Long-Run Effects of Tax Policies in a Mixed Market

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Abstract

The purpose of this paper is to provide a systematic treatment of tax policies in mixed markets with endogenous entry. We consider three types of tax-subsidy policies: a simple unit subsidy, an entry-license tax, and a policy mixture of the two instruments. Under the unit subsidy policy, in contrast to the results of the short-run analysis with exogenous entry, the optimal subsidy level in a mixed market is not higher than that in a private market, and privatization affects welfare. Under the entry-license tax policy, the optimal entry tax level in a mixed market is lower than that in a private market. Finally, we show that the privatization neutrality theorem holds under a two-part tax-subsidy policy: the first-best outcome is achieved in both mixed and private markets and the optimal tax-subsidy rate is the same across the two regimes.

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Key words: privatization, free entry, unit subsidy, entry tax, competition policy

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1 Introduction

Since the seminal work of Edgeworth (1925), many researchers have investigated tax and subsidy policies under imperfect competition (Musgrave, 1959; Seade, 1985; Myles, 1987, 1989; Besley and Suzumura, 1992; Hamilton, 1999; Anderson et al., 2001a, 2001b). Moreover, several works have investigated tax policies in a market with endogenous entry (For studies in this direction, see Besley, 1989; Delipalla and Keen, 1992; Hamilton, 1999; Anderson et al., 2001a, 2001b). We aim to clarify how the presence of a non-profit organization, i.e., a state-owned enterprise, affects taxation and subsidization under endogenous entry.

The purpose of this paper is to investigate the long-run effects of tax policies in mixed markets by endogenizing the number of entering firms. The studies of mixed oligopoly involving both state-owned public enterprises and private enterprises are increasingly becoming popular. In the recent financial crisis, many private enterprises facing financial problems have been nationalized, either fully or partially.[1] Hence, the studies on mixed oligopoly are receiving even more attention. However, even before the recent increase in the number of public enterprises, mixed oligopolies existed in a range of industries such as transportation, telecommunications, energy, steel, automobile, and overnight-delivery, as well as in services such as banking, home loans, health care, life insurance, hospitals, broadcasting, and education.[2] Moreover, the endogenous entry of private firms in such mixed markets is widespread.

There exist two lines of related works in mixed oligopoly. The first line of works, which has been prominent, comprises the literature on optimal subsidy in mixed oligopoly. White (1996) shows that a simple unit subsidy yields the first-best outcome in both mixed and private oligopolies and that the optimal subsidy rate is the same across the two regimes. His result implies that the privatization of the

[1] For a discussion on partial privatization, see Matsumura (1998).

[2] The pioneering work on mixed oligopolies is Merrill and Schneider (1966). They, as well as many works in this field, assume that objective of the public enterprises is total social surplus, while the private competitors maximize their own profits. Recently, the literature on mixed oligopoly has become richer and more diverse. For example, see Han and Ogawa (2008, 2009), Ishida and Matsushima (2009), and Ogawa and Sanjo (2007).

public firm has no effect on welfare and the optimal subsidy policy (privatization neutrality theorem). Poyago-Theotoky (2001) considers the public firm's leadership in mixed oligopoly, and Myles (2002) generalizes the analysis; Tomaru and Saito (2010) investigate the endogenous timing discussed by Pal (1998); Tomaru (2006) adopts the partial privatization approach formulated by Matsumura (1998); Kato and Tomaru (2007) investigate the various payoff functions of the private firms. All of the above works demonstrate that the privatization neutrality theorem is quite robust.[3] However, all of the works are based on the short-run analysis and ignore the tax-subsidy effects on net entry.

The second line of works comprises the literature on endogenous entry in mixed oligopoly. In many industries in mixed markets, entry restrictions have been significantly weakened. In spite of the importance of free entry markets in mixed oligopoly, the body of literature on mixed oligopoly discussing free entry markets is relatively small. Economists have recently started considering free entry in mixed oligopoly. Anderson et al. (1997) and Matsumura et al. (2009) discuss monopolistic competition models, while Matsumura and Kanda (2005), Brandão and Castro (2007), and Fujiwara (2007) discuss Cournot models. The above five studies show that the welfare implications of privatization in free entry markets are completely different from those in markets without free entry.[4] These papers, however, do not consider a tax-subsidy policy that controls entry, and concentrate only on the privatization policy.

First, we consider a unit subsidy policy in free entry markets.[5] We examine how privatization affects the optimal subsidy level. It is shown that the optimal subsidy rate in mixed oligopoly is lower

[3] Fjell and Heywood (2004) are an exception in that they consider the asymmetric order of moves in private oligopoly, while the other works assume that private firms move simultaneously in private oligopoly. They find that the first-best is not achieved after privatization by a simple unit subsidy. In this paper, we do not assume any asymmetry among the private firms before and after privatization.

[4] The literature on endogenous entry shows that short-run and long-run analyses often yield quite different implications in many other contexts. See Davidson and Mukherjee (2007), Etro (2004, 2006, 2007, 2008), Lahiri and Ono (1995), Marjit and Mukherjee (2008), and Mukherjee and Mukherjee (2008).

[5] This policy instrument has been intensively discussed in the literature on mixed markets. Further, all works mentioned earlier have discussed this policy instrument.

than that in private oligopoly, except for in the case where demand is linear. This result is in contrast to that derived from the short-run analysis mentioned above. In a market with a fixed number of firms, it is known that the simple unit subsidy yields the first-best outcome in both mixed and private oligopolies and that the optimal subsidy rate is the same across the two regimes. This result implies that the privatization of the public firm is neutral with regard to welfare and the optimal tax-subsidy rate. On the other hand, our result implies that in a market with endogenous entry, the privatization neutrality theorem does not hold under the simple unit subsidy policy. We find that privatization affects both the optimal subsidy rate and welfare in free entry markets.

Second, we examine the entry-tax policy that affects the number of firms entering the market. Because we consider the Cournot-type oligopoly model, the excess entry theorem holds in mixed markets.[6] An entry tax (or license fee) is a standard instrument for entry regulation. The government can improve economic welfare by the private cost of entry through an entry tax, and thus, the optimal entry-tax rate is positive in not only private markets but also mixed markets. The problem is how privatization affects the optimal entry-tax rate. It is shown that in general, the entry-tax rate in mixed oligopoly is lower than that in private oligopoly. The intuition behind this result is simple. The presence of a public firm weakens the business stealing effect of the private firms, which is the main cause of "excess entry," and thus, the optimal entry tax is relatively low in mixed markets.

Third, we consider the two-part tax-subsidy policy where the government introduces both a unit subsidy and an entry-license tax. Under this policy, the first-best outcome in both mixed and private oligopolies is achieved, and the optimal tax-subsidy rate is the same across the two regimes. That is, privatization does not affect the tax-subsidy rate and welfare. This implies that the privatization neutrality theorem holds under the two-part tax-subsidy policy in free entry markets.

Now, we comment on our postulate for the objective of a state-owned enterprise. Throughout this paper, we assume that the state-owned enterprise is a welfare maximizer. This assumption has been

[6] For discussions on the excess entry theorem in a private market, see Mankiw and Whinston (1986) and Suzumura and Kiyono (1987). Cato (2011) provides a formal argument on the excess entry theorem in a mixed market.

employed in this field since Merrill and Schneider (1966), and it is equivalent to the postulate that the state-owned enterprise uses the marginal cost pricing rule. The marginal cost pricing rule as a behavioral principle of a state-owned enterprise was suggested by many authors in the early twentieth century (Hotelling, 1938; Lerner, 1944; Meade, 1944). For example, James Meade argues that "the task of the manager of a State plant is ... simpler than that of a manager of a private plant; for the object of the former is to equate the price of the product to the cost of the marginal factors involved in its production" (Meade, 1944, p. 324). Another justification of our welfare-maximizer assumption comes from the statements on the management of state-owned enterprises by the Ministry of Internal Affairs and Communications (Japan). The ministry claims that the primary goal of state-owned enterprises is "common wealth."[7]

The rest of this paper is organized as follows. The next section presents the basic setting of our model. Section 3 investigates the optimal unit subsidy in mixed oligopoly. Section 4 examines the case where the government controls the entries using only the entry-license tax. Section 5 examines the case where the government introduces two-part subsidy-tax policy. Section 6 concludes this paper. The Appendix contains all the proofs.

2 The Basic Model

Firms produce perfectly substitutable commodities for which the market demand function is given by $P(Q) : \mathbb{R}_+ \to \mathbb{R}_+$ (price as a function of quantity). We assume that $P' < 0$ and $P'' \leq 0$.

Firm 0 is a state-owned public firm. Firm i ($i = 1, 2, ..., n$) is a private firm. Each private firm maximizes its profits, while firm 0 maximizes social welfare.[8] All firms have identical technologies.

[7] The statement by the Ministry of Internal Affairs and Communications can be founded at the following address (in Japanese): `http://www.soumu.go.jp/main_sosiki/c-zaisei/kouei/16690.html`.

[8] We do not allow the government to nationalize more than one firm. The need for an analysis of mixed oligopoly lies in the fact that it is impossible or undesirable, for political or economic reasons, to nationalize an entire sector. For example, without competitors, the public firms may lose the incentive to improve their costs, resulting in a loss of social welfare. As such, we neglect the possibility of nationalizing all firms. Our result holds true for cases where there is more than one public firm unless the number of private firms is zero.

The production cost function of each firm is $C(q)$ and the entry cost of each firm is $K > 0$. We assume that $C' > 0$ and $C'' > 0$. The government introduces a simple unit subsidy or an entry-license tax. Then, firm i's profit is given by $\Pi_i = Pq_i - C(q_i) - K + sq_i - T$, where q_i is firm i's output, s is the unit subsidy, and T is the entry-license tax. The tax revenue R is $R = nT - s\sum_i q_i$.

Social welfare W is the sum of the consumers' surplus, firms' profits, and tax revenue, and is given as follows:

$$
\begin{aligned}
W &= \int_0^Q P(q)dq - PQ + \sum_{i=0}^{n} \Pi_i + R \\
&= \int_0^Q P(q)dq - \sum_{i=0}^{n} (C(q_i) + K). \qquad (1)
\end{aligned}
$$

Neither subsidy expenditure nor tax revenue appears in (1). The subsidy and the entry tax are merely income transfers between the government and the firms; these are thus canceled out.

In this paper, we consider two regimes: mixed oligopoly and private oligopoly. In the mixed market, there is one public firm that maximizes social welfare. All other firms are private firms that maximize their own profits. In the private market, all firms are private.

The game runs as follows. In the first stage, the government chooses a tax-subsidy rate to maximize W. In the second stage, after observing s, the private firms choose whether or not to enter the market. After observing the number of entering private firms n, both the public and private firms choose their outputs simultaneously (Cournot competition).

3 Optimal Simple Unit Subsidy

This section considers the case where the government uses only the unit subsidy policy. Hence, the profit of firm i is reduced to the following form:

$$
\Pi_i = Pq_i - C(q_i) - K + sq_i.
$$

As mentioned before, this policy has been intensively examined in the literature on mixed oligopoly.

3.1 Mixed oligopoly

We first consider the mixed market. We solve this game by backward induction. In the third stage, each firm chooses its output simultaneously. The first-order conditions for firm 0 and for the private firms are, respectively, given as[9]

$$P(Q) - C'(q_0) = 0,$$
$$P'(Q)q_i + P(Q) - C'(q_i) + s = 0,$$

where $Q = \sum_{i=0}^{n} q_i$. In the second stage, each private firm enters the market if and only if it can earn a non-negative profit. Hence, the zero-profit condition for the private firms holds:

$$P(Q)q_1 - C(q_1) - K + sq_1 = 0,$$

where $Q = \sum_{i=0}^{n} q_i$. This condition requires that the price must be equal to the sum of average cost $(C(q_i) + K)/q_i$ and s.

We restrict our attention to the symmetric equilibrium where all private firms choose the same output level. Thus, each private firm chooses a common output q_1. The equilibrium conditions (in the second and third stages) are summarized as follows:

$$P(Q) - C'(q_0) = 0, \tag{2}$$
$$P'(Q)q_1 + P(Q) - C'(q_1) + s = 0, \tag{3}$$
$$P(Q)q_1 - C(q_1) - K + sq_1 = 0. \tag{4}$$

Let $q_0^M(s)$, $q_1^M(s)$, and $n^M(s)$ be the equilibrium values given s. These are derived by substituting $Q = q_0 + nq_1$ into (2)–(4), respectively, and solving them. Let $Q^M(s) := q_0^M(s) + n^M(s)q_1^M(s)$. Let $W^M(s)$ be given as follows:

$$W^M(s) = \int_0^{Q^M(s)} P(q)dq - \{C(q_0^M(s)) + K\} - n^M(s)\{C(q_1^M(s)) + K\}.$$

[9] Because $P'' \leq 0$, the second-order conditions are also satisfied.

In the first stage, taking into account the response functions of each firm, the government maximizes W^M with respect to s. Additionally, we assume that W^M is (strictly) concave with respect to s. Define s^M as follows:

$$s^M := \arg\max_s W^M(s).$$

That is, s^M is the optimal subsidy level. The concavity of W^M guarantees the existence and uniqueness of the optimal subsidy level.

3.2 Private oligopoly

Consider the situation where no public firm exists (after privatization). The same procedure as in the case of the mixed oligopoly can be applied here. Let $q_1^P(s)$ and $n^P(s)$ be q_1 and n at the equilibrium given s. These are derived by substituting $Q = nq_1$ into (3) and (4), respectively, and solving them.

Let $Q^P(s) := n^P(s)q_1^P(s)$. Let $W^P(s)$ be given as follows:

$$W^P(s) = \int_0^{Q^P(s)} P(q)dq - n^P(s)\{C(q_1^P(s)) + K\}.$$

In the first stage, the government maximizes W^P with respect to s. We assume that W^P is concave with respect to s. Let s^P be the optimal subsidy level in the private oligopoly.

3.3 Comparison

We now present our results on the simple unit subsidy policy. All proofs are relegated to the Appendix. We first compare the outcomes in mixed and private oligopolies and investigate how s affects them.

Lemma 1. (i) $\partial q_1^M/\partial s > (=) 0$ if $P'' < (=)\ 0$; (ii) $q_1^M(s) = q_1^P(s)$ and $Q^M(s) = Q^P(s)$ for all s; and (iii) $n^M(s) < n^P(s)$ and $dn^M/ds > dn^P/ds > 0$ for all s.

Lemma 1(i) implies that the output of each private firm is increasing in s if $P'' < 0$ and constant if $P'' = 0$. Lemma 1(ii) implies that given a fixed subsidy level s, the output of each private firm and total output are not affected by privatization. Lemma 1(iii) gives that the number of private firms in the mixed oligopoly is smaller than that in the private oligopoly, that both figures are increasing in s, and that the change is larger in the mixed oligopoly.

We now compare the optimal subsidy level in mixed and private oligopolies.

Proposition 1. $s^M \leq s^P$ with the equality being satisfied if and only if $P'' = 0$.

According to Proposition 1, the optimal subsidy level in the mixed oligopoly is less than that in the private oligopoly unless $P'' = 0$. When the optimal subsidy is introduced in the mixed market, the government should adjust the subsidy after privatization. As is discussed in the Introduction, if the number of private firms is given exogenously, $s^M = s^P$ holds regardless of the demand condition. On the contrary, in free entry markets, this is true only in exceptional cases. Subsidy stimulates the entry of new private firms and it can reduce welfare since the number of entering firms is excessive. On the other hand, subsidy stimulates private production and improves welfare. This trade-off yields the optimal subsidy rate. These two effects are different in mixed and private oligopolies (both effects are stronger in the mixed oligopoly)[10], and hence $s^M \neq s^P$ except for measure-zero events where the difference in the two effects is canceled out.

We now compare the equilibrium welfare under the optimal unit tax in mixed and private oligopolies.

Proposition 2. $W^P(s^P) < W^M(s^M)$.

Proposition 2 states that if the optimal subsidy is used, privatization affects welfare (non-neutral result) and that privatization reduces welfare. Further, welfare loss caused by excessive entry is less severe in the mixed market. As such, privatization of the public firm reduces welfare.

The result of welfare-reducing privatization depends on the assumption of identical technology between the public and private firms. If the public firm is less efficient than the private firms, privatization can improve welfare.[11] However, we emphasize that in that case, $W^P(s^P) \neq W^M(s^M)$ except for the measure-zero events where this welfare gain is canceled out by the welfare loss shown

[10] The entry effect can be seen from Lemma 1(iii). With regard to the production effect, there is an additional effect in the mixed market. An increase in s yields production substitution from the public firm to the private firms; this improves welfare. See Matsumura (1998) and Tomaru and Saito (2010).

[11] For the discussion on endogenous cost difference between public and private firms, see Matsumura and Matsushima (2004).

in Proposition 2.

The implications of Propositions 1 and 2 are in sharp contrast with those in the short-run case. As noted earlier, it is well-known that in a market with no entry, a simple unit subsidy yields the first-best outcome in both mixed and private oligopolies and the optimal subsidy rate is the same across the two regimes. That is, the privatization neutrality theorem holds in the short run. The privatization neutrality theorem has two parts: the first part concerns welfare and the second part concerns the optimal subsidy rate. Proposition 1 implies that in a market with endogenous entry, the neutrality theorem does not hold with regard to the optimal subsidy rate unless $P'' = 0$. That is, the second part of the neutrality theorem does not hold in general. One might think that if we restrict our attention to linear demand ($P'' = 0$), the first part of the neutrality theorem will hold. However, Proposition 2 implies that the privatization policy always affects welfare.

4 Optimal Entry-License Taxes

This section investigates entry regulation by entry-license taxes in mixed and private markets with endogenous entry. The proofs of the results are relegated to the Appendix. The government levies an entry-license tax T. Under this policy, the profit Π_i of firm i is given by

$$\Pi_i = Pq_i - C(q_i) - K - T.$$

The game runs as follows. In the first stage, the government chooses an entry-license fee T to maximize W. In the second stage, after observing T, the private firms choose whether or not to enter the market. In the third stage, both public and private firms engage in Cournot competition.

4.1 Mixed oligopoly

First, the mixed oligopoly is considered. Again, we solve this game by backward induction. In the third stage, the public firm maximizes social welfare, while each private firm maximizes its profit. The first-order conditions are given by

$$P(Q) - C_0'(q_0) = 0,$$

$$P'(Q)q_i + P(Q) - C'(q_i) = 0.$$

The second-order conditions are also satisfied. In the free-entry equilibrium, the following zero-profit condition should hold:

$$P(Q)q_i - (C(q_i) + K) - T = 0.$$

Note that the price must be equal to the sum of average cost $(C(q_i) + K)/q_i$ and average tax T/q_i. We restrict our attention to the symmetric equilibrium where all private firms choose the same output level. Thus, each private firm chooses a common output level q_1. Let $q_0^M(T)$ denote the equilibrium output of the public firm and $q_1^M(T)$ denote the equilibrium output of each private firm. Further, the equilibrium total output is $Q^M(T)$, and the equilibrium number of private firms is $n^M(T)$. In the symmetric equilibrium, we have the following equilibrium conditions:

$$P(Q^M) - C'(q_0^M) = 0, \tag{5}$$

$$P'(Q^M)q_1^M + P(Q^M) - C'(q_1^M) = 0, \tag{6}$$

$$P(Q^M)q_1^M - (C(q_1^M) + K) - T = 0. \tag{7}$$

We now present the comparative statics results.

Lemma 2. (i) $dq_0^M/dT > 0$, (ii) $dq_1^M/dT > 0$, and (iii) $dn^M/dT < 0$.

According to Lemma 2, the outputs of the public and private firms increase in T, and the number of private firms and the profit of the public firm decrease in T. The entry tax increases the economy of scale effect and increases the output of each firm.

Let $W^M(T)$ be

$$W^M(T) = \int_0^{Q^M(T)} P(q)dq - C(q_0^M(T)) - n^M(T)C(q_1^M(T)) - (n^M(T) + 1)K.$$

Additionally, we assume that W^M is strictly concave with respect to T.

In the first stage, the government sets an entry-license tax T to maximize social welfare. Let

$$T^M := \arg\max W^M.$$

That is, T^M is the optimal entry tax chosen by the government in the mixed market.

The following is the basic observation with regard to an entry tax policy in the mixed market.

Lemma 3. The optimal entry-license tax T^M is positive in the mixed market.

This result is intuitive. With no entry-license tax, the number of entering firms is excessive for social welfare in both mixed and private markets (excess entry theorem). Thus, the optimal entry-license tax is positive.

4.2 Private oligopoly

Next, we consider the private oligopoly, and solve this game along the same lines as in the case of the mixed oligopoly. We again focus on the symmetric equilibrium: $q_0 = q_1 = q_2 =, \ldots, = q_n$. Let $q_1^P(T)$ denote the equilibrium output of each private firm. Let $Q^P(T)$ and $n^P(T)$ be the equilibrium total output and the equilibrium number of private firms, respectively. Following the same procedure as earlier, we obtain the following equations:

$$P'(Q^P)q_1^P + P(Q^P) - C'(q_1^P) = 0, \tag{8}$$

$$P(Q^P)q_1^P - (C(q_1^P) + K) - T = 0. \tag{9}$$

We now present the comparative statics results for the private oligopoly.

Lemma 4. (i) $dq_1^P/dT > 0$ and (ii) $dn^P/dT < 0$.

Define $W^P(T)$ as

$$W^P(T) = \int_0^{Q^P(T)} P(q)dq - n^P(T)C(q_1^P(T)) - n^P(T)K.$$

In the first stage, the government sets an entry-license tax T to maximize social welfare. Let T^P be the equilibrium entry-license tax level. As in the mixed market, the tax level is positive to reduce the number of entering firms.

Lemma 5. The optimal entry-license tax T^P is positive in the private market.

4.3 Comparison

We now compare the outcomes in mixed and private oligopolies and investigate how T affects them. Let $CS^M(T)$ and $CS^P(T)$ denote the consumer surplus given T in mixed and private oligopolies, respectively. The following observations are useful for our analysis.

Lemma 6. For all T,
(i) $q_1^M(T) = q_1^P(T)$ and $Q^M(T) = Q^P(T)$;
(ii) $CS^M(T) = CS^P(T)$;
(iii) $n^M(T) < n^P(T)$ and $dn^M/dT < dn^P/dT$; and
(iv) $W^M(T) \geq W^P(T)$ if and only if $\Pi_0(T) + \{n^M(T) + 1\}T \geq n^P(T)T$.

It is known that Lemma 6(i) and Lemma 6(ii) hold when $T = 0$. Our results indicate that these hold true for any T. Lemma 6(iv) has a very important implication. When $T = 0$, privatization improves welfare if and only if $\Pi_0 < 0$ (Anderson et al., 1997; Matsumura and Kanda, 2005). Lemma 6(iv) implies that this is not true when $T > 0$. If an entry tax is imposed, privatization may improve welfare even when $\Pi_0 > 0$.

We now present one of our main results.

Proposition 3. $T^M < T^P$.

According to Proposition 3, the optimal entry-license tax in the mixed market is lower than that in the private market. Therefore, if the government levies the optimal entry tax, then the entry tax rate should be raised after privatization. We now explain why this result holds. As noted before, the number of entering firms is excessive from the normative viewpoint. Because of the aggressive behavior of the public firm in the mixed market, this loss is less severe in the mixed market. Thus, the government has a weaker incentive to raise T to restrict the entry of private firms.

5 Two-Part Tax-Subsidy Policy

We consider the policy mixture of unit subsidy and entry tax T. In this case, the profit of firm i is given by $P(Q)q_i - C(q_i) - K + sq_i - T$. Then, the zero-profit condition is replaced by the following condition:

$$P(Q)q_1 - C(q_1) - K + sq_1 - T = 0. \tag{10}$$

5.1 First-best outcomes

Before examining the equilibrium outcome, we characterize the first-best outcome. The optimal conditions are as follows:

$$\left[\frac{dW}{dq_i} = 0 \text{ for all } i = 0, 1, \ldots, n\right] \text{ and } \frac{dW}{dn} = 0.$$

These imply the following:

$$P(Q) - C'(q_i) = 0 \text{ for all } i = 0, 1, \ldots, n,$$
$$P(Q)q_i - C(q_i) - K = 0.$$

Obviously, the optimal output of each firm is identical, i.e., $q_0 = q_1 = \cdots = q_n$. Let q^{B*} and n^{B*} be the optimal output level of each firm and the number of firms, respectively. In the mixed oligopoly, since there exists a public firm, the optimal number of private firms is $n^{B*} - 1$. On the other hand, since there exists no public firm in the private oligopoly, the optimal number of private firms is n^{B*}.

5.2 Neutrality result

Define $(\hat{s}, \hat{T})$ as follows:

$$P'(Q^{B*})q^{B*} + \hat{s} = 0,$$
$$\hat{s}q^{B*} - \hat{T} = 0.$$

Note that $\hat{s} > 0$ and $\hat{T} > 0$. Under this policy pair $(\hat{s}, \hat{T})$, the government spending $\hat{s}q^{B*}$ is equal to the government revenue $\hat{T}$. That is, the government budget is balanced.

We first consider the mixed oligopoly. Given the policy pair $(\hat{s}, \hat{T})$, the first-order condition and the zero-profit condition under the mixed oligopoly are as follows:

$$P(Q) - C'(q_0) = 0,$$
$$P'(Q)q_i + P(Q) - C'(q_i) + \hat{s} = 0,$$
$$P(Q)q_i - C(q_i) - K + \hat{s}q_i - \hat{T} = 0.$$

It is clear that the first-best outcome satisfies the above equation. Hence, the first-best outcome is attained under the policy pair $(\hat{s}, \hat{T})$.

Subsequently, we consider the private oligopoly. Given the policy pair $(\hat{s}, \hat{T})$, the first-order condition and the zero-profit condition under the private oligopoly are given as follows:

$$P'(Q)q_i + P(Q) - C'(q_i) + \hat{s} = 0,$$
$$P(Q)q_i - C(q_i) - K + \hat{s}q_i\hat{T} = 0.$$

Again, the first-best outcome satisfies the above equation, and thus, the first-best outcome is attained under the policy pair $(\hat{s}, \hat{T})$.

Therefore, we have the following neutrality result.

Proposition 4. In both mixed and private oligopolies, the first-best outcome is attained by $(\hat{s}, \hat{T})$ and the government budget is balanced (i.e. $\hat{s}q_i = \hat{T}$).

Proposition 4 indicates that the privatization neutrality result holds in the free entry equilibrium if we deviate from the simple unit subsidy policy. The equilibrium output level, equilibrium welfare level, equilibrium subsidy level, and optimal entry tax level are identical for both mixed and private oligopolies. As seen above, the government budget is balanced under $(\hat{s}, \hat{T})$, and thus, the government can easily achieve the budget balance in the long-run without additional lump-sum taxes.[12]

[12] A related problem is argued by Cato (2010).

6 Concluding Remarks

In this paper, we analyzed tax-subsidy policies in mixed markets with endogenous entry. Three types of tax-subsidy policies are examined: unit subsidy policy, entry-license tax, and a policy mixture of the two instruments. Under the unit subsidy policy, in contrast to the results with exogenous entry, the optimal subsidy level in the mixed market is not equal to that in the private market and privatization affects welfare. Under the entry-license tax policy, the optimal entry tax level in mixed markets is lower than that in private markets; further, here too, the privatization neutrality theorem does not hold. Finally, we show that the neutrality theorem holds under the two-part tax-subsidy policy: the first-best outcome in both mixed and private markets is archived and the optimal tax-subsidy rate is the same across the two regimes. We also find that the government budget is balanced in the two cases.

In this paper, we focused on the case where all firms have an identical cost function. Our results on the optimal tax rates are robust under heterogeneous firms (Propositions 1 and 3). However, when there is a cost difference between public and private firms, our results on welfare comparison do not hold (Propositions 2 and 4). The technological heterogeneity of firms yields further problems. The cost difference between public and private firms may be endogenously determined by commitment activity, such as cost-reducing investment. Investigating these problems remains for future research.

Appendix

Proof of Lemma 1 (i) Differentiating (2)–(4), we have:

$$D\begin{pmatrix} dq_0^M/ds \\ dq_1^M/ds \\ dn^M/ds \end{pmatrix} = -\begin{pmatrix} 0 \\ 1 \\ q_1^M \end{pmatrix},$$

where

$$D = \begin{pmatrix} P' - C''(q_0) & nP' & P'q_1 \\ P''q_1 + P' & nP''q_1 + (n+1)P' - C''(q_1) & P''q_1^2 + P'q_1 \\ P'q_1 & nP'q_1 + P - C'(q_1) + s & P'q_1^2 \end{pmatrix}.$$

$|D| = q_1 C''(q_0)\{(P' + q_1P'')(P - C'(q_1) + s) - q_1P'(P' - C''(q_1))\} < 0.$

$$\frac{dq_1^M}{ds} = -\frac{P''C''(q_0)q_1^3}{|D|} = \frac{P''q_1^2}{(P' + q_1P'')(P - C'(q_1) + s) - q_1P'(P' - C''(q_1))}. \tag{A.1}$$

Since $|D| < 0$ and $C'' > 0$, we obtain Lemma 1(i).

(ii) Differentiating (3) and (4), we have:

$$G\begin{pmatrix} dq_1^P/ds \\ dn^P/ds \end{pmatrix} = -\begin{pmatrix} 1 \\ q_1^P \end{pmatrix}, \text{ where } G = \begin{pmatrix} nP''q_1 + (n+1)P' - C''(q_1) & P''q_1^2 + P'q_1 \\ nP'q_1 + P - C'(q_1) + s & P'q_1^2 \end{pmatrix}.$$

$|G| = -q_1\{(P''q_1 + P')(P - C'(q_1) + s) - q_1P'(P' - C''(q_1))\} > 0.$

$$\frac{dq_1^P}{ds} = -\frac{1}{|G|}P''q_1^3 = \frac{P''q_1^2}{(P''q_1 + P')(P - C'(q_1) + s) - q_1P'(P' - C''(q_1))}. \tag{A.2}$$

Since $P = (C(q_1) + K)/q_1$ in equilibrium (zero-profit condition) and $P' < 0$, the total output is dependent only on q_1. Thus, $q_1^M(s) = q_1^P(s)$ implies $Q^M(s) = Q^P(s)$. Therefore, we can interpret (A.1) and (A.2) as first-order ordinal differential equations, i.e., $dq_1^P(s)/ds = g(q_1^P(s))$ and $dq_1^M(s)/ds = g(q_1^M(s))$. Note that these forms are of the same autonomous system. Matsumura and Kanda (2005) show that $q_1^M(0) = q_1^P(0)$. In other words, the initial values are also the same. These imply Lemma 1(ii).

(iii) $n^P(s) - n^M(s) = Q^P(s)/q_1^M(s) - (Q^M(s) - q_0^M)/q_1^M(s) = q_0^M(s)/q_1^M(s) > 0$, where we use Lemma 1(ii). This implies the first part of Lemma 1(iii).

$$\begin{aligned}\frac{dn^M}{ds} &= \frac{-(P' - C_1'')P'q_1 + P'(P - C_1' + s)}{|D|} + \frac{C_0''\{q_1(nP''q_1 + P' - C_1'') - (P - C_1') - s\}}{|D|} \\ &= \frac{-(P' - C_1'')P'q_1 + P'(P - C_1' + s)}{|D|} + \frac{q_1(nP''q_1 + P' - C_1'') - (P - C_1' + s)}{q_1\{(P' + q_1P'')(P - C_1' + s) - q_1P'(P' - C_1'')\}}\end{aligned} \tag{A.3}$$

$$
\begin{aligned}
\frac{dn^P}{ds} &= \frac{q_1(nP''q_1 + P' - C_1'') - (P - C_1' + s)}{-|G|} \\
&= \frac{q_1(nP''q_1 + P' - C_1'') - (P - C_1' + s)}{q_1\{(P''q_1 + P')(P - C_1' + s) - q_1P'(P' - C_1'')\}},
\end{aligned} \tag{A.4}
$$

where $C_i = C(q_i)$ $(i = 0, 1)$. (A.3) minus (A.4) is equal to the first term of (A.3) and it is positive. (A.4) is positive since $|G| > 0$ and $P - C'(q_1) + s = -P'q_1 > 0$ (see (3)). These yield the second part of Lemma 1(iii). ■

Proof of Proposition 1

$$
\begin{aligned}
\frac{dW^M}{ds} &= (P - C'(q_0))\frac{dq_0^M}{ds} + n^M(P - C'(q_1))\frac{dq_1^M}{ds} + (Pq_1 - C(q_1) - K)\frac{dn^M}{ds} \\
&= n^M(P - C'(q_1))\frac{dq_1^M}{ds} + (Pq_1 - C(q_1) - K)\frac{dn^M}{ds} \\
&= n^M(P - C'(q_1))\frac{dq_1^M}{ds} - sq_1\frac{dn^M}{ds},
\end{aligned} \tag{A.5}
$$

where we use (2) to derive the second and (4) to derive the last. Similarly, we have

$$
\frac{dW^P}{ds} = n^P(P - C'(q_1))\frac{dq_1^P}{ds} - sq_1\frac{dn^P}{ds}. \tag{A.6}
$$

Suppose that $P'' = 0$. From Lemma 1(i), we have $dq_1^M/ds = dq_1^P/ds = 0$. The first-order conditions for maximizing W^M and W^P are satisfied if and only if $sq_1 = 0$. Thus, $s^M = s^P = 0$.

Suppose that $P'' < 0$. Substituting $s = 0$ into (A.6), we have that $dW^P/ds > 0$ (Note that $P - C'(q_1) > 0$ when $s = 0$). This implies $s^P > 0$. $P - C'(q_1) > 0$ when $s = s^P$ because otherwise $dW^P/ds < 0$ when $s = s^P$, and the first-order condition is not satisfied, which is a contradiction. By (A.5) and (A.6), we obtain the following:

$$
\frac{dW^P}{ds} - \frac{dW^M}{ds} = (n^P - n^M)(P(Q) - C'(q_1))\frac{dq_1^M}{ds} - sq_1\Big(\frac{dn^P}{ds} - \frac{dn^M}{ds}\Big), \tag{A.7}
$$

where we use Lemma 1 ($q_1^M = q_1^P$, $dq_1^M/ds = dq_1^P/ds$ and $Q^M = Q^P$). Thus,

$$
\frac{dW^P}{ds}\Big|_{s=s^P} - \frac{dW^M}{ds}\Big|_{s=s^P} = (n^P - n^M)(P(Q) - C'(q_1))\frac{dq_1^M}{ds} - s^Pq_1\Big(\frac{dn^P}{ds} - \frac{dn^M}{ds}\Big) > 0, \tag{A.8}
$$

where we use Lemma 1 ($n^P > n^M$ and $dn^M/ds > dn^P/ds$). ■

Proof of Proposition 2 From the definition of s^M, we have $W^M(s^M) \geq W^M(s^P)$. From Lemma 1(ii) we can say that the privatization does not affect the total output (and consequently the consumer surplus) as long as s remains unchanged. Suppose that the government sets $s = s^P$ in the mixed oligopoly. W is sum of consumer surplus plus firms' profits, excluding total subsidy. Thus, $W^M(s^P) - W^P(s^P)$ is the public firm's profit in the mixed oligopoly when $s = s^P$. In the proof of Proposition 1, we have shown that $P > C'(q_1)$ when $s = s^P$. Since $P = C'(q_0)$, we have $q_0^M(s^P) > q_1^M(s^P) = q_1^P(s^P)$. Given the price, the profit is maximized when $P = C'(q) + s^P$. Thus, given the price, the profit is increasing in q as long as $P \geq C'(q) + s^P$. These imply that the public firm's profit is larger than the private firm's, which is zero in equilibrium. Thus, the public firm's profit is positive in the mixed oligopoly. This implies that $W^M(s^P) > W^P(s^P)$. ■

Proof of Lemma 2 Differentiating (5)–(7), we obtain the following equation:

$$H \begin{pmatrix} dq_0^M/dT \\ dq_1^M/dT \\ dn^M/dT \end{pmatrix} = - \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix}$$

where

$$H = \begin{pmatrix} P' - C''(q_0) & nP' & P'q_1 \\ P''q_1 + P' & nP''q_1 + (n+1)P' - C''(q_1) & P''q_1^2 + P'q_1 \\ P'q_1 & nP'q_1 + P - C'(q_1) & P'q_1^2 \end{pmatrix}.$$

It follows that $|H| = q_1 C''(q_0)\{(P' + q_1 P'')(P - C'(q_1)) - q_1 P'(P' - C''(q_1))\} < 0$.

$$\begin{aligned} \frac{dq_0^M}{dT} &= \frac{1}{|H|}\Big(- (nP''q_1 + (n+1)P' - C''(q_1))P'q_1 + nP'q_1(P''q_1 + P')\Big) \\ &= \frac{-(P' - C''(q_1))P'q_1}{|H|}. \end{aligned}$$

Since $P' - C''(q_1) < 0$, $P' < 0$, and $|H| < 0$, Lemma 2(i) is proved.

$$\begin{aligned} \frac{dq_1^M}{dT} &= \frac{1}{|H|}\Big((P''q_1 + P')P'q_1 - (P''q_1^2 + P'q_1)(P' - C''(q_0))\Big) \\ &= \frac{q_1\{(P''q_1 + P')P' - (P''q_1 + P')(P' - C''(q_0))\}}{|H|} \\ &= \frac{q_1(P''q_1 + P')C''(q_0)}{|H|}. \end{aligned} \tag{A.9}$$

Since $P''q_1 + P' < 0$, $C''(q_0) > 0$, and $|H| < 0$, Lemma 2(ii) is proved.

$$\begin{aligned}\frac{dn^M}{dT} &= \frac{1}{|H|}\Big((nP''q_1 + (n+1)P' - C''(q_1))(P' - C''(q_0)) - nP'(P''q_1 + P')\Big) \\ &= \frac{-n(P''q_1 + P')C''(q_0) + (P' - C''(q_0))(P' - C''(q_1))}{|H|}. \qquad \text{(A.10)}\end{aligned}$$

By assumptions, $(P''q_1 + P')C''(q_0) < 0$, $(P' - C''(q_0))(P' - C''(q_1)) > 0$, and $|H| < 0$. Hence, Lemma 2(iii) is obtained. ■

Proof of Lemma 3 Differentiating W^M with respect to T, we have the following equation:

$$\frac{dW^M}{dT} = (P - C'(q_0))\frac{dq_0^M}{dT} + n^M(P - C'(q_1))\frac{dq_1^M}{dT} + (Pq_1 - C(q_1) - K)\frac{dn^M}{dT}.$$

By the first-order condition of the public firm, we have $P - C'(q_0) = 0$ (equation (5)). Hence, we obtain the following equation:

$$\begin{aligned}\frac{dW^M}{dT} &= n^M(P - C'(q_1))\frac{dq_1^M}{dT} + (Pq_1 - C(q_1) - K)\frac{dn^M}{dT} \\ &= n^M(P - C'(q_1))\frac{dq_1^M}{dT} + T\frac{dn^M}{dT}, \qquad \text{(A.11)}\end{aligned}$$

where we use equation (7). Evaluating dW^M/dT at $T = 0$, we have

$$\left.\frac{dW^M}{dT}\right|_{T=0} = n^M(P - C'(q_1))\left.\frac{dq_1^M}{dT}\right|_{T=0}.$$

Since $P - C'(q_1) > 0$ and $dq_1^M/dT > 0$ (Lemma 2(i)), $dW^M(0)/dT > 0$. Further, $dW^M/dT > 0$ for all $T < 0$. We thus complete the proof. ■

Proof of Lemma 4 Differentiating (8) and (9), we obtain the following equation:

$$I\begin{pmatrix} dq_1^P/dT \\ dn^P/dT \end{pmatrix} = -\begin{pmatrix} 0 \\ -1 \end{pmatrix}$$

where

$$I = \begin{pmatrix} nP''q_1 + (n+1)P' - C''(q_1) & P''q_1^2 + P'q_1 \\ nP'q_1 + P - C'(q_1) & P'q_1^2 \end{pmatrix}.$$

$|I| = -q_1\{(P''q_1 + P')(P - C'(q_1)) - q_1 P'(P' - C''(q_1))\} > 0.$

$$\frac{dq_1^P}{dT} = -\frac{q_1(P''q_1 + P')}{|I|} > 0. \tag{A.12}$$

Since $P''q_1 + P' < 0$ and $|I| > 0$, Lemma 4(i) is proved.

$$\frac{dn^P}{dT} = \frac{nP''q_1 + (n+1)P' - C''(q_1)}{|I|} < 0. \tag{A.13}$$

Since $P''q_1 + P' < 0$, $P' - C''(q_1) < 0$, and $|I| > 0$, Lemma 4(ii) is proved. ■

Proof of Lemma 5 Differentiating W^P with respect to T, we have the following equation:

$$\begin{aligned}\frac{dW^P}{dT} &= n^P(P - C'(q_1))\frac{dq_1^P}{dT} + (Pq_1 - C(q_1) - K)\frac{dn^P}{dT} \\ &= n^P(P - C'(q_1))\frac{dq_1^P}{dT} + T\frac{dn^P}{dT}.\end{aligned} \tag{A.14}$$

where we use equation (9). $dW^P/dT > 0$ for all $T \leq 0$; this completes the proof. ■

Proof of Lemma 6 (i) Arranging equation (A.9), we obtain the following:

$$\frac{dq_1^M}{dT} = \frac{P''q_1 + P'}{(P' + q_1 P'')(P - C'(q_1)) - q_1 P'(P' - C''(q_1))}. \tag{A.15}$$

Arranging equation (A.12), we obtain the following:

$$\frac{dq_1^P}{dT} = \frac{P''q_1 + P'}{(P' + q_1 P'')(P - C'(q_1)) - q_1 P'(P' - C''(q_1))}. \tag{A.16}$$

In both mixed and private markets, we have $P = (C(q_1) + K + T)/q_1$ in equilibrium (zero-profit condition) and $P' < 0$. The right-hand side depends only on the variable q_1. Thus, $q_1^*(T) = q_1^P(T)$ implies $Q^M(T) = Q^P(T)$. Then, we can interpret (A.15) and (A.16) as first-order ordinal differential equations, i.e., $dq_1^M(T)/ds = g(q_1^M(T))$ and $dq_1^P(s)/ds = g(q_1^P(T))$. Note that these forms are of the same autonomous system. Matsumura and Kanda (2005) show that $q_1^M(0) = q_1^P(0)$. That is, the initial values are also the same. We thus complete the proof.

(ii) Since $Q^M(T) = Q^P(T)$ for all T, it is clear that $CS^M(T) = CS^P(T)$ for all T.

(iii) Since $q_1^*(T) = q_1^P(T)$ and $Q^M(T) = Q^P(T)$,

$$n^M(T) = \frac{Q^M(T) - q_0^M}{q_1^M} = \frac{Q^M(T)}{q_1^M} - \frac{q_0^M}{q_1^M} < \frac{Q^M(T)}{q_1^M} = \frac{Q^P(T)}{q_1^P} = n^P(T).$$

Arranging equation (A.10), we obtain the following:

$$\frac{dn^M}{dT} = -\frac{(n+1)P''q_1 + (n+1)P' - C''(q_1)}{q_1\{(P' + q_1P'')(P - C'(q_1)) - q_1P'(P' - C''(q_1))\}} + \frac{P'(P' - C''(q_1))}{|H|}. \tag{A.17}$$

Arranging equation (A.13), we obtain the following:

$$\frac{dn^P}{dT} = -\frac{(n+1)P''q_1 + (n+1)P' - C''(q_1)}{q_1\{(P' + q_1P'')(P - C'(q_1)) - q_1P'(P' - C''(q_1))\}}. \tag{A.18}$$

From equations (A.17) and (A.18),

$$\frac{dn^M(T)}{dT} - \frac{dn^P(T)}{dT} = \frac{P'(P' - C''(q_1))}{|D|} < 0.$$

(iv) Since $CS^M(T) = CS^P(T)$ and $\Pi_i = 0$ for all $i = 1, \dots, n$,

$$W^M(T) - W^P(T) = \Pi_0 + \{n^M(T) + 1\}T - n^P(T)T. \quad \blacksquare$$

Proof of Proposition 3 It suffices to prove that $dW^M(T^P)/dT < 0$. By Lemma 6, $q_1^M(T) = q_1^P(T)$ and $Q_1^M(T) = Q_1^P(T)$. Hence, from equations (A.11) and (A.14), we have

$$\frac{dW^M}{dT} - \frac{dW^P}{dT} = \{n^M(T) - n^P(T)\}(P - C'(q_1))\frac{dq_1^*}{dT} + T(\frac{dn^*}{dT} - \frac{dn^P}{dT}).$$

Since $dW^P(T^P)/dT = 0$, we obtain

$$\frac{dW^M}{dT}\Big|_{T=T^P} = \{n^M(T^P) - n^P(T^P)\}(P - C'(q_1))\frac{dq_1^*}{dT}\Big|_{T=T^P} + T^P(\frac{dn^*}{dT} - \frac{dn^P}{dT}).$$

By Lemma 2(i) and Lemma 6(iii), $n^M(T^P) - n^P(T^P) < 0$, $dq_1^M/dT > 0$, and $dn^M/dT - dn^P/dT < 0$. We thus complete the proof. $\blacksquare$

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