0	0	$\pi(0,0)$	$\pi(0,0)$
T_F	T_{D2}	c	0	$\underline{\phi}$	0	$\pi(c,0)$	$\pi(0,c)$
T_{D1}	T_F	0	c	0	$\underline{\phi}$	$\pi(0,c)$	$\pi(c,0)$
T_{D1}	T_{D2}	c	c	$\bar{\phi}$	$\bar{\phi}$	$\pi(c,c)$	$\pi(c,c)$

From the data in Table 1, we construct the payoff matrix for choice of technology (see Figure 1). The first and second elements in each cell of the payoff matrix represent the profits for $U1$ and $U2$, respectively. As shown in Figure 1, the choice of flexible technologies is weakly dominated because $\bar{\phi} > \underline{\phi}$. Summarizing the above discussion, we propose the following proposition:

Proposition 1. The dominant strategy equilibrium is (T_{D1}, T_{D2}) in the choice of technologies, and the equilibrium profits are given by

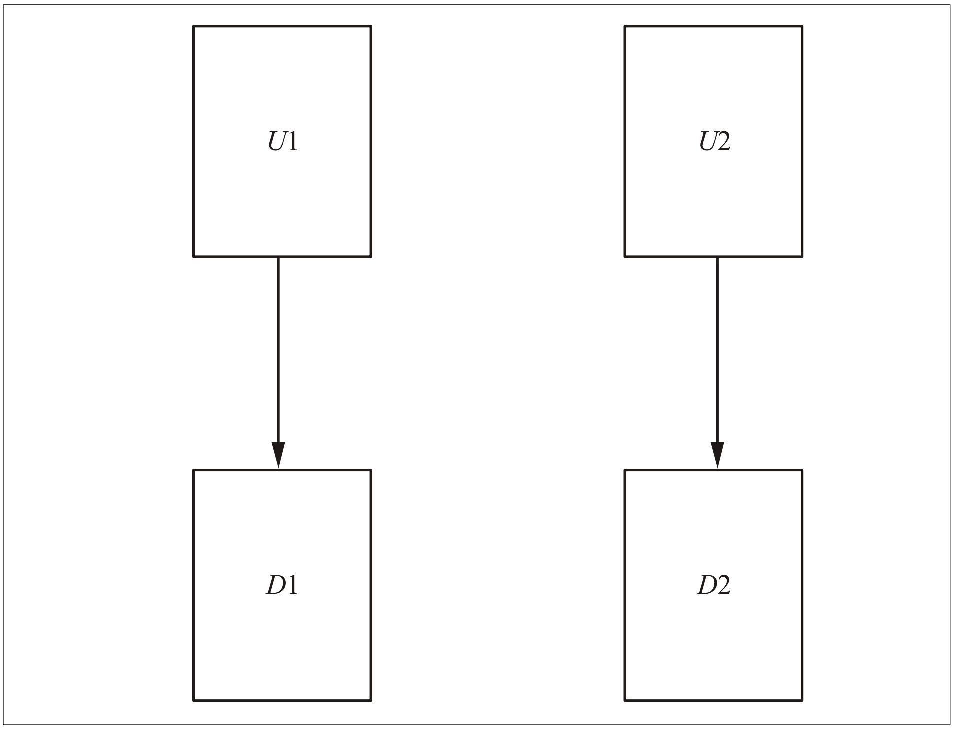
$$\Pi_{U1} = \Pi_{U2} = \bar{\phi}\text{, and } \Pi_{D1} = \Pi_{D2} = \pi(c,c).$$

The results of the above proposition can be explained intuitively as follows. Suppose that upstream firms $U1$ and $U2$ are initially assumed to choose dedicated technologies designed for downstream firms $D1$ and $D2$, respectively (see Figure 2). Let us consider what happens if $U1$ switches to a flexible technology as in Figure 3. In this case, both upstream firms will engage in Bertrand competition in the input market for $D2$. Thus, the equilibrium input price for $D2$ will be driven down to zero. As a result, $U1$ will not gain any profits from the new market. This seems to imply that switching to a flexible technology is neither beneficial nor harmful to $U1$.

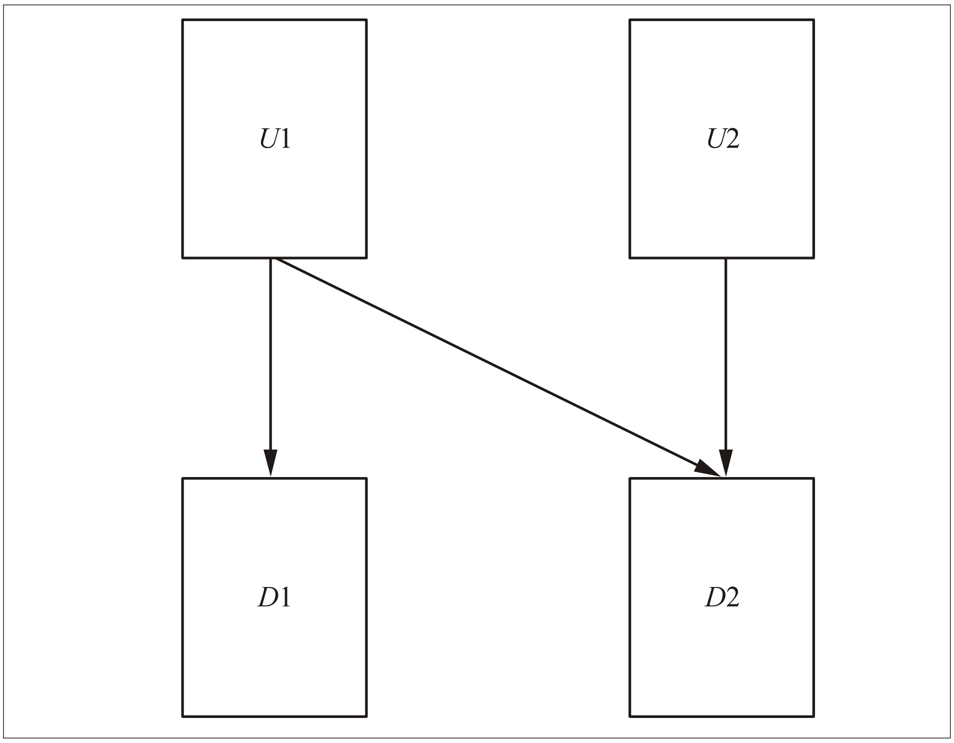
[Figure 1] Payoff Matrix for Technology Choices

		$U2$: T_F	$U2$: T_{D2}
$U1$	T_F	0, 0	$\underline{\phi}$, 0
$U1$	T_{D1}	0, $\underline{\phi}$	$\bar{\phi}$, $\bar{\phi}$

[Figure 2] The Case in which Both Upstream Firms Choose Dedicated Technologies



[Figure 3] The Case in which $U1$ Chooses a Flexible Technology and $U2$ a Dedicated Technology



However, this is not the end of story. If we consider the effect on $U1$'s own turf as well as on $U2$'s turf, we reach a different conclusion. The key logic here lies in the changes in downstream market share. When both upstream firms choose a dedicated technology, each charges a monopoly price to their respective captive downstream firm. Thus, the two downstream firms have the same market share. However, if $U1$ switches to a flexible technology, the input price for $D2$ decreases due to competition, while the input price for $D1$ remains as high as before. $D1$'s market share will then decrease, reducing $U1$'s profits from its captive buyer, $D1$.

In order to highlight the mechanic of our model, let us consider the following case.[3] Suppose that there is only one upstream firm and two downstream firms. If the upstream firm chooses a dedicated technology

[3] An anonymous referee suggested me to compare the mechanic of this case with that of our model.

for a certain downstream firm, the downstream firm may monopolize the downstream market, which in turn gives the upstream firm monopoly profits. However, if the upstream firm chooses a flexible technology, two downstream firms compete. The sum of profits two downstream firms make would be less than monopoly profits. As a result, the upstream firm prefers a dedicated technology.

Both the above case and our model have similar results in the choice of technologies. However they show striking contrasts in their mechanic. First, in the above case, the choice of dedicated technologies makes downstream firms' cost structures asymmetric. In our model, however, downstream firms' cost structures become symmetric if upstream firms choose dedicated technologies. Another difference lies in the role of dedicated technologies. When there is only one upstream firm, a dedicated technology is employed as a way to monopolize the downstream market. In our model, however, dedicated technologies are used as a device to facilitate upstream collusion.

IV. UPSTREAM COST UNCERTAINTY

In this section, we introduce upstream cost uncertainty as an extension of the basic model. Suppose that two upstream firms make uncertain R&D investments on a flexible technology or on a dedicated technology. If upstream firms make R&D investments on flexible technologies and succeed, they can produce both kinds of input at a lower cost of zero. However, if they make R&D investments on dedicated technologies and succeed, they can produce a specific kind of input at the cost of zero. We assume that if $U1$ and $U2$ make uncertain R&D investments, they will succeed with probabilities p_1 and p_2, respectively. For simplicity, we further assume that the probability of success is independent of the choice of technologies. Except for the upstream cost structures, all the assumptions of the basic model still hold.

The timing of the model with upstream cost uncertainty is as follows. In the first stage, upstream firms choose technologies on which they make R&D investments. In the second stage, input costs are realized and publicly observed. Given the cost realizations, input prices are determined in the third stage. Finally, the downstream equilibrium is determined in the fourth stage. Solving the model with upstream cost uncertainty, we obtain the following proposition.

Proposition 2. If $1/2 < p^* < p_1, p_2 < 1$, there are two equilibrium. The first one is that both upstream firms choose flexible technologies. The second one is that both upstream firms choose dedicated technologies. Otherwise, there exists the unique equilibrium: both upstream firms choose flexible technologies.
Proof: See Appendix.

Proposition 2 can be explained intuitively as follows. In the presence of upstream cost uncertainty, the choice of flexible technologies has two effects: the captive effect and the economy-of-scope effect.[4] When the upstream firm chooses a flexible technology, the former effect decreases profits on its own turf, but the latter effect increases profits on the other turf. If the rival firm chooses a flexible technology, there is no captive effect. Therefore, it is profitable to choose a flexible technology regardless of p_1 and p_2. However, if the rival firm chooses a dedicated technology, there are two effects. In this case, the choice of technologies is determined by the trade-off of the two effects, which, in turn, depends on the probability of success. When the probability of success is high, the captive effect dominates the economy-of-scope effect. As the probability of success is closer to one, the model with upstream cost uncertainty becomes more similar to the basic model. In the extreme case of $p_1 = p_2 = 1$, we exactly obtain the basic model in which there exist only captive effects.

V. CONCLUDING REMARKS

We have examined the strategic choice of manufacturing flexibility in the upstream-downstream context. We have focused on *indirect* interdependence of two upstream markets through downstream markets and have shown that downstream competition may have negative effects

[4] There are only captive effects in the basic model.

on the choice of flexible manufacturing technologies.[5]

We conclude by suggesting some applications of our model. First, Röller and Tombak (1993) conducted empirical studies about the effects of the degree of product differentiation on the choice of flexible technologies. They employed GLS and TOBIT as estimation techniques. According to their results, the expected effect of production differentiation on the choice of flexible technologies is empirically supported under the GLS specification. However, no significant influence can be detected under the TOBIT specification. They guessed that this might be explained by the difficulty of measuring product differentiation and missing variable problems. Our theoretical model suggests that one candidate missing variable might be the vertical structure. If we could develop the empirical models incorporating vertical structures, we might obtain the improved empirical results.

Second, our model can be also applicable to the issue of specialization versus diversification. Flexible technologies are matched to diversification, while dedicated technologies are matched to specialization. According to our results, diversification in the intermediate goods markets may cause the captive effects. Therefore, when the firms make decisions about whether or not to diversify in the intermediate goods markets, they should consider the interdependence between the final goods markets as well as the interdependence between the intermediate goods markets.

Last, the results of this paper have some implications for antitrust policies. Bonanno and Vickers (1988) showed that vertical separation with franchise fees can be used as a way to facilitate upstream collusion in successive vertical oligopolies. According to our results, dedicated technologies also might be used as a device for upstream collusion.[6]

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[5] Röller and Tombak (1990) focused on *direct* interdependence between two differentiated markets.

[6] In Ordover, Saloner, and Salop (1990), the integrated firm can increase market power in the downstream industry by foreclosure. In our model, however, upstream firms can facilitate implicit collusion through bilateral foreclosure that results from the choice of dedicated technologies.

APPENDIX

Proof of Proposition 2: First, let us consider the case in which both upstream firms choose flexible technologies. Input prices and upstream profits can be summarized as in Table A-1.

[Table A-1] Upstream Profits when Both Upstream Firms Choose Flexible Technologies

	Cost Realization		Input Prices		Profits	
	$U1$	$U2$	$D1$	$D2$	$U1$	$U2$
$(1-p_1)(1-p_2)$	c	c	c	c	0	0
$p_1(1-p_2)$	0	c	c	c	$2\overline{\phi}$	0
$(1-p_1)p_2$	c	0	c	c	0	$2\overline{\phi}$
p_1p_2	0	0	0	0	0	0

Next, suppose that $U1$ chooses a dedicated technology and $U2$ chooses a flexible technology. Given cost realization, upstream profits are determined as in Table A-2.

[Table A-2] Upstream Profits when $U1$ Chooses a Dedicated Technology and $U2$ Chooses a Flexible Technology

	Cost Realization		Input Prices		Profits	
	$U1$	$U2$	$D1$	$D2$	$U1$	$U2$
$(1-p_1)(1-p_2)$	c	c	c	c	0	0
$p_1(1-p_2)$	0	c	c	c	$\overline{\phi}$	0
$(1-p_1)p_2$	c	0	c	c	0	$2\overline{\phi}$
p_1p_2	0	0	0	c	0	$\underline{\phi}$

Finally, let us consider the case in which both upstream firms choose dedicated technologies. In this case, the outcomes are summarized as in Table A-3.

[Table A-3] Upstream Profits when Both Upstream Firms Choose Dedicated Technologies

	Cost Realization		Input Prices		Profits	
	$U1$	$U2$	$D1$	$D2$	$U1$	$U2$
$(1-p_1)(1-p_2)$	c	c	c	c	0	0
$p_1(1-p_2)$	0	c	c	c	$\overline{\phi}$	0
$(1-p_1)p_2$	c	0	c	c	0	$\overline{\phi}$
p_1p_2	0	0	c	c	$\overline{\phi}$	$\overline{\phi}$

From Table A-1 to Table A-3, we obtain the following results. The notation of $\Pi_{U1}(\alpha,\beta)$ represents the profits of $U1$ when $U1$ chooses technology α and $U2$ chooses technology β. The notation $\Pi_{U2}(\alpha,\beta)$ can be defined in the similar way.

$$\Pi_{U1}(T_F,T_F) = p_1(1-p_2)(2\overline{\phi}). \tag{A1}$$
$$\Pi_{U1}(T_{D1},T_F) = p_1(1-p_2)(\overline{\phi}). \tag{A2}$$
$$\Pi_{U1}(T_F,T_{D2}) = p_1(1-p_2)(2\overline{\phi}) + p_1p_2(\underline{\phi}). \tag{A3}$$
$$\Pi_{U1}(T_{D1},T_{D2}) = p_1(1-p_2)(\overline{\phi}) + p_1p_2(\overline{\phi}). \tag{A4}$$
$$\Pi_{U2}(T_F,T_F) = (1-p_1)p_2(2\overline{\phi}). \tag{A5}$$
$$\Pi_{U2}(T_F,T_{D2}) = (1-p_1)p_2(\overline{\phi}). \tag{A6}$$
$$\Pi_{U2}(T_{D1},T_F) = (1-p_1)p_2(2\overline{\phi}) + p_1p_2(\underline{\phi}). \tag{A7}$$
$$\Pi_{U2}(T_{D1},T_{D2}) = (1-p_1)p_2(\overline{\phi}) + p_1p_2(\overline{\phi}). \tag{A8}$$

From (A1) and (A2), we find that it is optimal for $U1$ to choose a flexible technology when $U2$ chooses a flexible technology, regardless of p_1 and p_2. Similarly, from (A5) and (A6) we see that it is profitable for $U2$ to choose a flexible technology when $U1$ chooses a flexible technology, regardless of p_1 and p_2. This leads to the result that it is an equilibrium for both upstream firms to choose flexible technologies for $0 < p_1, p_2 < 1$.

From (A3) and (A4), we can prove that it is optimal for $U1$ to choose a dedicated technology when $U2$ chooses a dedicated technology if

$$p^* \equiv \frac{\overline{\phi}}{2\overline{\phi} - \underline{\phi}} < p_2 . \qquad \text{(A9)}$$

Similarly, from (A7) and (A8), it is optimal for $U2$ to choose a dedicated technology when $U1$ chooses a dedicated technology if

$$p^* \equiv \frac{\overline{\phi}}{2\overline{\phi} - \underline{\phi}} < p_1 . \qquad \text{(A10)}$$

Through simple calculation, we can easily show that $1/2 < p^* < 1$. From (A9) and (A10), we find that it is an equilibrium for both upstream firms to choose dedicated technologies if $p^* < p_1, p_2 < 1$. (Q.E.D.)

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