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Abstract

This paper investigate how the corporate (profit) tax rate affects the optimal degree of privatization in a mixed duopoly, while introducing a minimum profit constraint for the private firm. Firstly, we show that the profit tax rate directly affects the behavior of the partially privatized firm and affects the behavior of the private firm through strategic interaction. In addition, we investigate the relationship between the optimal privatization policy and corporate tax policy, and find that the optimal degree of privatization increases with the corporate tax rate, regardless of whether the constraint is binding. The optimal degree of privatization decreases (increases) with the foreign ownership share in the private firm if the constraint is ineffective (effective). This result suggests that a minimum profit constraint can be crucial in the optimal privatization policy.

JEL classification numbers: D43, H44, L33

Keywords: profit tax, minimum profit constraint, foreign ownership, optimal public ownership

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1 Introduction

The world saw a wave of privatization of state-owned public enterprises for more than 50 years. 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 2,000 largest companies are public enterprises with sales 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, the presence of the public enterprises is more significant, and many state enterprises compete against private enterprises (Cai and Li, 2011; Huang and Yang, 2016; Huang *et al.*, 2017; Fridman, 2018).

One classic rationale for public enterprises is to prevent private monopolies in natural monopoly markets in which significant economies of scale prevail. However, due to technological improvements, many markets with public enterprises do not always have significant economies of scale. Indeed, a considerable number of public enterprises coexist with private enterprises in a wide range of industries (mixed oligopolies).[1] The optimal privatization policies in these mixed oligopolies attracted extensive attention from researchers in such fields as public economics, financial economics, industrial organization, and development economics.[2]

Specifically, the literature on mixed oligopolies investigates the optimal privatization policy in different situations. Matsumura (1998) shows that the optimal degree of privatization is never zero unless full nationalization yields a public monopoly. Chang (2005) demonstrates that the optimal degree of privatization depends on whether the public firm is the Stackelberg leader or all firms face Cournot competition. Chang (2007) examines optimal trade, industrial, and privatization policies in an international mixed duopoly with strategic managerial incentives, showing that the

[1]Examples of public and semi-public enterprises include the United States Postal Service, Deutsche Post AG, and Japan Post in the overnight delivery industry; NTT in the telecom industry; Areva, Electricite de France, and Petro China Company in the energy industry; Volkswagen and Renault in the automotive industry; and Japan Postal Bank, Kampo, Korea Development Bank, Korea Investment Corporation, and the Industrial and Commercial Bank of China in the financial industry.

[2]For examples of mixed oligopolies and recent developments in this field, see Pal and Saha (2014), Wang *et al.* (2014), and the works cited therein.

optimal degree of privatization depends crucially on the cost and demand parameters and on the availability of strategic trade and industrial policies. Lin and Matsumura (2012) show that the optimal degree of privatization decreases (increases) with the foreign ownership share in private firms (partially privatized firms). Matsumura and Okamura (2015) find that the optimal degree of privatization may increase when the market competition among private firms loosens. Chang and Ryu (2015) investigate vertically related markets in which an upstream public firm competes with a foreign private rival and show that full nationalization can be optimal, while full privatization cannot be, in contrast to Matsumura (1998).[3] Han and Ogawa (2012) show that an increase in the effectiveness of demand-boosting activities reduces the optimal degree of privatization. Fridman (2018) investigates the optimal privatization policy in an exhaustible resource industry. Sato and Matsumura (2018) find that the optimal degree of privatization can change dynamically.

In free entry markets, Matsumura and Kanda (2005) show that the optimal degree of privatization is zero when private competitors are domestic, while Cato and Matsumura (2012) find that it is strictly positive when private competitors are foreign and increases with the foreign ownership share in private firms. In addition, Chen (2017) illustrates that the optimal degree of privatization is positive, even in free entry markets, if privatization improves production efficiency. Fujiwara (2007) shows a monotonic (non-monotonic) relationship between the degree of product differentiation and the optimal degree of privatization in a free entry (non-free entry) market. However, no study as of yet investigates the role of corporate (profit) tax in mixed oligopolies.

The literature on mixed oligopolies discusses the relationship between tax subsidy and privatization policies. Mujumdar and Pal (1998) show that a production tax affects the behavior of public firms, which affects the behavior of private firms through strategic interaction. White (1996) investigates the optimal subsidy policy and finds that the privatization policy is irrelevant under the optimal subsidy policy (privatization neutrality theorem).[4] Cato and Matsumura (2015)

[3] For another discussion of upstream mixed oligopolies, see Matsumura and Matsushima (2012). For a discussion on downstream mixed oligopolies, see Wu *et al.* (2016).

[4] Cato and Matsumura (2013) show that the privatization neutrality theorem holds in free entry markets by considering an optimal production subsidy and entry license tax. However, this theorem is not robust because it does not hold unless the private firm has zero foreign ownership, both public and private firms have the same cost function, and there is no excess burden of taxation. See Matsumura and Tomaru (2012, 2013) and Lin and

discuss the relationship between the optimal import tariff and the optimal degree of privatization and show that a higher tariff rate reduces (increases) the optimal degree of privatization in free entry (non-free entry) markets.[5] Again, however, none investigate corporate tax policy. Corporate tax is one of main taxes in many developed, developing, and transitional economies.[6] Moreover, the corporate tax rate affects a firm's choice of location; thus, both central and local governments often use corporate tax policies strategically to attract firms, especially in developing and transitional economies. As the literature on mixed oligopolies shows, privatizing public firms increases private firms' profits and thus attracts firms (Mukherjee and Suetrong, 2009). Hence, privatization and corporate tax policies may play complementary roles.[7]

In this study, we introduce corporate tax policy and a minimum profit constraint for a private firm into a mixed duopoly model and investigate the relationship between privatization and corporate tax policies.[8] In a private oligopoly in which a public firm is fully private, the profit tax does not affect the firms' output levels. However, the profit tax rate directly affects the output level of a partially privatized firm and thus affects that of the private firm through strategic interaction. We then investigate how the tax rate affects the optimal degree of privatization. We find that whether or not the constraint is binding, the optimal degree of privatization increases with the corporate tax rate. Next, we investigate how the degree of privatization affects the optimal tax policy. We find that the tax rate increases with the degree of privatization.

We also investigate the relationship between the foreign ownership share in the private firm and the optimal privatization policy. Foreign ownership in private firms plays an important role in mixed oligopolies because it affects the behavior of the public firm directly and affects that of

Matsumura (2018).

[5] Chang (2005, 2007) also provides important contributions in terms of the relationship between the optimal degree of privatization and various other policies such as industrial and trade policies.

[6] It is the third largest source of federal revenue in the U.S. and of the central government in Japan, and the largest tax revenue source for the Tokyo Metropolitan government in Japan.

[7] The corporate tax rate in China averaged 29 percent from 1997 until 2018, reaching an all-time high of 33 percent in 1998 and a record low of 25 percent in 2008 (Urban Institute & Brookings Institute, and Trading Economics). For a discussion of privatization, capital income taxation, and foreign ownership of private firms, see Huizinga and Nielsen (1997, 2001).

[8] We assume that if the minimum profit constraint is not satisfied, the private firm exits or does not enter the market.

private firms through the strategic interaction between public and private firms. How the effect of the foreign ownership share on privatization changes with the corporate taxation policy and minimum profit constraint is another issue worth discussion under a mixed oligopoly. We show that without the minimum profit constraint, the optimal degree of privatization decreases with the foreign ownership share in the private firm. However, the inverse is true when the minimum after-tax profit constraint is effective. This result suggests that the minimum after-tax profit constraint of the private firm may be crucial for the optimal privatization policy.[9]

The rest of this paper proceeds as follows. Section 2 formulates the mixed duopoly model. Section 3 investigates how the corporate tax rate affects the optimal privatization policy. Section 4 introduces the minimum profit constraint. Section 5 investigates how the degree of privatization affects the optimal corporate tax. Section 6 concludes.

2 The Model

We consider a mixed duopoly model in which one state enterprise, firm 0, and one private enterprises, firm 1, compete.[10] Firm 0 is owned by domestic (local) investors, including the government.[11] The foreign ownership share in firm 1 is $\beta \in [0, 1]$. Firms produce homogeneous products for which the inverse demand function is $p(Q)$, where p is the price and Q is the total output. We assume that p is twice continuously differentiable and $p' < 0$ as long as $p > 0$. The marginal costs of firm i is c_i ($i = 0, 1$). We assume that $c_0 > c_1$.[12]

[9] See the literature starting with Corneo and Jeanne (1994) and Fjell and Pal (1996), as well as Bárcena-Ruiz and Garzón (2005a, 2005b), Han and Ogawa (2008), Lin and Matsumura (2012), Wang and Tomaru (2015), and Xu *et al.* (2016).

[10] Our results hold in more general mixed oligopolies with n-private firms as long as all private enterprises are identical.

[11] The assumption that the investors in privatized firms are domestic is standard in the literature (Cato and Matsumura, 2012; Chang, 2005, 2007; Chang and Ryu, 2015; Lee *et al.*, 2018; Wu *et al.*, 2016, Xu *et al.*, 2016, 2017), and may be realistic. On the other hand, foreign investors may also hold stakes in private. For example, the foreign private ownership share in the Postal Bank is about one-fifth of the Mitsubishi UFJ Financial Group. For discussions on foreign investors in privatized firms, see Lin and Matsumura (2012).

[12] If $c_0 \leq c_1$, then the public monopoly appears in equilibrium and there is no room to discuss mixed oligopolies. Assuming constant marginal costs with a cost disadvantage for a public firm is popular in the literature on mixed oligopolies. See Pal (1998), Mujumdar and Pal (1998), and Matsumura and Ogawa (2010). For a discussion on the endogenous cost disadvantage of public firms, see Matsumura and Matsushima (2004). Many empirical studies illustrate that public firms in developing countries and emerging markets produce less efficiently than do private firms (Vickers and Yarrow, 1988; Megginson and Netter, 2001; La Porta *et al.*, 2002).

Firm i's profit is $\pi_i = (p - c_i)q_i$, where q_i is firm i's output. The government imposes a corporate (profit) tax $\tau \in [0, 1)$ and the after-tax profit of firm i is $(1 - \tau)\pi_i$.[13]

Domestic (local) welfare W is given by

$$W = \int_0^Q p(z)dz - pQ + (1 - \tau)\pi_0 + (1 - \beta)(1 - \tau)\pi_1 + \tau(\pi_0 + \pi_1).$$

Following Matsumura (1998), the public firm's objective is a convex combination of social surplus and their own profit, $\alpha(1 - \tau)\pi_0 + (1 - \alpha)W$.[14] $\alpha \in [0, 1]$ represents the degree of privatization. In the case of full nationalization (i.e., $\alpha = 0$), firm 0 maximizes welfare. In the case of full privatization (i.e., $\alpha = 1$), firm 0 maximizes its (after-tax) profit. The private firm's objective is its after-tax profit.

The complete information game runs as follows. In the first stage, the government chooses the degree of privatization. In the second stage, each firm simultaneously chooses its output to maximize its objective. We solve this game by backward induction and the equilibrium concept is the subgame perfect Nash equilibrium. We assume interior solutions in the last stage subgames (i.e., we assume that both firms produce positive output in the quantity competition stage).

3 Equilibrium

First, we solve the second stage game given α. The first-order condition of the public firms is

$$\alpha(1 - \tau)p'q_0 - \beta(1 - \alpha)(1 - \tau)p'q_1 + (1 - \alpha\tau)(p - c_0) = 0. \tag{1}$$

We assume that the second-order condition is satisfied.[15]

[13] If π_i is negative, then the firm reduces the tax burden of other profitable departments, and thus reduces the tax payment. Therefore, we can see that firm i's after-tax profit is $(1-\tau)\pi_i$, even when it is negative. If we assume that the after-tax profit of firm i is π_i rather than $(1 - \tau)\pi_i$, then all Lemmas and Propositions except for Lemma 1(i) hold. In addition, we can drop the condition "if $\pi_0 \geq 0$" in Lemma 4(ii), Proposition 3(i), and Proposition 5(ii). We replace Lemma 1(i) with the statement " If $\alpha < 1$, q_0^S, and Q^S are decreasing in τ, and q_1^S is increasing in τ."

[14] For empirical evidence on the welfare-related rather than profit-maximizing objectives of public enterprises, see Ogura (2018). If we assume that firm 0's payoff is $\alpha\pi_0 + (1 - \alpha)W$ rather than $\alpha(1 - \tau)\pi_0 + (1 - \alpha)W$, then our Lemmas and Propositions except for Lemma 1(i) hold. In addition, we can drop the condition "if $\pi_0 \geq 0$" in Lemma 4(ii), Proposition 3(i), and Proposition 5(ii). We replace Lemma 1(i) with the statement " If $\alpha < 1$, q_0^S, and Q^S are decreasing in τ, and q_1^S is increasing in τ."

[15] This holds if $|p''|$ is small relative to $|p'|$.

The first order-condition for each private firm is

$$p + p'q_1 - c_1 = 0. \tag{2}$$

We assume that $p' + p''q_i < 0$ $(i = 0, 1)$, which ensures that the strategy of firm 1 is a strategic substitute and that the second-order condition is satisfied.

These first-order conditions yield the equilibrium outputs in the second stage. Let $q_0^S(\alpha)$, $q_1^S(\alpha)$, and $Q^S(\alpha)$ be the equilibrium firm 0's output, firm 1's output, and the total output in the second-stage subgame (the superscript S denotes the equilibrium outcome of the second stage). Totally differentiating (1) and (2), we obtain

$$\frac{\partial q_0^S}{\partial \alpha} = -\frac{(p''x_1 + 2p')X_1}{X_2} < 0, \quad \frac{\partial q_1^S}{\partial \alpha} = \frac{(p''x_1 + p')X_1}{X_2} > 0, \quad \frac{\partial Q^S}{\partial \alpha} = -\frac{X_1 p'}{X_2} < 0, \tag{3}$$

where

$$X_1 = (1-\tau)[q_0 + \beta(1-\tau)q_1] > 0, \tag{4}$$

$$X_2 = (1-\alpha\tau)\left\{\alpha(1-\tau)p''Q + [(1-\alpha\tau) + 2\alpha(1-\tau) + \beta(1-\alpha)(1-\tau)]p'\right\} < 0. \tag{5}$$

The three results from (3) are standard in the literature on mixed oligopolies and prior works show it repeatedly in various contexts. (3) indicates that these standard results hold in our model.

We investigate how τ affects the equilibrium outputs in the second stage given α. Totally differentiating (1) and (2), we obtain

$$\frac{\partial q_0}{\partial \tau} = -\frac{(p''x_1 + 2p')X_3}{X_2}, \quad \frac{\partial q_1}{\partial \tau} = \frac{(p''q_1 + p')X_3}{X_2}, \quad \frac{\partial Q}{\partial \tau} = -\frac{X_3 p'}{X_2}, \tag{6}$$

where

$$X_3 = (1-\alpha)[-\alpha q_0 + \beta(1-\alpha)q_1]. \tag{7}$$

If $\alpha = 1$, then $X_3 = 0$. From (1), we find that if $\alpha < 1$ and $p > c_0$ $(p < c_0)$, then $X_3 < 0$ $(X_3 > 0)$. Therefore, from (4), (5), (6), and (7), we obtain the following Lemma.

Lemma 1 *(i) If $\alpha < 1$, then q_0^S and Q^S are increasing (decreasing) in τ and q_1^S is decreasing (increasing) in τ as long as $\pi_0 > 0$ $(\pi_0 < 0)$. (ii) If $\alpha = 1$, then q_0^S, q_1^S, and Q^S are independent of τ.*

We explain the intuition behind Lemma 1. Let τ_0 be the corporate tax rate for firm 0 and τ_1 be that for firm 1. An increase in τ_0 reduces the after-tax profit of firm 0 and does not affect W. Thus, an increase in τ_0 decreases (increases) the weight of π_0 in firm 0's payoff if $\pi_0 > 0$ ($\pi_0 < 0$), which increases (decreases) q_0.

An increase in τ_1 increases the weight of π_1 in W, and thus, the higher τ_1 is, the larger is the incentive to increase π_1 for firm 0. Because an increase in q_0 reduces firm 1's profit, the higher τ_1 is, the larger is the incentive to decrease q_0 for firm 0. Therefore, an increase in τ_1 decreases q_0.

If $\pi_0 < 0$, both effects decrease q_0 as $\tau(= \tau_0 = \tau_1)$ increases, and thus, an increase in τ reduces q_0.[16] If $\pi_0 > 0$, the two effects have opposite directions. However, the effect of τ_0 dominates the effect of τ_1, and thus, q_0 is increasing in τ as long as $\pi_0 > 0$. Firm 0 produces more aggressively when τ is larger (direct effect).

Although τ does not directly affect the payoff of firm 1, τ affects q_0 and thus affects q_1 through strategic interaction. Because firm 1's strategy is that of a strategic substitute, the change in q_1 has the opposite sign as the change in q_0. Because the direct effect dominates this strategic effect, the change in Q has the same sign as the change in q_0.

This mechanism does not work when $\alpha = 1$ because firm 0 does not care about the outflow of firm 1's profit to foreign investors and consumer surplus; thus, q_0^S, q_1^S, and Q^S are independent of τ.

We next investigate how β affects the equilibrium outputs in the second stage given α. Totally differentiating (1) and (2), we obtain

$$\frac{\partial q_0}{\partial \beta} = -\frac{(p''x_1 + 2p')X_4}{X_2} \geq 0, \qquad \frac{\partial q_1}{\partial \beta} = \frac{(p''q_1 + p')X_4}{X_2} \leq 0, \qquad \frac{\partial Q}{\partial \beta} = -\frac{X_4 p'}{X_2} \geq 0, \tag{8}$$

where

$$X_4 = -(1-\tau)(1-\alpha)(1-\alpha\tau)q_1 \leq 0. \tag{9}$$

The equality in (9) holds if and only if $\alpha = 1$.

[16] If we assume that the after-tax profit of firm 0 is π_0 rather than $(1-\tau_0)\pi_0$, then when $\pi_0 < 0$, the effect of τ_0 disappears and only the effect of τ_1 remains. In this case, an increase in τ reduces q_0, and we obtain qualitatively the same results in this alternative setting. See also footnote 11.

From (5), (8), and (9), we obtain the following Lemma.

Lemma 2 *(i) If $\alpha < 1$, then q_0^S and Q^S are increasing in β and q_1^S is decreasing in β. (ii) If $\alpha = 1$, then q_0^S, q_1^S, and Q^S are independent of β.*

Again, from (1) we find that β directly affects the behavior of firm 0 unless $\alpha = 1$. Although β does not directly affect firm 1's payoff, β affects q_0 and thus affects q_1 through strategic interaction. Because firm 1's strategy is that of a strategic substitute, the change in q_1 has the opposite sign as the change in q_0. Because the direct effect dominates this strategic effect, the change in Q has the same sign as the change in q_0.

We now investigate the first stage. The first-order condition for the government is

$$\frac{dW^S}{d\alpha} = \frac{\partial W}{\partial q_0}\frac{dq_0^S}{d\alpha} + \frac{\partial W}{\partial q_1}\frac{dq_1^S}{d\alpha} = -\frac{1}{1-\alpha\tau}\frac{X_1 p'}{X_2}X_5 = 0, \tag{10}$$

where

$$X_5 = [(1-\alpha\tau)q_1 - \alpha X_1]p''q_1 + [(1-\alpha\tau)q_1 - 2\alpha X_1]p'. \tag{11}$$

We assume that the second-order condition is satisfied. Let α^E be the equilibrium degree of privatization.

Because $X_1 > 0$ and $X_2 < 0$, (10) is satisfied if and only if $X_5 = 0$. When $\alpha = 0$, $X_5 = q_1(q_1 p'' + p') < 0$. Therefore, we obtain $\alpha^E > 0$. Prior works on mixed oligopolies also show this result (full nationalization is not optimal) in various contexts.[17]

When $\alpha = 1$, $X_5 = ((1-\tau)q_1 - X_1)q_1 p'' + ((1-\tau)q_1 - 2X_1)p'$. Then $\alpha^E = 1$ if and only if $((1-\tau)q_1 - X_1)q_1 p'' + ((1-\tau)q_1 - 2X_1)p' \le 0$.

Suppose that $\alpha^E < 1$; then, we obtain α^E from $X_5 = 0$. Totally differentiating $X_5 = 0$ at the equilibrium point, we obtain

$$\frac{d\alpha^E}{d\tau} = -\frac{\partial X_5/\partial\tau}{\partial X_5/\partial\alpha} = \frac{[\alpha q_1 - \alpha q_0 - 2\alpha\beta(1-\tau)q_1]p''q_1 + [\alpha q_1 - 2\alpha q_0 - 4\alpha\beta(1-\tau)q_1]p'}{\partial X_5/\partial\alpha}. \tag{12}$$

From (12), we obtain the following result.

[17] Matsumura (1998).

Proposition 1 *The optimal degree of privatization* α^E *increases with the corporate tax rate* τ *as long as* $\alpha^E < 1$*.*

Proof See the Appendix.

We can explain the intuition behind Proposition 1. On the one hand, an increase in the degree of privatization makes the public firm less aggressive, which increases the outflow of the private firm's profit to foreign investors. This outcome deteriorates local welfare. On the other hand, an increase in the degree of privatization increases the private firm's output, which improves local welfare. This tradeoff explains the optimal privatization policy. An increase in the corporate tax weakens the former welfare-reducing effect, and thus increases the optimal degree of privatization. This yields Proposition 1.

We now discuss how β affects the optimal degree of privatization. Totally differentiating $X_5 = 0$ at the equilibrium point, we obtain

$$\frac{d\alpha^E}{d\beta} = -\frac{\partial X_5/\partial \beta}{\partial X_5/\partial \alpha} = \frac{-\alpha(1-\tau)^2 q_1(p'' q_1 + 2p')}{\partial X_5/\partial \alpha}. \tag{13}$$

From (13), we obtain the following result.

Proposition 2 *The optimal degree of privatization* α^E *decreases with the foreign ownership share* β *as long as* $\alpha^E < 1$*.*

Proof See the Appendix.

Lin and Matsumura (2012) show this result with a linear demand assumption when $\tau = 0$. Proposition 2 states that this result also holds with nonlinear demand. The larger β is, the more the outflow of the profit of firm 1 to foreign investors is. Therefore, the government chooses a smaller α to restrict this outflow.

Finally, we present a result that is useful for the discussion in Section 5. Let $W^F(\tau)$ denote the equilibrium local welfare in this game.

Lemma 3 *If* $\beta > 0$*, then* $W^F(\tau)$ *is increasing in* τ*.*

Proof See the Appendix.

When $\beta = 0$, W is independent of τ because corporate tax is only a transfer from domestic investors to the government. However, if $\beta > 0$, then W depends on β, even when q_0 and q_1 are exogenous because a higher tax rate increases the transfer from foreign investors to the government, and thus improves welfare. Lemma 3 states that this holds true if α is endogenous, and thus q_0 and q_1 are endogenous.

In the previous section, we assume that the private firm stays in the market, regardless of the government policies. However, if the corporate tax rate is too high, the private firm may exit the market or may not enter the market. In this section, we impose the minimum after-tax profit constraint to the private firm, firm 1. Specifically, we assume that firm 1 enters the market if and only if

$$(1-\tau)\pi_1 \geq F, \tag{14}$$

where F is a positive constant.

The game runs as follows. In the first stage, the government chooses α. In the second stage, firm 1 chooses whether to enter the market. In the third stage, firms face Cournot competition when firm 1 enters.

If F is sufficiently large, then the government chooses a public monopoly and $\alpha = 0$. Otherwise, the government chooses α under the constraint (14). To examine the property of mixed oligopolies, we focus on the latter case and restrict our attention to the case where $\pi_0 \geq 0$ in equilibrium.

The previous section provides the analysis of the third stage game. We now present a result on the relationship between the private firm's profit and the degree of privatization. Let $\pi_1^S(\alpha)$ denote the equilibrium profit of firm 1 in the second-stage game.

Lemma 4 *(i) The private firm's profit (π_1^S) increases with the degree of privatization (α). (ii) Given α, the private firm's after-tax profit ($(1-\tau)\pi_1^S$) decreases with the corporate tax rate (τ) if (but not only if) $\pi_0 \geq 0$. (iii) Given $\alpha(< 1)$ and τ, the private firm's profit (π_1^S) decreases with the foreign ownership share in firm 1 (β).*

Proof See the Appendix.

An increase of the degree of privatization makes the public firm (firm 0) less aggressive, which is beneficial for the private firm (firm 1). Similarly, a decrease in the foreign ownership share in the private firm makes the public firm (firm 0) less aggressive, which is beneficial for the private firm (firm 1).

Lemma 4(i) states that $(1-\tau)\pi_1^S(\alpha)$ is increasing in α. We define $\alpha^\dagger$ by $(1-\tau)\pi_1^S(\alpha^\dagger) = F$. Let α^C denote the equilibrium degree of privatization in this game (the superscript C indicates constraint).

If $\alpha^\dagger < \alpha^E$, then the constraint (14) is not binding. Therefore, $\alpha^C = \alpha^E$ and Propositions 1 and 2 hold. If $\alpha^\dagger \geq \alpha^E$, then the constraint (14) is binding. From the concavity of the welfare function, we obtain $\alpha^C = \alpha^\dagger$. From Lemma 4(ii), an increase in τ reduces $(1-\tau)\pi_1^S(\alpha)$ given α and β. To compensate for this reduction in firm 1's after-tax profit, the government must increase α (Lemma 4(i)). From Lemma 4(iii), an increase in β reduces $(1-\tau)\pi_1^S(\alpha)$ given α and τ. To compensate for this reduction in firm 1's after-tax profit, the government must increase α (Lemma 4(i)). This discussion leads to the following Proposition.

Proposition 3 *Under the minimum after-tax profit constraint, the optimal degree of privatization (α^C), (i) increases with the corporate tax rate (τ) if (but not only if) $\pi_0 \geq 0$; (ii) increases with the foreign ownership share in private firm as long as the constraint is binding.*

Proposition 3(i) states that Proposition 1 is robust. The optimal degree of privatization increases with the corporate tax rate, whether or not the minimum after-tax profit constraint exists. Proposition 3(ii) states that Proposition 2 may not be robust. When the minimum after-tax profit constraint is (is not) effective, the optimal degree of privatization increases (decreases) with the foreign ownership share of the private firm. Therefore, we obtain the opposite policy implication with and without the constraint.

Propositions 2 and 3 indicate a possible non-monotone relationship between the foreign ownership share in the private firm and the optimal degree of privatization. When β is small, π_1 is high; thus, the constraint (14) may not bind. An increase in β reduces α as long as the constraint does not bind (Proposition 2). An increase in β reduces π_1, and the constraint (14) may bind eventually. After that, a further increase in β increases α. Thus, a U-shaped relationship between α and β may appear.

4 Endogenous Corporate Tax

It may be unrealistic to assume that the government can choose a specific τ in a specific industry or market, whereas it is realistic to assume that the government chooses a specific degree of privatization in a specific industry. However, the government may extract firms' profits by imposing specific industry taxes, requiring bribes, or through foreign currency control in a targeted industry. The government may strategically reduce the corporate tax rate for specific firms or industries to attract firms, as we discuss in the Introduction. Therefore, in this section, we first discuss the outcome if we endogenize both τ and α.

We consider the following game in which the government chooses both the corporate tax and privatization policies. In the first stage, the government chooses τ and α. In the second stage, firm 1 enters the market if and only if (14) is satisfied. In the third stage, firms face Cournot competition when firm 1 enters the market.

Consider the final stage. Suppose that firm 1 enters the market. In Section 3, we derived the equilibrium output. From Lemma 3, we find that the constraint (14) is binding as long as $\beta > 0$. Again, we focus on the case where the mixed duopoly is better than a public monopoly for local welfare. The government chooses τ and α under the constraint (14).[18]

As we show in Section 3, $\alpha^E > 0$ even when the constraint (14) is not binding. An increase in α relaxes the constraint, and thus the welfare improving effect of an increase in α is larger with the constraint than without the constraint. Thus, we obtain $\alpha^E > 0$.

We now present our result.

Proposition 5 *Suppose that the government chooses both the degree of privatization and the corporate tax rate in the first stage. Suppose that $\beta > 0$.*[19] *(i) The optimal degree of privatization*

[18]If the constraint is not binding, the government can increase W by a marginal increase in τ. Moreover, at the equilibrium tax rate, $(1-\tau)\pi_1$ must be decreasing in τ because otherwise, the government can improve welfare by a marginal increase in τ.

[19]If $\beta = 0$, then the equilibrium pair of (τ, α) is indeterminate and any pair of (τ, α) that yields the optimal q_0 is

is increasing in β. (ii)The optimal corporate tax rate is decreasing in β if (but not only if) $\pi_0 \geq 0$.

Proof See the Appendix.

Because the minimum profit constraint is always binding when the corporate tax rate and the degree of privatization are endogenous, the changes in an exogenous variable that reduces the private firm's profit enhances the privatization policy and the tax exemption policy to attract private firms.

5 Concluding Remarks

In this study, we investigate the relationship between the privatization policy and corporate tax policy. We also investigate the effect of the foreign ownership share in the private firm on these policies and introduce a minimum after-tax profit constraint. We show that (1) whether or not the minimum after-tax profit constraint is effective, the optimal degree of privatization increases with the corporate tax rate; (2) the optimal degree of privatization decreases (increases) with the foreign ownership share in the private firm when the constraint is non-binding (binding); (3) the optimal corporate tax rate increases with the degree of privatization; and (4) the optimal corporate tax rate decreases with the foreign ownership share in the private firm.

In this study, we consider a single market model. The corporate tax rate is usually common across industries, while the privatization policy differs. Investigating this problem requires a multi-market model. While there are several recent studies on multi-market mixed oligopoly models, [20] extending our analysis to a multi-product model remains for future research.

the equilibrium pair of policies.

[20]For an analysis of multi-market mixed oligopolies, see Bárcena-Ruiz and Garzón (2017), Dong *et al.* (2018), and Haraguchi *et al.* (2018).

Appendix

Proof of Propositions 1 and 2

Let

$$-\frac{1}{1-\alpha\tau}\frac{X_1 p'}{X_2} := X_6.$$

From (10), we obtain

$$W^{S''}(\alpha) = \frac{\partial X_6}{\partial \alpha} X_5 + X_6 \frac{\partial X_5}{\partial \alpha}.$$

Because $W^{S''}(\alpha) < 0$ and $X_5 = 0$ at the equilibrium point and $X_6 < 0$,we obtain $\partial X_5/\partial\alpha > 0$. Therefore, the denominators in (12) and (13) are positive.

Because the numerator in (13) is negative, we obtain Proposition 2.

Finally, we show that the numerator in in (12) is positive as long as $\alpha^E < 1$. As we show after (11), $\alpha^E < 1$ if and only if $((1-\tau)q_1 - X_1)q_1 p'' + ((1-\tau)q_1 - X_1)p' > 0$. Substituting X_1 into it, we obtain

$$(q_1 - q_0 - \beta(1-\tau)q_1)p''q_1 + (q_1 - 2q_0 - 2\beta(1-\tau)q_1)p' > 0. \tag{15}$$

The numerator in (12) is

$$\begin{aligned} & \alpha[(q_1 - q_0 - 2\beta(1-\tau)q_1)p''q_1 + (q_1 - 2q_0 - 4\beta(1-\tau)q_1)p'] \\ = \; & \alpha[(q_1 - q_0 - \beta(1-\tau)q_1)(p''q_1 + p') - \beta(1-\tau)q_1(p''q_1 + 2p')] > 0, \end{aligned}$$

where we use (15). Q.E.D.

Proof of Lemma 3

Suppose that τ increases marginally, from τ_a to τ_b. Suppose that $\alpha^E < 1$ when $\tau = \tau_a$. Suppose that $\pi_0 > 0$ when $\tau = \tau_a$. Given α, this change increases the resulting q_0 (Lemma 1(i)). Suppose that the government increases α to keep the resulting q_0 unchanged. Note that q_1 remains unchanged if q_0 remains unchanged because neither τ nor α affects q_1 directly, and both affect q_1 through the change in q_0.

Because $q^S(1,\tau)$ is independent of τ and $q^S(\alpha,\tau) > q^S(1,\tau)$ for any $\alpha < 1$ and $\tau \in [0,1)$, the government can choose such an α as long as $\alpha^E < 1$. Because Q, q_0, and q_1 remains unchanged, CS, π_0, and π_1 remains unchanged. Thus, W increases by $\beta(\tau_b - \tau_a)\pi_1$. The above α with τ_b is not the optimal α. Nevertheless, W increases with the increase in τ, and much more if the government chooses the optimal α.

Suppose that $\alpha^E < 1$ when $\tau = \tau_a$. Suppose that $\pi_0 \leq 0$ when $\tau = \tau_a$. Given α, this change decreases the resulting q_0 (Lemma 1(ii)). Suppose that the government decreases α to keep the resulting q_0 unchanged. Because $q^S(\alpha, \tau)$ is decreasing in α and $\alpha^E > 0$, $q^S(0, \tau_a) > q^S(\alpha^E, \tau_a)$. Due to the continuity of $q^S(\alpha, \tau)$, there exists an α' such that $q^S(\alpha', \tau_b) = q^S(\alpha^E, \tau_a)$ if $\tau_b - \tau_a$ is sufficiently small. Because Q, q_0, and q_1 remains unchanged, CS, π_0, and π_1 remains unchanged. Thus, W increases by $\beta(\tau_b - \tau_a)\pi_1$. α' is not the optimal α. Nevertheless, W increases with the increase in τ, and much more if the government chooses the optimal α.

Suppose that $\alpha^E = 1$ when $\tau = \tau_a$. Suppose that the government keeps $\alpha^E = 1$ after the change in τ, which does not affect Q, q_0, and q_1. Thus, W increases by $\beta(\tau_b - \tau_a)\pi_1$ by the change in τ. Q.E.D.

Proof of Lemma 4

From (6), we find that an increase in α increases q_1 and reduces Q. Both increase π_1^S. No other effect on π_1 exists. Therefore, π_1^S is increasing in α. This implies Lemma 4(i).

We obtain

$$\frac{\partial[(1-\tau)\pi_1]}{\partial \tau} = -\pi_1 + (1-\tau)p'q_1\frac{\partial q_0}{\partial \tau} + (1-\tau)(p'q_1 + p - c_1)\frac{\partial q_1}{\partial \tau}. \tag{16}$$

The first term in (16) is negative, the second term in (16) is non-positive if $\pi_0 \geq 0$ (Lemma 1) and the third term in (16) is zero from (2). These imply Lemma 4(ii).

Lemma 2 states that an increase in β decreases q_1 and increases Q. Both reduce π_1^S. No other effect on π_1 exists. Therefore, π_1^S is decreasing in α. This implies Lemma 4(iii).

Proof of Proposition 5

Given that the constraint is binding when the government chooses the optimal α and τ simultaneously, we take total derivative of the constraint (i.e., $(1-\tau)\pi_1 = F$, where $\pi_1 = (p - c_1)q_1$)

$$-(p - c_1)q_1 d\tau + (1-\tau)p'q_1 dQ + (1-\tau)(p - c_1)dq_1 = 0,$$

$$-(p-c_1)q_1 d\tau + (1-\tau)p'q_1 dq_0 = 0,$$

$$-\pi_1 d\tau + (1-\tau)p'q_1 \left[-\frac{X_1(p''q_1+2p')}{X_2}\right] d\alpha + (1-\tau)p'q_1 \left[-\frac{X_3(p''q_1+2p')}{X_2}\right] d\tau$$
$$+(1-\tau)p'q_1 \left[-\frac{X_4(p''q_1+2p')}{X_2}\right] d\beta = 0.$$

From these, we obtain

$$\frac{d\alpha^E}{d\beta} = -\frac{X_4}{X_1} > 0, \tag{17}$$

$$\frac{d\tau^E}{d\beta} = -\frac{(1-\tau)p'q_1X_4(p''q_1+2p')}{X_2\pi_1 + (1-\tau)p'q_1X_3(p''q_1+2p')}. \tag{18}$$

From (17), we obtain Proposition 5(i).

The numerator in (18) is negative. Thus, if the denominator in (18) is negative, Proposition 5(ii) holds. Because $\pi_1 > 0$ in equilibrium, the denominator in (18) is negative if (but not only if) $X_3 \leq 0$. $X_3 \leq 0$ if and only if $\pi_0 \geq 0$. Q.E.D.

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