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Abstract

We investigate a mixed oligopoly in a free-entry market in the presence of shadow cost of public funding. The government chooses the degree of privatization before the entry of private firms and then adjusts the degree of privatization after the entry. We show that a pre-entry privatization policy may serve as a commitment device if the foreign ownership share of private firms is moderate, and substitutes the ideal privatization policy with complete commitment if the equilibrium pre-entry privatization policy is partial privatization.

JEL classification H42, L33

Keywords Shadow cost of public funds; free entry; state-owned public enterprises; foreign competition; time inconsistency

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1 Introduction

The privatization of state-owned public enterprises has been a global phenomenon for more than 50 years. Nevertheless, many public enterprises that have significant government ownership are still active in strategic industries and control large portions of the world's resources. According to an OECD report by Kowalski *et al.* (2013), public enterprises account for more than 10% of the 2000 largest companies in the world and their sales are equivalent to approximately 6% of global GDP. They are significant players in OECD countries in such industries as transportation, telecommunications, energy, and finance. In planned and transitional countries, the presence of public enterprises is further significant (Chen, 2017; Dong *et al.*, 2018; Fridman, 2018).

One classical rationale for public enterprises is to prevent private monopolies in natural monopoly markets in which significant economies of scale prevail. Thus, many public enterprises existed or still exist in such national monopoly markets. However, because of technological improvements, many markets in which public enterprises exist are not always characterized by significant economies of scale. Indeed, a considerable number of public enterprises compete with private enterprises in a wide range of industries (mixed oligopolies).[1] The optimal privatization policies in these mixed oligopolies have attracted extensive attention from economics researchers in such fields as industrial organization, public economics, financial economics, and development economics.[2] Owing to recent deregulation and liberalization, entry restrictions in mixed oligopolies have significantly weakened. As a result, private enterprises have newly entered many mixed oligopolies, such as the banking, insurance, telecommunications, energy, and transportation industries. The literature on mixed oligopolies has intensively investigated optimal privatization policy in free-entry markets. For example, by using a monopolistic competition framework, Anderson *et al.* (1997) showed that privatization may improve welfare when private competitors are domestic, and Matsumura *et al.* (2009) showed that privatization is more likely to improve welfare when private enterprises are foreign. Matsumura and Kanda (2005) adopted the

[1] Examples include United States Postal Service, Deutsche Post AG, Areva, Nippon Telecom and Telecommunication, Japan Tobacco, Volkswagen, Renault, Electricite de France, Japan Postal Bank, Kampo, Korea Development Bank, and Korea Investment Corporation.

[2] For examples of mixed oligopolies and recent developments in this field, see Ishida and Matsushima (2009), Colombo (2016), Chen (2017), and the works cited therein.

partial privatization approach formulated by Matsumura (1998) and showed that the optimal degree of privatization is zero when private competitors are domestic, while Cato and Matsumura (2012) showed that it is strictly positive when private competitors are foreign and that this is increasing in the foreign ownership share in private firms. Chen (2017) revisited the problem by introducing the cost-reducing effect of privatization. Fujiwara (2007) found a non-monotonic (monotonic) relationship between the degree of product differentiation and optimal degree of privatization in a non-free entry (free-entry) market. Cato and Matsumura (2015) discussed the relationship between optimal trade and privatization policies and showed that a higher tariff rate reduces the optimal degree of privatization and that the optimal tariff rate can be negative. Cato and Matsumura (2013) showed the privatization neutrality theorem originally discussed by White (1996) in a duopoly in a non-free entry market. These studies assumed that the government chooses its privatization policies before the entry of private enterprises. Recently, an alternative timeline has been adopted by several works (Xu *et al.*, 2017; Lee *et al.*, 2018) for analyzing free-entry markets. These studies have investigated cases in which the government chooses its privatization policies after the entry of private enterprises and have showed that the optimal degree of privatization depends on the timing of privatization.

However, all of these studies have assumed that the government chooses the degree of privatize only once. In reality, the government often changes the degree of privatization over time. For example, the Japanese government announced the sale of some of the government's share in Nippon Telecom and Telecommunication (NTT) when the telecommunication market opened up in 1985, and the 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 sold some shares in 2017, and plans to sell further shares in the future. The Japanese government first sold shares in Japan Tobacco (JT) in 1994, again in 1996, and last in 2004. In Japan, the government has rarely increased its ownership of partially privatized enterprises except when they have faced financial problems. However, this is not always the case in other countries. For example, the French government increased its ownership of Renault from 15% to 19.4% in 2015. All these examples suggest that the assumption that the government decides the degree of privatization only once might be restrictive.

In this study, we consider a model in which the government privatizes the public firm before the entry of private firms, and then it adjusts the degree of privatization after the entry. In other words, the government cannot commit not to adjust the degree of privatization after the entry.[3] We introduce the shadow cost of public funding[4] and showed that a pre-entry privatization policy may serve as a commitment device to mitigate the time-inconsistency problem in the pro-entry privatization policy.

There is a time-inconsistency problem when the government cannot commit not to adjust the degree of privatization after the entry. More aggressive behavior of the public firm restricts the entry of private firms, resulting in the reduction of private firms, which might improve welfare. Keeping the public firm more aggressive, the government holds more shares than the static optimal share. After the entry of the private firms, the government might have a stronger incentive to make the public firm less aggressive, because it induces welfare-improving production substitution from the public firms to the private firms (Matsumura, 1998).[5] Therefore, the government chooses a larger degree of privatization after the entry. Expecting this change of privatization policy after the entry, more private firms enter the market, resulting in welfare loss.

If there is no shadow cost of public funding, the privatization policy before the entry is useless, because the government can freely adjust the degree of privatization after the entry with or without a pre-entry privatization policy without costs. However, in the presence of the shadow cost of public funding, a pre-entry privatization policy affects the government's incentive after the entry. If the government sells shares in the public firm before the entry, the government only partially reduces the shadow cost of public funding by increasing the public firm's profit at the post-entry stage. Therefore, the government's behavior after the entry is distorted by the pre-entry privatization policy. This

[3]The government may commit not to reduce public ownership in the future by enacting a law with a minimal public ownership share obligation. For example, by law, the Japanese government must hold more than one-third of the shares in NTT and JT. However, it was mandatory for the Japanese government to hold a two-thirds share in JT until 2012, which was subsequently reduced to one-third. Because the government can change the law, it is difficult to implement a commitment not to change the public ownership share in the future.

[4]The shadow cost of public funds is quite popular in many fields of economics. Meade (1944) undertook pioneering work, which was developed in Laffont and Tirole (1986). Instead, we can interpret The shadow cost of public funds as a coefficient of the budget constraint (the larger the shadow cost of public funds is, the more sever the budget constraint is). We discuss this point in Section 2.

[5]For an excellent discussion on welfare-improving production substitution in general contexts, see Lahiri and Ono (1988).

distortion might mitigate the abovementioned time-inconsistency problem. We investigate under what conditions this distortion in fact mitigates this problem. We find that the government improves welfare by the pre-entry privatization policy, unless the foreign ownership share in the private firms is close to zero or one.

Sato and Matsumura's (2018) study is closely related to the present study. They formulated a two-period model in which government chooses the degree of privatization in the first period and then adjusts it in the second period. Sato and Matsumura (2018) showed that the government chooses a smaller degree of privatization than the optimal one so as not to distort the second-period privatization policy. This study is different from theirs in three important aspects. First, Sato and Matsumura (2018) assumed that the number of firms is given exogenously and is not affected by privatization policies (i.e., the authors did not consider a free-entry market). Second, in this study the government may choose a larger degree of privatization in an early stage than the optimal one, which never appears in Sato and Matsumura (2018). Third, in this study, the government strategically distorts future privatization policy by the initial privatization policy to improve welfare, whereas the distortion of privatization policy always reduces future welfare in Sato and Matsumura (2018). In other words, an early-stage privatization has contrasting welfare implications in free-entry markets.

2 Model

There are three types of players in the game, a government, a state-owned public enterprise, and private firms as potential entrants. Before the game, the government holds all the shares of the public enterprise and sells a part of the shares in a perfect financial market. Observing the share of the public enterprise sold, private enterprises simultaneously decide whether to enter the market. Being unable to commit to the initial privatization policy, the government again sells (or buys back) a share of the public enterprise after observing the entry. Finally, the public enterprise and private enterprises compete in quantities.

The government sells α_B shares **before** the entry of private firms and $\alpha_A - \alpha_B$ shares **after** the entry of private firms. We assume that the investors of firm 0 are domestic.[6] α_B and α_A are measures

[6]The assumption that the investors in privatized firms are domestic is standard in the literature (Cato and Matsumura, 2012; Xu *et al.*, 2017; Lee *et al.*, 2018), and might be realistic. For example, the foreign ownership share in Postal Bank

of the degree of privatization **before** and **after** the entry of private firms, respectively. If $\alpha_A - \alpha_B < 0$, this implies that the government buys back the shares in firm 0 and renationalizes it.

Let W denote domestic welfare and π_i denote firm i's profit. Following the standard formulation in the literature on mixed oligopolies formulated by Matsumura (1998), we assume that firm 0 maximizes the weighted average of social welfare and its own profit, and that the weight depends on the degree of privatization after the entry α_A, whereas private firms maximize their own profits. Specifically, we assume that firm 0 maximizes $(1 - \alpha_A)W + \alpha_A \pi_0$.

Firms produce perfectly substitutable commodities for which the inverse demand function is denoted by $p = p(Q) = a - Q$, where p is the price and Q is the total output. We assume that a is sufficiently large for some private firms to enter the market in equilibrium. Firm 0's cost function is $c_0(q_0) = q_0^2/2 + K_0$, where q_0 is the output of firm 0. Each private firm i $(= 1, \ldots, n)$ has an identical cost function, $c(q_i) = q_i^2/2 + K$, where q_i is the output of private firm i and $c(q_i)$ is the cost.

The profit of firm 0 is given by $\pi_0 = p(Q)q_0 - c_0(q_0)$ and that of firm i $(= 1, \ldots, n)$ by $\pi_i = p(Q)q_i - c(q_i)$. Domestic welfare is defined as

$$W = \int_0^Q p(q)dq - p(Q)Q + \pi_0 + (1 - \theta)\sum_{i=1}^{n} \pi_i + \lambda(D + R_B + R_A), \quad (1)$$

where $\lambda > 0$ is the additional social cost of public funding,[7] D is the revenue from firm 0's dividends, R_B and R_A are the revenue from privatization before and after the entry, respectively, and θ is the foreign ownership share in private firms. Private firms are foreign (domestic) when $\theta = 1$ $(\theta = 0)$.[8] The social cost of public funding is the deadweight loss from collecting a unit of tax (i.e., the excess burden of taxation). Instead, we can interpret λ as a coefficient of the budget constraint (the larger λ is, the more severe the budget constraint is). Thus, the government's revenue from firm 0 yields a λ welfare gain, because it saves the excess burden of taxation in other markets or relaxes the budget constraint.[9]

among private ownership is about one-fifth of the Mitsubishi UFJ Financial Group. If the investors of firm 0 are foreign, the time-inconsistency problem discussed below becomes more serious, and the government more likely uses pre-entry privatization policy. For discussions on foreign investors for privatized firms in a non-free entry model, see Lin and Matsumura (2012).

[7] $(1 + \lambda)$ is the so-called marginal cost of public funding.

[8] For discussions on the nationality of private enterprises in mixed oligopolies, see the literature starting with Corneo and Jeanne (1994) and Fjell and Pal (1996). See also Pal and White (1998), Bárcena-Ruiz and Garzón (2005a, 2005b), Lin and Matsumura (2012), and Xu *et al.* (2016).

[9] See Matsumura and Tomaru (2013). Introducing the shadow cost of public funding λ is popular in many contexts, as

We assume that $\lambda < 1$ for the tractability of our analysis.[10]

We assume that the financial market is perfect. In other words, the government sells its shares in firm 0 at the fair value of the firm. The fair value of firm 0, V, is equal to π_0. Therefore, before (after) the entry of private firms, the government obtains $R_B = \alpha_B V$ ($R_A = (\alpha_A - \alpha_B)V$). In addition, at the end of the game, the government obtains $D = (1 - \alpha_A)\pi_0$.

The timeline of our model is as follows. In the first stage, the government chooses $\alpha_B \in [0, 1]$. In the second stage, each private firm decides whether to enter the market. In the third stage, the government chooses $\alpha_A \in [0, 1]$. In the fourth stage, each firm simultaneously chooses q_i. We adopt subgame-perfect equilibrium as a solution concept.

3 Equilibrium

We solve the game by backward induction. In the last stage, each firm chooses its output simultaneously. Note that at the competition stage, the government has already sold firm 0's shares. Therefore, when firm 0 chooses q_0, R_B and R_A are given exogenously. Firm 0 maximizes $(1 - \alpha_A)W + \alpha_A \pi_0$. By substituting $D = (1 - \alpha_A)\pi_0$ into (1), we obtain the payoff of firm 0. The first-order condition of firm 0 is

$$(1+(1-\alpha_A)^2\lambda)p+(1-(1-\alpha_A)(1-\theta)+(1-\alpha_A)^2\lambda)p'q_0-(1+(1-\alpha_A)^2\lambda)c_0'-(1-\alpha_A)\theta p'Q = 0. \quad (2)$$

The first-order condition of private firm i ($i = 1, \ldots, n$) is

$$p + p'q_i - c' = 0. \quad (3)$$

Henceforth, we focus on the symmetric equilibrium wherein all private firms produce the same output level q (i.e., $q_i = q_j = q$ for all $i, j = 1, \ldots, n$). Solving equations (2), (3), and the following equation (4) leads to the equilibrium outputs in the fourth stage, given α_A and n:

$$Q = q_0 + nq. \quad (4)$$

used by studies listed in footnote 2, and is also popular in mixed oligopolies. See Capuano and De Feo (2010), Matsumura and Tomaru (2015), and Xu *et al.* (2016).

[10] According to Laffont (2005), λ is estimated to be around 0.3 in developed countries.

Let $q_0^F(\alpha_A, n)$, $q^F(\alpha_A, n)$, and $Q^F(\alpha_A, n) := q_0^F(\alpha_A, n) + nq^F(\alpha_A, n)$ be the equilibrium output of firm 0, that of each private firm, and the equilibrium total output in the third stage subgame (given α_A and n), respectively. The superscript F indicates the fourth-stage subgame.

Lemma 1 *$q_0^F(\alpha_A, n)$ and $Q^F(\alpha_A, n)$ are decreasing in α_A, and $q^F(\alpha_A, n)$ is increasing in α_A.*

Lemma 1 is intuitive and indicates the standard results in the literature. Thus, we omit the formal proof. A decrease in α_A makes the public firm, firm 0, more aggressive, because it is more concerned about the consumer surplus. Although the objective of each private firm is not related to α_A, a decrease in α_A reduces the output of each private firm through the strategic interaction. Note that private firms' strategies are strategic substitutes. Then, the first direct effect dominates the second indirect strategic effect and thus, a decrease in α_A increases the total output.

After the entry of private firms, the government chooses α_A to maximize W given α_B (and thus, given R_B). By substituting $R_A = (\alpha_A - \alpha_B)\pi_0$ and $D = (1 - \alpha_A)\pi_0$, we obtain the following first-order condition for the interior solution:

$$\begin{aligned}\frac{dW}{d\alpha_A} = & \Big(\frac{dq_0^F}{d\alpha_A}\Big)(-p'Q^F + (1+\lambda)(p + p'q_0^F - c_0') + (1-\theta)np'q^F) \\ & + n\Big(\frac{dq^F}{d\alpha_A}\Big)(-\theta(p'Q^F - p'q_0^F) - (1-\theta)p'q^F + \lambda p'q_0^F) \\ & - \lambda\alpha_B\left(\frac{dq_0^F}{d\alpha_A}\left(p + p'q_0^F - c_0'\right) + n\frac{dq^F}{d\alpha_A}p'q_0^F\right) = 0. \end{aligned} \tag{5}$$

From (5), we observe that the equilibrium α_A of this subgame depends on α_B. Let $\alpha_A^T(\alpha_B, n)$ be the equilibrium degree of privatization after the entry of private firms (the superscript T indicates the third-stage subgame).

Anticipating the value of α_A, private firms enter up to the point at which they obtain zero profit, that is,

$$p(Q)q - c(q) - K = 0. \tag{6}$$

Let $\alpha_A^S(\alpha_B) = \alpha_A^T(\alpha_B, n^S(\alpha_B))$, $n^S(\alpha_B)$, $q^S(\alpha_B) = q(\alpha_A^S(\alpha_B))$, $Q^S(\alpha_B) = Q(\alpha_A^S(\alpha_B), n^S(\alpha_B))$, and $q_0^S(\alpha_B) = q_0(\alpha_A^S(\alpha_B), n^S(\alpha_B))$ be the equilibrium degree of privatization, the number of private firms entering to the market, the output of each private firm, the total output, and the output of firm 0, respectively, given α_B (the superscript S indicates the second-stage subgame).

Lemma 2 *$Q^S(\alpha_B)$ and $q^S(\alpha_B)$ do not depend on α_B, λ and θ.*

A change of α_B affects α_A and thus, it affects the behavior of firm 0. A change in λ or θ also affects the behavior of firm 0. If a change of these variables makes firm 0 more (less) aggressive, residual demand of each private firm shrinks (expands), resulting in a decrease (increase) of the number of entering firms. However, this change does not affect the equilibrium output of each private firm, and thus, does not affect the price. This result is also shown in the literature in various contexts and we omit the proof.[11]

Finally, the government chooses α_B anticipating the firm entry, future privatization, and market competition. Using Lemma 2 and the zero profit condition, we obtain the first-order condition with respect to α_B as

$$\frac{dW}{d\alpha_B} = \frac{dq_0^S}{d\alpha_B}\Big((1+\lambda)(p(Q^S) - c_0'(q_0^S(\alpha_B))\Big) = 0 \tag{7}$$

for the interior solution. For the corner solution, $dW/d\alpha_B|_{\alpha_B=0} \leq 0$ and $dW/d\alpha_B|_{\alpha_B=1} \geq 0$.

Let the superscript E denote the equilibrium outcome of the full game. Let $\alpha_B^E(\theta)$, $q_0^E(\theta)$, and $n^E(\theta)$ be the equilibrium degree of privatization, the output of firm 0, and the number of private firms given θ, respectively.

4 Results

Before discussing the characterization of α_B and α_A, we discuss two cases as benchmarks. One is the case wherein the government chooses the degree of privatization only before the entry of the private firms (privatization-then-entry model). The other is the case wherein the government chooses the degree of privatization only after the entry of the private firms (entry-then-privatization model). Let the superscript * (**) denote the equilibrium value of the privatization-then-entry model (entry-then-privatization model). It is known that the equilibrium degree of privatization in the privatization-then-

[11]See Matsumura and Kanda (2005), Cato and Matsumura (2012), and Chen (2017).

entry model, α^* is efficient for welfare.[12] We can show that α^* is derived from the following system of equations.[13]

$$\begin{aligned} p^E &= c_0'(q_0^*), \\ Q^E &= n^* q^E + q_0^*, \\ q_0^* &= q_0(\alpha^*, n^*), \end{aligned} \tag{8}$$

where p^E, q^E, and Q^E are common equilibrium price, outputs of private firms, and total output, respectively, among privatization-then-entry, entry-then privatization, and flexible privatization models.

Because α^{**} is the equilibrium degree of privatization when there is no pre-entry privatization, we obtain $\alpha^{**} = \alpha_A^S(0)$.

We now compare the equilibrium levels of privatization-then-entry and entry-then-privatization models.

Lemma 3 *There exists θ_c such that $\alpha^* > \ (=,<)\ \alpha^{**}$ if and only if $\theta < \ (=,>)\ \theta_c$.*

Proof See the Appendix.

Lee *et al.* (2018) have already shown this result when $\lambda = 0$. Lemma 3 states that this result holds regardless of λ. When $\theta = \theta_c$, $\alpha^* = \alpha^{**}$. In other words, in the entry-then-privatization model, the equilibrium price is equal to firm 0's marginal cost when $\theta = \theta_c$.

Let

$$\theta_d := \frac{(n^{**})^2 - 8}{3n^{**}(n^{**} + 4)}.$$

We now discuss the property of $\alpha_A(\alpha_B)$. We obtain the following proposition.

Proposition 1 *(i) $\alpha_A^S(\alpha_B)$ is increasing in α_B if and only if $\theta < \theta_d$. (ii) $\theta_d < \theta_c$.*

Proof See the Appendix.

Proposition 1(i) states that how the initial degree of privatization affects the final degree of privatization depends on the foreign ownership share in private firms. If the foreign ownership share in

[12] This is shown by Cato and Matsumura (2012) when $\lambda = 0$ and their principle can apply to the case with positive λ.
[13] See Sato and Matsumura (2017).

private firms is small (large), an increase in the initial degree of privatization increases (decreases) the final degree of privatization.

We explain the intuition behind Proposition 1. An increase in α_B decreases the weight of π_0 in the government's payoff in the subsequent stage.

Suppose that θ is small. An increase in α_A makes firm 0 less aggressive, which improves welfare through welfare-improving production substitution from firm 0 to private firms at the cost of the reduction of π_0 (Matsumura, 1998). Therefore, the government chooses larger α_A when α_B is larger.

Suppose that θ is large. A decrease in α_A makes firm 0 more aggressive, which improves welfare because it reduces the outflow of profits to foreign investors, at the cost of the reduction of π_0. Therefore, the government chooses smaller α_A when α_B is larger.

From these discussions, we observe that when $\theta < \theta_d$ ($\theta > \theta_d$), a decrease (an increase) in α^{**} increases π_0 in the entry-then-privatization model. In other words, when $\theta < \theta_d$ ($\theta > \theta_d$), α^{**} is too large (small) for the resulting public firm's profit-maximization in the entry-then-privatization model.

As discussed earlier in this section, when $\theta = \theta_c$, the public firm's marginal cost is equal to the price in the entry-then-privatization model. Because marginal cost pricing by the public firm is too aggressive for the profit-maximizing level, a marginal increase of α from $\alpha = \alpha^{**}$ increases the public firm's profit in the entry-then-privatization model. This implies that $\theta > \theta_d$ holds when $\theta = \theta_c$. Therefore, $\theta_c > \theta_d$ holds.

We now discuss the property of α_B^E. To this end, we present an auxiliary lemma.

Lemma 4 $q_0^S(\alpha_B)$ *is increasing in* α_B *if and only if* $\theta > \theta_d$.

Proof See the Appendix.

Using this lemma, we obtain the following proposition.

Proposition 2 *(i) For* $\theta \in [0, \theta_d] \cup [\theta_c, 1]$, $\alpha_B^E = 0$. *(ii) For* $\theta \in (\theta_d, \theta_c)$, $\alpha_B^E = \min\{\hat{\alpha}(\theta), 1\} > 0$, *where* $\hat{\alpha}$ *is given by equation* $c_0'(q_0^E(\alpha_A^S(\hat{\alpha}(\theta)))) = p^E$.

Proof See the Appendix.

We explain the intuition behind Proposition 2. When $\theta < \theta_c$, the government's incentives for privatization given the number of private firms are too large from the ex-ante (pre-entry) welfare viewpoint. Thus, decreasing the ex-post incentive for privatization improves welfare. When $\theta > \theta_d$, an increase in the degree of privatization before the entry decreases the incentive for pro-entry privatization, which improves welfare. Therefore, the government chooses a strictly positive degree of privatization before the entry of private firms when $\theta_d < \theta < \theta_c$.

When $\theta > \theta_c$, the government's incentives for privatization given the number of private firms are too small from the ex-ante (pre-entry) welfare viewpoint. Thus, increasing the ex-post (pro-entry) incentive for privatization improves welfare. However, because $\theta > \theta_d$, an increase in α_B decreases the incentive for pro-entry privatization, which reduces welfare. Therefore, the government does not privatize firm 0 before the entry of private firms.

When $\theta < \theta_d$, the government's incentives for privatization given the number of private firms are too large from the ex-ante welfare viewpoint because $\theta < \theta_c$. Thus, decreasing the ex-post incentive for privatization improves welfare. However, an increase in α_B increases the incentive for pro-entry privatization, which reduces welfare. Therefore, the government does not privatize firm 0 before the entry of private firms.

Figure 1 describes how λ affects θ_i $i = c, d$ (we set $a = 15$ and $K = 1/2$). From Figure 1, we observe that pre-entry privatization serves as a commitment (i.e., it affects the pro-entry privatization policy) for relevant range of θ. Note that pre-entry privatization is useful if $\theta \in (\theta_d, \theta_c)$.[14]

Figures 2 describes how θ affects α_B^E and α^* (we set $a = 15$, $K = 1/2$, and $\lambda = 1/2$). From Figure 2, we find that α_B^E is discontinuous and non-monotone with respect to θ. When $\theta \leq \theta_d$, $\alpha_B^E = 0$ (Proposition 2(i)). When θ exceeds θ_d, α_B^E jumps to one and remains one when θ is close to θ_d. When θ is close to θ_c, α_B^E is decreasing in θ. Finally, α_B^E again becomes zero when θ reaches θ_c. Note that $\alpha_A^E = \alpha^{**}$ when $\alpha_B^E = 0$, $\alpha_A^E = \alpha^*$ when $\alpha_B^E \in (0, 1)$, and α_A^E lies between α^* and α^{**} when $\alpha_B^E = 1$.

We discuss how λ affects θ_d and θ_c.

[14] In 2016, the average foreign ownership share in listed firms in Japan was 30.1%. The foreign ownership share in KDDI, which competes with partially privatized firm NTT, is 31.7%, while the foreign ownership shares in Mitsubishi UFJ Financial Group and Mizuho Financial Group, which compete with partially privatized firm Postal Bank and pure state bank the Development Bank of Japan, were 38.2% and 23.4%, respectively, in 2018.

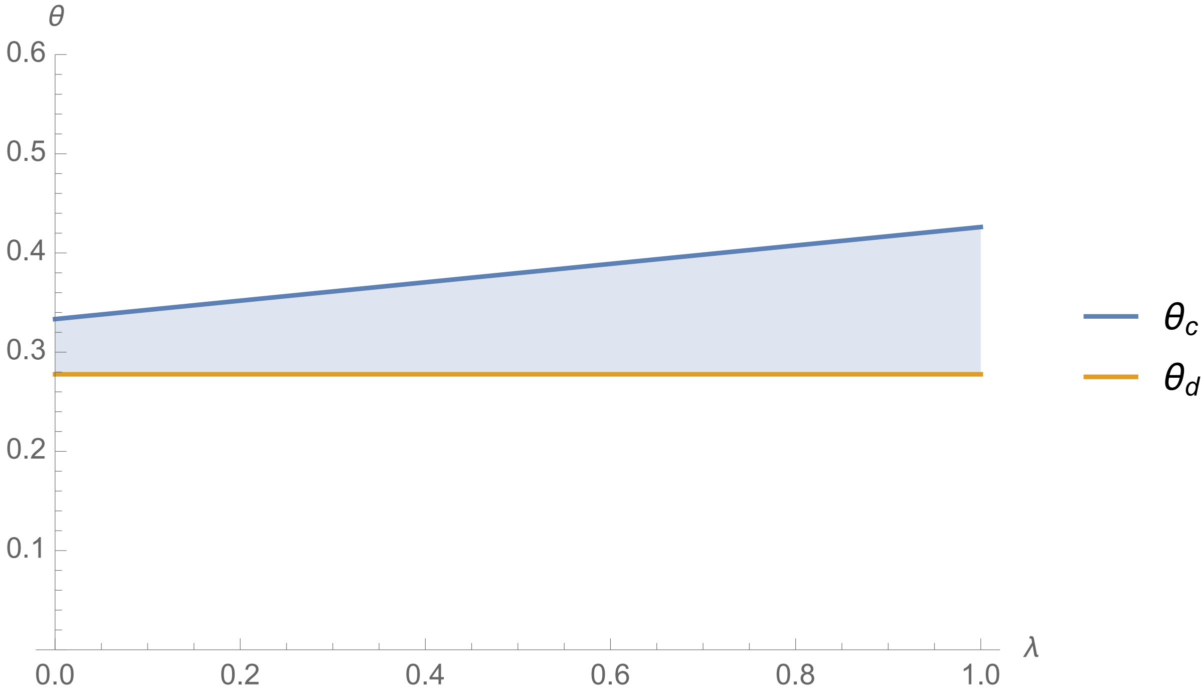

Figure 1: The relationship between θ_c (θ_d) and λ.

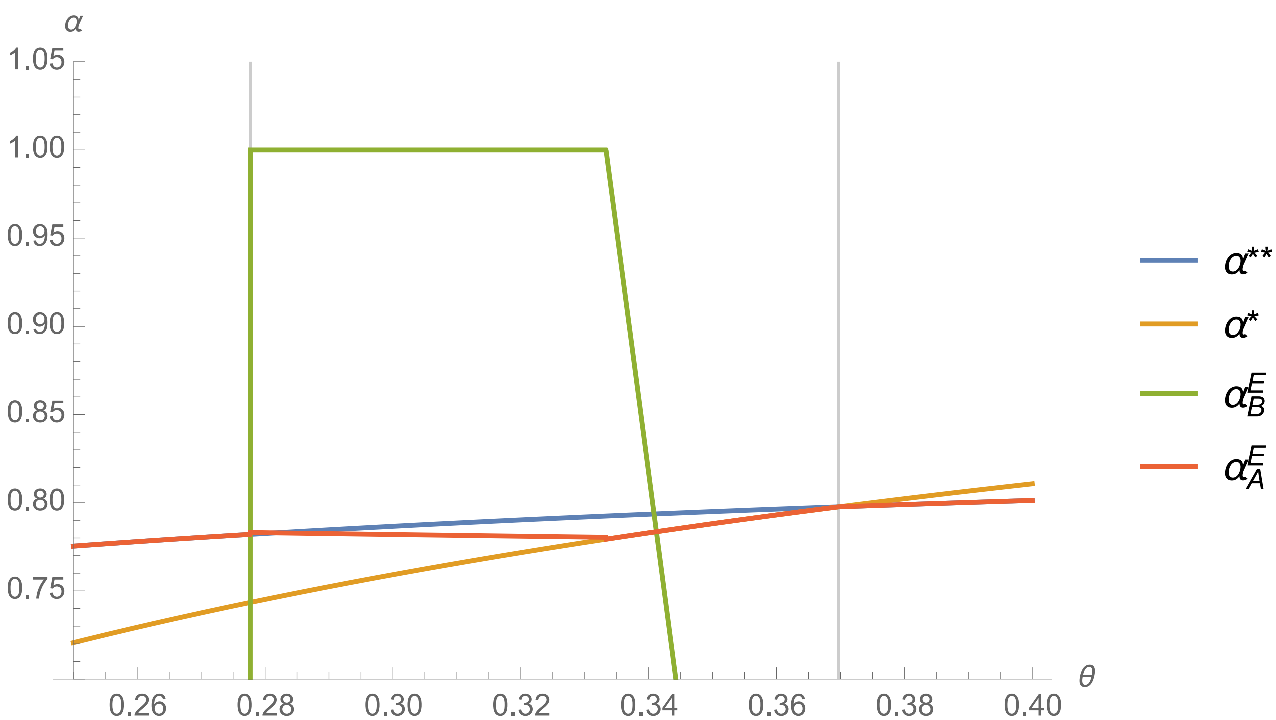

Figure 2: The relationship between θ and α

Lemma 5 *(i) θ_d does not depend on λ. (ii) θ_c is increasing in λ.*

Proof See the Appendix

Lemma 5 states that pre-entry privatization more likely serves as a commitment when λ is larger. From Lemma 5, we define the inverse function $\lambda_c(\theta)$ by $\lambda_c := \theta_c^{-1}(\theta)$. Proposition 2 and Lemma 5 lead to the following proposition.

Proposition 3 *Suppose that $\theta > \theta_d$. $\alpha_B^E > 0$ if and only if $\lambda > \lambda_c(\theta)$.*

Finally, we compare welfare among three games.

Proposition 4 *(i) $W^* \geq W^E \geq W^{**}$. (ii) $W^* = W^E$ if $\alpha_B^E = \hat{\alpha}$, (iii) $W^E > W^{**}$ if $\alpha_B^E > 0$.*

Proof See the Appendix.

Proposition 4(i) implies that if the government commits not to adjust the degree of privatization, it improves welfare. Proposition 4(ii) states that even if the government could not commit not to adjust the degree of privatization after the entry of private firms, the optimal initial privatization policy might substitute the full commitment not to change the degree of privatization. The initial privatization policy substitutes the full commitment not to change the degree of privatization if the equilibrium initial privatization policy is partial privatization. Proposition 4(iii) indicates that initial privatization improves welfare as long as the initial degree of privatization is positive. These results suggest that the initial privatization policy is welfare improving although it might not yield the best outcome for welfare.

5 Concluding Remarks

In this study, we investigate the situation in which the government cannot commit not to adjust the degree of privatization after the entry of private firms. We find that a privatization policy prior to the liberalization of the market may substitute the full commitment not to change the privatization policy and improve welfare. We also show that the optimal degree of privatization prior to the liberalization of the market is non-monotone with respect to the foreign ownership share in private firms. The optimal degree of privatization prior to the liberalization of the market is zero when the foreign ownership share in private firms is close to zero and to one, whereas the optimal degree of privatization is positive and even can be one when the foreign ownership share is intermediate.

In this study, as well as in other studies in the literature on mixed oligopolies, the foreign ownership share in private firms is given exogenously. Moreover, foreign ownership share does not affect the efficiency of private firms. Introducing the cost-efficiency effect of foreign ownership and endogenizing the foreign ownership share is a promising future research topic.

Moreover, we consider a single market model. As Haraguchi *et al.* (2017) pointed out, public firms receive competitive pressure from neighboring markets, and extending our analysis to a multi-product model remains for future research.[15]

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

Appendix

Before presenting the formal proofs of lemmas and propositions, we present some properties that are used in the proofs.

Material for the Proofs of Lemmas and Propositions

In all of the privatization-then-entry, entry-then-privatization, and flexible privatization games, Q and q are determined by the same free-entry condition and the first-order condition for the private firms:

$$p(Q)q - c(q) - K = 0, \tag{9}$$

$$p(Q) + p'(Q)q - c'(q) = 0. \tag{10}$$

Second, α^*, n^*, and q_0^* is the solution to the following system of equations:

$$p(Q) - c_0'(q_0^*) = 0, \tag{11}$$

$$q_0^* = q^F(\alpha^*, n^*), \tag{12}$$

$$Q = n^* q + q_0^*. \tag{13}$$

Finally, α^{**}, n^{**}, and q_0^{**} equal $\alpha_A^S(0)$, $n^S(0)$, and $q_0^S(0)$, where $\alpha_A^S(\alpha_B)$, $n^S(\alpha_B)$ and $q_0^S(\alpha_B)$ are the solution to the following system of equations:

$$\alpha_A^S(\alpha_B) = \alpha_A^T(\alpha_B, n^S(\alpha_B)), \tag{14}$$

$$Q = n^S(\alpha_B)q + q_0^S(\alpha_B), \tag{15}$$

$$q_0^S(\alpha_B) = q_0^F(\alpha_A^S(\alpha_B), n^S(\alpha_B)). \tag{16}$$

In addition, in the course of presenting the proofs, we repeatedly use the fact that

$$\frac{\partial q^F}{\partial \alpha_A} = -\frac{1}{n+2}\frac{\partial q_0^F}{\partial \alpha_A},$$

which follows from (3) and (4).

Proof of Lemma 3

We show Lemma 3 in the following steps:

1. When $\theta = 0$, $q_0^* > q_0^{**}$:

   Let $\theta = 0$. The first-order condition for α^{**} yields

$$(1+\lambda)(p - c_0') = -p' \left[\frac{n}{n+2}(q + \lambda q_0) + q_0 \right] > 0.$$

   Because $p^E - c_0'(q^*) = 0$, $p^E - c_0'(q^{**}) > 0$ implies that $q_0^* > q_0^{**}$ at $\theta = 0$.

2. q_0^{**} is increasing in θ:

   From the equilibrium conditions (14), (15), and (16) for $\alpha_B = 0$, we obtain

$$q_0^{**}(\theta) = \frac{A - \sqrt{A^2 - 4(1+\lambda)B}}{2(1+\lambda)},$$

   where

$$A = (1+\lambda)(a - Q) - (\theta + \lambda)Q + (Q + 2q)[2(1+\lambda) - (1-\theta)] - (1-\theta)q,$$

$$B = (Q + 2q)[(1+\lambda)a - (1 + \lambda - \theta)Q] - Q[\theta Q + (1-\theta)q].$$

   We obtain

$$\begin{aligned} \frac{\partial q_0^{**}}{\partial \theta} &= \frac{3q}{2(1+\lambda)\sqrt{A^2 - 4(1+\lambda)B}} \left(\sqrt{A^2 - 4(1+\lambda)B} - A + 2(1+\lambda)Q \right) \\ &= \frac{3q}{2(1+\lambda)\sqrt{A^2 - 4(1+\lambda)B}} \left(\sqrt{A^2 - 4(1+\lambda)B} - (1+\lambda)(3a - 4Q) + 3(1-\theta)q \right) > 0. \end{aligned}$$

   The last inequality follows from

$$(1+\lambda)(3a - 4Q) - 3(1-\theta)q = -(1+\lambda)a + 2(5 + 8\lambda + \theta)\sqrt{\frac{2}{3}K} < 0$$

   for sufficiently large a.

3. $q_0^{**} < q_0^*$ if and only if $\theta < \theta_c$, where θ_c is derived from

$$-Q + (1+\lambda)q_0^* + (1-\theta_c)(Q - q_0^*) - \frac{Q - q_0^*}{Q - q_0^* + 2q}(-\theta_c(Q - q_0^*) - (1-\theta_c)q + \lambda q_0) = 0. \quad (17)$$

   This condition for θ_c means that the first-order condition for $\alpha_A(0)$, (5), is satisfied at $q_0 = q_0^* = a - Q$. This implies $q_0^* = q_0^{**}$ when $\theta = \theta_c$.

   Because q_0^* is independent of θ and q_0^{**} is increasing in θ, $q_0^{**} < q_0^*$ if and only if $\theta < \theta_c$.

4. $\alpha^{**} > \alpha^*$ if and only if $q_0^{**} < q_0^*$.

   Lemma 4(ii) of Sato and Matsumura (2017) showed that $q_0^L(\alpha)$, which solves

$$q_0^L = q_0^F(\alpha, n^L) \tag{18}$$

$$Q = n^L q + q_0^L \tag{19}$$

$$p(Q)q - c(q) - K = 0, \tag{20}$$

$$p(Q) + p'(Q)q - c'(q) = 0. \tag{21}$$

   is decreasing in α. In this notation, $q_0^{**} = q_0^L(\alpha^{**})$ and $q_0^* = q_0^L(\alpha^*)$, which implies that $q_0^{**} < q_0^*$ if and only if $\alpha^{**} > \alpha^*$.

Thus, we obtain that $\alpha^{**} > \alpha^*$ if and only if $\theta < \theta_c$, which completes the proof. Q.E.D.

Proof of Proposition 1(i)

The proof of Proposition 1(i) proceeds in the following steps:

1. The sign of $\partial\alpha_A^S/\partial\alpha_B$ is equal to the sign of $\partial\alpha_A^T/\partial\alpha_B$.

2. In the neighborhood of $\alpha_B = 0$ (i.e., $\alpha_A^S = \alpha^{**}$, $n^S = n^{**}$, $q_0^S = q_0^{**}$), $\partial\alpha_A^T/\partial\alpha_B >\ (=, <)\ 0$ if $\theta <\ (=, >)\ \theta_d$.

3. If $\partial\alpha_A^S/\partial\alpha_B >\ (=, <)\ 0$ in the neighborhood of $\alpha_B = 0$, then $\partial\alpha_A^S/\partial\alpha_B >\ (=, <)\ 0$ for all $\alpha_B > 0$, which implies that $\partial\alpha_A^S/\partial\alpha_B >\ (=, <)\ 0$ if $\theta <\ (=, >)\ \theta_d$.

We show each of the steps.

1. First, we show the condition under which $\alpha_A^S(\alpha_B)$ increases with α_B.

   Differentiating equations (14), (15), and (16), we obtain

$$\frac{\partial\alpha_A^S}{\partial\alpha_B} = \frac{\partial\alpha_A^T}{\partial\alpha_B} + \frac{\partial n^S}{\partial\alpha_B}\frac{\partial\alpha_A^T}{\partial n}, \tag{22}$$

$$0 = \frac{\partial n^S}{\partial\alpha_B}q + \frac{\partial q_0^S}{\partial\alpha_B} \tag{23}$$

$$\frac{\partial q_0^S}{\partial\alpha_B} = \frac{\partial\alpha_A^S}{\partial\alpha_B}\frac{\partial q_0^F}{\partial\alpha_A} + \frac{\partial n^S}{\partial\alpha_B}\frac{\partial q_0^F}{\partial n}. \tag{24}$$

Equation (23) can be rewritten as

$$\frac{\partial n^S}{\partial \alpha_B} = -\frac{1}{q}\frac{\partial q_0^S}{\partial \alpha_B},$$

and thus, using this equation, equation (24) can be further rewritten as

$$\frac{\partial q_0^S}{\partial \alpha_B} = \frac{\frac{\partial \alpha_A^S}{\partial \alpha_B}\frac{\partial q_0^F}{\partial \alpha_A}}{1 + \frac{1}{q}\frac{\partial q_0^F}{\partial n}}.$$

Substituting these two equations into equation (22), we obtain

$$\frac{\partial \alpha_A^S}{\partial \alpha_B} = \frac{\frac{\partial \alpha_A^T}{\partial \alpha_B}}{1 + \frac{\partial \alpha_A^T}{\partial n}\frac{\partial q_0^F}{\partial \alpha_A}\frac{1}{q+(\partial q_0/\partial n)}}.$$

A tedious calculation shows that $1+\frac{\partial \alpha_A^T}{\partial n}\frac{\partial q_0^F}{\partial \alpha_A}\frac{1}{q+(\partial q_0/\partial n)} > 0$ in our specification. Thus, $\partial \alpha_A^S/\partial \alpha_B > 0$ if and only if $\partial \alpha_A^T/\partial \alpha_B > 0$.

2. Next, we consider the condition under which $\partial \alpha_A^T/\partial \alpha_B > 0$. Sato and Matsumura (2018) showed that for fixed number of private firms n, $\partial \alpha_A/\partial \alpha_B > 0$ if and only if

$$n^2 - 8 - 3n(n+4)\theta > 0.$$

Let $g(\theta, \alpha^B) = \left(n^S(\alpha^B, \theta)\right)^2 - 8 - 3n^S(\alpha^B, \theta)(n^S(\alpha^B, \theta)+4)\theta$. At $\alpha_B = 0$, $n = n^{**} = (Q - q_0^{**})/q$, and $g(\theta, 0)$ can be rewritten as

$$g(\theta, 0) = \left(\frac{Q - q_0^{**}}{q}\right)^2 - 8 - 3\left(\frac{Q - q_0^{**}}{q}\right)\left[\left(\frac{Q - q_0^{**}}{q}\right) + 4\right]\theta.$$

Because q_0^{**} is increasing in θ and Q is independent of θ, $g(\theta, 0)$ is decreasing in θ. $g(\theta, 0) = 0$ when $\theta = \theta_d$. Thus, we obtain $\partial \alpha_A/\partial \alpha_B > 0$ at $\alpha_B = 0$ if and only if $\theta < \theta_d$. Note that $\theta_d < 1$ because $g(\theta, 0)$ is continuous and $g(1, 0) < 0$.

3. Finally, we show that for any $\alpha_B \in [0, 1]$, α_A^S increases with α_B if and only if $\theta < \theta_d$. Suppose $\theta < \theta_d$. On the contrary, also suppose that there exists the smallest $\bar{\alpha}_B > 0$ such that α_A^S decreases with α_B at $\bar{\alpha}_B$ and α_A^S increases with α_B at $\alpha_B \in [0, \bar{\alpha}_B)$. We must have $\alpha_A(\bar{\alpha}_B) > \alpha_A(0)$. Thus, we must have $n^S(\bar{\alpha}_B) > n^S(0)$ from equation (15) and the fact that q_0^F is decreasing in α_B, which implies that $\partial \alpha_A/\partial \alpha_B > 0$, which in turn implies that $d\alpha_A/d\alpha_B > 0$, a contradiction. The same principle applies when $\theta > \theta_d$. Q.E.D.

Proof of Proposition 1(ii)

Sato and Matsumura (2018) showed that α^{**} maximizes the profit of firm 0 given the number of private firms at $\theta = \theta_d$. Therefore, we obtain

$$\frac{\partial q_0^F}{\partial \alpha_A}(p + p'q_0 - c_0') + n\frac{\partial q^F}{\partial \alpha_B}p'q_0 = 0$$

$$\Longrightarrow \frac{\partial q_0^F}{\partial \alpha_A}\left(a - Q - 2q_0 + \frac{n}{n+2}q_0\right) = \frac{\partial q_0^F}{\partial \alpha_A}\left(a - Q - 2q_0 + \frac{Q - q_0}{Q - q_0 + 2q}q_0\right) = 0$$

$$\Longrightarrow q_0^{**}(\theta_d) = \frac{3a - 2Q - \sqrt{5a^2 - 8aQ + 4Q^2}}{2}, \tag{25}$$

where we use the first-order condition of the private firms, $a - Q - 2q = 0$ and the fact that $\partial q^F/\partial \alpha_A = -(\partial q_0^F/\partial \alpha_A)/(n+2)$.

When $\theta = \theta_c$, $p = c_0'$ is satisfied. This implies $q_0^{**}(\theta_c) = a - Q$.

Finally, we obtain

$$q_0^{**}(\theta_c) - q_0^{**}(\theta_d) = \frac{a + \sqrt{5a^2 - 8aQ + 4Q^2}}{2} > 0,$$

which implies that $\theta_c > \theta_d$. Note that we have shown that $q_0^{**}(\theta)$ is increasing in the proof of Lemma 3. Q.E.D.

Proof of Lemma 4

As seen in the proof of Proposition 1(i), using the equations (23) and (24), we obtain

$$\frac{\partial q_0^S}{\partial \alpha_B} = \frac{\frac{\partial q_0^F}{\partial \alpha_A}}{1 + \frac{1}{q}\frac{\partial q_0^F}{\partial n}}\frac{\partial \alpha_A^S}{\partial \alpha_B}.$$

Because $(\partial q_0^F/\partial \alpha_A)/(1 + (1/q)(\partial q_0^F/\partial n)) < 0$ and $\partial q_0^F/\partial \alpha_A < 0$, $q_0^S(\alpha_B)$ increases with α_B if and only if $\alpha_A^S(\alpha_B)$ decreases with α_B, which holds if and only if $\theta > \theta_d$ (Proposition 1(i)). Q.E.D.

Proof of Proposition 2

First note that at the first stage, welfare

$$W = \int_0^Q p(x)dx - pQ + (1+\lambda)(pq_0 - c_0 - K_0) + n(pq - c - K) \tag{26}$$

is affected by α_B only through the term

$$(1+\lambda)(p(Q)q_0^S(\alpha_B) - c_0(q_0^S(\alpha_B))) \tag{27}$$

because Q and q are independent of α_B. Because c_0 is a convex function, this welfare function is concave in q_0^S.

Because q_0^S is monotone with respect to α_A, $\alpha_B > 0$ if and only if

$$\left.\frac{dW}{d\alpha_B}\right|_{\alpha_B=0} = (1+\lambda)(p - c_0')\left.\frac{\partial q_0^S}{\partial \alpha_B}\right|_{\alpha_B=0} > 0. \tag{28}$$

Suppose that $\theta \in [0, \theta_d]$. Because $\theta_d < \theta_c$ and $(p - c_0') > 0$ for $\theta < \theta_c$, $(1+\lambda)(p - c_0') > 0$. Lemma 4 yields $\partial q_0^S / \partial \alpha_B \leq 0$. Thus, (28) is negative. Suppose that $\theta \in [\theta_c, 1]$. Because $(p - c_0') > 0$ for $\theta \geq \theta_c$, $(1+\lambda)(p - c_0') \geq 0$. Because $\theta_d < \theta_c$, Lemma 4 yields $\partial q_0^S / \partial \alpha_B \geq 0$. Thus, (28) is nonpositive. These results imply Proposition 2(i).

Suppose that $\theta \in (\theta_d, \theta_c)$. The above discussions imply that $\alpha_B > 0$. Welfare is maximized when $(1+\lambda)(p(Q)q_0^S(\alpha_B) - c_0(q_0^S(\alpha_B)))$ is maximized. Because q_0^S is increasing in α_A and $\alpha_A \in [0, 1]$, we obtain Proposition 2(ii). Q.E.D.

Proof of Lemma 5

(i) From (25), we obtain $q_0^{**}(\theta_d) = (3a - 2Q - \sqrt{5a^2 - 8aQ + 4Q^2})/2$. Because $n^{**} = (Q - q_0^{**})/q$, θ_d is the solution to

$$\left(\frac{Q - q_0^{**}(\theta_d)}{q}\right)^2 - 8 - 3\left(\frac{Q - q_0^{**}(\theta_d)}{q}\right)\left[\left(\frac{Q - q_0^{**}(\theta_d)}{q}\right) + 4\right]\theta_d = 0,$$

where

$$q_0^{**}(\theta_d) = \frac{3a - 2Q - \sqrt{5a^2 - 8aQ + 4Q^2}}{2}.$$

Because these equations do not involve λ, θ_d does not depend on λ.

(ii) Applying the implicit function theorem to the condition for θ_c (17), we obtain

$$\frac{d\theta_c}{d\lambda} = \frac{2q_0^* q}{3(Q - q_0^*)} > 0.$$

This implies Lemma 5(ii). Q.E.D.

Proof of Proposition 4

(i) W^*, W^E, and W^{**} differ only through q_0 because Q and q are identical among the three games. Thus, welfare depends only on $(1+\lambda)[pq_0 - c_0(q_0)] = (1+\lambda)\pi_0^S$. Because $p = p^E$ and does not depends on the resulting q_0 in free-entry markets, π_0^S is strictly concave with respect to q_0 and is maximized when $q_0 = q_0^*$.

When $\theta \in [0, \theta_d]$, $q_0^E = q_0^{**} \geq q_0^*$. When $\theta \in (\theta_d, \theta_c)$, $q_0^* \geq q_0^E > q_0^{**}$. When $\theta \in [\theta_c, 1]$, $q_0^E = q_0^{**} \leq q_0^*$ These results imply that $W^* \geq W^E \geq W^{**}$.

(ii) If $\alpha_B^E = \hat{\alpha}$, we obtain $q_0^E = q^*$, which implies $W^* = W^E$.

(iii) When $\alpha_B^E > 0$, because $q_0^* \geq q_0^E > q_0^{**}$, $W^E > W^{**}$ holds. Q.E.D.

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