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Privatization and the Environment in a Mixed Duopoly with Pollution Abatement

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Abstract

The purpose of this note is to re-examine whether privatization improves the environment or not in a mixed duopolistic model. In our model, both firms adopt pollution abatement technologies in response to the environmental tax imposed by the government. It is shown that privatization unambiguously reduces the pollution levels of firms. Namely, privatization does improve the environment. Moreover, by implementing partial-privatization policy, social welfare can be enhanced.

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1. Introduction

Since 1990s, concerns over the environmental quality have been prominent in public domain and government imposes green taxes or/and sets pollution standards to control pollution. We have concurrently witnessed that mixed markets exist in a broad range of industries such as oil, telecommunications, electricity and the postal sector, which were formerly dominated by public monopolies in many developing economies. Such mixed market with competition between firms with different objectives deserves further study. This paper examines whether privatization improves (or deteriorates) the environment and social welfare in a mixed duopolistic framework.

In the literature of pollution issues under oligopolistic framework, Simpson (1995) derived the optimal pollution for a Cournot duopoly and found that if firms have different production costs, the optimal tax rate may exceed the marginal damage, whereas Yin (2003) showed that when the externalities are substantial and/or the number of polluters is large, the effluent levies on these firms do not necessarily result in a deadweight loss.[1] To explore the relationship between privatization and environment, Bárcena-Ruiz and Garzón (2006) showed how the decision on whether to privatize a public firm interacts with the environmental policy.[2] Beladi and Chao (2006) proved that privatization paradoxically exerts a negative effect on the environment. Their result is, however, restricted to the case of monopoly in the absence of pollution abatement. This paradox may be attributed to the failure of a monopolistic firm to control pollution, since public monopolies are believed to reflect inefficient management (see Vickers and Yarrow 1991) and high labor costs (see Bradburd 1995). Cato (2008) investigated the privatization policy of an industry where the production process generates emissions, and showed that the high degree of negative externality leads to production substitution from the public firm to private firms; if the degree of negative externality is sufficiently high, then a mixed oligopoly is preferable to a pure oligopoly for social welfare, even if the number of firms in the market is large.

The model presented in this paper reflects the real-world scenario in Taiwan steel industry. China Steel Corporation (CSC), the state-owned corporation possessing the largest market share, competes against the private steel firm Yueh United Steel Corporation (YUSCO) in the domestic market. In 1995, CSC was privatized by the Ministry of Economic Affairs of Taiwan government. These two Kaohsiung-located corporations have been intensively criticized by the public for contaminating the environment of Kaohsiung metropolis. Recently, Taiwan government proposes green taxes to mitigate the unceasing increase of pollution damage resulting from production and consumption-generated negative externalities. Recognizing the industrial scenario and government-proposed policy, in this paper we want to examine the effects of environmental tax and see whether privatization improves (or deteriorates) the environment in a mixed duopolistic framework with pollution abatement, and show that privatization unambiguously reduces the pollution levels of firms. Moreover, it is proved that by implementing partial-privatization policy the social welfare can be enhanced.

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[1] Bárcena-Ruiz and Garzón (2002) analyzed the environmental policy in a pure duopolistic model with incentive schemes, and showed that firm owners have to pay a higher environmental tax and both environmental damage and social welfare increase compared with the profit-maximization case.

[2] Kato (2006) investigated the effects of tradable emission permits in a mixed oligopoly, and found that under certain conditions, social welfare is greater (resp. smaller) under Tradable Emission Permits (TEP) than under Non-Tradable Emission Permits (NTEP) when the weight of social welfare in each public firm's objective function and the degree of convexity of the production cost function and that of the abatement cost function are small (resp. large).

2. The model

We depict a single market made up of one partially privatized firm (indexed by 0) and one private firm (indexed by 1) producing a homogeneous commodity. For simplicity, the inverse demand function is linearly defined:

$$p = 1 - q_i - q_j, \quad i, j = 0,1, \quad i \neq j. \tag{1}$$

Accordingly, total consumer surplus is $CS = (q_0 + q_1)^2 / 2$. We assume that both firms have identical technologies, and the production cost function takes the quadratic form $C(q_i) = F + q_i^2$, where $F = 0$. It is noteworthy that the less cost efficiency of a partially privatized firm is not emphasized here for focusing on the issues of degree of privatization and pollution abatement.

The production of this commodity in both firms leads to pollution e_i. The environmental damage is measured by a quadratic form $ED = (\sum_i e_i)^2 / 2$. However, each firm can prevent pollution by undertaking abatement measures. Suppose that firm *i* chooses pollution abatement level a_i, then the pollution level of each firm is $e_i = q_i - a_i$. The cost of pollution abatement of firm *i* is $a_i^2 / 2$. Each firm has to pay an environmental tax *t* per unit of pollutant emitted and as a result, the tax revenues collected by the government are $T = t\sum_i e_i$.

The environmental tax is imposed by the government and its objective is to maximize social welfare, which comprises the consumer surplus *CS*, the producer surplus $\pi_0 + \pi_1$, and the tax revenues collected by the government *T*, less the environmental damage *ED*. Thus, the social welfare can be expressed as:

$$W = CS + \pi_0 + \pi_1 + T - ED, \tag{2}$$

where the profit of firm *i* is given by:

$$\pi_i = pq_i - q_i^2 - te_i - a_i^2 / 2. \tag{3}$$

In Matsumura (1998), Matsumura and Kanda (2005) and Fujiwara (2007), the objective function of privatized firm is defined as the weighted sum of social welfare and profit. The private firm seeks profit maximization, whereas the partially privatized firm takes into account both social welfare and profit considerations in mixed oligopoly. In Beladi and Chao (2006), the public firm's objective function is defined as the sum of consumer surplus and the firm's profit. We formulate the objective function of the partially privatized firm as the weighted sum of social welfare and the firm's profit:

$$U = (1-k)W + k\pi_0, \quad 0 \leq k \leq 1. \tag{4}$$

where *k* is the degree of private ownership: the larger the value of *k*, the more the private ownership. When $k = 0$, it is completely state-owned, and when $k = 1$, it is fully private-owned.

We propose a two-stage game with the following timing. In the first stage, the government sets the environmental tax to maximize the social welfare, i.e. $\max_t W$. In the second stage, the two firms compete in the market by choosing output and abatement levels, i.e. $\max_{q_0, a_0} U$

and $\max_{q_1,a_1} \pi_1$. As usual in such models, a backward induction is applied to obtain the Subgame Perfect Nash Equilibrium (SPNE).

In the second stage of the game, differentiating (4) with respect to q_0 and a_0 for public firm, and differentiating (3) with respect to q_1 and a_1 for private firm, we have the following first-order conditions:

$$\frac{\partial U}{\partial q_0} = 1 - kt + (1-k)(a_0 + a_1) - 4q_0 - (2-k)q_1 = 0,$$

$$\frac{\partial U}{\partial a_0} = kt - (2-k)a_0 - (1-k)a_1 + (1-k)(q_0 + q_1) = 0,$$

$$\frac{\partial \pi_1}{\partial q_1} = 1 - t - q_0 - 4q_1 = 0,$$

$$\frac{\partial \pi_1}{\partial a_1} = t - a_1 = 0.$$

From the above first-order conditions, we obtain

$$q_0 = \frac{5 + 7t - 2(k + 5kt)}{25 - 6k - 4k^2}, \quad q_1 = \frac{5 - 8t + k(4t + kt - 1 - k)}{25 - 6k - 4k^2},$$

$$a_0 = \frac{5 - 13t + k(19t + 9kt - 4 - k)}{25 - 6k - 4k^2}, \quad a_1 = t.$$

In the first stage of the game, the government sets the environmental tax to maximize the social welfare. We substitute q_i and a_i $(i = 0,1)$ into (2), and thus social welfare is given by,

$$W = \frac{125 - 60k - 40k^2 + 9k^3 + 2k^4 + (125 - 54k + 35k^2 + 84k^3 + 8k^4)t}{(25 - 6k - 4k^2)^2} - \frac{(595 - 348k + 331k^2 + 273k^3 + 58k^4)t^2}{(25 - 6k - 4k^2)^2}.$$

Differentiating it with respect to t, we obtain the optimal environmental tax,

$$t^* = \frac{125 - 54k + 35k^2 + 84k^3 + 8k^4}{D}. \tag{5}$$

Substituting t^* back to a_i and q_i, we get the SPNE outcomes denoted by asterisk, as follows:

$$t^* = a_1^* = \frac{125 - 54k + 35k^2 + 84k^3 + 8k^4}{D},$$

$$a_0^* = \frac{173 - 165k + 170k^2 + 9k^3 + 11k^4}{D},$$

$$q_0^* = \frac{3(91 - 78k + 69k^2 + 26k^3)}{D},$$

$$q_1^* = \frac{3(66 - 34k + 35k^2 + 32k^3 + 9k^4)}{D},$$

$$Q^* \equiv q_0^* + q_1^* = \frac{3(157 - 112k + 104k^2 + 58k^3 + 9k^4)}{D},$$

$$ED^* = \frac{(173 - 117k + 107k^2 + 81k^3 + 8k^4)^2}{2D^2},$$

$$W^* = \frac{3(167 - 96k + 86k^2 + 84k^3 + 11k^4)}{2D},$$

where $D = 2(595 - 348k + 331k^2 + 273k^3 + 58k^4)$.

Our results are consistent with Bárcena-Ruiz and Garzón (2006), who without considering partial privatization, have pointed out that both abatement and pollution levels of the firms mainly depend on their output levels.

Lemma 1. $q_0 > q_1$, $a_0 > a_1$ and $e_0 > e_1$.

Proof. $q_0 - q_1 = \dfrac{3(1-k)(25 - 19k + 15k^2 + 9k^3)}{D} > 0$;

$a_0 - a_1 = \dfrac{3(1-k)(16 - 21k + 24k^2 - k^3)}{D} > 0$[3];

$e_0 - e_1 = \dfrac{3(1-k)(9 + 2k - 9k^2 + 10k^3)}{D} > 0$.

The effects of increasing privatization (i.e. increasing k) on relevant variables can be studied. The following proposition summarizes our main comparative-statics results.

Proposition 1. *In equilibrium, an increase in the degree of privatization of the partially privatized firm:*

(a) *Decreases the output level of the partially privatized firm but increases the output level of the private firm.*
(b) *Decreases the total output level, and thus increases the market price.*
(c) *Decreases the abatement level of the partially privatized firm.*
(d) *Improves the environment.*

Proof. Since the exposition of the equilibrium value of each variable is rather complicated, we adopt numerical simulation for proof. The figures below illustrate the relationship between increasing privatization and the equilibrium value of relevant variables.

As in Figures 1 and 2, dq_0/dk and dq_1/dk are always negative and positive, respectively. Therefore, part (a) of proposition 1 holds. In Figures 3, dQ/dk is always negative, showing that part (b) of proposition 1 holds. As in Figures 4, 5, and 6, both da_0/dk and dED/dk are always negative even though the sign of da_1/dk depends on

[3] Numerical simulation shows that the numerator of this equation is positive.

the degree of privatization. Consequently, we can argue that the abatement level of the partially privatized firm and the environmental damage decrease with privatization, i.e. part (c) and (d) of proposition 1 holds.

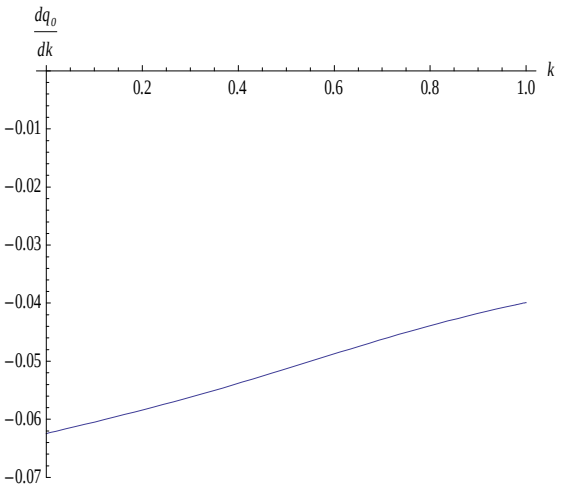

Figure 1. Privatization Effect on q_0

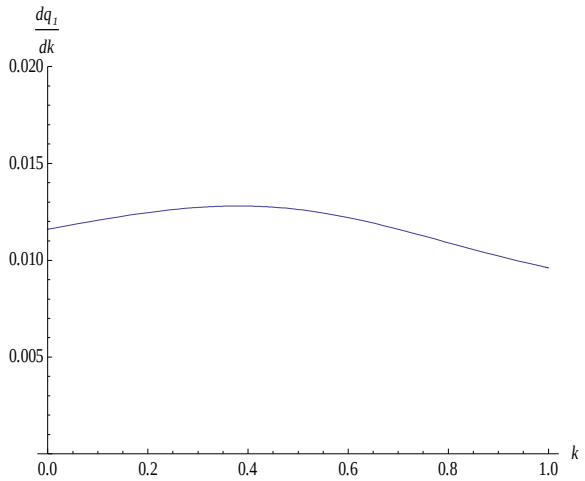

Figure 2. Privatization Effect on q_1

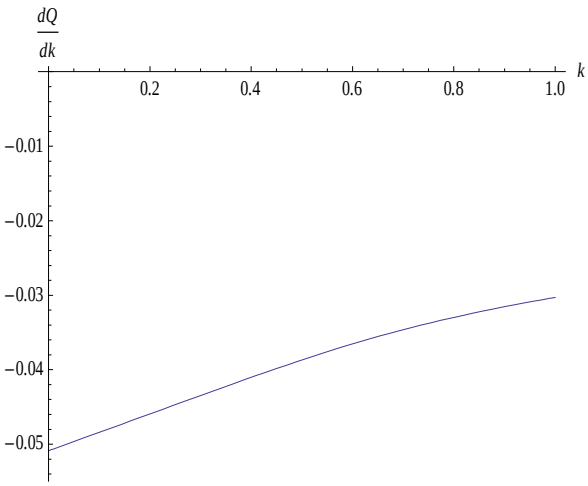

Figure 3. Privatization Effect on Q

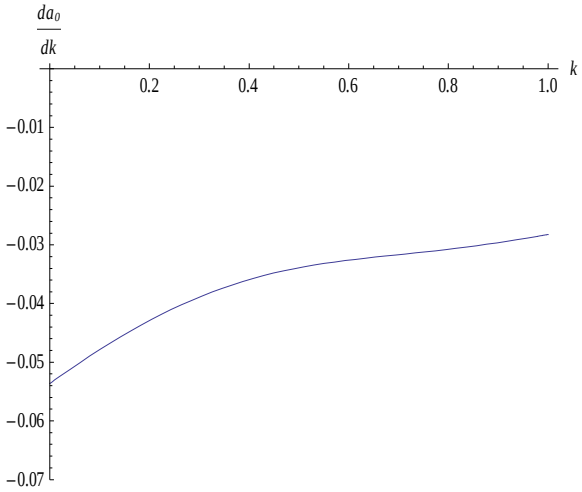

Figure 4. Privatization Effect on a_0

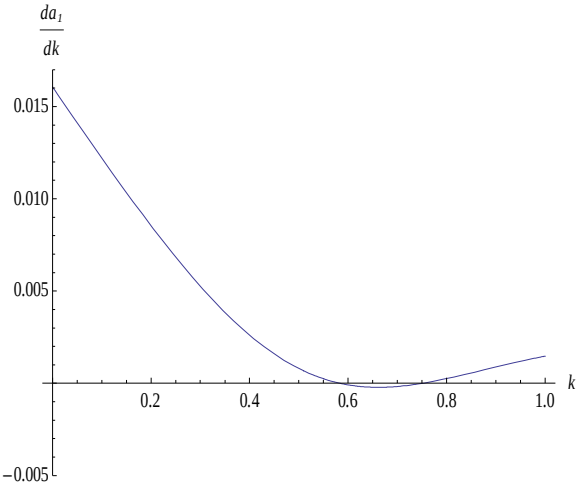

Figure 5. Privatization Effect on a_1

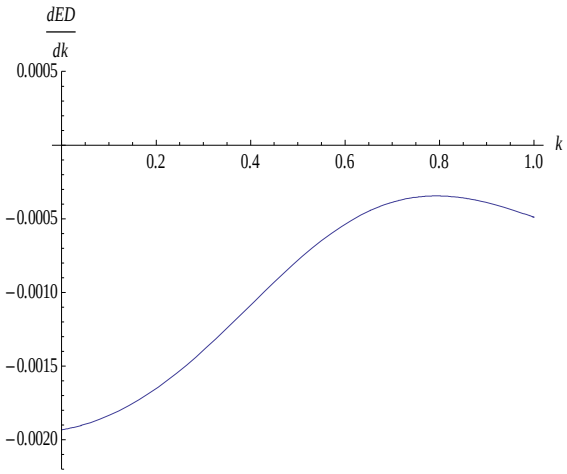

Figure 6. Privatization Effect on ED

The above results are interpreted with the following economic intuition. Due to an obligation towards social welfare, the public firm tends to produce more than under profit maximization. However, along with the increasing degree of privatization, the privatized firm attaches higher weight to profit and thus produces less, and the profit-maximizing private firm then produces more. Nevertheless, the higher output level of the private firm is not able to outweigh the lower output level of the privatized firm. Therefore, the total output decreases, the market price increases and consumers are worse off. Moreover, because the privatized firm is less concerned about social welfare and decreases its output, the abatement effort is reduced. However, even though the pollution abatement of the privatized firm is decreased, the less total output along with an increasing degree of privatization decreases total environmental damage, which may then improve the environment. Our result on privatization-environment is different from the result of Beladi and Chao (2006) in the case of monopoly without considering pollution abatement.

3. The Welfare Implication of Partial Privatization

The fact that $\frac{dW^*(k)}{dk}|_{k=0} > 0$ implies that privatization policy can improve the social welfare. From the equilibrium value of social welfare, we can derive the critical value of $k^* \doteq 0.16$ such that $\frac{dW^*(k)}{dk}|_{k^* \doteq 0.16} = 0$ and $\frac{d^2W^*(k)}{dk^2}|_{k^* \doteq 0.16} < 0$. The importance of this critical value is that it explicitly depicts the degree of privatization that maximizes social welfare. Therefore, we obtain the following Corollary.

Corollary 1. *The government maximizes the social welfare by implementing partial-privatization policy for an optimal environmental tax.*

Proof. See Figures 7 and 8.

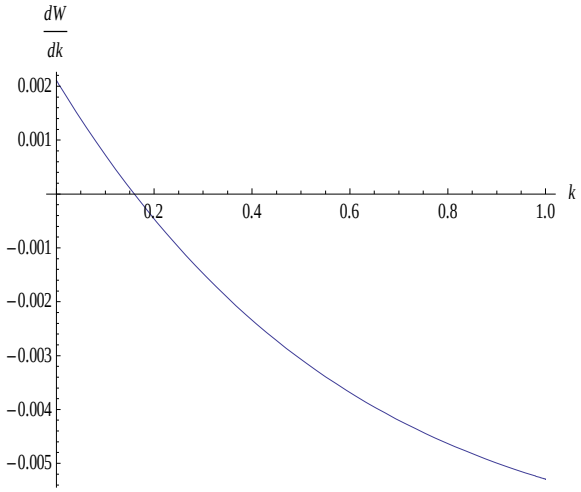

Figure 7. Privatization Effect on W

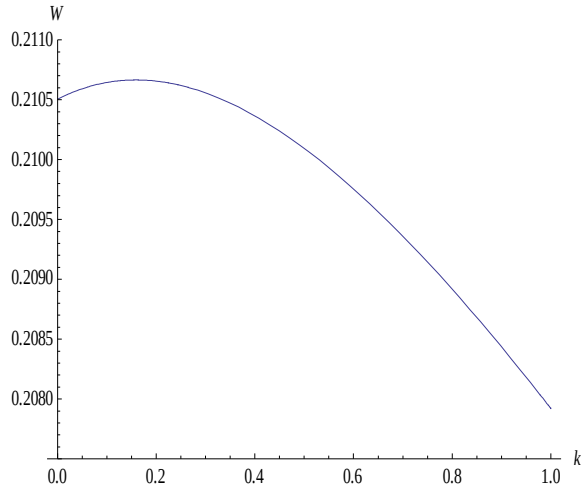

Figure 8. Welfare Improvement

4. Concluding Remarks

Proposition 1 paves the way for us to analyze the environmental effect of privatization. Taking the output effect of privatization into account, the above results indicate that the abatement and the pollution level of the privatized firm decrease with privatization and, although the private firm reacts by increasing its output and pollution level, this

pollution-increasing effect does not offset the first one. In sum, we can argue that the environment is improved, since the total pollution level decreases with privatization. Moreover, by implementing partial-privatization policy, the social welfare can be enhanced.

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