Implicit Protectionism via State Enterprises and Technology Transfer from Foreign Enterprises

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Implicit Protectionism via State Enterprises and Technology Transfer from Foreign Enterprises*

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Abstract

We formulate a mixed triopoly in which one state enterprise competes with one domestic and one foreign private enterprise. The private enterprise can transfer its technology to the private rival, which reduces the rival's production cost. We show that if the privatization policy is endogenous, the foreign firm voluntary transfers its technology, even without fees. We also show that the domestic private firm does not transfer its technology to the foreign firm. Consequently, the domestic private enterprise extracts rents from the foreign enterprise and increases its market share. We also show that the foreign enterprise may strategically raise its local ownership share, which implies that the existence of a state enterprise and its potential future privatization serve as an industrial policy that improves the domestic firm's competitive advantage relative to the foreign enterprise or the implicit foreign ownership regulation.

JEL classification numbers: D43, H44, L33

Keywords: industry policy, mixture ownership, voluntary technology transfer, constant marginal costs, endogenous foreign ownership share

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Highlights

A mixed oligopoly with constant marginal costs is examined.

A firms' profit may increase with the reduction of rivals' costs.

Foreign firms voluntary transfer their technology to domestic firms.

Foreign firms voluntary accept domestic ownership, even if it raises costs.

State firms serve as implicit protection policies.

1 Introduction

The last 50 years saw a worldwide wave of privatization of state-owned public enterprises. Nevertheless, many public enterprises with significant government ownership are still active in strategic sectors and control large portions of the world's resources. According to an OECD report by Kowalski *et al.* (2013), more than 10% of the 2000 largest companies are public enterprises, and their sales are equivalent to approximately 6% of worldwide GDP. They are significant players in sectors such as transportation, telecommunications, energy, and finance in OECD countries. In planned and transitional countries such as China, Vietnam, and Russia, public enterprises still have a significant presence and compete with private enterprises (Huang and Yang, 2016; Chen, 2017; Fridman, 2018).

We often observe technology transfers from foreign to domestic enterprises in such countries, as well as international disputes over technology transfers. For example, US and EU claimed unfair technology transfer from foreign to domestic enterprises in China, and the EU took the issue to the World Trade Organization (WTO) against China (Bloomberg, 2018/6/2). However, the issue of unfair technology transfers is not limited to formal legislation and regulations. For example, Kawasaki Heavy Industries, Ltd. voluntary transferred its high speed train technology without a license fee, a move criticized by the media and other Japanese enterprises (Business Journal, 2013/6/28).

In this study, we discuss voluntary technology transfer without formal license fees. We demonstrate that even without government pressure on foreign enterprises, these firms voluntary transfer technology to domestic (local) enterprises when the economy has state enterprises that face potential privatization in the future. We also show that technology transfer will likely occur in only one direction (i.e., domestic enterprises do not transfer technology to foreign enterprises even if domestic enterprises have superior knowledge). These results suggest that state enterprises may serve as an implicit industrial policy that extracts advanced technology from foreign firms and improves domestic firms' productivity. Therefore, a stricter implementation of the WTO rule might not be sufficient to protect firms from such an implicit industry policy.

Next, we formulate a model in which foreign ownership share in private enterprises is endogenous.[1] We show that foreign enterprises voluntary increase the local ownership share in them, even when it raises their production costs. This result suggests that state enterprises may serve as an implicit foreign ownership regulation.

The literature on mixed oligopolies investigated the property of optimal license contracts (Ye, 2012; Niu, 2015; Gelves and Heywood, 2016; Kim *et al.*, 2018) and optimal patent protection policy (Ishibashi and Matsumura, 2006). However, this study differs in that we focus on voluntary technology transfer without license fees and patent protection.

The rest of this study is organized as follows. Section 2 presents the basic model. Section 3 discusses voluntary technology transfer. Section 4 formulates the model of endogenous foreign ownership share. Section 5 concludes.

2 The Model

We consider a mixed triopoly model with competition between one state enterprise, firm 0, and two private enterprises, firms 1 and 2.[2] Domestic investors, including the government, own firm 0.[3]

The foreign ownership share in firm 1 (firm 2) is θ_1 (θ_2). Firms produce homogeneous products with an inverse demand function of

$$p(Q) = a - Q,$$

where p denotes price, a is a positive constant, and $Q := \sum_{i=0}^{2} q_i$ is the total output.

The marginal costs of firm i is c_i ($i = 0, 1, 2$). Private firm i chooses whether to transfer its

[1] Whether the private firm is domestic or foreign often yields contrasting results in the literature on mixed oligopolies; see Corneo and Jeanne (1994), Fjell and Pal (1996), Pal and White (1998), and Bárcena-Ruiz and Garzón (2005a, 2005b). The optimal degree of privatization decreases with the foreign ownership rate in private firms when the number of private firms is exogenous (Lin and Matsumura, 2012), while it increases with the foreign ownership rate in private firms in free-entry markets (Cato and Matsumura, 2012). However, in these studies, the foreign ownership share of private enterprises is given exogenously.

[2] Our results hold in more general mixed oligopolies with n-private firms. We discuss this point in footnote 11.

[3] The assumption that the investors in privatized firms are domestic is standard in the literature (Cato and Matsumura, 2012; Lee *et al.*, 2018; Xu *et al.*, 2016;2017), and may be realistic. For example, the foreign ownership share among the private owners in Postal Bank is about one-fifth of the Mitsubishi UFJ Financial Group. For a discussion of foreign investors in privatized firms, see Lin and Matsumura (2012).

knowledge to its private rival, firm j $(i, j = 1, 2, i \neq j)$.[4] If firm i transfers its technology, firm j's marginal cost is $c_j = \bar{c}_j - d_i$. We assume that the technology transfer is not verifiable and thus not contractible. Therefore, firm i cannot charge fees for the transfer, and only a voluntary transfer without a fee is possible. We assume that $c_0 > \bar{c}_i$ and $\bar{c}_i > d_j > 0$ for $(i, j = 1, 2,\ i \neq j)$.[5]

Firm i's profit is $\pi_i = (p - c_i)q_i$, where q_i is firm i's output. The domestic social surplus W is

$$W = \int_0^Q p(q)dq - pQ + \pi_0 + (1 - \theta_1)\pi_1 + (1 - \theta_2)\pi_2.$$

Following Matsumura (1998), the public firm's objective is a convex combination of social surplus and their own profit $\Omega = \alpha\pi_0 + (1 - \alpha)W$.[6] $\alpha \in [0, 1]$ represents the degree of privatization. In the case of full nationalization (i.e., $\alpha = 0$), firm 0 maximizes social welfare. In the case of full privatization (i.e., $\alpha = 1$), firm 0 maximizes its profit. Each private firm's objective is its profit.

The complete information game runs as follows. In the first stage, each private firm i independently chooses whether it transfers its knowledge to its private rival, firm j $(i, j = 1, 2, i \neq j)$. In the second stage, the government chooses α.[7] In the third stage, each firm simultaneously chooses its output to maximize its objective. Throughout this study, we solve the game by backward induction and the equilibrium concept is the subgame perfect Nash equilibrium.

3 Equilibrium

First, we solve the third stage game given α and c_i. The public firm's first-order condition is

$$p + \alpha p' q_0 - c_0 - p'(1 - \alpha)(\theta_1 q_1 + \theta_2 q_2) = 0. \tag{1}$$

The first order-condition for each private firm is

$$p + p' q_i - c_i = 0. \tag{2}$$

[4] A foreign firm may transfer its advanced technology to a domestic firm. A domestic firm may transfer its knowledge of how to manage a domestic market, such as how to negotiate with the local government or how to advertise their products for local consumers effectively.

[5] The assumptions of linear demand and constant marginal costs with a cost disadvantage for the public firm over private firms is popular in the literature on mixed oligopolies. See Pal (1998), Capuano and De Feo (2010), and Matsumura and Ogawa (2010). For a discussion of the endogenous cost disadvantage of public firms, see Matsumura and Matsushima (2004).

[6] For an empirical evidence supporting welfare-concerned objectives of public enterprises rather than profit-maximizing, see Ogura (2018).

[7] We rationalize this timeline in the last paragraph in Section 3.

The second-order conditions are satisfied. These first-order conditions yield the following equilibrium quantities of public and private firms in the third stage:

$$
\begin{aligned}
q_0^T(\alpha) &= \frac{(1+(1-\alpha)(\theta_1+\theta_2))(a+c_1+c_2)-3c_0-3(1-\alpha)(\theta_1 c_1+\theta_2 c_2)}{1+3\alpha+(1-\alpha)(\theta_1+\theta_2)}, && (3)\\
q_i^T(\alpha) &= \frac{\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)-(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_i}{1+3\alpha+(1-\alpha)(\theta_1+\theta_2)}, && (4)
\end{aligned}
$$

respectively (the superscript T indicates the "third-stage subgame").

We obtain the following equilibrium total output, price, private firms' profit, and welfare:

$$
\begin{aligned}
Q^T(\alpha) &= \frac{(1+2\alpha+(1-\alpha)(\theta_1+\theta_2))a-c_0-\alpha(c_1+c_2)-(1-\alpha)(\theta_1 c_1+\theta_2 c_2)}{1+3\alpha+(1-\alpha)(\theta_1+\theta_2)}, && (5)\\
p^T(\alpha) &= \frac{\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)}{1+3\alpha+(1-\alpha)(\theta_1+\theta_2)}, && (6)\\
\pi_i^T(\alpha) &= \Big(\frac{\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)-(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_i}{1+3\alpha+(1-\alpha)(\theta_1+\theta_2)}\Big)^2, && (7)\\
W^T(\alpha) &= \frac{X_1}{2(1+(n+1)\alpha)^2+3\alpha+(1-\alpha)(\theta_1+\theta_2)}, && (8)
\end{aligned}
$$

respectively, where we describe X_1 in Appendix A.

Next, we discuss the government's welfare maximization problem in the second stage. The first-order condition is

$$
\frac{\partial W^T}{\partial \alpha} = -\frac{X_2}{\big(1+3\alpha+(1-\alpha)(\theta_1+\theta_2)\big)^3} = 0, \tag{9}
$$

where we describe X_2 in Appendix A.[8]

Let α^S be the equilibrium degree of privatization (the superscript S indicates the "second-stage subgame"). From the first-order condition, we obtain the following result.

Lemma 1 *Let*

$$
\begin{aligned}
\bar{c}_0 &:= \frac{(1+2(\theta_1+\theta_2))a+5(c_1+c_2)+2(c_2-3c_1)\theta_1+2(c_1-3c_2)\theta_2}{11-2(\theta_1+\theta_2)},\\
\alpha^* &:= \frac{(2+\theta_1+\theta_2)c_0-(1+\theta_2)c_1-(1+\theta_1)c_2}{(1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_1+\theta_2)c_1+(4+\theta_1-6\theta_2)c_2} > 0,\\
\bar{\theta}_i &:= \frac{a-c_0+\theta_j(a+2c_0-3c_j)}{3(c_0-c_j)}.
\end{aligned}
$$

[8]We show that the relevant second-order condition is satisfied in the proof of Lemma 1 in Appendix B.

(i) If $c_0 < \bar{c}_0$*, then* $\alpha^S = \alpha^*$*. (ii) If* $c_0 \geq \bar{c}_0$*, then* $\alpha^S = 1$*. (iii)* α^* *is increasing in* c_0*. (iv) For* $i, j = 1, 2,\ i \neq j$*, if* $\theta_i < \bar{\theta}_i$ *(*$\theta_i > \bar{\theta}_i$*), then* α^* *is decreasing (increasing) in* c_i *where* $\bar{\theta}_i \geq \frac{2}{3} + \frac{\theta_j}{6}$*.*

Proof See Appendix B.

Lemma 1(i,ii) implies that $\alpha^S > 0$.[9] Lemma 1(iii) states that as long as $\alpha^S < 1$ (i.e., full privatization is not optimal), the optimal degree of privatization increases with the cost of firm 0. Lemma 1(iv) states that as long as $\alpha^S < 1$, the optimal degree of privatization decreases (increases) with the cost of firm 1 when the foreign ownership share in firm 1 is small (large).

An increase of the degree of privatization makes firm 0 less aggressive because it is less concerned with consumer surplus. Through the strategic interaction, firm 0's less aggressive behavior makes the private firms more aggressive. In other words, there is production substitution from the public firm to the private firms. Because the public firm has higher marginal cost than any private firm does, this production substitution improves welfare (welfare-improving effect).[10] However, because the total output is decreasing in α, an increase of the degree of privatization reduces welfare (welfare-reducing effect). This trade-off determines the optimal degree of privatization. The higher c_0 is, the stronger is the welfare-improving effect of production substitution. Therefore, the optimal degree of privatization is increasing in c_0.

Suppose that the foreign ownership share in firm 1 is small; then, the lower c_1 is, the stronger is the welfare-improving effect of production substitution. Therefore, the optimal degree of privatization is decreasing in c_1.

Suppose that foreign ownership share in firm 1 is large. The welfare-improving effect of production substitution is weaker when c_1 is lower because the rent firm 1 obtains flows out to foreign investors and this is higher when c_1 is lower. Therefore, the optimal degree of privatization is increasing in c_1.

Let π^S be the equilibrium profit of the second-stage subgame. Suppose that the solution of the second stage is interior (i.e., $\alpha^S < 1$). By substituting α^* into $\pi_i^T(\alpha)$, we obtain the following

[9] Matsumura (1998) showed this result for duopolies and Matsumura and Kanda (2005) show this result for oligopolies in the case of domestic private firms.

[10] For an excellent discussion of welfare-improving production substitution, see Lahiri and Ono (1988).

equilibrium profit of private firms:

$$\pi_i^S = \left(\frac{3c_0 - 2c_i - c_j - 2\theta_j(c_i - c_j)}{1 + 2(\theta_1 + \theta_2)}\right)^2 \quad (i, j = 1, 2, i \neq j). \tag{10}$$

Suppose that $\alpha^S = 1$. By substituting $\alpha = 1$ into $\pi_i^T(\alpha)$, we obtain the following equilibrium profit of private firms:

$$\pi_i^S = \left(\frac{a + c_0 - 3c_i + c_j}{4}\right)^2 \quad (i, j = 1, 2, i \neq j). \tag{11}$$

We now present an important result that describes the key properties we use throughout this study.

Proposition 1 *For $i, j = 1, 2,\ i \neq j$, (i) private firm i's profit is decreasing in c_i; (ii) private firm i's profit is increasing in c_j as long as α^S remains unchanged; (iii) α^S remains unchanged by the change of c_j if $\alpha^* \geq 1$ (and thus, $\alpha^S = 1$) with and without a change in c_j; (iv) if $\theta_j < 1/2$ ($\theta_j > 1/2$, $\theta_j = 1/2$), then private firm i's profit is decreasing in (increasing in, independent of) c_j as long as the optimal privatization policy is not full privatization (i.e., $\alpha^S < 1$).*

Proof See Appendix B.

Proposition 1(i–iii) is intuitive. We explain the intuition behind Proposition 1(iv).

Given α, a decrease in c_j increases q_j and reduces the price, which reduces firm i's profit ($i = 1, 2, i \neq j$). However, c_j may affect α.

Suppose that $\theta_j < \bar{\theta}_j$; then, a decrease in c_j strengthens the welfare-improving effect of production substitution from the public firm (firm 0) to private firm j. Thus, a decrease in c_j increases the degree of privatization unless $\alpha = 1$, which makes the public firm less aggressive and raises the profits of each private firm. Because the welfare-improving effect of production substitution from the public firm (firm 0) to private firm j is stronger when θ_j is smaller, the latter (former) effect dominates the former (latter) effect when θ_j is small (large).

Suppose that $\theta_j > \bar{\theta}_j (> 1/2)$. A decrease in c_j decreases the degree of privatization unless $\alpha = 1$. Thus, both effects reduce firm i' profit. These yield Proposition 1(iv).[11]

[11] This Proposition holds in more general mixed oligopolies with n private firms. For $i, j = 1, 2, ..., n,\ i \neq j$, firm i's profit is decreasing in c_j if $\alpha^S < 1$ and $\theta_j < 1/2$, and increasing if $\alpha^S = 1$ or $\theta_j > 1/2$.

We now discuss the first stage. From Proposition 1, we obtain the following result:

Proposition 2 *For $i, j = 1, 2,\ i \neq j$, (i) firm i does not transfer its technology to firm j if $\theta_j > 1/2$ or $\alpha = 1$ without its transfer; (ii) firm i transfers its technology to firm j if $\theta_j < 1/2$ and $\alpha < 1$ with its transfer.*

Suppose that $\theta_1 < 1/2$ and $\theta_2 > 1/2$; as long as the solution in the second stage is interior (i.e., $\alpha < 1$), the foreign firm (firm 2) voluntary transfers its technology to the domestic firm (frim 1), whereas the domestic firm does not transfer its technology to the foreign firm. This implies that even without government pressure on the foreign firm, the foreign firm voluntary transfers its technology to the domestic firm. The existence of the state enterprise and its potential future privatization encourage the foreign firm to transfer its technology to the domestic firm. This result suggests that the state enterprises may serve as an implicit industrial policy that extracts advanced technology from foreign firms and improves domestic firms' productivity.

We note that Proposition 2 depends on the assumption that the government implements the privatization policy given the firms' costs. If the government implements the privatization policy and then the firms' costs are determined, Proposition 2 does not hold. Each private firm's profit always increases with the rivals' costs, and thus, each private firm never transfers its technology to the rival. Although several works on mixed oligopolies assume that the government implements the privatization policy before the firms' costs are determined, we believe that our time structure is equally realistic.[12]

As Lee *et al.* (2018) and Sato and Matsumura (2018) point out, even when the government chooses α before the cost structure is determined, our timeline is adequate because the government can change α after observing the cost structure. For example, the Japanese government reduced its ownership of NTT gradually over 30 years. Japan Post, which owns part of Postal Bank, the largest bank in Japan, was first privatized in 2015; the government then sold some shares in 2017, and plans to sell further shares in the future. The Japanese government first sold shares in Japan

[12]See Matsumura and Matsushima (2004), Ishibashi and Matsumura (2006), and Gil-Moltó *et al.* (2011).

Tobacco (JT) in 1994, again in 1996, and finally in 2004. The French government increased its ownership of Renault from 15% to 19.4% in 2015, and again reduced it to 15% thereafter. These examples suggest that our timeline is realistic.

4 Endogenous Foreign Ownership

In this section, we endogenize the foreign ownership share in firm 2. We again consider a mixed triopoly model in which one state enterprise, firm 0, and two private enterprises, firms 1 and 2, compete. Firms 0 and 1 are domestic enterprises, and firm 2 is a foreign enterprise. Initially, firm 2 is a pure foreign firm. Firm 2 sells an ownership share of $1-\theta$ to domestic (local) investors. We assume that firm 1 cannot obtain this share due to anti-trust legislation. We also assume that the financial market is complete and firm 2 sells its share at a competitive price. In other words, domestic investors obtain a share of $(1-\theta)$ at the price of $(1-\theta)\pi_2^e$, where π_2^e is the expected profit of firm 2.

The marginal costs of firms 0 and 1 are c_0 and $c_1 = \bar{c}_1 - d_2 (< c_0)$, respectively, and are given exogenously. Firm 2's marginal cost $c_2 = \bar{c}_2 - k\theta - d_1$ if firm 1 transfers its knowledge to firm 2 and $c_2 = \bar{c}_2 - k\theta$ otherwise, where k is a positive constant and $\bar{c}_2 - k\theta - d_1 > 0$. In other words, a lager foreign ownership share in firm 2 reduces its cost. This assumption may be rational if better governance through the larger foreign ownership share improves the firm's productivity.[13] We assume that $k > \bar{k} := 3c_0 - c_1 - 2(\bar{c}_2 - d_1)$.[14]

The game runs as follows. In the first stage, firm 2 chooses θ_2. In the second stage, firm 1 chooses whether it transfers its knowledge to firm 2. In the third stage, the government chooses α. In the fourth stage, three firms independently choose their outputs.

We analyzed the fourth and third stages in the previous section. In the second stage, firm 1 transfers its knowledge to firm 2 only if $\theta_2 \leq 1/2$. Suppose that $\theta_2 \leq 1/2$. When firm 1 transfers

[13] See Arnold and Javorcik (2009), Guadalupe *et al.* (2012), Syverson (2011), and Huang and Yang (2016).

[14] If $k < \bar{k}$, firm 2 chooses $\theta_2 = 0$ to make firm 0 less aggressive, and no firm with a positive foreign ownership share exists in equilibrium.

its knowledge to firm 2, firm 1's profit is

$$\pi_1 = \begin{cases} \left(\dfrac{3c_0 - 2c_1 - \bar{c}_2 + d_1 + (k - 2d_1 + 2\bar{c}_2 - 2c_1)\theta_2 - 2k\theta_2^2}{1 + 2\theta_2}\right)^2 \text{ if } c_0 < \hat{c}_0 & \text{(12a)} \\ \left(\dfrac{a + c_0 - 3c_1 + \bar{c}_2 - d_1 - k\theta_2}{4}\right)^2 \text{ otherwise} & \text{(12b)} \end{cases}$$

where

$$\hat{c}_0 := \frac{a + 5(c_1 + \bar{c}_2 - d_1) + (2a + 2c_1 - 6(\bar{c}_2 - d_1) - 5k)\theta_2 + 6k\theta_2^2}{11 - 2\theta_2}.$$

When firm 1 does not transfer its knowledge to firm 2, firm 1's profit is

$$\pi_1 = \begin{cases} \left(\dfrac{3c_0 - 2c_1 - \bar{c}_2 + (k + 2\bar{c}_2 - 2c_1)\theta_2 - 2k\theta_2^2}{1 + 2\theta_2}\right)^2 \text{ if } c_0 < \check{c}_0 & \text{(13a)} \\ \left(\dfrac{a + c_0 - 3c_1 + \bar{c}_2 - k\theta_2}{4}\right)^2 \text{ otherwise} & \text{(13b)} \end{cases}$$

where

$$\check{c}_0 := \frac{a + 5(c_1 + \bar{c}_2) + (2a + 2c_1 - 6\bar{c}_2 - 5k)\theta_2 + 6k\theta_2^2}{11 - 2\theta_2}.$$

From (12a)–(13b), we find that firm 1 transfers its knowledge if and only if $\theta_2 \leq 1/2$ and

$$c_0 < c_0^*(\theta_2) := \frac{a + 5(c_1 + \bar{c}_2) - d_1 + (2a + 2c_1 - 6\bar{c}_2 - 2d_1 - 5k)\theta_2 + 6k\theta_2^2}{11 - 2\theta_2}. \tag{14}$$

From (14), we obtain

$$\frac{\partial c_0^*(\theta_2)}{\partial \theta_2} = \frac{24a + 32c_1 - 56\bar{c}_2 - 24d_1 - 55k + 132k\theta_2 - 12k\theta_2^2}{(11 - 2\theta_2)^2} > 0$$
$$\text{if and only if} \quad a > \frac{12k\theta_2^2 - 132k\theta_2 + 55k + 56\bar{c}_2 + 24d_1 - 32c_1}{24}.$$

Thus, we obtain the following Lemma.

Lemma 2 *Suppose that a is sufficiently large that*

$$a > \frac{12k\theta_2^2 - 132k\theta_2 + 55k + 56\bar{c}_2 + 24d_1 - 32c_1}{24}. \tag{15}$$

If firm 1 does not transfers its knowledge when $\theta = \theta' < 1/2$, then firm 1 does not transfer its knowledge when $\theta < \theta'$.

If α^S becomes one when firm 1 transfers its knowledge to firm 2, firm 1 has less incentive to transfer knowledge because it does not increase α further. α^S is less likely to become one when θ_2 is larger, which yields Lemma 2.

In the first stage, firm 2 chooses θ_2. Suppose that firm 1 transfers its knowledge regardless of θ_2 as long as $\theta_2 \leq 1/2$. Then, firm 2's profit is

$$\pi_2 = \begin{cases} \left(\dfrac{3c_0 - c_1 - 2(c_2 - d_1) + 2k\theta_2}{1 + 2\theta_2}\right)^2 \text{ if } c_0 < \hat{c}_0, & (16a) \\ \left(\dfrac{a + c_0 + c_1 - 3(\bar{c}_2 - d_1) + k\theta_2}{4}\right)^2 \quad \text{otherwise.} & (16b) \end{cases}$$

Suppose that firm 1 does not transfer its knowledge, regardless of θ_2. Then, firm 2's profit is

$$\pi_2 = \begin{cases} \left(\dfrac{3c_0 - c_1 - 2c_2 + 2k\theta_2}{1 + 2\theta_2}\right)^2 \text{ if } c_0 < \check{c}_0, & (17a) \\ \left(\dfrac{a + c_0 + c_1 - 3\bar{c}_2 + k\theta_2}{4}\right)^2 \quad \text{otherwise.} & (17b) \end{cases}$$

Both are increasing in θ. Therefore, firm 2 chooses either $\theta = 1$ or the maximum θ that induces technology transfer, if it exists.

Henceforth, we assume that a is sufficiently large that (15) is satisfied.

If $c_0 \geq c_0^*(1/2) := (2a + 6c_1 + 2(\bar{c}_2 - d_1) - k)/10$, then firm 1 does not transfers its knowledge, regardless of the value of θ. Given this fact, firm 2's profit is increasing in θ, and thus firm 2 chooses $\theta_2 = 1$.

If $c_0 < c_0^*(1/2)$, then firm 1 transfers its knowledge if and only if $\theta_2 \leq 1/2$. Thus, firm 2's profit is increasing in θ for $\theta_2 \in [0, 1/2)$, it is discontinuously down at $\theta_2 = 1/2$, and again increases in θ for $\theta_2 \in (1/2, 1]$ (See Figure 1). Therefore, the optimal θ_2 is either $\theta = 1/2$[15] or $\theta = 1$. The former is better for firm 2 if and only if k is small (See the Proof of Proposition 3 in Appendix B). This leads to our second main result.

Proposition 3 *The equilibrium foreign ownership share is 1/2 if $k < k^*$, where $k^* := 3c_0 - c_1 - 2\bar{c}_2 + 6d_1 (> \bar{k})$. Otherwise, the equilibrium foreign ownership share is one.*

Proof See Appendix B.

[15]Strictly speaking, the maximum ownership share satisfying $\theta_2 < 1/2$, such as 0.49.

Firm 2 will accept a minor foreign ownership share to receive support from firm 1. This suggests that the existence of a state firm and its possible future privatization may serve as an implicit foreign ownership regulation.

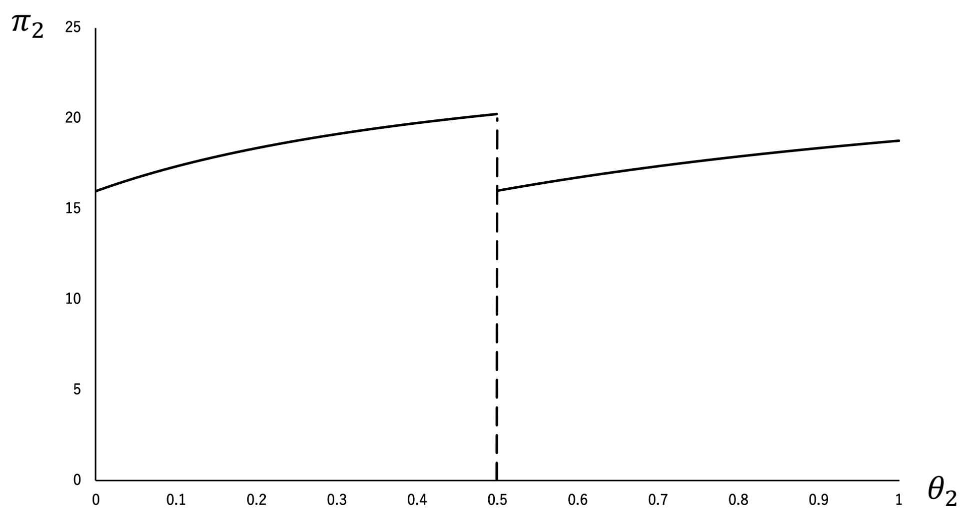

Figure 1: The Foreign Firm's Profit

5 Concluding Remarks

In this study, we investigate how privatization policy serves as an industrial policy. The existence of state enterprises and their potential future privatization encourages voluntary technology transfers from foreign enterprises to domestic enterprises. We also show that foreign enterprises may strategically increase the domestic ownership share, even when it raises costs, to cooperate with domestic enterprises when state enterprises will be privatized in future. Therefore, privatization policy serves as implicit foreign ownership regulation. These results suggest that even the implementation of a formal WTO may not be sufficient to protect foreign firms from technology transfer without fees or restrictions of foreign ownership shares.

In this study, we focus only on voluntary technology transfer without fees. If we consider license contracts, the type of contract (royalty or fixed fee) also affects the degree of privatization and the private firm's resulting profits. Extending our analysis to license contracts remains a task for future research.

In this study, we assume that all enterprises compete in a homogeneous product market. Public enterprises or domestic enterprises may provide vertically or horizontally differentiated products from private enterprises or foreign enterprises. Extending our analysis to a multi-product model remains for future research.[16]

[16]For discussions of optimal privatization policy in multi-market models, see Bárcena-Ruiz and Garzón (2017), Dong *et al.* (2018), and Haraguchi *et al.* (2018).

Appendix A

$$
\begin{aligned}
X_1 \quad := \quad & ((1+2\alpha+(1-\alpha)(\theta_1+\theta_2))a - c_0 - \alpha(c_1+c_2) - (1-\alpha)(\theta_1 c_1+\theta_2 c_2))^2 \\
& +2\Big(\alpha(a+c_1+c_2)+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)-(3\alpha+(1-\alpha)(\theta_1+\theta_2))c_0\Big) \\
& \quad \Big((1+(1-\alpha))(a+c_1+c_2)-3c_0-3(1-\alpha)(\theta_1 c_1+\theta_2 c_2)\Big) \\
& +2(1-\theta_1)(\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)-(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_1)^2 \\
& +2(1-\theta_2)(\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1 c_1+\theta_2 c_2)-(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_2)^2. \\
X_2 \quad := \quad & \Big((1+(1-\alpha)(\theta_1+\theta_2))(a+c_1+c_2)-3c_0-3(1-\alpha)(\theta_1 c_2+\theta_2 c_2)\Big) \\
& \Big(\alpha((1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_1+\theta_2)c_1+(4+\theta_1-6\theta_2)c_2) \\
& \quad -((2+\theta_1+\theta_2)c_0-(1+\theta_2)c_1-(1+\theta_1)c_2)\Big).
\end{aligned}
$$

Appendix B

Proof of Lemma 1

First, we show Lemma 1(ii). We show that $X_2 < 0$ if $c_0 \geq \bar{c}_0$.

Because we assume interior solutions in the third stage, from (3), we obtain $(1+(1-\alpha)(\theta_1+\theta_2))(a+c_1+c_2)-3c_0-3(1-\alpha)(\theta_1 c_1+\theta_2 c_2) > 0$. When $c_0 \geq \bar{c}_0$, $\alpha((1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_1+\theta_2)c_1+(4+\theta_1-6\theta_2)c_2)-((2+\theta_1+\theta_2)c_0-(1+\theta_2)c_1-(1+\theta_1)c_2) < 0$ for $\alpha < 1$. Thus, from (9) we obtain $\partial W^T/\partial\alpha > 0$ for $\alpha < 1$. This implies Lemma 1(ii).

Next, we show Lemma 1(i). Suppose that $c_0 < \bar{c}_0$; by solving $\partial W^T/\partial\alpha = 0$ with respect to α, we obtain

$$
\alpha^* = \frac{(2+\theta_1+\theta_2)c_0-(1+\theta_2)c_1-(1+\theta_1)c_2}{(1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_1+\theta_2)c_1+(4+\theta_1-6\theta_2)c_2} \in (0,1). \tag{18}
$$

The second-order condition

$$
-\frac{(a-9c_0+4(c_1+c_2)+\theta_1(2a+3c_0-6c_1+c_2)+\theta_2(2a+3c_0+c_1-6c_2))^4}{(1+2(\theta_1+\theta_2))^3(a-3c_0+c_1+c_2+\theta_1(a+c_0-3c_1+c_2)+\theta_2(a+c_0+c_1-3c_2))^2} < 0
$$

is satisfied. Therefore, the optimal degree of privatization is α^*. This implies Lemma 1(i).

From (18), we obtain

$$\frac{\partial \alpha^*}{\partial c_0} = \frac{(1+2(\theta_1+\theta_2))(2a-c_1-c_2+\theta_1(a-3c_1+2c_2)+\theta_2(a+2c_1-3c_2))}{((1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_1+\theta_2)c_1+(4+\theta_1-6\theta_2)c_2)^2} > 0.$$

This implies Lemma 1(iii).

From (18), we obtain

$$\begin{aligned}\frac{\partial \alpha^*}{\partial c_i} &= -\frac{(1+2(\theta_1+\theta_2))(a-c_0-3\theta_i(c_0-c_j)+\theta_j(a+2c_0-3c_j))}{((1+2(\theta_1+\theta_2))a-3(3-\theta_1-\theta_2)c_0+(4-6\theta_i+\theta_j)c_i+(4+\theta_i-6\theta_j)c_j)^2} \gtrless 0 \\ &\leftrightarrow \quad \theta_i \gtrless \frac{a-c_0+\theta_j(a+2c_0-3c_j)}{3(c_0-c_j)} \ (i,j=1,2,i\neq j).\end{aligned}$$

This implies that α^* is decreasing (increasing) in c_i if $\theta_i <\ (>)\ \bar{\theta}_i$.

Finally, we show that $\bar{\theta}_i \geq 2/3+\theta_j/6$ by showing that α^* is decreasing in c_i if (but not only if) $\theta_i < 2/3+\theta_j/6$. Since the numerator of α^* is decreasing in c_i, then α^* is decreasing in c_i if the denominator of α^* is increasing in c_i. The denominator of α^* is increasing in c_i if $4-6\theta_i+\theta_j > 0$, which implies that α^* is decreasing in c_i if $\theta_i < 2/3+\theta_j/6$. These imply Lemma 1(iv). ■

Proof of Proposition 1

Suppose that α is given exogenously. Because we assume interior solutions in the quantity competition stage, from (4), we obtain $\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1c_1+\theta_2c_2)-(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_i > 0 \ \ (i,j=1,2,i\neq j)$. From (7), we obtain

$$\begin{aligned}\frac{\partial \pi_i^T(\alpha)}{\partial c_i} &= -\frac{2}{(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))^2}\Big((\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1c_1+\theta_2c_2) \\ &- (1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_i\Big)(1+2\alpha+(1-\alpha)\theta_j) < 0 \ \ (i,j=1,2,i\neq j), \\ \frac{\partial \pi_i^T(\alpha)}{\partial c_j} &= \frac{2}{(1+3\alpha+(1-\alpha)(\theta_1+\theta_2))^2}\Big((\alpha(a+c_1+c_2)+c_0+(1-\alpha)(\theta_1c_1+\theta_2c_2) \\ &- (1+3\alpha+(1-\alpha)(\theta_1+\theta_2))c_i\Big)(\alpha+(1-\alpha)\theta_j) > 0 \ \ (i,j=1,2,i\neq j).\end{aligned}$$

These imply Proposition 1(i,ii).

From Lemma 1(ii), $\alpha^S=1$ for any $\alpha^*\geq 1$. Thus, the change in α^* due to the change in c_j does not affect α^S and $\alpha^S=1$ as long as $\alpha^*\geq 1$. This implies Proposition 1(iii).

Suppose that the solution of the second stage is interior (i.e., $\alpha^S<1$). By substituting α^* into

$q_i^T(\alpha)$, we obtain the following equilibrium output of private firms:

$$q_i^S = \frac{3c_0 - 2c_i - c_j - 2\theta_j(c_i - c_j)}{1 + 2(\theta_1 + \theta_2)} \quad (i, j = 1, 2, i \neq j). \tag{19}$$

Because we assume interior solutions in the quantity competition stage, from (19), we obtain $3c_0 - 2c_i - c_j - 2\theta_j(c_i - c_j) > 0 \;\; (i, j = 1, 2, i \neq j)$.[17] From (10), we obtain

$$\begin{aligned}
\frac{\partial \pi_i^S}{\partial c_i} &= -\frac{4(1+\theta_j)(3c_0 - 2c_i - c_j + 2\theta_j(c_j - c_i))}{(1 + 2(\theta_1 + \theta_2))^2} < 0 \quad (i, j = 1, 2, i \neq j), \\
\frac{\partial \pi_i^S}{\partial c_j} &= -\frac{(1-2\theta_j)(3c_0 - 2c_i - c_j + 2\theta_j(c_j - c_i))}{(1 + 2(\theta_1 + \theta_2))^2} \gtrless 0 \leftrightarrow \theta_j \gtrless \frac{1}{2} \quad (i, j = 1, 2, i \neq j).
\end{aligned}$$

These results imply Proposition 1(iv). ■

Proof of Proposition 3

Suppose that $c_0^*(1/2) > c_0$ and a is sufficiently large such that (15) is satisfied; then, the optimal degree of privatization is interior for $\theta \in [1/2, 1]$.[18] Comparing (16a) with $\theta_2 = 1/2$ and (17a) with $\theta_2 = 1$, we obtain

$$\begin{aligned}
\pi_2(1/2) - \pi_2(1) &= \frac{(15c_0 - 5c_1 - 10\bar{c}_2 + 6d_1 + 7k)(3c_0 - c_1 - 2\bar{c}_2 + 6d_1 - k)}{36} \gtrless 0 \\
&\leftrightarrow \;\; k \lesseqgtr 3c_0 - c_1 - 2\bar{c}_2 + 6d_1 := k^*.
\end{aligned}$$

This implies Proposition 3.■

[17] $3c_0 - 2c_i - c_j - 2\theta_j(c_i - c_j)$ is positive if c_0 is sufficiently large. Even when c_0 is large, the equilibrium output of the public firm can be positive if a is sufficiently large such that $a > (9c_0 - 2(2 - 2\theta_1 + \theta_2)c_1 - 2(2 + \theta_1 - 2\theta_2)c_2)/(1 + 2(\theta_1 + \theta_2))$.

[18] This is because $\partial c_0^*/\partial \theta_2 > 0$ and $\check{c}_0 > \hat{c}_0 \geq c_0^*$ for any $\theta_2 \in [1/2, 1]$.

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