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# Corporate Control, Foreign Ownership Regulation and Technology Transfer\*

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## Abstract

In order to undertake foreign direct investment (FDI), multinationals are often required to form joint ventures (JVs) with local firms. This paper examines the effects of technology transfer in the presence of foreign ownership regulation. We specifically consider technology spillover from JVs to local firms, and its relationship with corporate control. It is shown that foreign ownership regulation may facilitate both technology transfer and spillover when the multinational has corporate control. Under corporate control by the local partner firm, however, such regulation may hamper technology transfer.

*JEL Classification Numbers:* F12, F13, F23

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# 1 Introduction

Regulation on foreign ownership is widely observed. Some developed countries impose such regulations in the service industries such as aviation, postal and telecommunications. In many developing countries, regulations are also found in manufacturing. Even though the current trend of “globalization” may help to bring them down to a certain degree, some developing countries require foreign multinational enterprises (MNEs) to form joint venture (JV) with local firms in order to attract foreign direct investment (FDI) and to learn superior foreign technology.<sup>1</sup>

The existing theoretical literature argues that foreign technology transferred in this way can raise the productivity of local firms through technology spillovers from the partially foreign owned firms. Papers in this tradition include for instance Horstmann and Markusen (1989) and Markusen and Venables (1998).<sup>2</sup> And Vishwasrao and Bosshardt (2001), Dimelis and Louri (2002), Griffith et al. (2002) and Smarzynska Javorcik (2004) find empirical evidence supporting this view for various countries.

However, using Venezuelan data, Aitken and Harrison (1999) found a negative effect of FDI on the productivity of domestically owned plants.<sup>3</sup> Other empirical plant-level studies have also questioned the findings that FDI has a positive impact on the productivity of local firms (see for instance, Haddad and Harrison, 1993; Djankov and Hoekman, 2000; and Saggi, 2002).

These empirical findings motivate us to build a theoretical model that can help to explain the contrasting findings in the existing literature. We wish to analyze how foreign ownership regulation affects control, technology transfer and competition with local independent and partner firms. We believe that there are two central issues. One is technology spillover from the (partially) foreign-owned branch to local firms. Such spillovers

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<sup>1</sup>For example, the Chinese government does not allow foreign automakers to have their own subsidiaries. World-leading automakers have been producing in China through JVs with local automakers. The upper limit of foreign ownership is currently 50%. Also, in Malaysia, Proton was established as a national car, which is a JV with Mitsubishi Motors.

<sup>2</sup>Moreover, Markusen and Venables (1999) even show that the domestic firms may grow to the point where local production overtakes and forces out FDI plants.

<sup>3</sup>They argue that an increase in FDI may raise the market share of the partially foreign owned firms, forcing local firms to cut output over the same level of fixed costs.

reduce the multinational's incentives to invest in technology used in the partially owned branch. We examine the interactions in the home market of a domestic incumbent firm with a given inferior technology and a potential foreign entrant with a superior technology. Due to government regulations on foreign ownership, the foreign firm must form a JV with a local firm in order to enter the home market. The JV incurs a setup cost which determines the degree of technology transfer. This new JV technology can further be spilled over to the domestic partner firm.

The other is corporate control, which the existing literature has largely neglected. To be more specific, the existing literature has focused almost exclusively on financial interest, i.e., how profits are shared among joint owners. Corporate control depends on financial interest, but plays markedly different roles. It refers to the right to make the decisions that affect the firm, such as decisions about levels of prices, outputs, investments and where to purchase inputs and locate plants. In a sole proprietorship, a single individual has the right to 100 percent of the firm's profit. The same individual also has complete control over the company. In the case of a partial ownership, nobody has 100 percent ownership. However, a principal shareholder may have 100 percent corporate control and the others have none.

Once corporate control is introduced, it is not hard to see that if the local partner firm does not have a high financial interest, then it may not have much say in the daily decision makings of the jointly owned firm. A direct consequence could be that the foreign technology transferred is at low levels or outdated. In fact, in a couple of informative surveys on Intellectual Property Rights protection, Mansfield (1994, 1995) finds that the quality and extent of technology transfer depends crucially on the control of ownership.

The present paper is built along these lines. We start with the simplest case: the partner with the higher financial interest has 100 percent control of the JV and it thus decides on how much final output to produce. Regardless of who has corporate control, the foreign firm which has superior technology always determines the investment in technology. All costs and profits, however, are shared between the parents according to their financial interests. The technology developed with the investment is partially spilled over to the local partner firm through the JV.

We consider two settings. In the first one, the foreign firm has corporate control. We find that regulations on foreign ownership facilitate such technology transfer/spillover. It arises because an increase in the foreign ownership share makes the local partner firm more aggressive and the scale of the JV smaller, lowering the incentive for the foreign firm to invest in technology. These imply that when the foreign firm has majority ownership and corporate control, regulation on foreign ownership may be effective in inducing the foreign firm to invest more in technology and facilitating technology transfer.

In the second setting, we allow the local partner firm to have corporate control, and find that regulation on foreign ownership can hamper technology transfer. It arises because local corporate control can induce the foreign firm to invest more in technology if spillover is low. In this case, deregulation on foreign ownership induces more investment in technology and consequently higher spillover to the local partner. If spillover is too high, then the foreign firm loses interest in technology investment. These may provide an explanation for the contrasting findings in the empirical literature, and also hopefully provide guidance to governments in designing policies to attract foreign technology.

There are a number of papers on foreign ownership and technology transfer that are related to ours.<sup>4</sup> As mentioned earlier, however, the existing studies abstract from analyzing corporate control. In the present paper, taking corporate control into account and using an oligopolistic framework, we are able to analyze cases of technology transfer to a local partner firm, regulations on foreign ownership and their impacts on independent rival firms, which give rise to insights that match the findings in the empirical literature.

The work by Dasgupta and Sengupta (1995) is an exception. They also tackle the control problem, using a mechanism-design approach and focusing on transfer pricing. They start by assuming a positive “control gain”, the amount of which is private information of the MNE. The host-country government then chooses the optimal regulation of the MNE by maximizing tax revenue. They show that the optimal mechanism involves restricting the MNE’s ownership and also setting a ceiling on the transfer price of an input that the MNE provides. For low realizations of “control gain”, the MNE transfers

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<sup>4</sup>See Lee and Shy (1992), Marjit and Mukherjee (1998), Mukherjeet and Sengupta (2001), Sinha (2001), Glass and Saggi (2002), Kabiraj and Marjit (2003), Lin and Saggi (2004), and Müller and Schnitzer (2006), among others.

control to a domestic partner, while for high realizations, it retains control.<sup>5</sup>

The rest of the paper is organized as follows. Section 2 sets up the basic model. Section 3 examines technology transfer and regulation on foreign ownership. Section 4 investigates corner solutions. And finally, Section 5 concludes the paper.

## 2 The Model

### 2.1 Basic structure

Following the findings in the empirical literature, we consider three firms F, X and Y, interacting in the home market. Firm F is a foreign firm, which can only enter the home market through FDI. However, due to foreign ownership regulations imposed by the home government, it has to form a JV with a local partner X. Firm X may be willing to do so because firm F posses superior technology, which is used in the JV and can potentially be spilled over to firm X. There is also an independent local firm Y, which competes with firm X and the JV. We wish to use this structure to analyze how foreign ownership regulation affects control, technology transfer and competition with local independent and partner firms.

Assume that the JV formed is a completely new plant Z, which produces output  $z$ . Firm F owns a share  $k$  of the JV, and the other share  $(1-k)$  goes to firm X. For simplicity,  $k$  is assumed to be exogenously given. With its superior technology, firm F would always choose to go alone (choosing  $k = 1$ ) if allowed. However, we are more interested in how the home government can impose ownership regulation to attract foreign technology. In this paper, therefore, we assume  $k$  to be set by the home government.<sup>6</sup> A new investment  $f$  is required when setting up the JV.

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<sup>5</sup>Moreover, Nakamura and Xie (1998) argue that a firm's ownership share in its foreign operation reflects the importance of its intangible assets used in the operation and the resulted bargaining power relative to its local partners'. They test these implications using data on foreign firms' manufacturing operations located in Japan and find them to be consistent.

<sup>6</sup>One could also introduce bargaining to determine the ownership shares. However, this makes the analysis much more complicated. For our purpose, it is sufficient to assume that the foreign ownership share detemined in the bargain is always greater than the upper limit set by the foreign government.

The inverse demands for the imperfectly substitutable goods are respectively

$$\begin{aligned} p_z &= a_z - z - \gamma(x + y), \\ p_q &= a_q - (x + y) - \gamma z, \end{aligned}$$

where  $z$  is the output of plant Z (i.e., the JV), and  $x$  and  $y$  are those of firms X and Y respectively, with  $q = x + y$ , and  $\gamma \in (0, 1)$  is a parameter indicating the degree of substitutability between the output of the JV and those of local firms, and  $a_z$  and  $a_q$  are parameters. Product differentiation can be justified on the grounds that the JV uses superior foreign technology, which potentially leads to products that meet consumer demands better than local ones.

The setup investment required when building the JV reduces the marginal cost of production. As a result, the total cost of the JV can be written as

$$TC_Z = c(f)z + f,$$

where  $c'(f) < 0$ ,  $c(0) = c_X$ ,  $c''(f) > 0$ . The variable  $f$  can also be called an investment in technology, capacity or R&D. It can only be conducted by firm F, which has superior technology. Then, only firm F can determine how much to invest in  $f$ . However, the financial interests are arranged such that both partner firms share all costs and profits according to the shares they respectively hold. Thus, firms F and X pay the investment costs  $kf$  and  $(1 - k)f$ , respectively.

If the JV is formed successfully, its technology is spilled over to the local partner-firm X, such that:

$$\tilde{c}_X = c_X - g(c_X - c(f)) = c_X - \tau(f), \quad (1)$$

where  $g \in (0, 1)$  is a parameter and  $\tau(f) \equiv g(c_X - c(f))$ . However, the technology of the local independent firm Y is not affected.

We focus only on the home market. If the JV is not formed, the foreign firm F cannot enter because of trade costs or host government regulations.<sup>7</sup> Since we are interested in technology transfer, we assume that without foreign entry, the domestic firm cannot

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<sup>7</sup>When firm F has to incur a large fixed cost (say, a beach head cost) to start exports, even a small tariff or transport cost becomes prohibitive.

invest on its own to improve technology. If the JV is formed, then there are three plants X, Y and Z in the home market. The profits of the JV can be written as:

$$\pi_Z \equiv (p_z - c(f))z - f.$$

Thus, the profit functions of firms F, X and Y become respectively,

$$\pi_F \equiv k\pi_Z,$$

$$\pi_X \equiv \pi_{XX} + (1 - k)\pi_Z,$$

$$\pi_Y \equiv (p_q - c_Y)y.$$

where  $\pi_{XX} \equiv (p_q - \tilde{c}_X)x$  is the profit from the local plant for partner firm X, which also obtains a share  $(1 - k)$  of the JV profit.

The following sections examine the effects of ownership regulation on technology transfer, by explicitly taking corporate control into account. We model financial interests and corporate control in a simple way. The partner with the higher financial interest takes total control of the JV; that is, it determines the JV's output. Since there are two cases  $k \geq 1/2$  and  $k < 1/2$  (if  $k = 1/2$ , we assume firm F has corporate control since it possesses better technology), we shall investigate them sequentially, given that firm F determines  $f$ .

The game has two stages. In the first stage, taking the foreign ownership  $k$  as given, firm F chooses the amount of investment on technology. In the second stage, firms compete in a Cournot fashion. The game is solved by backward induction, by going from output competition to technology investment and spillover.

### 2.1.1 Output competition stage

There are three plants X, Y and Z. Firms X and Y determine the outputs of their own plants,  $x$  and  $y$ , respectively. And the firm holding corporate control determines the output of the JV, i.e., it is firm X if  $k < 1/2$  and firm F if  $k \geq 1/2$ .

Profit maximization with respect to its own output by firms X and Y results in the following first order conditions (FOCs) respectively,

$$p_q - (1 - g)c_X - gc(f) - x - (1 - k)\gamma z = 0, \quad (2)$$

$$p_q - c_Y - y = 0. \quad (3)$$



For the JV, the FOCs for output  $z$  are

$$\frac{\partial \pi_X}{\partial z} = (1-k)(p_z - c(f) - z) - \gamma x = 0, \quad \text{if } k < 1/2; \quad (4)$$

$$\frac{\partial \pi_F}{\partial z} = k(p_z - c(f) - z) = 0, \quad \text{if } k \geq 1/2. \quad (5)$$

When  $k < 1/2$ , the second order condition (SOC) for firm X is satisfied for all  $k$  if and only if  $\gamma < \sqrt{8/9} \approx 0.942$ . Throughout this paper, we assume  $\gamma < \sqrt{8/9}$ . Other SOC's are always satisfied.

Let us introduce an index variable  $\eta$ , which is *the control ratio of firm X*, expressing the ratio of control to ownership by firm X,

$$\eta = \begin{cases} \frac{1}{1-k} & \text{if } k < 1/2 \\ 0 & \text{if } k \geq 1/2 \end{cases} \quad (6)$$

Using the above, we can express the two FOCs (4) and (5) in one equation

$$R - \gamma \eta x = 0, \quad (7)$$

where  $R(\equiv p_z - c(f) - z)$  is the marginal profit of output  $z$ .

Condition (7) implies that firm X's control ratio,  $\eta$ , and firm X's production scale matter for the determination of output  $z$ . In fact, we have the following lemma.

**Lemma 1** *When  $k < 1/2$ , an increase in  $\eta x$  leads the JV to restrict its output.*

The reason is that when  $k < 1/2$ , firm X determines both outputs  $x$  and  $z$  to maximize its total profits from the JV share and its own plant. When  $x$  is large, firm X has an incentive to lower  $z$  to reduce its intra-marginal losses. Moreover, as its control ratio  $\eta$  rises, firm X can more easily restrict the JV output.

Although foreign ownership share affects firm X's control ratio, the relationship between  $k$  and  $\eta$  is not monotonic:

$$\frac{d\eta}{dk} = \eta^2 = \begin{cases} \frac{1}{(1-k)^2} & \text{if } k < 1/2 \\ 0 & \text{if } k > 1/2 \end{cases}. \quad (8)$$

Figure 1 illustrates this relationship. When firm X has control ( $k < 1/2$ ), a small increase in foreign ownership leads to a higher control ratio. If the foreign firm holds the control

right ( $k \geq 1/2$ ), the control ratio falls to zero and is not affected by any small change of ownership share. This non-monotonicity of  $\eta$  simply reflects the fact that a 1% increase in ownership does not necessarily entail a 1% increase in the control right.

### 2.1.2 Technology Choice Stage

In the technology transfer stage, given  $k$ , firm F decides the level of investment in technology  $f$ , i.e.,

$$\max_f \pi_F = k\pi_Z.$$

Using the envelope theorem and (7), the first order condition is obtained as

$$\frac{\partial \pi_F}{\partial f} = k \left[ -z \left( \gamma \frac{\partial (x+y)}{\partial f} + c'(f) \right) + R \frac{\partial z}{\partial f} - 1 \right] = 0. \quad (9)$$

A large  $c''(f)$  assures the second order condition.

By the implicit function theorem and (9), we obtain the effect of foreign ownership on investment,

$$\frac{df}{dk} = - \frac{\partial^2 \pi_F / \partial f \partial k}{\partial^2 \pi_F / \partial f^2},$$

thus, the sign of  $\partial^2 \pi_F / \partial f \partial k$  determines whether an increase in foreign ownership ratio facilitates investment in technology. This is investigated in the next section in detail.

## 3 Technology Transfer

### 3.1 Comparative Statics

Let us derive some expressions that will become handy to determine the sign of  $\partial^2 \pi_F / \partial f \partial k$ . The FOCs (2), (3), and (7) determine the outputs  $x(f, k)$ ,  $y(f, k)$ ,  $z(f, k)$  as functions of investment and the ownership ratio. Total differentiation gives rise to:

$$\begin{pmatrix} 2 & 1 & \gamma(2-k) \\ 1 & 2 & \gamma \\ \gamma(1+\eta) & \gamma & 2 \end{pmatrix} \begin{pmatrix} dx \\ dy \\ dz \end{pmatrix} = -c'(f) \begin{pmatrix} g \\ 0 \\ 1 \end{pmatrix} df + \begin{pmatrix} \gamma z \\ 0 \\ -\eta R \end{pmatrix} dk$$

The Hessian is positive, i.e.,  $\Delta \equiv 6 - \gamma^2(3-k) - \gamma^2\eta(3-2k) > 0$  from the assumption  $\gamma < \sqrt{8/9}$ .

Straightforward calculations give

$$\frac{\partial x}{\partial k} = \frac{\gamma z (4 - \gamma^2) + \gamma \eta R (3 - 2k)}{\Delta} > 0, \quad (10)$$

$$\frac{\partial y}{\partial k} = \frac{\gamma k \eta R - \gamma z \{2 - \gamma^2 (1 + \eta)\}}{\Delta}, \quad (11)$$

$$\frac{\partial z}{\partial k} = -\frac{3\eta R + \gamma^2 z (2\eta + 1)}{\Delta} < 0, \quad (12)$$

$$\frac{\partial (x + y)}{\partial k} = \frac{\gamma z (2 + \gamma^2 \eta) + \gamma \eta R (3 - k)}{\Delta} > 0. \quad (13)$$

To interpret the above, let us define  $k_1 \equiv 2(1 - \gamma^2) / (2 - \gamma^2)$  such that  $2 - \gamma^2(1 + \eta) < 0$  in (11) if and only if  $k_1 < k < 1/2$ . Then, we establish the following lemma.

**Lemma 2** *An increase in foreign ownership with a given setup investment, (i) reduces the output of the JV, but raises that of the local partner firm, and the sum of the outputs of all local firms; (ii) increases the output of the 100%-locally-owned firm when  $k_1 \leq k < 1/2$  but decreases it when  $k \geq 1/2$ .*

The intuition for Lemma 2 is straightforward from FOCs (2) and (7). Under foreign corporate control (i.e.,  $k \geq 1/2$ ), an increase in foreign ownership lowers firm X's earnings from the JV. Hence, firm X becomes more aggressive and increases the output, which forces other firms to lower their outputs. On the other hand, under local corporate control (i.e.,  $k < 1/2$ ), an increase in foreign ownership has an additional effect through an increase of  $\eta$ . From Lemma 1, an increase of  $\eta$  leads to a reduction of  $z$  and expansions of  $x$  and  $y$ . Therefore, the net effect on  $x$  is positive, while that on  $y$  is generally ambiguous.

Next, the impacts of technology investment on outputs with a given foreign ownership are derived as,

$$\frac{\partial x}{\partial f} = \frac{-c'(f)\{g(4 - \gamma^2) - \gamma(3 - 2k)\}}{\Delta}, \quad (14)$$

$$\frac{\partial y}{\partial f} = \frac{c'(f) [\gamma k + g\{2 - \gamma^2(1 + \eta)\}]}{\Delta}, \quad (15)$$

$$\frac{\partial z}{\partial f} = \frac{-c'(f)\{3 - \gamma g(2\eta + 1)\}}{\Delta}. \quad (16)$$

Again these can be examined more closely in two separate cases. Define  $g_x \equiv \gamma(3 - 2k) / (4 - \gamma^2)$ . In the case of foreign corporate control (i.e.,  $k \geq 1/2$  and  $\eta = 0$ ), they become

$$\begin{aligned}\frac{\partial x}{\partial f} &= \frac{-c'(f)\{g(4 - \gamma^2) - \gamma(3 - 2k)\}}{\Delta} > 0, \quad \text{iff } g > g_x, \\ \frac{\partial y}{\partial f} &= \frac{c'(f)\{\gamma k + g(2 - \gamma^2)\}}{\Delta} < 0, \\ \frac{\partial z}{\partial f} &= \frac{-c'(f)(3 - \gamma g)}{\Delta} > 0.\end{aligned}$$

Investment improves technologies of the JV and firm X through technology transfer/spillover. Therefore, it is straightforward that it increases the JV's output and decreases the independent local firm's output. The net change of firm X's output depends on the degree of the technology transfer/spillover, which offsets the substitution effect due to the expansion of the JV. The threshold  $g_x$  falls as the foreign ownership rises, because an increase in  $k$  makes firm X more aggressive to expand its output.

In the case of local corporate control ( $k < 1/2$ ), the effects of technology investment on outputs are more complicated. Define  $g_y \equiv \gamma k(1 - k) / \{\gamma^2(2 - k) - 2(1 - k)\}$  and  $g_z \equiv 3(1 - k) / \{\gamma(3 - k)\}$  and substitute  $\eta = (1 - k)^{-1}$  into (14), (15) and (16). Then, we obtain

$$\begin{aligned}\frac{\partial x}{\partial f} &= \frac{-c'(f)\{g(4 - \gamma^2) - \gamma(3 - 2k)\}}{\Delta} > 0, \quad \text{iff } g > g_x, \\ \frac{\partial y}{\partial f} &= \frac{c'(f)[\gamma k(1 - k) - g\{\gamma^2(2 - k) - 2(1 - k)\}]}{\Delta(1 - k)} < 0, \quad \text{iff } g < g_y, \\ \frac{\partial z}{\partial f} &= \frac{-c'(f)\{3(1 - k) - \gamma g(3 - k)\}}{\Delta(1 - k)} > 0, \quad \text{iff } g < g_z.\end{aligned}$$

By using the fact that  $g_y > g_z > g_x > 0$  when  $g_y > 0$ , we can summarize the effects of investment on each output in terms of parameters  $(k, g)$  in Figure 2 as follows.

**Lemma 3** *Suppose  $k < 1/2$ .*

- (i) *If  $(k, g)$  belongs to area A, then  $\partial x/\partial f < 0$ ,  $\partial y/\partial f < 0$ , and  $\partial z/\partial f > 0$ ;*
- (ii) *if  $(k, g)$  belongs to area B, then  $\partial x/\partial f > 0$ ,  $\partial y/\partial f < 0$ , and  $\partial z/\partial f > 0$ ;*
- (iii) *if  $(k, g)$  belongs to area C, then  $\partial x/\partial f > 0$ ,  $\partial y/\partial f < 0$ , and  $\partial z/\partial f < 0$ ;*
- (iv) *if  $(k, g)$  belongs to area D, then  $\partial x/\partial f > 0$ ,  $\partial y/\partial f > 0$ , and  $\partial z/\partial f < 0$ .*

The first two cases (i) and (ii) in Lemma 3 are the same as under foreign corporate control. However, cases (iii) and (iv) are not straightforward and arise only under local corporate control. Quite surprisingly, technology investment of the JV may reduce the JV output. The intuition follows from Lemma 1. Under local control, firm X restricts the JV's output to secure its own profit. Since the extent of restriction is increasing in the scale of firm X, a large technology spillover (i.e.,  $g > g_z$ ) leads firm X to shift production from the JV to its own plant, and hence resulting in  $\partial z / \partial f < 0$ . If the spillover becomes sufficiently large (i.e.,  $g > g_y$ ), then the JV output is reduced by so much that firm Y's output is also pushed up, yielding  $\partial y / \partial f > 0$ . This effect is the most counter-intuitive, because the 100%-locally-owned firm increases its output even when the technology of the other two firms improves.

Finally, we should remark that the counter intuitive cases (iii) and (iv) hold under low product differentiation between the outputs of the JV and the local firms, i.e., under high values of  $\gamma$ . In fact, in Figure 2, area C emerges iff  $\gamma > \sqrt{2/3} \simeq 0.81$ , and area D appears iff  $\gamma > (1 + \sqrt{97}) / 12 \simeq 0.90$ . We draw the cases of intermediate product differentiation ( $\gamma = 0.85$ ) and high product differentiation ( $\gamma = 0.5$ ) in Figures 3 and 4, respectively.

### 3.2 Control by the Foreign Firm: $k > 1/2$

We are now ready to determine the sign of  $\partial^2 \pi_F / \partial f \partial k$ . We first look at the case in which firm F holds majority share and hence has corporate control of the JV. From (9), (12), and  $R = 0$ , we obtain

$$\begin{aligned} \frac{1}{k} \frac{\partial^2 \pi_F}{\partial f \partial k} &= -\frac{\partial z}{\partial k} \left( \gamma \frac{\partial (x+y)}{\partial f} + c'(f) \right) - \gamma z \frac{\partial^2 (x+y)}{\partial f \partial k} \\ &= \frac{1}{z} \frac{\partial z}{\partial k} - \gamma z \frac{\partial^2 (x+y)}{\partial f \partial k} < 0, \end{aligned} \tag{17}$$

where the inequality holds because (13) and (16) yield

$$\frac{\partial^2 (x+y)}{\partial f \partial k} = \frac{2\gamma}{\Delta} \frac{\partial z}{\partial f} > 0.$$

Thus,  $df/dk < 0$ . Differentiating the technology transfer variable  $\tau$  with respect to  $k$ , we obtain

$$\frac{d\tau}{dk} = -gc'(\cdot)\frac{df}{dk} < 0.$$

Therefore, we can formally state:

**Proposition 1** *Under  $k > 1/2$ , an increase in the foreign ownership share decreases the parents' investment in technology, eventually resulting in less technology spillover from the JV to the local partner firm.*

In view of Lemma 2, an increase in  $k$  raises  $x$  and reduces  $z$ . When the scale of the JV shrinks, the technology investment by firm F falls. It arises because keeping the same level of investment becomes costly due to the convexity of the cost function. These imply that when the foreign firm has majority ownership and corporate control, regulation on foreign ownership may be effective in inducing the foreign firm to invest more in technology and facilitating technology transfer. And they seem to be in line with some empirical findings such as Haddad and Harrison (1993), Mansfield (1994, 1995), Aitken and Harrison (1999), Djankov and Hoekman (2000), and Saggi (2002).

Moreover, in view of Lemmas 2 and 3 and Proposition 1, the following proposition can be established.

**Proposition 2** *Under  $k > 1/2$ , an increase in the foreign ownership share raises the output of the local partner firm if  $g < g_x$  and decreases that of the JV. The effect on the output of the independent local firm is ambiguous.*

### 3.3 Control by the Local Partner: $k < 1/2$

When the local partner holds control of the JV, an increase in foreign ownership brings an additional effect on the marginal profit of investment  $f$ . Since the marginal profit of the JV,  $R$ , is non-zero, the cross partial derivative is

$$\frac{1}{k} \frac{\partial^2 \pi_F}{\partial f \partial k} = -\frac{\partial z}{\partial k} \left( \gamma \frac{\partial (x+y)}{\partial f} + c'(f) \right) - \gamma z \frac{\partial^2 (x+y)}{\partial f \partial k} + \frac{\partial \left( R \frac{\partial z}{\partial f} \right)}{\partial k}. \quad (18)$$

The first two terms appeared in (17) and it is straightforward to confirm that they remain negative. The last term is new to the case of foreign control. Noting  $R = \gamma\eta x$ , we obtain

$$\begin{aligned} \frac{\partial \left( R \frac{\partial z}{\partial f} \right)}{\partial k} &= \gamma\eta \frac{\partial x}{\partial k} \frac{\partial z}{\partial f} + \gamma\eta x \frac{\partial^2 z}{\partial f \partial k} + \gamma\eta^2 x \frac{\partial z}{\partial f} \\ &= \gamma\eta \left( \frac{R(6 - 2\gamma^2(3 - k)) + \gamma z(4 - \gamma^2)}{\Delta} \right) \frac{\partial z}{\partial f} - \frac{3\gamma\eta^2 R}{\Delta} \frac{\partial x}{\partial f}. \end{aligned} \quad (19)$$

>From Lemma 3, this term becomes positive when  $g$  is small, i.e.,  $\partial z/\partial f > 0$  and  $\partial x/\partial f < 0$  hold. Now define  $g_a \equiv 3\gamma k(2 - k)/[12(1 - \gamma^2) + k\gamma^2(6 - k)]$  and  $g_b \equiv [\gamma^2(3 + k^2 - 3k) - 3(1 - k)^2]/\gamma(3 - k)(k - \gamma^2 + 1)$ , where  $g_a > g_b$ . The following proposition then shows how ownership regulation affects technology investment and the extent of technology transfer.

**Proposition 3** *Under  $k < 1/2$ , (i) When  $g \leq g_b$ , an increase in the foreign ownership share raises the investment in technology, resulting in more technology spillover from the JV to the local partner firm. (ii) When  $g \geq g_a$ , exactly the opposite arises.*

**Proof.** See the Appendix. ■

Some intuition follows. First note that the JV output is smaller under local control than under foreign control (see Lemma 1). Thus, an increase in the JV output caused by firm F's further investment creates a first order positive effect on the profit of the JV. This effect becomes stronger as the JV output is reduced more. In other words, the larger  $\eta x$  is, the bigger the marginal profit of investment is. From Lemma 2, an increase in foreign ownership raises both  $\eta$  and  $x$ , which then makes investment more appealing. Proposition 3 specifically states that since technology spillover to firm X weakens the effect of technology investment on the JV output, i.e.,  $\partial^2 z/\partial f \partial g < 0$ , investment increases only when technology transfer/spillover is sufficiently low.

Proposition 3 says that both corporate control and technology spillover are important in determining whether local firms gain or lose from FDI, as explained in the introduction of the paper. Under local corporate control, when technology spillover is low, the foreign firm has both incentive and necessity to invest in technology, eventually leading to more technology transfer. If technology spillover is high, such an incentive disappears. These may explain the contrasting findings in the empirical literature.

We should add a technical note. First of all, it is straightforward to confirm  $g_x > g_a > g_b$  for all  $k < 1/2$  and  $\gamma$ . Figure 5 draws  $g_a$ ,  $g_b$  and  $g_x$  in the case of low product differentiation ( $\gamma = 0.85$ ). When  $(k, g)$  belongs to areas I and II, an increase in foreign ownership reduces investment in technology. Area IV represents the range of parameters where an increase in foreign ownership increases investment, while area III represents the range of parameters where the effect is ambiguous. Therefore,  $df/dk > 0$  arises only for a limited range of  $k$  and requires a low degree of product differentiation, i.e., high  $\gamma$ . Area IV in Figure 5 emerges iff  $\gamma > \sqrt{3/7} \simeq 0.65$ . The case of relatively high product differentiation ( $\gamma = 0.5$ ) is shown in Figure 4.

Finally, in view of Lemmas 2 and 3 and Proposition 3, we also establish:

**Proposition 4** *Suppose  $k < 1/2$  and  $k_1 < 1/2$ . An increase in the foreign ownership share, (i) increases the output of the independent local firm if  $g_a \leq g < g_y$  and  $k > k_1$  hold; (ii) increases the output of the local partner firm if  $g_a \leq g \leq g_x$ ; (iii) and decreases the output of the JV if  $g_a \leq g \leq g_z$ .*

### 3.4 Discrete Jump: $k = 1/2$

In the previous subsections, we have focused only on small changes of the foreign ownership without transferring corporate control. To complete the analysis of ownership change, we now examine the effect of a shift in control rights at the threshold  $k = 1/2$ . As seen in Figure 1, the control-ownership ratio  $\eta$  of firm X drops in discrete amount at  $k = 1/2$ . To focus on this discrete effect, we consider an increase in  $\eta$  while keeping  $k$  constant, and examine its effect on technology investment, i.e.,  $\partial f(k, \eta)/\partial \eta$ .

We rewrite variables as functions of  $(k, f, \eta)$  with a tilde. Then, total differentiation of the FOCs in the output competition stage yields

$$\frac{\partial \tilde{x}(k, f, \eta)}{\partial \eta} = \frac{\gamma^2 x (3 - 2k)}{\Delta} > 0, \quad \frac{\partial \tilde{y}(k, f, \eta)}{\partial \eta} = \frac{k\gamma^2 x}{\Delta} > 0, \quad \text{and} \quad \frac{\partial \tilde{z}(k, f, \eta)}{\partial \eta} = \frac{-3\gamma x}{\Delta} < 0. \quad (20)$$

The intuition follows from Lemma 1. An increase in  $\eta$  reduces the output of the JV, which leads to increases in other firms' outputs. It can be also confirmed that the effects of investment remain the same as in the previous section; that is,  $\partial \tilde{x}(k, f, \eta)/\partial f = \partial x(f, k)/\partial f$ ,  $\partial \tilde{y}(k, f, \eta)/\partial f = \partial y(f, k)/\partial f$  and  $\partial \tilde{z}(k, f, \eta)/\partial f = \partial z(f, k)/\partial f$ .



The implicit function theorem yields the sign of  $\partial f(k, \eta) / \partial \eta$  as identical to that of  $\partial^2 \tilde{\pi}_Z(k, f, \eta) / \partial f \partial \eta$ . Analogous to (18), the cross derivative is expressed as

$$\frac{\partial^2 \tilde{\pi}_Z(k, f, \eta)}{\partial f \partial \eta} = -\frac{\partial \tilde{z}}{\partial \eta} \left( \gamma \frac{\partial(x+y)}{\partial f} + c'(f) \right) - \gamma z \frac{\partial^2(\tilde{x} + \tilde{y})}{\partial f \partial \eta} + \frac{\partial \left( R \frac{\partial z}{\partial f} \right)}{\partial \eta}. \quad (21)$$

From Lemma 3 and (20), the first two terms in (21) are negative and the last term is positive when  $g$  is small. The following lemma shows that the net effect depends on the size of  $g$ .

**Lemma 4** (i)  $\partial f(k, \eta) / \partial \eta > 0$  if  $g < g_a$ , (ii)  $\partial f(k, \eta) / \partial \eta < 0$  if  $g > g_x$ .

**Proof.** See the Appendix. ■

Similar to Proposition 3, an increase in  $\eta$  causes two opposite effects on investment. On the one hand, as seen in (20), an increase in  $\eta$  leads firm X to lower the scale of the JV, which tends to decrease the level of technology investment because of the convex cost function  $c(f)$ . This effect is expressed as the first two terms in (21). On the other hand, the opposite effect is drawn from Lemma 1. An increase in  $\eta$  and  $x$  raises the JV's marginal profit  $R = \gamma \eta x$ , which in turn increases the return from the JV's additional output. Therefore, this effect leads the foreign firm to invest more. Lemma 4 also shows the former effect dominates the latter one when technology spillover is large. This arises because technology spillover to firm X reduces firm F's technology-investment incentive by weakening its effect on the JV output.

From Lemma 4, we can obtain the effects of a discrete change in ownership on the level of investment.

**Proposition 5** *There exists a small number  $\varepsilon > 0$  such that (i) when  $g < g_a$ , an increase in the foreign ownership from  $k = 1/2 - \varepsilon$  to  $k = 1/2 + \varepsilon$  entails a discrete drop of the investment in technology; and (ii) when  $g > g_x$ , an increase in the foreign ownership from  $k = 1/2 - \varepsilon$  to  $k = 1/2 + \varepsilon$  entails a discrete rise of technology investment.*

Proposition 5 underlines the importance of taking into account the shift of control rights, when examining the effects of foreign ownership on technology investment. For example, when technology transfer is large such that  $g > g_x$ , an increase in foreign

ownership reduces technology investment within regimes  $k \in [0, 1/2)$  and  $k \in (1/2, 1]$ , but a shift of control rights from a local firm to a foreign firm at  $k = 1/2$  improves technology investment. Therefore, empirical analysis that fails to consider the shift of control rights may not find any strong effects of ownership shares on technology investment.

## 4 Corner Solutions

So far we have assumed that the two local firms remain in the market after the JV is formed. However, it is possible that one of the local firms or both of them exit from the market. In this section, we investigate these cases and show that an allocation of corporate control between operating firms is crucial for examining the relationship between foreign ownership ratio and technology transfer.

First, suppose the JV becomes the monopolist. In this case, it does not matter which firm has corporate control. When  $f$  is given, the optimal output is  $(a - c(f))/2$  which is unique and independent of  $k$  regardless of whether the output level is determined by firm F or firm X. That is, given the setup investment, a change in  $k$  does not affect the output level.

Now the JV determines the level of investment in technology  $f$  by

$$\max_f \pi_F = k\pi_Z.$$

Noting that the profits of the JV are given by  $\pi_Z = z^2 - f$ , the FOC and SOC can then be written respectively as

$$\begin{aligned} \frac{d\pi_F}{df} &= k \left( 2z \frac{\partial z}{\partial f} - 1 \right) = k(-zc'(f) - 1) = 0, \\ \frac{d^2\pi_Y}{df^2} &= -k \left( \frac{\partial z}{\partial f} c'(f) + zc''(f) \right) < 0. \end{aligned}$$

The SOC is satisfied if  $c''$  is sufficiently high.

Next consider the effect of a change in  $k$  on  $f$ . Since  $z$  is independent of  $k$ , we have

$$\frac{df}{dk} = -\frac{\partial^2 \pi_F / \partial f \partial k}{\partial^2 \pi_F / \partial f^2} = 0.$$

That is, the optimal  $f$  is independent of the ownership share in the case of the monopoly.

Thus, we obtain

**Proposition 6** *Suppose that the JV becomes the monopolist. Then, the parents' investment in technology is independent of the ownership share.*

Finally, we look into the case where one of the two local firms stops its production. If the local independent firm (firm Y) exits from the market, the analysis is similar to that in the previous section. Since firm Y does not play any crucial role, the qualitative results obtained there remain valid. In other words, our main results on the technology transfer/spillover to the local partner firm can be obtained even without the independent local firm.<sup>8</sup> However, incorporating firm Y allows us to examine the effects of foreign ownership regulation on firms which have no relationship with foreign firms.

In the case where the local partner firm stops its production, the analysis is similar to that in the monopoly case above. Specifically, the outputs of the JV and firm Y are, respectively,  $z = [2(a_z - c(f)) - \gamma(a_q - c_X)]/(4 - \gamma^2)$  and  $y = [2(a_q - c_X) - \gamma(a_z - c(f))]/(4 - \gamma^2)$ . Thus, both  $z$  and  $\pi_Z$  are independent of  $k$ .

## 5 Concluding Remarks

We have examined the effects of technology transfer from a foreign firm to a JV and technology spillover from the JV to the local partner firm in the presence of foreign ownership regulation. It is shown that foreign ownership regulation may facilitate both technology transfer and spillover when the multinational has corporate control. Under corporate control by the local partner firm, however, such regulation may hamper technology transfer. Moreover, foreign ownership regulation may not benefit the local independent firm.

In concluding this paper, three final remarks are in order. First, we have assumed that firm X and firm F form a JV. It would be interesting to analyze how the foreign firm chooses its partner. And the local firms may compete so as to be selected as the partner.

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<sup>8</sup>Propositions 1, 3, and 5 hold simply by redefining  $g_x \equiv \gamma(2 - k)/2$ ,  $g_a \equiv \{k(2 - \gamma) - 2(1 - \gamma)\}\{2(1 - k) + \gamma(2 - k)\}/2\gamma k(2 - k)$ , and  $g_b \equiv 2\gamma k(2 - k)/[\{2 + \gamma(2 - k)\}\{2(1 - \gamma) + k\eta\}]$ .

Second, we have incorporated only one type of spillover generated by the JV: the technology spillover from the foreign firm to the local partner firm. There may exist other types and in a different direction, such as spillovers of market knowledge from the local partner firm to the foreign firm. In the presence of such spillovers, not only the local firm but also the foreign firm may have more incentives to form a JV.

Lastly, we have assumed that the upper limit on foreign ownership is exogenously given and binding. This assumption is made because our focus is on the relationship between foreign ownership regulation and technology transfer. However, it is worthwhile to analyze the optimal level of regulation when foreign ownership is endogenously determined by the parent firms. These remain fruitful avenues for further research.

## Appendix

**Proof of Proposition 3.** We drive  $\partial^2\pi_Z/\partial f\partial k$  by differentiating  $\partial\pi_Z/\partial k$  with respect to  $f$  instead of calculating (18) directly. From FOC (3), we obtain

$$\begin{aligned}\frac{\partial\pi_Z}{\partial k} &= -\gamma z \frac{\partial(x+y)}{\partial k} + R \frac{\partial z}{\partial k} \\ &= -\gamma^2 \left( \frac{3x^2 + 2\gamma xz(3-k)(1-k) + z^2(1-k)^2(2(1-k) + \gamma^2)}{(1-k)^3 \Delta} \right),\end{aligned}$$

and differentiation yields

$$\frac{\partial^2\pi_Z}{\partial k\partial f} = \frac{2\gamma^2 x c'(f)}{(1-k)^3 \Delta^2} (xA + zB),$$

where

$$\begin{aligned}A &\equiv \{12(1-\gamma^2) + k\gamma^2(6-k)\}(g-g_a), \\ B &\equiv 2\gamma(1-k)(3-k)(1+k-\gamma^2)(g-g_b).\end{aligned}\tag{A1}$$

Since

$$g_a - g_b = \frac{\Delta^2(1-k)^2}{\gamma(3-k)(k-\gamma^2+1)\{12(1-\gamma^2) + k\gamma^2(6-k)\}} > 0,$$

we can conclude that  $\partial^2 \pi_Z / \partial f \partial k > 0$ , i.e.,  $df/dk > 0$  when  $g \leq g_b$ , and  $df/dk < 0$  when  $g \geq g_a$ . ■

**Proof of Lemma 4.** Similar to the proof for Proposition 3, we calculate the following:

$$\begin{aligned} \frac{\partial \tilde{\pi}_Z(k, f, \eta)}{\partial \eta} &= -\gamma z \frac{\partial (\tilde{x} + \tilde{y})}{\partial \eta} + R \frac{\partial \tilde{z}}{\partial \eta} \\ &= -\frac{\gamma^2}{1-k} \left( \frac{3x^2 + \gamma x z (3-k)(1-k)}{\Delta} \right), \\ \frac{\partial^2 \tilde{\pi}_Z(k, f, \eta)}{\partial \eta \partial f} &= \frac{-\gamma^2}{\Delta} \left[ xA + \{3x + \gamma z (3-k)(1-k)\} \frac{\partial x}{\partial f} \right]. \end{aligned}$$

Recall  $A > 0$  if and only if  $g > g_a$  from (22) and  $\partial x / \partial f > 0$  if and only if  $g > g_x$  from (14).

Since

$$g_x - g_a = \frac{2\gamma(3-k)(1-k)\Delta}{(4-\gamma^2)\{12(1-\gamma^2) + k\gamma^2(6-k)\}} > 0,$$

we have  $\partial^2 \tilde{\pi}_Z(k, f, \eta) / \partial \eta \partial f > 0$  if  $g < g_a$  and  $\partial^2 \tilde{\pi}_Z(k, f, \eta) / \partial \eta \partial f < 0$  if  $g > g_x$ . It follows that  $df/d\eta > 0$  when  $g < g_a$ , and  $df/d\eta < 0$  when  $g > g_x$ . And since  $\eta$  drops in a discrete amount at  $k = 1/2$ , the effect of a change in  $\eta$  outweighs that of a change in  $k$ , in the neighborhood of  $k = 1/2$ . ■

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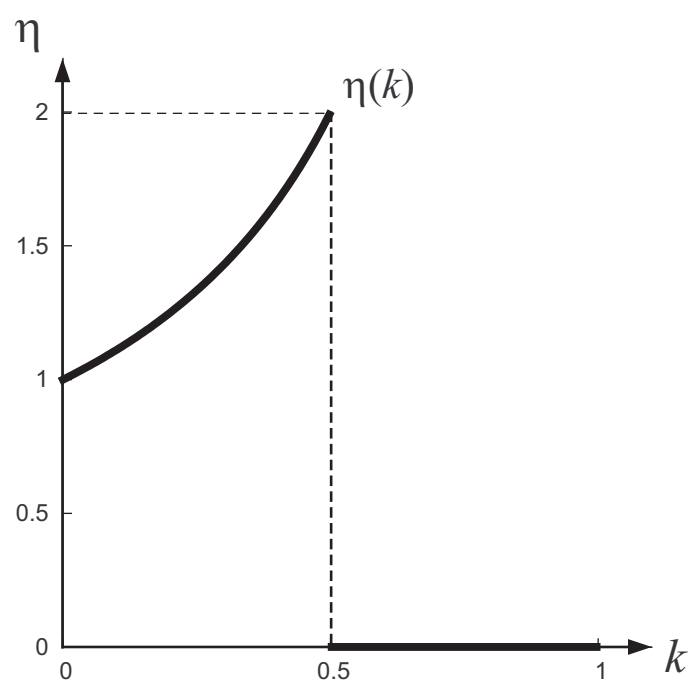


Figure 1: Schedule of the control-ownership ratio

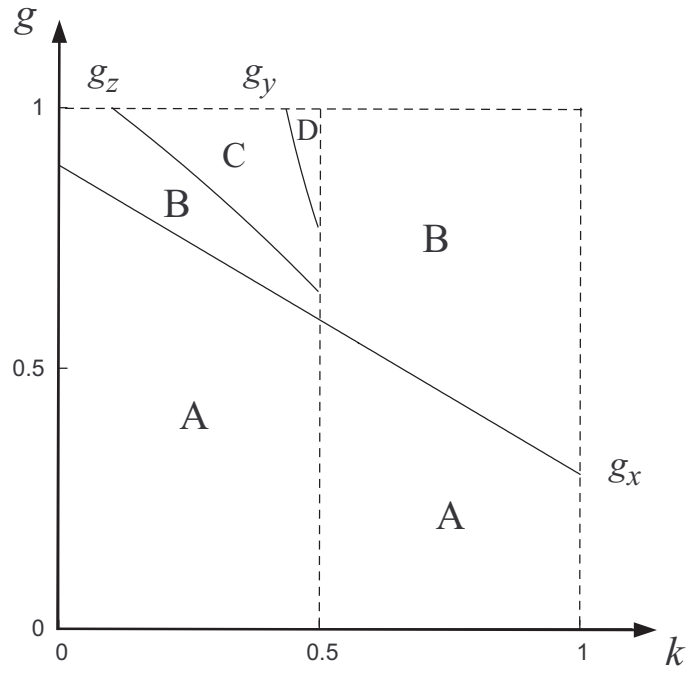


Figure 2: Effect of investment on outputs ( $\gamma = 0.93$ )

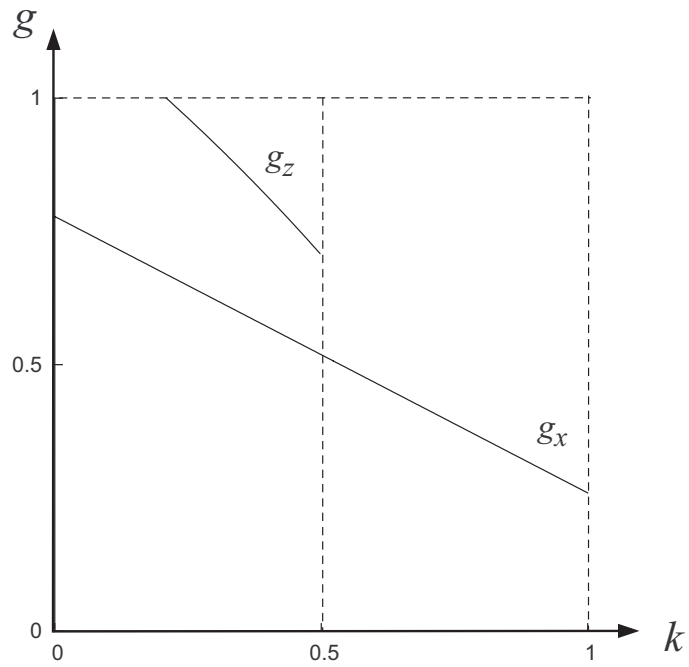


Figure 3: Intermediate product differentiation ( $\gamma = 0.85$ )

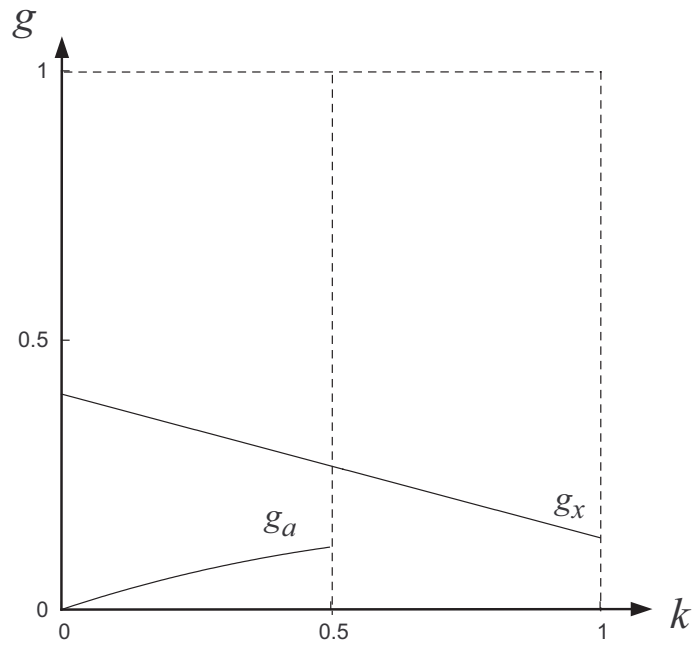


Figure 4: High product differentiation( $\gamma = 0.5$ )

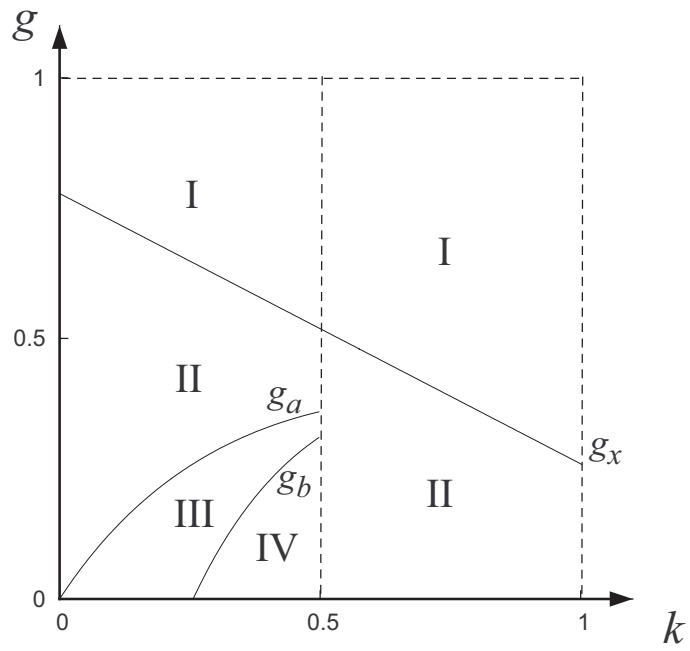


Figure 5: Effect of foreign ownership on investment ( $\gamma = 0.85$ )