Hitotsubashi Journal of Economics 56 (2015), pp.135-154.

STRATEGIC PRIVATIZATION WITH TARIFFS AND ENVIRONMENTAL TAXES IN AN INTERNATIONAL MIXED DUOPOLY*

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Received March 2014; Accepted October 2014

Abstract

We examine the strategic interaction between two governments in an international mixed duopoly market, in which a state-owned enterprise competes with private enterprises under different regimes of privatization policies with import tariffs and environmental taxes. We find that bilateral privatization leads to higher tariffs than no privatization, but unilateral privatization yields the highest tariff for a privatized country and the lowest tariff for a non-privatized country. However, a higher environmental tax is called for when a privatization policy is practiced. We also investigate a privatization choice game between two governments and show that unilateral privatization is the Nash equilibrium of the game. Finally, we compare the local optimum with the global optimum and show that the latter is independent of the regimes of privatization policies. We find a need for trade and environmental policy coordination between the two governments for global welfare maximization.

Keywords: privatization, tariffs, environmental taxes, international mixed duopoly
JEL Classification Codes: L33, D43, F18

* This paper was presented at the international conferences of Eurasia Business and Economics Society (Singapore; 2014), Korean Economic Association (Seoul, Korea; 2014), East Asian Association of Environment and Resource Economics (Busan, Korea; 2014), Fudan University (Shanghai, China; 2014), and National University of Kaohsiung (Kaohsiung, Taiwan; 2014). We are grateful to an anonymous referee of this journal and the participants of the conferences for their careful and constructive comments on an earlier version of this paper. All remaining errors are ours. This study was financially supported by Chonnam National University, 2013.
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I. *Introduction*

In recent years, in accordance with the global trend of privatization[1], many researchers have expressed a global concern on the impact of trade liberalization and environment.[2] Although the trend toward privatization of state-owned enterprises generates a positive effect on social welfare in general,[3] many developing countries such as China, India, and the central and eastern European countries in the transitory economy have confronted policy issues raising from open competition with foreign firms and poor environmental quality owing to the failure to control industrial pollution.

In 1978, China, for instance, started an economic reform with focus on two main policies: privatization and trade liberalization, including opening up to foreign capital through relaxation of regulations. The position of its state-owned enterprises in the national industrial structure continued to decline over the following two decades. After its entry into the World Trade Organization (WTO) in 2001, China's average tariff rate was also brought down through several adjustments. After all, China has achieved remarkable economic growth at an average annual growth rate of 9.98% in gross domestic product (GDP) from 1978 to 2012. Despite its impressive economic performance, China's environmental quality worsened during the last two decades. Particularly, the smog in Beijing and much of northern China reached alarming levels in 2013, forcing the Chinese government to acknowledge its serious pollution problem. Thus, one of the hottest issues for many developing countries, including China, India and many other low-income countries, is how to adjust their strategic industrial and privatization policies with tariffs and environmental taxes in an international open competition economy.

Since the earlier studies on privatization policies in a mixed market, wherein a public firm competes with private firms[4], the recent decade has witnessed an increasing volume of research on the mixed oligopoly framework. Many researchers have found it a very useful instrument to study and to analyze the interactions between governments and private firms in the international markets. They investigated the welfare effects of privatization in an international mixed market, involving the trade policy. For example, Fjell and Pal (1996) examined the effects of an open door policy on privatization. Pal and White (1998) introduced a production subsidy and an import tariff to determine the interaction between privatization and strategic trade policies. Fjell and Heywood (2002, 2004) and Wang et al. (2009) considered the role of leadership and showed that the relative efficiency of public firm determines the decision on privatization. Chang (2005) used a mixed duopoly model with cost asymmetry to examine the optimal trade

[1] We have witnessed a recent widespread wave of privatization. According to the World Bank Group (2008), 48 developing countries executed 249 privatization transactions valued at US$104.9 billion in 2006 and 51 developing countries executed 236 privatization transactions valued at US$132.6 billion in 2007, mostly through initial public offerings (IPOs).

[2] Past empirical studies have examined the effects of trade liberalization on the environment. For example, Managi et al. (2009) found that trade openness decreases (increases) the level of carbon dioxide in the OECD (non-OECD) countries.

[3] Based on the various empirical results, Megginson and Netter (2001) and Megginson and Sutter (2006) reported that privatization generates positive effects on the society, as well as on privatized firms

[4] Merill and Schneider (1966) is a pioneering study on mixed oligopoly. De Fraja and Delbono (1989, 1990) introduced a game approach on mixed oligopoly to examine the welfare effect of privatization under different competition models.

and privatization policies. Chao and Yu (2006) constructed a mixed oligopoly model to examine how privatization affects the optimal import tariff. Han (2012) and Yu and Lee (2011) examined strategic privatization and trade policies in a mixed oligopoly model and analyzed the welfare effect of subsidy and tariff policies. Finally, Lee, et, al. (2013) investigated the interaction between two countries on the strategic choices of privatization and tariffs, and showed that the optimal condition of privatization depends on the relative efficiency of the state-owned-enterprise and private firms, as well as the degree of economic openness and tariffs.

On the other hand, some recent studies explored the relationship between privatization policy and environmental regulation in a mixed oligopoly market. Beladi and Chao (2006) considered a state-owned enterprise in a monopoly market, and showed that full privatization harms the environment. Ohori (2006) examined the optimal environmental tax level under a mixed duopoly market, and showed that partial privatization is the optimal decision when the environmental tax is lower than the standard Pigouvian level. Kato (2013) also found that partial privatization is always desirable when the private firms are owned by domestic private investors, and the optimal degree of privatization is independent of the degree of environmental damage. However, Naito and Ogawa (2009) showed that the optimal level of environmental regulation critically depends on the degree of privatization with a non-monotonous relationship. Bárcena-Ruiz and Garzón (2005, 2006) also explored the objective function of the government, and found that the optimal decision of the government whether or not to privatize a public firm depends on the government's decision on internalizing the environmental damage. On the other hand, Wang and Wang (2009) considered a mixed duopoly market with differentiated products and pollution abatement, and examined whether privatization improves (or deteriorates) the environment. They showed that with privatization, the less (more) are the substitutable products, the more (less) is the damage to the environment. Finally, Pal and Saha (2015) showed that, if the privatization in a mixed duopoly with differentiated products is less (more) than a certain level, the environmental damage increases (decreases) with the level of privatization.

All the previous studies on the international mixed market focused on the strategic relationship between privatization and a single policy instrument, for example, tariffs or environmental taxes only. However, in order to address the strategic aspects of multiple policies, we sometimes have to coordinate the policy instruments.[5] Thus, it is worthwhile to examine the strategic interaction between two different policy instruments, along with the privatization policy, in an open global competition. In this paper, we consider an international mixed duopoly market, in which a public firm in the home country compete with a foreign public firm as well as domestic and foreign private firms under three different regimes of privatization policies – privatization of both the public firms (i.e., bilateral privatization), privatization of one of the public firms (i.e., unilateral privatization), and nationalization of both the public firms (i.e., no privatization) – by comparing the equilibrium tariffs, environmental

[5] According to the "strategic environmental policy" trade literature, when both tariffs and environmental taxes coexist in pure oligopoly market, the relationship between the two instruments is positive. For example, if environmental taxes are increased, the optimal tariff can be set higher to protect domestic industries. Likewise, if tariff protections increase, the optimal environmental tax can be set higher. For a more detailed discussion, see Brander and Spencer (1985) and Tsai et al. (2015) among others.

taxes, and the social welfare of the three cases. In particular, instead of examining a single government privatization framework, in which the approach of most previous studies examined only a single country, we consider the strategic interaction between two governments under different regimes of privatization policies. This strategic interaction between two governments is discussed in Barcena and Garzon (2005), Han and Ogawa (2008), and Lee, et, al. (2013). However, we add some policy concerns on environmental damage and clarify the effects of the different regimes of privatization policies, chosen by the two competitive governments. This feature differentiates our work from previous studies.

We present below a few of our findings: First, bilateral privatization leads to higher tariffs than no privatization, whereas unilateral privatization calls for the highest tariff for a privatized country and the lowest tariff for a non-privatized country. This is similar to the result of Chang (2005), who considered unilateral privatization along with cost asymmetry and showed that the optimal tariff rate and the share of government ownership are complementary and that the optimal tariff rate is lower at full nationalization than at full privatization. The main difference is that our approach includes environmental damage in a strategic governmental competition framework and considers the equilibrium choice between tariffs and environmental taxes.

Second, more privatization further damages the environment and thus, calling for a higher optimal environmental tax level when the government practices privatization policy. Similarly, Pal and Saha (2015) showed that environmental damage increases with the level of privatization when the latter is less than a certain level. On this property of non-linearity, Naito and Ogawa (2009) also showed that environmental regulations critically depend on the degree of privatization and that the relationship is non-monotonous. In their model, for example, if we examine the two extreme cases of bilateral privatization and no privatization, our results still hold. Thus, privatization policy would always call for a higher environmental tax when considering a trade policy.

Finally, we consider a privatization choice game between two governments and compare the local and global optimum levels. We find that unilateral privatization is the Nash equilibrium of the privatization choice game. This result provides a different policy suggestion compared to that of Serizawa (2000), who considered unilateral privatization and showed that in an economy where the government uses an optimal tariff, full privatization improves welfare. However, under a strategic privatization choice game, the optimal choice of privatization depends on the other country's choice of privatization. In particular, if the rival country chooses privatization, the best response would be the no privatization. This is similar to the result of Dadpay and Heywood (2006) where countries face a prisoners' dilemma when deciding on privatization. Privatizing both public firms in general increases welfare, but unilateral privatization is usually found to decrease the welfare of that country but increase the welfare of the rival country. On the other hand, Heywood and Ye (2009) took into account the timing of the move and found that moving first enables the leader earn greater profits, which is consistent with our finding. We also show that the global optimum is independent of privatization, but we find a need for policy coordination on the optimal tariffs and environmental taxes for global welfare maximization.

Let us now briefly explain the role of the cost function in determining the optimal privatization decision under a strategic interaction between two countries in an open economy. We assume that the cost function of a firm is increasing in output and therefore leads to diseconomies of scale. Thus, privatization helps to improve welfare in a mixed market because

the output substitution effect between the public firm and private firm is socially beneficial. That is, when a public firm reduces its output to save its large costs under privatization, the domestic private firm can increase its output at lower costs.[6] However, when we consider an open economy in which foreign private firms enter the home market, the output substitution effect is not always beneficial to society because the increased profit of foreign firms will not benefit domestic social welfare. Thus, when foreign firms substitute the output of public firm, there should be restrictions on the privatization policy, compared the case of a closed economy. Furthermore, an internationally bilateral case in which domestic private firm in home country can export its outputs to the foreign market, the increased output of the domestic private firm will increase the marginal cost of production, implying a reduction in the competitiveness of domestic private firm when participating in exports. Then, privatization policy should be more restricted in a bilaterally open economy. Therefore, there are trade-offs between privatization and nationalization policies and hence, the strategic choice on privatization is more important in bilateral international competition.

The remainder of this paper is organized as follows. Section II introduces the basic model. In section III, we analyze three models, no privatization, bilateral privatization, and unilateral privatization, and describe the basic framework in a mixed market. In section IV, we compare the results of output, optimal tariff, environmental tax, and welfare in the three models. In section V, we also consider a privatization choice game between two countries, and examine the cooperative situation in which both countries maximize global welfare. We provide an economic interpretation of the interaction between privatization, trade policies, and environmental tax. In section VI, we summarize and conclude this paper.

II. *The Model*

Suppose that there are two countries, country 1 and country 2, and both countries have symmetric duopoly. Each country has a state-owned enterprise (SOE) and a private enterprise (PE), which produce homogeneous goods and trade those products. That is, both the firms in each country produce goods and export them to the other country. We denote the SOE's domestic output in country i as q_{hi}^{SOE} and its export output as q_{ei}^{SOE}. Similarly, q_{hi}^{PE} and q_{ei}^{PE} denote the PE's domestic output and export output in country i, respectively. Then, for country i, the production of goods can be denoted as $Q_i^P = q_{hi}^{SOE} + q_{ei}^{SOE} + q_{hi}^{PE} + q_{ei}^{PE}$ and the consumption of goods can be denoted as $Q_i^C = q_{hi}^{SOE} + q_{ej}^{SOE} + q_{hi}^{PE} + q_{ej}^{PE}$.

Government in each country imposes tariff on the imported goods produced by the other country's SOE and PE: the import tariff is defined as $t_i (\geq 0)$ for country $i = 1, 2$. Then, the import tariff revenue is $T_i = t_i(q_{ej}^{SOE} + q_{ej}^{PE})$ for country i.

The inverse demand functions of both markets are the same, which are given by $P_i = A - Q_i^C$, where the price of market i is denoted by P_i. We also assume that the cost functions of the two countries' SOEs and PSs are the same and quadratic[7],

[6] Note that a public firm will produce more output than a private firm because it maximizes not only its profit but also consumer surplus. As long as the consumer surplus-reducing effect, due to the reduced industry outputs, is not very significant, this output substitution effect from privatization will improve welfare. Numerous researches emphasize the role of the increasing cost function of public firms since the pioneering work of De Fraja and Delbono (1989, 1990).

$C(q_{hi}^M+q_{ei}^M)=\frac{1}{2}(q_{hi}^M+q_{ei}^M)^2$, where $M=SOE, PE$.

Finally, we assume that the production process causes environmental pollution in both countries. The damage due to the production is denoted as $D_i=dQ_i^P$, where d is the marginal environmental damage. Each country imposes an environmental tax on the production of goods,[8] and the environmental tax of for country i is defined as $\tau_i(\geq 0)$. Then, the environmental tax revenue of each country is given as $E_i=\tau_i Q_i^P$.

III. *Analysis*

We examine the welfare effect of the privatization choice of two countries in the following three policy regimes: (i) the SOEs of both countries are fully nationalized, (ii) the SOEs of both countries are fully privatized, and (iii) only one of the SOEs is privatized.

1. No Privatization Model

Suppose there is an SOE and a PE in both countries, and that the SOEs of both countries are fully nationalized. Then, the profits of the firms can be expressed as follows:

$$\pi_i^M=(P_i-\tau_i)q_{hi}^M+(P_j-t_j-\tau_i)q_{ei}^M-\frac{1}{2}(q_{hi}^M+q_{ei}^M)^2,\ where M=SOE, PE \tag{1}$$

Consumer surplus is denoted as $CS_i=\frac{1}{2}(Q_i^C)^2=\frac{1}{2}(q_{hi}^{SOE}+q_{ej}^{SOE}+q_{hi}^{PE}+q_{ej}^{PE})^2$. Then, social welfare can be defined as the sum of the consumer surplus, industry profits, import tariff revenue, $T_i=t_i(q_{ej}^{SOE}+q_{ej}^{PE})$, environmental tax revenue, $E_i=\tau_i Q_i^P$, and the loss from damage, $D_i=dQ_i^P$:

$$W_i=CS_i+\pi_i^{SOE}+\pi_i^{PE}+t_i(q_{ej}^{SOE}+q_{ej}^{PE})+(\tau_i-d)Q_i^P \tag{2}$$

In this paper, two-stage game is constructed. In the first stage, the government chooses its tariff and environmental tax levels to maximize the country's domestic social welfare. In the second stage, the firms observe the tariff and environmental tax levels and then choose their output level. Each firm's behavior is constrained by its ownership structure. We assume that the PE, having its own private property rights, maximizes its profits, whereas the SOE, fully owned

[7] When the SOEs and PEs hold the same production technology under constant or decreasing marginal costs, social welfare is maximized by the public firm that monopolizes the entire market. In order to focus on active mixed oligopoly markets, we assume increasing marginal costs, similar to the standard mixed oligopoly literature. In particular, under the assumption of the same production efficiency between SOE and PE, many researchers have used a quadratic cost function. For recent works, see Dadpay and Heywood (2006), Yu and Lee (2011), Han (2012), and Matsumura and Tomaru (2013), among others.

[8] When government owns the public firm, it can directly control the quantity of production and the pollution level in a perfect world where it has full authority and complete information to monitor the production process of the public firm. Instead, we assume that the government uses an indirect regulation to levy environmental tax on both public and private firms that face the trend of liberalization and privatization policies. See, for example, Beladi and Chao (2006), Bárcena-Ruiz and Garzón (2005, 2006) and Ohori (2006).

by the government, maximizes the objective of the government, which is assumed to be social welfare[9].

From the first-order conditions of the SOE and PE, in which the SOE maximizes (2) and the PE maximizes (1), we have the following equilibrium outputs:

$$q_{hi}^{SOE}=\frac{20A-25d-5t_i-5t_j+7\tau_i-2\tau_j}{45}; \quad q_{ei}^{SOE}=0$$

$$q_{hi}^{SOE}=\frac{5A+5d+10t_i+10t_j-14\tau_i+4\tau_j}{45}; \quad q_{ei}^{PE}=\frac{5A+5d-20t_j-5t_i+\tau_j-11\tau_i}{45}$$

The optimal output of the SOE for exports is $q_{ei}^{SOE}=0$. This is because $q_{hi}^{SOE}>q_{hi}^{PE}+q_{ei}^{PE}$ at equilibrium and thus the marginal production cost of the SOE is higher than that of the PE, resulting in a cost disadvantage of exports to the SOE[10]. We should note that the government will strategically want the home country SOE to play the role of a trade barrier and promote domestic market competition to achieve higher domestic social welfare.

The market output and price are, respectively:

$$Q_i^C=\frac{10A-5d-5t_i-2\tau_i-3\tau_j}{15} \text{ and } P_i=\frac{5A+5d+5t_i+2\tau_i+3\tau_j}{15}$$

The resulting profit of each firm is:

$$\pi_i^{SOE}=\frac{(20A-25d-5t_i-5t_j+7\tau_i-2\tau_j)(2A+11d+7t_i+t_j-17\tau_i+4\tau_j)}{810}$$

$$\pi_i^{PE}=\frac{1}{4050}[200(A+d)^2+275t_i^2+1100t_j^2+\tau_i(-1000(A+d)+1259\tau_i)+2(100(A+d)$$
$$-259\tau_i)\tau_j+59\tau_j^2-20t_j(20(A+d)-41\tau_i+\tau_j)+10t_i(20(A+d)+70t_j-59\tau_i+19\tau_j)]$$

Then, we have the following consumer surplus and welfare functions:

$$CS_i=\frac{(10A-5d-5t_i-2\tau_i-3\tau_j)^2}{450},$$

$$W_i=\frac{1}{810}[-295t_i^2+215t_j^2+10t_i(8A-d+t_j+7\tau_i-14\tau_j)-2t_j(35A-55d+7\tau_i+13\tau_j)$$
$$+2(5(26A^2-47Ad+8d^2)-92\tau_i^2+\tau_j(4A-41d+10\tau_j)+t_i(-29A+196d+17\tau_j)]$$

The differentiation of W_i with respect to t_i and τ_i yields the equilibrium import tariff and environmental tax:[11]

$$t_i^N=\frac{19(A-d)}{122} \text{ and } \tau_i^N=\frac{70d-9A}{61} \tag{3}$$

[9] Political debate on this assumption can be found in White (2002), Cook and Fabella (2002), Lee and Hwang (2003), Lee (2006) and Donder and Roemer (2009), among others.

[10] Existing literature shows that international trade induces only the more productive firms to enter the export market, while some less productive firms will continue to produce only for the domestic market when there are export market entry costs (Melitz, 2003; Helpman et. al., 2004) or cost inefficiency of the SOE (Chang, 2005; Lee, et. al., 2013).

[11] For a non-negative tariff and environmental tax, it should be satisfied that $9a/70\le d\le a$. When a negative environmental tax is imposed, it will be an output subsidy. See recent discussions in Lee (1999) and Lee and Park (2011), among others, on this logic of output tax (or subsidy). The second-order conditions for the maximization problem are also satisfied.

Finally, the equilibrium outputs of the no privatization model are: $q_{hi}^{SOE}=0.393(A-d)$, $q_{ei}^{SOE}=0$, $q_{hi}^{PE}=0.213(A-d)$, and $q_{ei}^{PE}=0.057(A-d)$. A comparison of the SOE's production and PE's production yields $q_{hi}^{SOE}=0.393(A-d)>q_{hi}^{PE}+q_{ei}^{PE}=0.270(A-d)$. This indicates that the output of the SOE is larger than that of the PE in the home market and thus the SOE would not choose to export to the foreign country due to a cost disadvantage. The market output and price are, respectively, $Q_i^C=Q_i^P=0.664(A-d)$ and $P_i=0.336A+0.664d$. Finally, the resulting social welfare is $W_i^N=0.330(A-d)^2$.

2. Bilateral Privatization Model

Suppose that the SOE in each country is fully privatized and therefore there are two private firms in each country. Then, both the firms will maximize their own profits in (1) and produce the following equilibrium outputs:

$$q_{hi}^{SOE}=q_{hi}^{PE}=\frac{26t_i+19t_j+5(3A-5\tau_i+2\tau_j)}{105}\ ;\ q_{ei}^{SOE}=q_{ei}^{PE}=\frac{-44t_i-16t_j+5(3A+2\tau_i-5\tau_j)}{105}$$

Note that both the privatized SOE and PE in each country will participate in export at equilibrium.

The market output and price are, respectively:

$$Q_i^C=\frac{2(10A-6t_i+t_j-5\tau_i-5\tau_j)}{35}\ \text{ and }\ P_i=\frac{12t_i-2t_j+5(3A+2\tau_i+2\tau_j)}{35}$$

The resulting profit of each firm is:

$$\pi_i^{PE}=\frac{1}{22050}[1964t_i^2+5219t_j^2-1000t_j(3A-5\tau_i+2\tau_j)+200(3A-5\tau_i+2\tau_j)^2 +4t_i(1073t_j+100(3A-5\tau_i+2\tau_j)]$$

Then, we have the following consumer surplus and welfare functions:

$$CS_i=\frac{2(10A-6t_i+t_j-5\tau_i-5\tau_j)^2}{1225}.$$

$$W_i=\frac{1}{11025}[-6628t_i^2+5237t_j^2+t_i(716t_j+10(219A-210d+328\tau_i-337\tau_j) -10t_j(264A-525d+43\tau_i+218\tau_j)+50(18A(4A-7d)-\tau_j(30(A-7d)+101\tau_i) +2(6A-42d+11\tau_i)\tau_j+25\tau_j^2]$$

The differentiation of W_i with respect to t_i and τ_i yields the equilibrium import tariff and environmental tax, respectively, as follows[12]:

$$t_i^B=\frac{10(A-d)}{57}\ \text{ and }\ \tau_i^B=\frac{10d-A}{9} \tag{4}$$

[12] For non-negative tariff and environmental tax, it should be satisfied that $a/10\leq d\leq a$. The second-order conditions for the maximization problem are also satisfied.

Finally, the equilibrium outputs of the firms in the bilateral privatization model are $q_{hi}^{SOE}=q_{hi}^{PE}=0.234(A-d)$ and $q_{ei}^{SOE}=q_{ei}^{PE}=0.058(A-d)$, and the market output and price are $Q_i^C=Q_i^P=0.585(A-d)$ and $P_i=0.409A+0.585d$, respectively. The resulting social welfare in the bilateral privatization model is $W_i^B=0.328(A-d)^2$.

3. Unilateral Privatization Model

Suppose an asymmetric privatization case, in which an SOE and a PE exist in the home country i and two private firms exist in the foreign country j. From the first-order conditions of the SOE in country i for maximizing welfare in (2) and of the PEs in countries i and j for maximizing profits in (1), we have thefollowing equilibrium outputs:[13]

$$q_{hi}^{SOE}=\frac{60A-72d-22t_i-17t_j+20\tau_i-8\tau_j}{129}; \qquad q_{ei}^{SOE}=0$$

$$q_{hi}^{PE}=\frac{9A+15d+44t_i+34t_j-40\tau_i+16\tau_j}{129}; \qquad q_{ei}^{PE}=\frac{24A-3d-26t_i-67t_j-35\tau_i+14\tau_j}{129}$$

$$q_{hi}^{SOE}=q_{hi}^{PE}=\frac{24A-3d+17t_i+19t_j+8\tau_i-29\tau_j}{129}; \quad q_{ej}^{SOE}=q_{ej}^{PE}=\frac{3A+5d-14t_i-3t_j+\tau_i-9\tau_j}{43}$$

The market output and price in each country are, respectively:

$$Q_i^C=\frac{87A-27d-62t_i-t_j-14\tau_i-46\tau_j}{129} \text{ and } P_i=\frac{42A+27d+62t_i+t_j+14\tau_i+46\tau_j}{129}$$

$$Q_j^C=\frac{72A-9d+8t_i-29t_j-19\tau_i-44\tau_j}{129} \text{ and } P_j=\frac{57A+9d-8t_i+29t_j+19\tau_i+44\tau_j}{129}$$

Then, we have the following welfare functions:

$$W_i=\frac{1}{11094}\begin{Bmatrix}3804A^2-7272Ad+2583d^2-5164t_i^2+4019t_j^2-t_i(904A-5402d\\+2573\tau_i)+4t_i(197A+185d+362t_j+381\tau_i-763\tau_j)+8(71A\\-412d+81\tau_i)\tau_j+1040\tau_j^2-4t_j(569A-958d-54\tau_i+443\tau_j)\end{Bmatrix}$$

$$W_j=\frac{1}{33282}\begin{Bmatrix}9(1110A^2-1804Ad-543d^2)+9526t_i^2-14477t_j^2-t_i(468A-4638d+\\895\tau_i)+4(-1053A+7662d+595\tau_i)\tau_j-14408\tau_j^2-4t_i(477A-1527d\\+641t_j+331\tau_i+719\tau_j)+t_j(6336A-6468d-6488\tau_i+6620\tau_j)\end{Bmatrix}$$

The first-order conditions to maximize welfare in each country provide the following equilibrium import tariffs and environmental taxes in the two countries:[14]

$$t_i^U=\frac{19009(A-d)}{157827},\ t_j^U=\frac{33652(A-d)}{157827},\ \tau_i^U=\frac{60307d-7698A}{52609},\ \tau_j^U=\frac{58990d-6381A}{52609} \qquad (5)$$

[13] Note that $q_{ei}^{SOE}=0$. This is also because $q_{hi}^{SOE}>q_{hi}^{PE}+q_{ei}^{PE}$ at equilibrium and thus, the government will use the SOE at home to act as a trade barrier and promote domestic market competition for reaching a higher domestic social welfare. However, the marginal production cost of the SOE is higher than that of the PE, resulting in export cost disadvantage to the SOE.

[14] For non-negative tariff and environmental tax, it should be satisfied that $7698a/60307\le d\le a$. The second-order conditions for the maximization problem are also satisfied.

Note that we obtain $t_i^U < t_j^U$ and $\tau_i^U < \tau_j^U$. That is, the privatization policy calls for a higher tariff and environmental tax between the two countries in the unilateral privatization model. The equilibrium outputs in the unilateral privatization model are $q_{hi}^{SOE}=0.401(A-d)$, $q_{ei}^{SOE}=0$, $q_{hi}^{PE}=0.197(A-d)$, and $q_{ei}^{PE}=0.078(A-d)$, while $q_{hj}^{SOE}=q_{hj}^{PE}=0.252(A-d)$ and $q_{ej}^{SOE}=q_{ej}^{PE}=0.038(A-d)$. In the home market, a comparison of the productions of the SOE's and the PE's yields $q_{hi}^{SOE}=0.401(A-d)>q_{hi}^{PE}+q_{ei}^{PE}=0.275(A-d)$. That is, in the home market, the output of the SOE is much larger than that of the PE, and the home SOE would not choose to export to the foreign country. However, the privatized SOE can export to the foreign country. In the foreign market, the import from the home country exceeds the exports to the home country. Thus, the foreign government would impose a higher tariff than that of the home government to protect its domestic firms. Conversely, the foreign government would impose a higher environmental tax to improve social welfare.

The market output and price of the two markets are $Q_i^C=0.674(A-d)$, $P_i=0.326A+0.673d$ and $Q_j^C=0.581(A-d)$, $P_j=0.419A+0.581d$, respectively. The home and foreign production of goods are $Q_i^P=0.672(A-d)$ and $Q_j^P=0.583(A-d)$, respectively. From a comparison of the outputs, we obtain $Q_i^C>Q_j^C$, $Q_i^P>Q_j^P$, and $P_i<P_j$. That is, the foreign country reduces its market output and increases its market price due to privatization.

IV. *Comparison*

In this section, we first examine the production and consumption levels, and compare the optimal tariff and environmental tax of the three models. We then consider the privatization choice game of the two countries and then examine the cooperative situation in which each country maximizes global welfare.

1. Production and Consumption

First, we provide the four combinations of equilibrium production and consumption in each model in Fig.1. Owing to symmetry, the production and consumption levels are equal under both the no privatization and bilateral privatization models, but the total product level under the no privatization model is greater than that under the bilateral privatization model; that is, $Q_i^{NC}=Q_i^{NP}=0.664(A-d)>Q_i^{BC}=Q_i^{BP}=0.585(A-d)$. This is because privatization reduces not only the production level but also the consumption level in an international mixed market. However, under the unilateral privatization model, a non-privatized country produces and consumes more goods than a privatized country. Furthermore, for non-privatized country, the consumption level is higher than the production level, but for a privatized country, the consumption level is lower than the production level; that is, $Q_i^{UC}=0.674(A-d)>Q_i^{UP}=0.672(A-d)$ for a non-privatized country and $Q_j^{UC}=0.581(A-d)<Q_j^{UP}=0.582(A-d)$ for a privatized country. This is because a privatized firm will participate in exports to increase its profits. Therefore, we have $Q_j^{UC}<Q_i^{NC}<Q_i^{BC}<Q_I^{UC}$ and $Q_j^{UP}<Q_i^{NP}<Q_i^{BP}<Q_I^{UP}$.

FIG.1. EQUILIBRIA OF PRODUCTIONS AND CONSUMPTIONS

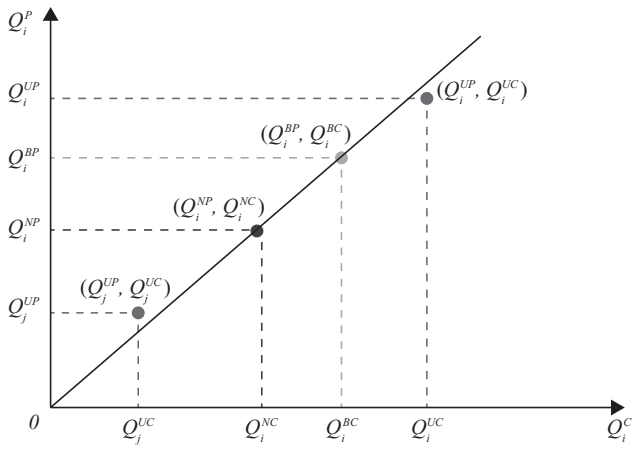
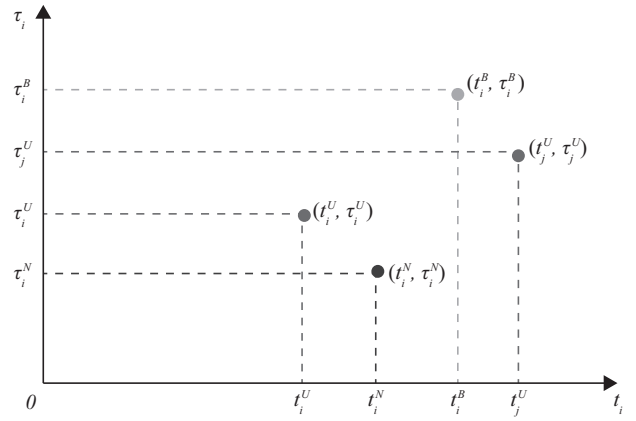


FIG.2. OPTIMAL TARIFFS AND ENVIRONMENTAL TAXES



2. Tariff and Environmental Tax

Fig.2. depicts four combinations of equilibrium tariffs and environmental taxes for each model. Note that a bilateral privatization policy reduces the local market outputs but raises the imports from the other country[15]. Both the countries will then choose to impose higher tariffs to maximize their domestic economic welfares[16]. In contrast, the unilateral privatization model

[15] The market output and imports in no privatization and bilateral privatization models satisfy the following: $Q_i^N = 0.664(A-d) > Q_i^B = 0.585(A-d)$ and $(q_{ej}^{SOE})^N + (q_{ej}^{PE})^N = 0.057(A-d) < (q_{ej}^{SOE})^B + (q_{ej}^{PE})^B = 0.116(A-d)$.

[16] Note that a reduction in tariffs can actually be welfare-reducing as long as the other country continues to impose higher tariffs.

leads to the highest tariffs for the country that privatizes its SOE to protect itself against more imports from the non-privatized country. In the non-privatized country, the profits of the SOE and PE will decrease because of the prior privatization of the other country. The non-privatized country will then lower its tariffs to attract more production from the privatized country.

Proposition 1: *Bilateral privatization leads to higher tariffs than no privatization. However, unilateral privatization calls for the highest tariff for the privatized country and the lowest tariff for the non-privatized country.*

Proof: A comparison of the optimal tariffs in the models yields, $t_i^U < t_i^N = t_j^N < t_i^B = t_j^B < t_j^U$. q.e.d.

In contrast, the privatization policy improves the firms' profits but makes them ignore environmental hazards. Thus, privatization calls for higher environmental taxes to reduce environmental damage; that is, environmental tax is monotonous in the degree of privatization.[17]

Proposition 2: *Privatization policy always calls for higher environmental taxes.*

Proof: A comparison of the optimal environmental tax in the models from equation (3), (4) and (5) yields $\tau_i^N = \tau_j^N < \tau_i^U < \tau_j^U < \tau_i^B = \tau_j^B$. q.e.d.

3. Privatization Choice Game

We consider a privatization choice game between two countries, as shown in TABLE I. When we consider a simultaneous choice game between two governments, the pure-strategy Nash equilibrium in the game is unilateral privatization, where one country chooses nationalization and the other chooses privatization.

TABLE 1. PRIVATIZATION CHOICE GAME

Country *i, j*	Nationalization	Privatization
Nationalization	$0.330(A-d)^2$, $0.330(A-d)^2$	$0.329(A-d)^2$, $0.332(A-d)^2$
Privatization	$0.332(A-d)^2$, $0.329(A-d)^2$	$0.328(A-d)^2$, $0.328(A-d)^2$

The economic reasoning is as follows: When the foreign country privatizes its public firm and both the foreign firms participate in exports, the home country should maintain its public firm to protect itself against the welfare-reducing effect of output-substitution between the privatized firm and the foreign private firm. On the other hand, if foreign country does not privatize its public firm, the privatized home firm can export its output to the foreign market, and thereby increase the profit of the domestic firms. Thus, a privatization policy should help the government increase its welfare.

[17] Naito and Ogawa (2009) showed that environmental regulation critically depends on the degree of privatization and this relationship is non-monotonous. Pal and Saha (2015) showed that environmental damage increases with the level of privatization if it is less than a certain level. However, if we are constrained to the extreme cases of no privatization and full privatization, we can have the same results in which privatization policy always calls for higher environmental taxes, even under trade policy.

This asymmetric choice is reminiscent of the pre-emption in the chicken game, with each country rushing to privatize its own SOE before the other country does[18]. Both countries might pre-commit to privatize their own SOEs, raise their tariffs, and reduce environmental taxes[19]. However, this strategic privatization policy is not globally optimal from the perspective of the global economy. This is similar to the situation with the prisoner's dilemma; each country cannot cooperate its trade, environment, and privatization policies because its strategic privatization involves less privatization, although they are jointly suboptimal[20]. In the next section, we examine how the appropriate tariffs and environmental taxes should be well-coordinated to achieve the global optimum.

V. *Discussion*

1. Global Optimum

In this section, we consider global welfare, examine a cooperative situation in which each country maximizes global welfare, and provide global policy coordination on the optimal tariffs and environmental taxes.

(1) Direct Allocation

We will examine a cooperative situation in which each country maximizes global welfare, which is defined as the sum of every country's social welfare, $\overline{W}=W_1+W_2$. Then, the global welfare is:

$$\begin{aligned}\overline{W}&=CS_i+\pi_i^{SOE}+\pi_i^{PE}+t_i(q_{ej}^{SOE}+q_{ej}^{PE})+(\tau_i-d)Q_i^P+CS_j+\pi_j^{SOE}+\pi_j^{PE}+t_j(q_{ei}^{SOE}+q_{ei}^{PE})+(\tau_j-d)Q_j^P\\&=\int_0^{Q_i^C}P(v)dv-C_i^{SOE}-C_i^{PE}-dQ_i^P+\int_0^{Q_j^C}P(v)dv-C_j^{SOE}-C_j^{PE}-dQ_j^P\\&=(a-d)\sum_{i=1}^{2}Q_i^C-\frac{1}{2}\sum_{i=1}^{2}(Q_i^C)^2-\sum_{i=1}^{2}(C_i^{SOE}+C_i^{PE})\end{aligned}$$

Proposition 3: *Under direct allocation, the global optimum is the first-best, which is*

[18] Serizawa (2000) considered single government privatization and showed that if the government uses an optimal tariff, full privatization will improve welfare. However, under a strategic privatization game with sequential choice, full privatization is not the best response; the no privatization is particularly the best response when the rival country chooses full privatization.

[19] When there are multiple equilibria, we can examine the observable delay game, formulated by Pal (1998) and Matsumura and Ogawa (2010) in a mixed duopoly market. In particular, countries simultaneously choose whether to privatize in period 1 or period 2 in the first stage. Once they choose their strategies, the three different privatization policy regimes with tariffs and environmental taxes follow in the second stage. Then, we have the symmetric probability of 2/3 that country i chooses period 1 in the mixed-strategy equilibria. That is, neither of two different unilateral privatization equilibria is risk dominant.

[20] Without considering environmental damages, Dadpay and Heywood (2006) indicated this prisoners' dilemma. Heywood and Ye (2009) showed that a similar situation exists when one takes into account the timing of moves. Even under a strategic choice of privatization, Lee, et, al. (2013) showed that international competitive equilibrium involves less privatization and a higher tariff. Dapay (2010) reported that subsidization can be a way out of this prisoners' dilemma for any country wishing to conduct a unilateral privatization policy.

independent of the regime of privatization.

Proof: We first analyze the three global welfare maximization models under direct allocation.

1) In the no privatization model, we have $Q_i^C = q_{hi}^{SOE} + q_{ej}^{SOE} + q_{hi}^{PE} + q_{ej}^{PE}$. The differentiation of $\overline{W}$ with respect to the output of the home and foreign country SOEs and PEs yields $q_{hi}^{SOE} + q_{ei}^{SOE} = q_{hi}^{PE} + q_{ei}^{PE} = \frac{A-d}{3} i = 1, 2$. Substituting the optimal output, we obatin the maximized global welfare, $\overline{W}^{GN} = \frac{2}{3}(A-d)^2$.
2) In the bilateral privatization model, both the home and foreign governments privatize their SOEs, and thus we have $Q_i^c = 2(q_{hi}^{PE} + q_{ej}^{PE})$. The differentiation of $\overline{W}$ with respect to the output yields $q_{hi}^{SOE} + q_{ei}^{SOE} = q_{hi}^{PE} + q_{ei}^{PE} = \frac{A-d}{3} i = 1, 2$. Substituting the optimal output, we obatin the same maximized global welfare, $\overline{W}^{GB} = \frac{2}{3}(A-d)^2$.
3) In the unilateral privatization model, there are two PEs in the foreign country, and we have $Q_i^C = q_{hi}^{SOE} + q_{hi}^{PE} + 2q_{ej}^{PE}$ and $Q_j^C = q_{hj}^{SOE} + 2q_{hj}^{PE} + q_{ei}^{PE}$. The differentiation of $\overline{W}$ with respect to the output yields $q_{hi}^{SOE} + q_{ei}^{SOE} = q_{hi}^{PE} + q_{ei}^{PE} = \frac{A-d}{3} i = 1, 2$. Substituting the optimal output, we obatin the same maximized global welfare, $\overline{W}^{GU} = \frac{2}{3}(A-d)^2$.

Therefore, the first-best allocation, which is the maximized global welfare, $\overline{W}^G = \frac{2}{3}(A-d)^2$ is independent of the regime of privatization. q.e.d.

(2) Indirect Allocation

We now consider a cooperative situation in which two countries use tariffs and environmental taxes to achieve the global optimum. Under the indirect allocation approach, we restrict our attention to non-negative environmental taxes,[21] assuming that $\frac{1}{4}A < d < A$. That is, we consider the case in which environmental damage to the global economy is serious.

Proposition 4: *Under indirect allocation, both governments achieve the global optimum irrespective of the regime of privatization, but they need to adjust their tariffs and environmental taxes accordingly.*

Proof: We analyze the three global welfare maximization models under indirect allocation through tariffs and environmental taxes.

1) The no privatizationmodel provides the following global welfare:

[21] If $0 < d < A/4$, the globally cooperative government should provide a subsidy (negative tax) to firms, instead of imposing an environmental tax, in order to achieve the first-best. For a discussion on the optimal subsidy, see the recent discussions in Lee (1999) and Lee and Park (2011), among others.

$$\overline{W}^{N}=\frac{1}{405}\begin{Bmatrix}10(26A^2-47Ad+8d^2)-40t_i^2-40t_j^2-\tau_i(25A-155d+82\tau_i)+t_i(5A+50d+\\10t_j+22\tau_i-77\tau_j)+(-25A+155d+34\tau_i)\tau_j-82\tau_j^2+t_j(5A+50d-77\tau_i+22\tau_j)\end{Bmatrix}$$

Assuming non-negative environmental tax, we obtain the following optimal tariff and environmental tax: $t_i^{GN}=t_j^{GN}=\frac{A-d}{3}$ and $\tau_i^{GN}=\tau_j^{GN}=\frac{4d-A}{3}$. Note that the global optimum in the no privatization model requires no trade at equilibrium: $q_{hi}^{SOE}=q_{hi}^{PE}=\frac{A-d}{3}$, $q_{ei}^{SOE}=q_{ei}^{PE}=0$, $i=1, 2$. That is, the global optimum leads to a closed economy in which the government sets higher tariffs to block exports and sets an appropriate environmental tax to achieve the maximized global welfare: $\overline{W}^{GN}=\frac{2(A-d)^2}{3}$.

2) The bilateral privatization model provides the following global welfare:

$$\overline{W}^{B}=\frac{1}{11025}\begin{Bmatrix}-1391t_i^2-1391t_j^2-50t_j(9A-63d+76\tau_i-22\tau_j)+100[18A(4A-7d)-38\tau_i^2+(-9A\\+63d-38\tau_j)\tau_j+\tau_i(-9A+63d+22\tau_j)]+t_i[1432t_j-50(9A-63d-22\tau_i+76\tau_j)]\end{Bmatrix}$$

Assuming non-negative environmental tax, we obtain the following optimal relationship between tariffs and environmental taxes: $t_i^{G}+2\tau_i^{G}=\frac{7d-A}{3}$. Note that the relationship is negative for maximizing global welfare.[22] In particular, $t_i^{GB}=t_j^{GB}=\frac{7d-A}{3}$ when there is no environmental tax, that is, $\tau_i^{GB}=\tau_j^{GB}=0$, while $\tau_i^{GB}=\tau_j^{GB}=\frac{7d-A}{6}$ when there is no tariff, that is, $t_i^{GB}=t_j^{GB}=0$. This result will be discussed in the next section. The equilibrium outputs are $q_{hi}^{PE}+q_{ei}^{PE}=\frac{A-d}{3}$, $i=1, 2$. Therefore, the global optimum leads to an open economy in which both the domestic firms export their products to the foreign country in the bilateral privatization model. Finally, the maximized global welfare is the same as with $\overline{W}^{GB}=\frac{2(A-d)^2}{3}$.

3) The unilateral privatization model provides the following global welfare:

$$\overline{W}^{U}=\frac{1}{16641}\begin{Bmatrix}9(1189A^2-2114Ad+159d^2)-2893t_i^2-1210t_j^2-2\tau_i(561A-2892d\\+1706\tau_i)+2t_i(114A+2082d+445t_j+812\tau_i-3008\tau_j)+2(-627A\\+5190d+1081\tau_i)\tau_j-5644\tau_j^2+t_j(-246A+2514d-2920\tau_i+652\tau_j)\end{Bmatrix}$$

Assuming non-negative environmental tax, we obtain the following optimal tariff and environmental tax: $t_i^{GU}=t_j^{GU}=\frac{A-d}{3}$ and $\tau_i^{GU}=\tau_j^{GU}=\frac{4d-A}{3}$. Note that the global optimum in the unilateral privatization model also requires no trade; a closed economy at equilibrium:

[22] Note that the optimal tariff and environmental tax in the no privatization model satisfy the optimal conditions in the bilateral privatization model. That is, if we set $t_i^{GB}=t_j^{GB}=(A-d)/3$ and $\tau_i^{GB}=\tau_j^{GB}=(4d-A)/3$, it will also satisfy that $t_i^{G}+2\tau_i^{G}=(7d-A)/3$. Thus, the bilateral privatization model can also lead to a closed economy.

$q_{hi}^{SOE}=q_{hi}^{PE}=\frac{A-d}{3}$, $q_{ei}^{SOE}=q_{ei}^{PE}=0$, $i=1, 2$. This can also lead to the maximized global welfare $\overline{W}^{GU}=\frac{2(A-d)^2}{3}$. q.e.d.

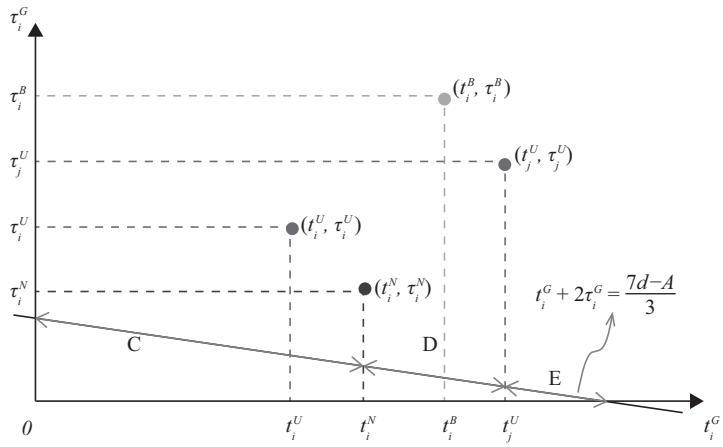
Proposition 4 indicates the same maximized global welfare in the three models: $\overline{W}^{GN}=\overline{W}^{GB}=\overline{W}^{GU}=\frac{2}{3}(A-d)^2$. Thus, privatization does not matter for the global optimum. However, there would be no trade in both no privatization as well as unilateral privatization regimes. This implies that in bilateral privatization, it has more feasibility to achieve the global optimum in an open economy as long as the tariffs and environmental taxes are well-adjusted. However, as shown in TABLE I, if each country considers only its own maximized domestic welfare under bilateral privatization, it would result in lower welfare to both countries. That is, $W_i^B=0.328(A-d)^2<W_i^{GB}=0.333(A-d)^2$. Therefore, the appropriate tariffs and environmental taxes should be well-coordinated to achieve the global optimum.

2. Policy Coordination

We now examine the policy coordination of tariffs and environmental taxes, and offer some policy suggestions on global welfare. In particular, when $\frac{1}{4}A<d<A$, Fig.3 provides the global optimum conditions of tariffs and environmental taxes under bilateral privatization, $t_i^G+2\tau_i^G=\frac{7d-A}{3}$, and the equilibrium points of tariffs and environmental taxes in the three cases of privatization. Note that the equilibrium of the privatization choice game is unilateral privatization and the global optimum can be achieved at the global optimum conditions of tariffs and environmental taxes under bilateral privatization.

Non-privatized country i can reduce its tariffs as well as environmental taxes in region C,

FIG.3. COORDINATION BETWEEN OPTIMAL TARIFFS AND ENVIRONMENTAL TAXES



which might be politically acceptable to its importers and polluters, but it will have to raise its tariffs in regions D and E. On the other hand, privatized country *j* will have to raise its tariffs in region E or reduce its tariffs and environmental taxes in regions C and D. From a comparison of these asymmetric situations, we make three policy suggestions to improve global welfare.

1) Region C: Both the countries should lower their tariffs and environmental taxes simultaneously to achieve the global optimum conditions of tariffs and environmental taxes under bilateral privatization, $t_i^G+2\tau_i^G=\frac{7d-A}{3}$. Note that the free trade policy will be feasible for the two countries, where $t_i^{GB}=t_j^{GB}=0$, but the environmental tax will have to be the highest, $\tau_i^{GB}=\tau_j^{GB}=\frac{7d-A}{6}$.
2) Region D: Privatized country *j* will have to lower its tariffs as well as environmental taxes, but the non-privatized country *i* will have to raise its tariffs but lower its environmental taxes.
3) Region E: Both the countries should cooperate with each other and lower their environmental taxes, but they will have to raise their tariffs. Note that it includes the case that there would be no environmental taxes, $\tau_i^{GB}=\tau_j^{GB}=0$, but the tariff will be the highest, $t_i^{GB}=t_j^{GB}=\frac{7d-A}{3}$.

In region C, the trade policy and environment taxes in both countries are positively related. Therefore, both countries should lower their import tariff and environmental tax levels simultaneously. Thus, this region is more acceptable to the importers and polluters of both countries politically. In region D, the trade policy and environment taxes are positively related in the privatized country, but negatively related in the non-privatized country. Finally, in region E, the trade policy and environment taxes are negatively related in both countries. Particularly, if both the governments implement free trade or the no environmental tax policy, both the governments will have to raise their other taxes to improve global welfare.

VI. *Conclusion*

This paper considered the privatization policies of two countries with tariffs and environmental taxes in an international mixed duopoly framework in which a public firm in the home country competes with a foreign public firm as well as domestic and foreign private firms. We particularly examined the strategic interaction between the two governments under three different privatization policies regimes — no privatization, bilateral privatization, and unilateral privatization — with a comparison of the equilibrium tariffs, environmental taxes, and social welfare of the regimes. We show how a bilateral relationship in an open economy is important for the competing governments when they have to decide on tariffs and environmental taxes. Some of our findings are summarized below:

First, while a bilateral privatization leads to higher tariffs than the no privatization, unilateral privatization calls for the highest tariff in a privatized country and the lowest tariff in a non-privatized country. However, more privatization would worsen the environmental quality and thereby lead to higher optimal environmental taxes.

Second, unilateral privatization is the Nash equilibrium of the privatization choice game. If

the environmental damage is serious, the global optimum will be independent of the privatization regimes and the two governments will have to adjust their tariffs and environmental taxes accordingly.

Finally, when the equilibrium in a privatization choice game involves less privatization, a need would arise for global policy coordination on tariffs and environmental taxes. In particular, if the two governments agree to free trade, both the governments will have to adjust their other regulatory instruments (environmental tax or subsidy) to improve global welfare.

This paper does have some limitations. First, we did not consider the effect of partial privatization. Second, we used linear demand and cost functions for tractability. Third, the number of private firms needs to be managed. The extensions for the specification on these problems should be examined to achieve robust results. Finally, it would be worthwhile to consider the other trade policies, such as an export-subsidy or a combination of a subsidy and import tariff, when coordinating the optimal policy combinations on privatization, international trade, and environmental regulation.

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