

Ex-ante versus ex-post privatization policies with foreign penetration in free-entry mixed markets*

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Abstract This study investigates the impact of the order of privatization and liberalization policies on degree of privatization and number of entering firms in free-entry markets. For this purpose, we formulate two models: *ex-post* privatization and *ex-ante* privatization. In the former, the government liberalizes the market and then privatizes the public firm, and in the latter, the order of the policies is reversed. We find that *ex-ante* privatization yields a higher (lower) level of privatization and larger (smaller) equilibrium number of entering private firms when the foreign ownership in private firms is high (low). We also show that the optimal level of privatization is increasing (decreasing) in the share of foreign ownership in the *ex-ante* (*ex-post*) privatization case. Finally, we find that although both *ex-ante* and *ex-post* cases yield the same consumer welfare, *ex-ante* privatization always yields higher social welfare than *ex-post* privatization.

Keywords Partial privatization, Free entry, Foreign penetration, Mixed oligopoly

JEL Classification H42, L13, C72

1. Introduction

In recent decades, mixed oligopoly in free-entry markets has been a subject of extensive research because of economic liberalization, which involves the privatization of public firms and the abolition of entry restrictions. Matsumura and Kanda (2005) showed that full nationalization is always optimal in the long run under free entry when private firms are owned by domestic investors. Cato and Matsumura (2012) also showed that partial privatization is optimal when private firms are owned by foreign investors. Brandao and Castro (2007) showed that the presence of a public firm can serve as an alternative to direct entry regulations in precluding the excess-entry problem.¹

The literature on mixed oligopoly in free-entry markets is rich and diverse.² Wang and Chen (2010) and Cato (2012) considered firms' cost efficiency gap and Wang *et al.* (2014)

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¹ For discussions on the excess-entry problem in private oligopolies, see Mankiw and Whinston (1986), Suzumura and Kiyono (1987), and Lahiri and Ono (1988).

² In various contexts, contrasting implications are often obtained in free-entry markets, and thus, the literature on the analysis of free-entry markets in both private and mixed oligopolies is nascent. See Etro (2007), Lahiri and Ono (1995, 2007), Ino and Matsumura (2012), and Hattori and Yoshikawa (2016) for further details.

examined foreign competitors in a free-entry market. These studies provided some reasonable explanations for the persistence of public firms in certain industries. Ino and Matsumura (2010) investigated the leader-follower relationship, while Cato and Matsumura (2013) and Matsumura and Okumura (2014) investigated the privatization neutrality theorem. Cato and Matsumura (2015) examined the optimal trade policy in free-entry markets. However, none of these studies has paid attention to the impact of the timing of a game between privatization and liberalization policies.

This study investigates the impact of foreign penetration on the privatization and liberalization policies in a free-entry market.³ We examine two different scenarios in which the government chooses the optimal level of privatization before or after private firms enter a market. In one model, the government liberalizes the market and then privatizes the public firm (*ex-post* privatization), and in the other model, the order of the policies is reversed (*ex-ante* privatization).

Matsumura (1998), Han and Ogawa (2007), and Lin and Matsumura (2012) showed that the optimal level of privatization is never zero regardless of the number of firms and the share of foreign ownership in private firms in restricted-entry markets.⁴ In contrast, Matsumura and Kanda (2005) showed that it is zero if the privatization policy is determined before entry and foreign ownership share in private firms is zero. Therefore, we naturally expect that the optimal level of privatization will be higher when the privatization policy is decided after entry. However, we show that this is not always true, and the results depend on the share of foreign ownership in private firms. We find that *ex-ante* privatization yields a higher (lower) level of privatization and larger (smaller) number of private firms when the foreign ownership is high (low). We also show that, although both *ex-ante* and *ex-post* privatization cases yield the same consumer surplus, the former always yields higher social welfare. This suggests that earlier privatization improves welfare without affecting consumer surplus. Moreover, the difference of the timing of a game in privatization and liberalization policies produces another contrasting policy implication. We show that the optimal level of privatization is increasing (decreasing) in the foreign ownership share in private firms if privatization is implemented before (after) the entry of private firms.

The remainder of this paper is organized as follows. Section 2 presents the basic model. Section 3 analyzes the *ex-ante* and *ex-post* privatization models respectively, and presents a comparative analysis of the two cases. Section 4 concludes the study.

2. Model

We consider a mixed oligopoly market in which $n+1$ operating firms produce homogenous products. Firm 0 is a (partially privatized) public firm that is jointly owned by both the government and domestic private sectors. The share of private ownership is denoted by

³ As shown by Corneo and Jeanne (1994) and Fjell and Pal (1996), public enterprises' behavior drastically changes in the presence of foreign firms in the product markets, because the existence of foreign firms affects the objective of the public enterprises. Thus, foreign penetration in the product market is intensively discussed in the literature on mixed oligopolies. See also Pal and White (1998), Wang and Chen (2011), Lin and Matsumura (2011), Cato and Matsumura (2015), and Wang and Tomaru (2015).

⁴ This holds true even when private firms do not maximize profits. See Matsumura and Okamura (2015).

$\theta \in [0,1]$. Firm i ($=1,2, \dots, n$) is a private firm owned by both domestic and foreign investors.

The inverse demand function is $P = \alpha - Q$, where Q is the market output and α is a positive constant. The cost functions are given as $C(q^j) = (q^j)^2 / 2 + F$ ($j = 0,1, \dots, n$), where $(q^j)^2 / 2$ is the production cost and F is the fixed (sunk) cost. Then, the profits of the public firm and private firm are $\pi^j = Pq^j - (q^j)^2 / 2 - F$, where $j = 0,1, \dots, n$. The consumer surplus and producer surplus are denoted as $CS = Q^2 / 2$ and $PS = \pi^0 + \sum_{i=1}^n (1 - \beta)\pi^i$, where $\beta \in [0,1]$ is the ownership share of foreign investors in private firm i .⁵

We consider a free-entry market in which private firms can enter the market without any entry regulation. Then, the number of private firms is determined at the point where the profit of the private firm is zero. The social welfare is defined as the sum of consumer surplus and producer surplus (i.e., $W = CS + PS$).

A firm's objective functions are subject to its ownership structure. According to Matsumura (1998), a private firm seeks profit maximization, whereas a public firm's objective V is the share-weighted objectives between both social welfare and profits (i.e., $V = \theta\pi^0 + (1 - \theta)W$). We can interpret $\theta \in [0,1]$ as a level of privatization. $\theta = 0$ implies full nationalization, $\theta = 1$ implies full privatization, and $\theta \in (0,1)$ implies partial privatization.

To analyze the optimal level of privatization in free-entry mixed oligopolies, we examine two different cases. The first one is *ex-ante* privatization, in which the government chooses the optimal level of privatization before private firms enter the market. The other is *ex-post* privatization, in which the government chooses the optimal level of privatization after private firms enter the market.

3. Analysis and comparison

3.1. Ex-ante privatization

In this subsection, we consider the *ex-ante* privatization model in which the government chooses the level of privatization before the private firms' entry into the market. The timing of this game is as follows. In the first stage, the government chooses the level of privatization θ to maximize social welfare. In the second stage, given θ , each private firm decides whether to enter the market (entry cost is sunk if a private firm enters the market), where the number of private firms is endogenously determined by a free-entry market condition (zero-profit condition). In the third stage, the public firm and the private firms compete in quantities in a Cournot fashion. The subgame perfect Nash equilibrium will be solved by backward induction.

In the third stage, the public firm chooses output level q^0 to maximize its objective function V , and the private firm chooses output level q^i to maximize its own profits π^i . The first-order conditions are respectively⁶

⁵ We can interpret that the share of foreign ownership indicates the level of market openness in financial markets (Haraguchi and Matsumura, 2014).

⁶ In this study, all of the second-order conditions are satisfied.

$$\frac{\partial V}{\partial q^0} = (\alpha - n(1 - \lambda)q^i - 2q^0)(1 - \theta) + (\alpha - nq^i - 3q^0)\theta = 0, \quad (1)$$

$$\frac{\partial \pi^i}{\partial q^i} = \alpha - (2 + n)q^i - q^0 = 0. \quad (2)$$

From equations (1) and (2), we obtain the following equilibrium quantities.

$$q^0 = \frac{\alpha(2 + n\beta(1 - \theta))}{2(2 + \theta) + n(1 + \theta + \beta - \beta\theta)}, \quad (3)$$

$$q^i = \frac{\alpha(1 + \theta)}{2(2 + \theta) + n(1 + \theta + \beta - \beta\theta)}. \quad (4)$$

The profits of the public and private firms are respectively

$$\pi^0 = \frac{\alpha^2(2 + n\beta(1 - \theta))(2 - n\beta + \theta(4 + n\beta))}{2(2(2 + \theta) + n(1 + \theta + \beta - \beta\theta))^2} - F, \quad (5)$$

$$\pi^i = \frac{3\alpha^2(1 + \theta)^2}{2(2(2 + \theta) + n(1 + \theta + \beta - \beta\theta))^2} - F. \quad (6)$$

The social welfare is given by

$$W = \frac{\alpha^2(1 + \theta)(8 + n(7 + n + (3 + n)\theta) + n\beta(1 + 2n(1 - \theta) - 7\theta))}{2(2(2 + \theta) + n(1 + \theta + \beta - \beta\theta))^2} + (\beta n - n - 1)F. \quad (7)$$

In the second stage, each private firm earns zero profit in the equilibrium. Setting the profit of the private firms in equation (6) equal to zero yields the following number of private firms:

$$n = \frac{\sqrt{6\alpha}(1 + \theta) - 4\sqrt{F}(2 + \theta)}{2\sqrt{F}(1 + \theta + \beta - \theta\beta)}. \quad (8)$$

The resulting social welfare is given by

$$W = \frac{2F\mu + 4\sqrt{6F}\alpha((1 - \theta)^2\beta^2 + (\theta^2 + \theta - 2)\beta - (1 + \theta)^2) + \alpha^2(3 + 6\beta + 6\theta + 3\theta^2 - 6\theta^2\beta)}{6(1 + \theta + \beta - \theta\beta)^2}, \quad (9)$$

where $\mu = 5 + 10\theta + \theta^2 + 2(5 - 8\theta + 3\theta^2)\beta - 11(1 - \theta)^2\beta^2$.

In the first stage, the government chooses the optimal level of privatization. The differentiation of W in equation (9) with respect to θ yields⁷

$$\theta_B = \frac{\beta(\alpha\sqrt{6F}(1 - 7\beta) + 3\alpha^2\beta - 8F(1 - 3\beta))}{\alpha\beta\sqrt{6F}(3 - 7\beta) + 3\alpha^2\beta^2 + 4F(1 - \beta(5 - 6\beta))}, \quad (10)$$

where subscript ‘‘B’’ denotes the equilibrium outcome of this game (privatization **before** the entry). From equation (10), we find that $\theta_B = 0$ when $\beta = 0$, while $0 < \theta_B < 1$ when

⁷ Note that $\left. \frac{\partial W}{\partial \theta} \right|_{\theta=0} \geq 0$ when $0 \leq \beta \leq 1$.

$0 < \beta \leq 1$. The optimal level of privatization is increasing in the share of foreign ownership in private firms (i.e., $\partial \theta_B / \partial \beta > 0$. See footnote 8 for proof.). This implies that the privatization policy can be complementary with the liberalization policy of the capital market under *ex-ante* privatization. We will provide the intuition after presenting Proposition 2.

Substituting equation (10) into equation (8), we obtain the following equilibrium number of private firms:

$$n_B = \alpha \sqrt{\frac{3}{2F}} - 4. \quad (11)$$

The number of private firms decreases as the fixed cost increases (i.e., $\partial n_B / \partial F < 0$). Thus, if the fixed cost is sufficiently high, no private firms enter the market. To ensure that the number of private firms is positive, we assume $0 < F < 3\alpha^2 / 32$. From equation (11), we obtain the following lemma.

Lemma 1: *In the ex-ante privatization case, the number of entering firms is independent of the share of foreign ownership in private firms.*

This result is in sharp contrast to Lemma 3, which is a counterpart of this lemma in the *ex-post* privatization case. We explain the intuition behind Lemmas 1 and 3 after presenting Lemma 3.

The resulting market output and price are

$$Q_B = \alpha - 2\sqrt{\frac{2F}{3}}, \quad (12)$$

$$P_B = 2\sqrt{\frac{2F}{3}}. \quad (13)$$

From equation (13), we obtain the following lemma.

Lemma 2: *In the ex-ante privatization case, consumer welfare is independent of the foreign ownership share in private firms.*

This result corresponds with that in the private oligopoly case in which all firms are private, and with that in the *ex-post* privatization case.

The social welfare is given by

$$W_B = \frac{3\alpha^2 - 4\alpha\sqrt{6F} + 10F}{6}. \quad (14)$$

The following proposition summarizes the above discussions on the optimal level of privatization θ_B .

Proposition 1: *In the ex-ante privatization case, full nationalization is optimal without foreign penetration, while partial privatization is optimal when there is foreign ownership in private firms. The optimal level of privatization is increasing in the foreign ownership share in private*

firms.⁸

The first part of Proposition 1 states that foreign penetration is essential to determine the optimal level of privatization in a free-entry market. When there is no foreign ownership in private firms, the government should choose a full nationalization policy when it can decide the level of privatization before private firms enter the market, which is exactly proved by Matsumura and Kanda (2005). On the other hand, the government should choose partial privatization when there is foreign ownership in private firms (Cato and Matsumura, 2012).

The second part of Proposition 1 is in sharp contrast to the result in the *ex-post* privatization case that is presented in Proposition 2. We discuss this point as well as the intuition behind this result in the next subsection, after presenting Proposition 2.

3.2. Ex-post privatization

In this subsection, we consider the case of *ex-post* privatization in which the government chooses the level of privatization after the entry of private firms. In other words, each private firm decides whether to enter the market in the first stage before the government decides the level of privatization.

In the third stage, both public and private firms simultaneously choose their output levels. The equilibrium quantities of the firms are derived from equations (3) and (4). In the second stage, the government chooses the optimal level of privatization. The differentiation of W in equation (7) with respect to θ yields the following result:

$$\theta = \frac{n + \beta(n^2 - n)}{4 + n + \beta(n^2 + 5n)}. \quad (15)$$

From equation (15), we obtain that θ is zero when n is zero and θ is increasing in n . We also obtain that θ is decreasing in β . These results are obtained in Matsumura (1998), Han and Ogawa (2007), and Lin and Matsumura (2012) as well.

Substituting equation (15) into equations (5) and (6), we obtain the following profit functions of public and private firms.

$$\pi^0 = \frac{\alpha^2(4 + n + 3n\beta)(4 + 3n - 3n\beta)}{2(8 + n(5 + n + 3\beta))^2} - F, \quad (16)$$

$$\pi^i = \frac{3\alpha^2(2 + n)^2}{2(8 + n(5 + n + 3\beta))^2} - F. \quad (17)$$

The resulting social welfare is given by

⁸ We can prove that $\partial\theta_B/\partial\beta > 0$ without relying on complicated calculations. Because the equilibrium price is equal to the average cost of each firm (zero-profit condition) and it is independent of β (equation 12), the output of each private firm is independent of β . Because the equilibrium number of entering firms n_B and total output Q_B are independent of β (equations 11 and 12), the output of the public firm (firm 0) must be independent of β . Lin and Matsumura (2012) showed that under more general situations, the output of the public firm is increasing in β and is decreasing in θ given n . Because the output of the public firm is independent of β , θ_B must be increasing in β .

$$W = \frac{\alpha^2(2+n)^2}{2(8+n(5+n+3\beta))} - (n(1-\beta)+1)F. \quad (18)$$

In the first stage, each private firm enters the market until it earns zero profit. Setting equation (17) equal to zero yields the following number of private firms in equilibrium:

$$n_A = \frac{\sqrt{6\alpha} + \sqrt{2H}}{4\sqrt{F}} - \frac{5}{2} - \frac{3\beta}{2}, \quad (19)$$

where $H = \sqrt{3\alpha^2 - 2\alpha\sqrt{6F}(1+3\beta) - 2F(7-30\beta-9\beta^2)}$. The subscript ‘‘A’’ denotes the equilibrium outcome of this game (privatization **after** entry). The number of private firms decreases as fixed cost increases (i.e., $\partial n_A / \partial F < 0$) or the share of foreign ownership in private firms increases (i.e., $\partial n_A / \partial \beta < 0$). It is also ensured that the number of private firms is positive ($n_A > 0$) as long as $0 < F < 3\alpha^2 / 32$. From (19), we obtain the following lemma.

Lemma 3: *In the ex-post privatization case, the number of entering firms is decreasing in the share of foreign ownership in private firms.*

This result is in sharp contrast to that in the *ex-ante* privatization case in Lemma 1. We discuss the intuition behind these results. Given the number of private firms in the *ex-post* privatization case, the public firm is more aggressive when the foreign ownership share in the private firms is larger, and this reduces the number of entering firms (Lemma 3). In the *ex-ante* privatization case, however, the government adjusts the level of privatization to induce the optimal number of entering firms. Thus, when the share of foreign ownership in private firms is larger, the government chooses a lower level of privatization to restore efficient entries of private firms (Lemma 1).

Substituting equation (19) into equation (15), we obtain the following optimal level of privatization:

$$\theta_A = \frac{3\alpha^2\beta + \alpha\sqrt{6F}(1-7\beta-6\beta^2) + \sqrt{3}\alpha\beta H + \sqrt{2F}(1-6\beta-3\beta^2)H + 2F(-5+11\beta+33\beta^2+9\beta^3)}{3\alpha^2\beta + \sqrt{3}\alpha\beta H + \sqrt{2F}(1-3\beta^2)H + \alpha\sqrt{6F}(1-\beta-6\beta^2) + 2F(3-19\beta+15\beta^2+9\beta^3)}. \quad (20)$$

The optimal level of privatization is partial privatization (i.e., $0 < \theta_A < 1$). Moreover, the optimal level of privatization is decreasing in the foreign ownership share in private firms. (i.e., $\partial \theta_A / \partial \beta < 0$. See footnote 9 for proof.) In contrast to the *ex-ante* privatization case, the privatization policy under the *ex-post* privatization case can be substitutable with the liberalization policy of the capital market.

The resulting market output and price are

$$Q_A = \alpha - 2\sqrt{\frac{2F}{3}}, \quad (21)$$

$$P_A = 2\sqrt{\frac{2F}{3}}. \quad (22)$$

From equation (22), we obtain the following lemma.

Lemma 4: *In the ex-post privatization case, consumer welfare is independent of the foreign ownership share in private firms.*

This result corresponds with that in the *ex-ante* privatization case. Moreover, the equilibrium price level is the same in the *ex-post* and *ex-ante* privatization cases.

The social welfare is given by

$$W_A = \frac{3\alpha^2 + \sqrt{3}\alpha H - 4\alpha\sqrt{6F} - 3\sqrt{2F}(1-\beta)H + 6F(3-\beta(2+3\beta))}{12}. \quad (23)$$

The following proposition summarizes the above discussions on the optimal level of privatization θ_E .

Proposition 2: *In the ex-post privatization case, partial privatization is always optimal, irrespective of the share of foreign ownership. The optimal level of privatization is decreasing in the share of foreign ownership in private firms.⁹*

The first part of Proposition 2 suggests that the government should privatize the public firm in order to commit to less aggressive behavior of the firm and to induce more aggressive behavior of the private firms that have already entered the market.

The second part of Proposition 2 is in sharp contrast to the result in the *ex-ante* privatization case. In the *ex-ante* privatization case, the optimal level of privatization is increasing in the share of foreign ownership in private firms, while the reverse is true in the *ex-post* privatization case. Thus, Propositions 1 and 2 suggest that if the government privatizes the public firm before deregulation of entry restriction for the product market, the government should privatize more in more open financial markets, while the opposite is true if the government privatizes the public firm after such deregulation. Again, policy implications are contradictory when privatization is implemented before or after the market liberalization.

We explain the intuition behind these results. In the *ex-post* privatization case, given the number of firms, a decrease in the level of privatization reduces the output of private firms and the outflow of profits to foreign investors. Thus, the optimal level of privatization is smaller when the share of foreign ownership in private firms is larger. By contrast, in the *ex-ante* privatization case, a decrease in the level of privatization reduces the number of entering firms and this effect is more significant when the share of foreign ownership is larger. Thus, the government must adjust the level of privatization to maintain the efficient number of entering firms. Accordingly, responding to an increase in foreign ownership, the government increases the level of privatization, because otherwise, the number of entering firms becomes too small to achieve domestic social welfare.

⁹ We can show that $\partial\theta_A/\partial\beta < 0$ without relying on complicated calculations. As Han and Ogawa (2007) and Lin and Matsumura (2012) showed, in the non-free entry market, the optimal degree of privatization is decreasing in β and increasing in n . In our *ex-post* privatization model, n is endogenous and it is decreasing in β (equation 19). Therefore, an increase in β reduces θ directly and further reduces it indirectly through a decrease of n caused by an increase of β . Therefore, θ_A must be decreasing in β .

3.3. Comparisons

We now compare the two privatization cases.

Proposition 3: *The ex-post privatization case yields higher (lower) level of privatization and larger (smaller) number of private firms than the ex-ante privatization case when the foreign ownership is low (high). Both cases yield the same consumer welfare, while ex-ante privatization case yields strictly higher social welfare, unless $\beta = 1/3$.*

Proof: Comparing the equilibrium results of the two models, we have the following relations:

$$(i) \quad \theta_B \begin{matrix} < \\ > \end{matrix} \theta_A \quad \text{when} \quad \beta \begin{matrix} < \\ > \end{matrix} \frac{1}{3},$$

$$(ii) \quad n_B \begin{matrix} < \\ > \end{matrix} n_A \quad \text{when} \quad \beta \begin{matrix} < \\ > \end{matrix} \frac{1}{3},$$

$$(iii) \quad P_B = P_A,$$

$$(iv) \quad W_B \geq W_A \quad \text{and the equality holds only when} \quad \beta = \frac{1}{3}. \quad \text{Q.E.D.}$$

The first part of Proposition 3 states that the ranking of the optimal level of privatization and the equilibrium number of private firms between *ex-ante* and *ex-post* privatization cases depend on the share of foreign ownership. Specifically, *ex-ante* privatization yields a higher (lower) level of privatization and larger (smaller) number of private firms than *ex-post* privatization when the foreign ownership share is high (low). We explain the intuition behind these results.

When the foreign ownership share is low, the number of entering firms is excessive for welfare in the *ex-post* privatization case. In the *ex-ante* privatization case, however, the government can control the number of private firms, because it chooses the level of privatization of the public firm before entry. Thus, in the *ex-ante* privatization case, the government chooses a lower level of privatization to make the public firm more aggressive, resulting in a smaller number of entering firms.

By contrast, when the foreign ownership share is high, the number of entering firms is insufficient for welfare in the *ex-post* privatization case. Note that in the *ex-post* privatization case, the number of firms is decreasing in β . Thus, in the *ex-ante* privatization case, the government chooses a higher level of privatization to make the public firm less aggressive, resulting in a larger number of entering firms.

The second part of Proposition 3 states that although *ex-ante* and *ex-post* privatization cases yield different levels of privatization, both cases yield the same equilibrium price (and thus the same consumer welfare). The intuition comes from the first part of Proposition 3: When the share of foreign ownership in private firms is high, both the optimal level of privatization and the equilibrium number of private firms are lower in the *ex-post* privatization case than in the *ex-ante* privatization case. Given the number of private firms, a decrease in the level of privatization lowers the price and thus increases consumer surplus. However, expecting the lower price caused by the lower level of privatization, private firms are reluctant to enter the market because of the low profitability of the market, resulting in a smaller number of entering firms. A smaller number of entering firms raises the equilibrium price, and these two effects are

canceled out in the *ex-post* privatization case. This is why the two cases yield the same equilibrium price.¹⁰

From the viewpoint of social welfare, however, *ex-ante* privatization is preferable because the government more efficiently controls the number of entering firms. In other words, the earlier timing of privatization improves welfare without the cost of consumer surplus.

4. Concluding remarks

In this study, we compare two free-entry models that have a different timing of privatization. We find that the optimal privatization policy depends on whether privatization is implemented before or after the entry of private firms. We find that earlier privatization requires higher level of privatization when the share of foreign ownership in private firms is high, while the opposite result is obtained when it is low. Although earlier privatization does not improve consumer welfare, it definitely improves social welfare.

We also find that if privatization is implemented before (after) entry, the optimal level of privatization is increasing (decreasing) in the share of foreign ownership in private firms. These results may suggest that the financial market liberalization policy and the privatization policy can be either complements or substitutes, depending on the timing of privatization. However, investigating the relationship between these two policies requires us to endogenize the share of foreign ownership in private firms and specify the policy that affects it. This remains for future research.

Another limitation of this study is that we assume that neither privatization policy nor foreign ownership affects the production cost. Although these are standard assumptions in the literature on mixed oligopolies, an extension in this direction may be interesting. Incorporating licensing contracts and spillovers might be a way for possible modeling in this direction. This also remains for future research.¹¹

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¹⁰ More strictly speaking, the number of entering firms falls until the price remains unchanged at free-entry markets.

¹¹ Chang *et al.* (2016) and Wang *et al.* (2016) presented models of international licensing in private oligopolies.

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