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最適關稅與環保政策組合

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【摘要】

本文以兩階段、雙占模型探討政府所面臨的關稅與環保政策組合，並推導出三種可能出現的最適政策體制。最適關稅跟環保標準有可能同時為正值，另外，也有可能出現污染補貼與關稅，或是進口補貼與環保標準的組合。嚴格環保標準出現的一個前提是要有足夠的壟斷租金。本文同時也推導出子博奕完美的成本效益政策法則並顯示有二十八種不同的政策區間，這些不同的區間主要是由公共污染、公司污染成本以及非污染成本等三個關鍵參數所共同決定。每個政策區間分別顯示出關稅成本效益大於、等於或是小於環保成本效益，也就是對政府而言，那個政策的租金移轉功能比較強。

關鍵字：策略性貿易政策、岐視性關稅、雙占、 外部性

Optimal Environmental Policy and Tariffs

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【Abstract】

We discuss a model where the government is faced with a choice of an optimal policy mix of environmental standards and tariffs. We show that there are three possible combinations of optimal policy portfolio, namely positive tariffs and environmental standards, pollution subsidies and tariffs, import subsidies and positive environmental standards. Regardless of the types of policy portfolio, a stricter environmental standard can be sustained by a sufficiently large monopoly rent. We derive the subgame perfect benefit and cost policy rule and show there are multiple policy regions through the interplay of abatement technology, non-abatement technology, and public abatement parameters. Each policy region suggests whether the tariff benefits/costs dominate, or are dominated, by the environmental benefits/costs, i.e. which instrument is ultimately more effective for government rent-shifting purpose.

Key Words： Strategic Trade Policy; Discriminatory Tariffs; Duopoly; Externality

JEL Classification：F12; Q28; D23

1. Introduction

A recent development relevant to the strategic trade policy discussions has being staged in the strategic environmental policy literature.[1] Since most trade policies are governed under WTO or other regional treaties, the status of environmental policy has received increasing attentions and, from a strategic viewpoint, it could potentially function as an industrial or trade policy in disguise. Barrett (1994), Kennedy (1994), Conrad (1993), Rauscher (1994), Ulph (1992, 1996), Markusen (1993, 1995), Nannerup (1998), and Duval and Hamilton (2002) all constructed two-stage model with two governments and two (or N) firms. Basically, these are variants of the Spencer and Brander (1983) and Brander and Spencer (1985) models, as opposed to the general equilibrium models of trade and environment discussed in Copeland and Taylor (2005). The government faces only the choice of environmental policy because tariffs are assumed to be unavailable in a free trade world. Imperfect competition and negative externality are two notable features. They suggested that government might have an incentive to rely on environmental policy for rent-shifting purpose as tariffs are no longer available. This brings up the environmentalist argument that governments may relax their environmental standards in order to gain a competitive advantage in the international

[1] See Helpman and Krugman (1989), Chang and Katayama (1992) for a review of the strategic trade literature, Grossman (1992), Chang and Katayama (1995), for a collection of papers., and Lai (1996) for a discussion of policy implications under multiple imperfections.

markets. Again, imperfect competitive market structure, together with externality, provides the raison d'être for a protectionist policy stemming from the environmental perspective. Interventionalist policies under single imperfection have been double-checked for their robustness under the context of multiple imperfections.

This paper considers the situation where there are international duopolistic firms that produce a homogeneous product. Some sort of local pollution is being created during the process of production. In contrast to the strategic environmental policy literature, which focuses predominately on the free trade context, this paper considers the case when both tariffs and environmental policies are available based on a couple of reasons. First, we are interested in comparing which instrument is more effective for government rent-shifting purpose. According to environmentalist argument, environmental policy is ineffective for rent-shifting purpose and government will not consider using it when tariffs are available. This has been a focus of some researches. For example, in an empirical study by Ederington & Minier (2003), they discussed whether environmental policies are secondary trade barriers. Our analysis addresses the relative effectiveness of tariffs vs. environmental policies in terms of their rent-shifting function and thus directly confronts this part of discussions, i.e. whether environmental policies could edge out tariffs as rent-shifting instruments. Second, assuming tariffs are still available, our model could shed light on policy issues faced by some recently "graduated" economies such as Taiwan and South Korea, as well as other South East Asian countries where environmental issues have been receiving increasing attentions. Unlike the developed and less developed countries, environmental policies, as well as tariffs, are policy decisions faced by governments in these newly graduated and developing economies. In the absence of free trade deal or harmonization of standards, each country will solve its own optimum policy mix. However, if free trade deal or harmonization of standards are tailor made to one type of country and requires a great deal of adjustments from other types of countries, then free-trade or harmonization of standards could potentially create unequal footing problem as some countries have to accept policies or standards that are very different from their original optimum.

Under this setup, the home country has an incentive to set its environmental standards at the level where marginal environmental benefit due to a cleaner environment is equal to marginal abatement cost plus marginal loss in consumer surplus. In addition, the government also has an incentive to impose import tariffs so that marginal gain of the domestic firm plus marginal increase in government revenue would be equal to marginal loss in consumer surplus. Thus, higher tariffs and stricter environmental standards are equivalent in terms of increasing government revenue/public welfare and reducing consumer surplus, while they work in the opposite directions in affecting the relative market share between domestic and foreign firms. In this paper, we are mainly concerned with the optimal policy portfolio of the domestic government.

We find the case of positive tariffs and environmental standards can be sustained where there is a substantial monopoly rent. In the case when the monopoly rent is low, the government could resort to pollution subsidies to alleviate the thin margin problem suffered by its domestic firm. Alternatively, when domestic firm suffers a high marginal cost, after accounting for external environmental benefit, from the imposing of environmental regulations, the government would instead opt for import subsidies to satisfy the consumer demand in its domestic market. Overall, there can be three types of policy regime: positive environmental standards and tariffs, pollution subsidies and tariffs, and positive environmental standards and import subsidies. In contrast to the Schumpeterian argument, which suggested that monopoly rent provided the support for R&D, we show that monopoly rent acts a cushion for stricter environmental standards. Intuitively, the efficiency loss due to the imposing of stricter environmental standards is smaller when there is a large monopoly rent. Monopoly rent and net marginal abatement benefit/cost (as defined in later discussions), which in turn are underpinned by demand, cost and abatement parameters, turn out to be two key factors that affect the signs of policy variables.

We also find the optimality condition in environmental economics could have been violated. This suggests the optimality condition is not necessarily appropriate for evaluating the effectiveness of environmental policy in a world where there are multiple policy considerations, as any single-minded policy purpose will have to be balanced against another, likely very different kind of policy purpose. In addition, we derive various benefit and cost policy regions as defined by abatement cost, non-abatement cost, and externality parameters. Each policy region suggests whether environment benefits (costs) dominate, or are dominated, by tariff benefits (costs). These policy regions present a clear supply side picture regarding the factors that affect the policy weights, i.e., which instrument is ultimately more effective for government rent-shifting purpose.

Our focus on one country policy making when faced with environmental externalities is closer to Vandendorpe (1972), Markusen (1975), and Krutilla (1991). We follow the strategic environmental policy literature in adopting a stage game approach. Specifically, we follow the Barrett formulation in its private abatement cost function.[2] From a methodological perspective, this paper is connected with the discriminatory tariffs literature. There have been discussions centered around the policy implications of discriminatory tariffs and the 'Most Favored Nation' (MFN) clause. Gatsios (1990), Hwang and Mai (1991), Choi (1995), and Liao and Wong (2006) investigated optimal discriminatory tariffs when two foreign firms are located in different foreign countries. One of their major concerns is the possibility that the tariffs imposed on a low-cost firm will be higher than those on a high-cost firm. Intuitively, a low-cost firm offers more rent for a rent-driven government, thereby justifying higher tariffs. We make the observation that there is an analytical similarity between the problem of discriminatory tariffs as discussed in Hwang and Mai (1991), and the benefits and costs problem relating to environmental policies and tariffs. Since discriminatory tariffs are two policies imposed on two different firms, we can interpret the environmental policies as tariffs in disguise since it collects revenue, i.e. public welfare, for the government and is a cost borne by one

[2] The abatement cost function is the one that has been followed in literature of environmental policy, for example, Baumol and Oates (1988), among others.

of the duopolistic firms. Seeing from this perspective, our formulation of environmental standards can also be interpreted, when necessary, as environmental taxes or pollution subsidies. The additional complication here is that the domestic firm's profit function is included as part of the government's welfare function. It turns out that the inclusion of the firm's profit function does not matter much and the mathematical structures of these two problems are quite similar.

The format of this paper is as follows. Section 2 sets up the Cournot competition model with two firms. Section 3 presents the second stage optimal solutions and comparative statics. Section 4 and 5 cover the first stage results, three different policy regimes, and subgame perfect benefit and cost policy rule. In Section 6, we draw the conclusions.

2. The Model

There are two firms that produce a homogeneous product. Denote the domestic product as x_1 and foreign product as x_2, respectively. The domestic government faces the unilateral choice of two policy variables, tariff policy t, and environmental standard e, for the maximization of country's welfare. Structurally, the setting is a two-stage game with the domestic government maximizing its social welfare in the first stage and the two firms each maximizing their profits in the second stage. By solving the game backwards, we could derive three different policy regimes and the subgame perfect policy rule.

The government wishes to find an optimal value for its tariff policy since higher tariffs will increase tariff revenue and the competitiveness of its domestic firm at the cost of the forgone consumer surplus.[3] For this government, an optimal value for the environmental standard is also desirable since raising its environmental standards will decrease the environmental damage at the cost of a decreased market share of the domestic firm and consumer surplus. As mentioned in the introduction section, the environmental standard formulated here is quite general, and can also be interpreted as environmental taxes or subsidies.

Assume that there are two different technologies in the production process, an abatement related technology for the domestic firm only and a non-abatement technology for both firms. It follows that there are two different kinds of cost function. Let $C(x_1)$ and $C^*(x_2)$ denote the non-abatement cost functions for domestic and foreign firms, respectively, and $A(e, x_1)$ denotes the abatement cost function of the domestic firm. A higher e stands for stricter environmental standards, or higher taxes, thus, $A_e > 0, A_{x_1} > 0$ and $A_{ex_1} > 0$. The environmental standards are assumed to be binding on the firm's production process. This cost function is the same one used in

[3] Our discussion is limited to the case of a specific tariff. As pointed out by Mai and Hwang (1991), results will change in the case of ad valorem tariffs.

Barrett (1994) except we define higher e as stricter rather than looser standards. For illustration purposes, we could assume for the moment a linear abatement cost function $\eta e x_1$, where $\eta > 0$.[4] This form of abatement cost function follows directly from the assumption of constant returns to scale in abatement related technology.[5] Thus it follows that η is a function of factor prices.

We formulate the public environmental benefit function as $N(e, x_1)$. Since a higher value of e stands for stricter environmental standards, we have $N_e > 0$ and $N_{x_1} < 0$. The pollution considered here is production related only. In Barrett (1994), matters are simplified as N_{x_1} is assumed to be equal to zero. In the following, we will bring up that simplification when it helps to clarify some policy issues. The inverse demand in the domestic market is $P(X)$, where $X = x_1 + x_2$. Let π_1 and π_2 denote the profits for the domestic and foreign firms. At the second stage, firms maximize their profits by choosing output simultaneously, with the policy variables taken as given.

[4] Alternatively, we can interpret η as a tax or subsidy parameter.
[5] Conrad (1993) suggested the firm's aggregate abatement technology is constant returns to scale.

3. Second Stage Results

At the second stage, the domestic and foreign firms face the following maximization problems:

$$\max_{x_1} \pi^1 = x_1 P(X) - C(x_1) - A(e, x_1) \tag{1}$$

$$\max_{x_2} \pi^2 = x_2 P(X) - C^*(x_2) - tx_2 \tag{2}$$

By differentiating with respect to each firm's output, we obtain the following first order conditions:

$$\pi^1_{x_1} = P_x x_1 + P - C_{x_1} - A_{x_1} = 0 \tag{3}$$

$$\pi^2_{x_2} = P_x x_2 + P - C_{x_2} - t = 0 \tag{4}$$

The solutions of equations 3 and 4 can be written as $x_1 = f_1(e,t)$, and $x_2 = f_2(e,t)$. Assuming both the second order and stability conditions are satisfied, we can derive the following comparative statics by total differentiating equations 3 and 4 with respect to domestic output, foreign output, tariff, and environmental standard:

$$\frac{\partial x_1}{\partial e} = f_1^1 = \frac{A_{x_1 e}\pi^2_{x_2 x_2}}{D} = \frac{A_{x_1 e}}{D}(P_{XX} x_2 + 2P_X - C^*_{x_2 x_2}) < 0 \tag{5}$$

$$\frac{\partial x_2}{\partial e} = f_2^1 = -\frac{A_{x_1 e}\pi^2_{x_2 x_1}}{D} = -\frac{A_{x_1 e}}{D}(P_{XX}x_2 + P_X) > 0 \tag{6}$$

$$\frac{\partial x_1}{\partial t} = f_1^2 = -\frac{\pi^1_{x_1 x_2}}{D} = -\frac{1}{D}(P_{XX}x_1 + P_X) > 0 \tag{7}$$

$$\frac{\partial x_2}{\partial t} = f_2^2 = \frac{\pi^1_{x_1 x_1}}{D} = \frac{1}{D}(P_{XX}x_1 + 2P_X - C_{x_1 x_1} - A_{x_1 x_1}) < 0 \tag{8}$$

$$\frac{\partial X}{\partial e} = \frac{A_{x_1 e}}{D}(P_X - C^*_{x_2 x_2}) < 0 \tag{9}$$

$$\frac{\partial X}{\partial t} = \frac{1}{D}(P_X - C_{x_1 x_1} - A_{x_1 x_1}) < 0 \tag{10}$$

where $D = \pi^1_{x_1 x_1}\pi^2_{x_2 x_2} - \pi^1_{x_1 x_2}\pi^2_{x_2 x_1} > 0$, assuming that stability conditions are satisfied.

Equations 5 to 10 have some straightforward explanations. Since environmental standards are regarded as a cost imposed on the domestic firm, higher environmental standards will decrease domestic production and increase foreign production due to the duopoly assumption, as suggested by equations 5 and 6. Similarly, since tariffs are a cost imposed on the foreign firm, higher tariffs will decrease foreign production, and domestic production will increase due to the duopoly assumption, as suggested by equations 7 and 8. Finally, equations 9 and 10 simply say that total output will decrease when domestic or foreign firm's costs increase.

By total differentiating equations 3 and 4 with respect to x_1 and x_2, we can obtain the reaction functions $x_1 = g_1(x_2)$ and $x_2 = g_2(x_1)$. These two reaction functions are the standard reaction functions under Cournot competition, which are assumed to be downward sloping.

4. First Stage Results: Two Critical Sets of Parameters and Three Different Regimes

Now consider the first stage game when a central government chooses its tariff and environmental policy to maximize its domestic welfare. The second stage results, such as the first order conditions and comparative statics, i.e. equations 3 to 10, will be taken into account as the government solves the following maximization problem:

$$\max_{t,e} \quad W = \int_0^X P(v)dv - PX + tx_2 + N(e,x_1) + P(X)x_1 - C(x_1) - A(e,x_1) \tag{11}$$

The first and second term stand for consumer surplus, the third term is tariff revenue, the fourth term is public abatement benefits, and the remaining terms are the domestic firm's profits. We can obtain the optimum value of tariff and environmental standard by differentiating this welfare function with respect to tariff and environmental standard. The first order conditions at the government level are:

$$W_t = -XP_t + tx_{2t} + x_2 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1t} + x_1 P_t = 0 \tag{12}$$

$$W_e = -XP_e + tx_{2e} + Sx_1 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1e} + x_1 P_e = 0 \tag{13}$$

where $S = L - R$ and $L = \dfrac{N_e}{x_1} > 0$, $R = \dfrac{A_e}{x_1} > 0$

L is the per unit marginal public abatement benefit (*MPUAB*) and *R* is the per unit marginal private abatement cost, (*MPRAC*), i.e. the parts of marginal benefit and cost that are not directly related to changes in output. $S = L - R$ is the difference between the *MPUAB* and the *MPRAC*, and is therefore the per unit net marginal abatement benefit (*NMAB*). When that value turns negative, *S* is better understood as positive net marginal abatement cost, which could mean that the private sector is suffering from the high costs imposed by environmental regulations. Alternatively, we can rewrite equations 12 and 13 as equations 14 and 15, respectively:

$$MTG - MTL = 0 \tag{14}$$

$$MEG - MEL = 0 \tag{15}$$

where

$$MTG = tx_{2t} + x_2 + (P - C_{x_1} - A_{x_1})x_{1t}$$

$$MTL = XP_t - x_1 P_t - N_{x_1} x_{1t}$$

$$MEG = N_{x_1} x_{1e} + Sx_1 + tx_{2e}$$

$$MEL = XP_e - x_1 P_e - (P - C_{x_1} - A_{x_1}) x_{1e}$$

Equation 14 says the marginal gain from imposing higher tariffs (*MTG*), which includes marginal tariff revenue and marginal gain in firm's surplus, should be equal to marginal loss in consumer surplus and environmental benefits (*MTL*). Equation 15 says the marginal gain from imposing stricter environmental standards (*MEG*), which includes the marginal gain in environmental benefits and tariff revenue, must be equal to the marginal loss in consumer surplus and domestic firm's profits (*MEL*). In equation 15, when all indirect effects due to changes in output vanish, per unit marginal public abatement benefit, the *MPUAB* (*L*), is equal to per unit marginal private abatement cost, the *MPRAC* (*R*), i.e. *S* is equal to zero. This is the optimality rule in environmental economics, and was referred by Barrett (1994) as the environmentally optimal emission standards (*EOSs*). In a world where strategic interactions between government and firms, as well as among firms, are largely missing, and where environmental policy is the sole policy concern, this condition could potentially serve as the criterion for evaluating the effectiveness of environmental policy, i.e. whether environmental regulations are too weak or too strict.

Assume that second order conditions and stability conditions for welfare maximization also hold, we could then solve for the optimum value of tariffs and environmental standards, respectively. Substituting equations 3-10 into equation 12 and

13 and solving simultaneously, we can obtain the optimal level of tariff and environmental standard:

$$t = -x_2 (P_X - C^*_{x_2 x_2}) - P_{XX} (\frac{S}{A_{x_1 e}} x_1^2 + x_2^2) - \frac{S}{A_{x_1 e}} P_X x_1 \tag{16}$$

$$A_{x_1} - N_{x_1} = \frac{S}{A_{x_1 e}} x_1 (P_X - C_{x_1 x_1} - A_{x_1 x_1}) + P_{XX} (\frac{S}{A_{x_1 e}} x_1^2 + x_2^2) + \frac{S}{A_{x_1 e}} P_X x_1 + (P - C_{x_1}) \tag{17}$$

The left-hand side of equation 17 is the sum of internal and external marginal environmental cost that are directly related to output, where A_{x_1} stands for private marginal abatement cost, and $-N_{x_1}$ stands for public marginal abatement cost, i.e. the flip side of public marginal abatement benefit. Under the case of linear public and private environmental cost, equation 17 is the optimal environmental standard multiplied by a positive constant. If the second term is, as assumed in Barret (1994), equal to zero, the left-hand side reduces to just one term, the marginal private abatement cost. Under that scenario, the left-hand side of equation 16 are the costs borne by foreign firm, while the left-hand side of equation 17 are the costs borne by domestic firm, that are due to the imposing of policies. Clearly, $(P_X - C^*_{x_2 x_2})$, and $(P_X - C_{x_1 x_1} - A_{x_1 x_1})$ are negative by the first-stage stability conditions.

The signs of policy variables depend on the usual concavity and convexity of demand, the elasticity of cost conditions, and other demand and supply conditions that normally arise in the context of international trade literature. Under this setup, however, there are two novel factors that are critical to the signs of policy variables and deserve some special attentions: the value of *S*, the *NMAB*, and the final term of equation 17, the monopoly rent, or more precisely, the duopoly rent. Both factors, in turn, are underpinned by demand, cost and abatement parameters. Whether optimal tariffs and public environmental standards are positive or negative thus will depend on the sign of P_{XX}, which measures the concavity and convexity of the demand function, the net marginal abatement benefit, *NMAB*, and the monopoly rent. It thus follows that optimum tariffs are positive if the demand is linear or concave, and S is positive, or at least not very negative. Both are quite general assumptions and can be easily satisfied. The relationship between demand conditions and tariffs here are similar to those obtained in Brander and Spencer (1984a, 1984b) and Hwang and Mai (1991). Furthermore, the optimal environmental standards will also be positive as long as the final term in equation 17 greatly outweighs all other terms. This will be the case if the optimal price level lies well above the optimal cost level, i.e., a case when the monopoly power is substantial.

Overall, there are three possible cases, the positive tariffs and environmental standards, the import subsidies and positive environmental standards, and the positive tariffs and pollution subsidies. The possibility of import subsidies and pollution subsidies can be ruled out as shown in Appendix A. After all, it makes no sense for a government to subsidize both domestic and foreign firm such that competition between firms cancels out much of the effects of both subsidies. In contrast, the case of positive tariffs and environmental standards is likely to be vindicated by empirical cases since stricter environmental standards could potentially increase environmental benefits, after deducting the costs that they impose, while positive tariffs can decrease the competitive disadvantage suffered by the domestic firm. Other things equal, the government tends to impose stricter environmental standards when there is a large monopoly rent. In contrast to the Schumpeterian argument, which suggested that monopoly rent provides support for R&D, this results here indicate that monopoly rent acts as a cushion for stricter environmental standards.

Aside from monopoly rent, another key factor that is crucially relevant to the signs of policy variables is *S*, the *NMAB*. By rearranging the first order conditions in a different way, we can derive the following condition that helps to see things from a different perspective. Assuming that $0 < P_t < 1$ as discussed in Brander and Spencer (1984a, 1984b), we can derive the following inequality:

$$x_2 P_e + \frac{(1-P_t)x_2 x_{1e}}{x_{1t}} < Sx_1 < x_2 P_e + \frac{(1-P_t)x_2 x_{2e}}{x_{2t}} - (1-K)(P - C_{x_1})x_{1e} \quad (18)$$

where $K = \frac{x_{1t}x_{2e}}{x_{2t}x_{1e}}$, and $0 < K < 1$

A detailed derivation is contained in Appendix A. As long as the *NMAB* lies in some medium range, we can have positive optimum tariffs and environmental standards. If the value of *NMAB* is higher than the upper bound on equation 18, we are in the case of positive tariffs and pollution subsidies. If instead, the value of *NMAB* lies below the lower bound, we enter the case of import subsidies and positive environmental standards. When the value of *S* is high relative to the monopoly rent, the domestic government cannot afford to impose strict environmental standards due to the thin profit margin suffered by its domestic firm, and could instead provide pollution subsides so that the domestic firm could at least stay competitive. On the contrary, when the value of *S* is quite low or negative, the domestic firm faces a high marginal cost due to environmental regulations, and the government may instead rely on import subsidies to satisfy its domestic consumer demand.

In the positive tariffs and pollution subsidies regime, for example, much focus has been placed on enhancing domestic firm's international competitiveness through the support of import tariffs and pollution subsidies at the costs of worsening the environment. In recent decades, as China defied expectations again and again and made marvelous progress in its increases in living standards, it has also imposed enormous demand on its environment, thereby casting doubts on whether its manufacturing powerhouse model can be sustained in the long run, an issue that has become a prime focus in numerous editorials, such as Stiglitz (2006), among others. In contrast, in the case of import subsidies and positive environmental standards, government makes great endeavors in safeguarding its environment through scarifying its interests in industrial sector. The case of Alaska oil drilling could be a case in point as much policy debates have been centered on whether the US should allow for more oil drilling in Alaska, thereby lessening its dependence on foreign oil imports, as discussed in Barro (2000). Although the case of import subsidies is rarely seen in practices, a strong currency/dollar policy that helps to bring in more imports and create current account deficit is perhaps a different policy tool with similar underlying policy purpose. In addition, equation (18) can also be expressed as:

$$\frac{1-P_t}{P_e}\frac{x_{1e}}{x_{1t}} < \frac{Sx_1}{x_2 P_e} - 1 < \frac{1-P_t}{P_e}\frac{x_{2e}}{x_{2t}} - (1-K)(P - C_{x_1})\frac{x_{1e}}{x_2 P_e} \tag{19}$$

where the lower bound can be expressed as relative price response multiplied by relative quantity response of domestic output, while the first term of upper bound can be expressed as the relative price response multiplied by relative quantity response of foreign output.

Alternatively, we can also express equation (17) as

$$h(e) = P - C_{x_1} - A_{x_1} + N_{x_1}$$

$$= -\frac{S}{A_{x_1 e}} x_1 (P_X - C_{x_1 x_1} - A_{x_1 x_1}) - P_{XX}(\frac{S}{A_{x_1 e}} x_1^2 + x_2^2) - \frac{S}{A_{x_1 e}} P_X x_1 \tag{20}$$

Since optimal tariffs are actually the marginal rent earned by the domestic government from the increase in foreign output, as shown on Figure 1, the function *h(e)* indicates the marginal rent earned by the domestic government from the increase in domestic output, as shown on Figure 2. Again, the sign of *h(e)* and the sign of the optimum tariffs are determined by demand and cost conditions, as well as public and private abatement benefit and cost parameters.

5. The Subgame Perfect Benefit and Cost Policy Rule

Equations 16 and 17 can be used to derive the subgame perfect policy rule.[6] Mathematically, these are similar to the discriminatory tariffs derived in Hwang and Mai (1991). By summing up equations 16 and 17 and plugging in the first order conditions, equations 3 and 4, we can derive the following policy rule, which is expressed as the differences between tariff and environmental benefits, or costs:

$$2t-\left(\frac{S}{A_{x_1e}}A_{x_1}-A_{x_1}+N_{x_1}\right)$$

$$=-C^*_{x_2}\left(1-\frac{x_2C^*_{x_2x_2}}{C^*_{x_2}}\right)+\frac{S}{A_{x_1e}}C_{x_1}\left(1-\frac{x_1C_{x_1x_1}}{C_{x_1}}\right)-C_{x_1}\left(1-\frac{Sx_1A_{x_1x_1}}{A_{x_1e}C_{x_1}}\right)+2P-\frac{S}{A_{x_1e}}P \quad (21)$$

A detailed derivation is contained in Appendix B. Equation 21 is a benefit and cost rule for domestic government as it measures the differential benefits and costs between its two policy instruments, tariffs and environmental standards. On the left-hand side, the first term stands for tariff benefits when the value of tariff is positive, and tariff costs when that value is negative. The expressions inside the parenthesis, which measure the environmental benefits or costs, however, are not as straightforward. The first terms

[6] We can use equation 20 instead of 17 to derive the optimal policy rule with a marginal rent type of interpretation.

inside the parenthesis are the net marginal abatement benefits *S*, when *S* is positive, or the net marginal abatement costs, when *S* is negative. Because *S* is composed of two terms, it would be positive if the public benefits associated with increase in environmental standards outweigh the costs that they impose on the private sector. These are direct effects of a possible enhancement or deterioration in overall environmental benefits due to stricter environmental standard, after subtracting its likely effects on the private sector. On top of that, we must also add additional benefits, i.e. costs saved on the production process, as represented by the marginal public environment damage $-N_{x_1}$, and the marginal private abatement cost A_{x_1} . Overall, there are three kinds of benefits contained in equation 21, direct public marginal environmental benefit, indirect public marginal benefit due to the decrease of domestic output, and private costs saved due to less output, that are associated with the increase in environmental standards. All three benefits must be weighed against the marginal abatement costs imposed on the private sector.

To see through this more clearly, assume that $N(x_1, e) = N^1(e)$, and $A(x_1, e) = A^1(e)x_1$, and define $\frac{N_e^1}{x_1} = \bar{N}_e^1$, and if necessary, further assume that $\bar{N}_e^1 = (1 + \theta)A_e^1$, the terms inside the parenthesis on the left-hand side of equation (21) can be simplified as

$$\frac{\bar{N}_e^1 A^1}{A_e^1} - 2A^1 = (\theta - 1)A^1 \qquad (21a)$$

It follows that the left- hand side of equation 21 can be simplified into the following form:

$$2t-\left(\frac{N_e^1 A^1}{A_e^1}-2A^1\right)=2t-(\theta-1)A^1 \tag{21b}$$

This is almost like the 50 percent rule for optimum discriminatory tariffs discussed in Hwang and Mai (1991), with additional complications stemming from the assumed functional form of environmental benefit and abatement cost functions.

Turning back to equation 21, where assumptions on the abatement benefit and cost functions remain quite general, we see higher tariffs bring in tax revenues toward the government budget, while stricter environmental standards will directly contribute net abatement benefit or cost, depending on whether S is positive or negative. This social benefit or cost is scaled by the factor $\frac{A_{x_1}}{A_{x_1 e}}$, and adjusted by marginal public abatement cost and private abatement cost, i.e. the part of costs being saved and/or benefits generated due to decrease in domestic output. By construction, consumer surplus does not enter the left-hand side of equation 21 as higher tariffs and stricter environmental standards will have similar effects on consumer surplus and these effects will basically, if not exactly, cancel out each other. After all, the purpose of equation 21 is to capture the differential benefits/costs of the two policy instruments faced by domestic government.

Assuming the private abatement cost function is of the linear form $A(x_1, e) = \eta e x_1$, and constant elasticity cost functions across two firms such that

$\frac{x_1 C_{x_1 x_1}}{C_{x_1}} = \varepsilon = \frac{x_2 C_{x_2 x_2}}{C_{x_2}}$, an alternative expression for equation 21 can be obtained:

$$2t - (\frac{L}{\eta}\eta e - 2\eta e + N_{x_1}) = (1-\varepsilon)(\frac{S}{\eta}C_{x_1} - C^*_{x_2}) - C_{x_1} + 2P - \frac{S}{\eta}P \qquad (22)$$

The only difference between equation 22 and 21 is that the first term inside the parenthesis of 22 is *MPUAB*, instead of *NMAB*. After all, *NMAB* is defined as the difference between *MPUAB*, *L*, and the *MPRAC* η. Under specific functional form, *MPUAB* and *MPRAC* show up in place of *NMAB*. As opposed to expressions on equation 16 and 17, which depend on monopoly rent and net per unit marginal abatement benefit that in turn, are composed of demand, cost and abatement parameters, the expressions in equation 22 depend directly on the very basic, i.e. demand, cost and abatement parameters. Several observations can be made regarding the policy rule in equation 22. First, the demand side and supply side both enter this policy rule.[7] Unlike the optimal policy rule in Hwang and Mai (1991) model, where the optimized level demand factors are missing, both optimized demand and supply factors enter this policy rule.

[7] Although the influence of demand and supply factors actually shows up everywhere through the determination of optimal output, we can draw the distinction between optimized level of demand and supply side factors and the demand and supply side factors before optimization, and conclude that the optimized demand and supply side factors enter the policy rule.

Second, the optimal policy rule in equation 22 depends crucially on three parameters: the cost elasticity ε,[8] the *MPUAB*, L, and the *MPRAC* η. A total of twenty-eight different policy regions can be generated through assuming different critical values for the two parameters L and ε, while holding η as given. The critical values for ε are zero and one, while the critical values for L are η, 2η, and 3η. These different policy regions are illustrated in Table 1 and Figure 3.

When ε is equal to one, the benefit and cost policy rule does not depend on the optimized level marginal cost of firm 2. When ε is equal to zero, we are in the linear cost case. When L is equal to 3η, the policy rule does not depend on the optimized level demand side factor as the final two terms on the right-hand side of equations 22 cancel out each other. When L is equal to 2η, this benefit cost policy rule does not include the private abatement cost and public abatement benefit as they cancel out each other. Also, when L is equal to η, the optimal rule from environmental economics holds. These five critical lines, together with the intersected areas above and below these critical lines, showcase the many different policy regions, each with its own implications. Since the right-hand side of equation 22 could be positive, zero, or negative, we conclude that tariff benefits (costs) could be greater, equal to, or smaller than the environmental benefits (costs).

[8] The elasticity of the abatement cost function will show up on equation 22 if we assume the abatement cost function to be nonlinear.

The benefits and costs associated with environmental standards should not be confused with positive or negative value of environmental standards, or alternatively, taxes or subsidies, because for a given value of environmental standards/taxes or subsidies, be it positive or negative, there might associate with it environmental benefits or costs, depending on the specification of functional form and functional parameter values. Consider the case of positive environmental standards. When L is greater than 2η, we enter the case of environmental benefits. The tariff benefits could dominate, equal to, or be dominated by the environmental benefits. When L is equal to 2η, there is no environmental benefits or costs. However, there still might be import tariffs or subsidies. When L is below 2η, the environmental costs could dominate, equal to, or be dominated by tariff costs. Which benefits or costs ultimately dominate will depend on the right-hand side of equation 22. Similar type of argument will apply to the case of pollution subsidies.

These various policy regions show that the relationship between tariffs and environmental policies can vary from country to country, depending on the relevant technology and public abatement factors. Thus, unless the relevant technology and public abatement factors are revealed, it is difficult to ascertain which policy instrument is more important for governmental rent-shifting purpose. Barrett (1994) focused on the case that government interferes through environmental policy when other instruments are unavailable. Our result indicates that environmental policy can be a major rent-shifting instrument for some governments, likely in the form of pollution subsidies, even when tariffs are available. It is a well-known fact that some developing and less developed countries export their resources in exchange of foreign capital. Such behaviors showcase the possibility that environmental policy can be a major rent-shifting instrument.

Third, we find the optimality rule of environmental economics could have been violated in a world where tariffs are available, as represented by many possible policy regions, or simply by the first order condition equation 15. In a multiple policy setting, one policy purpose will need to be balanced by another, likely very different policy purpose. Thus, it is neither effective nor fair to rely on the optimality rule of environmental economics as a sole criterion for evaluating policy effectiveness, not only because it ignores strategic interactions between government and firms and among firms, but also because it is a narrowly focused policy condition. Instead, more strategic and well-balanced conditions that incorporate the purposes of other types of policy such as tariffs, as illustrated by equation 15, could surge out as a better criterion for addressing the environmentalist concern in a multi-faceted world.

6. Conclusions

There are many models built upon NAFTA and EU related environmental issues, while there have been limited discussions regarding environmental issues in newly graduated and developing countries, even though some of these countries are facing ever-rising environmental consciousness. This paper treats both tariffs and environmental policies as government choice variables and makes this model especially relevant for, although not limited to, environmental issues faced by newly graduated and developing countries. We show that there are three possible regimes of optimal policy portfolio: positive tariffs and environmental standards, import subsidies and positive environmental standards, and pollution subsidies and positive tariffs. Regardless of the types of policy portfolio, stricter environmental standards can be sustained by a sufficiently large monopoly rent, as higher rent provides cushion for rent-shifting government. Other things equal, stricter environmental standards are also supported by medium or low values of net marginal abatement benefit, as high values of net marginal abatement benefit, relative to that of monopoly rent, are associated with thin profit margin of domestic firm, thereby justifying pollution subsidies. Alternatively, a low or negative value of net marginal abatement benefit means high marginal cost suffered by domestic industry due to the imposing of environmental regulations, and government could instead rely on import subsidies to satisfy its domestic demand.

We also find the environmental optimality condition could have been violated in this model. This suggests optimality condition as such is not appropriate for evaluating the effectiveness of environmental policy in a model where other types of policy considerations have been taken into consideration. In addition, we derive a set of benefit and cost policy rule. Multiple policy regions are generated through the assumptions of the abatement and non-abatement cost functions. Each policy region stands for a specific kind of government regime with the implication that tariff benefits (costs) dominate, or are dominated, by environmental benefits (costs). The various policy regions provide a clear supply side picture of the optimal policy mix, and thus, the relative importance of environmental policies and tariffs as rent-shifting instruments from a one country perspective. Under our one country and two policies model, environmental policy is not necessarily an inferior policy instrument in terms of its rent-shifting function, as claimed by some literature in strategic environmental policy.

One interesting implication stemming these different types of policy regimes is related to the welfare enhancing effects of free trade deals. In the absence of free trade deal, if it is optimum for one type of policy regime to concentrate much on its pursuit of international competitiveness through the imposing of tariffs and subsidizing of its polluting manufacturing, while it is also optimum for another type of policy regime to focus on the safeguarding of its environment through the imposing strict environmental standards and import subsidies, then free trade deal that is relatively tailored made to one type of regime will put another type of regime in unequal footing. This remains to be the case, even though, under free trade deals, there are still welfare-enhancing effects due to benefits such as economies of scale and economies of scope. Such unequal footing problems are more likely to arise and could potentially be more serious in North-South trade as the North is very different from the South. Furthermore, if that deal is tailored made, relatively speaking, for the North, then that might explain the reluctance of developing countries in embracing the free trade deals, as has been witnessed by trade talks in recent decades.

Similar argument can also apply to the harmonization of standards. When the demand, supply, and environmental parameters among countries are of very different kinds, harmonization of environmental standards across the board likely will pull some economies further away from their original optimum in the absence of harmonization agreement, while others could stay relatively intact as such standards are tailored made for them. Again, like free trade deal, harmonization of standards might create the problem of unequal footing, thereby enhancing the possibilities that the benefits of globalization could be very unevenly distributed among members countries who join a deal. Overall, the unequal footing problem could function much like the terms of trade effects in the general equilibrium models, where some countries are able to reap the terms of trade gains at the costs of terms of trade disadvantages suffered by others. As argued in Rodrik (2007), global rules such as the Washington Consensus might not serve as panacea of poverty reduction for developing countries, as specific local constraints have been largely ignored. Clearly, one can see how such argument can be extended to other fronts such as intellectual property, food safety, and others.

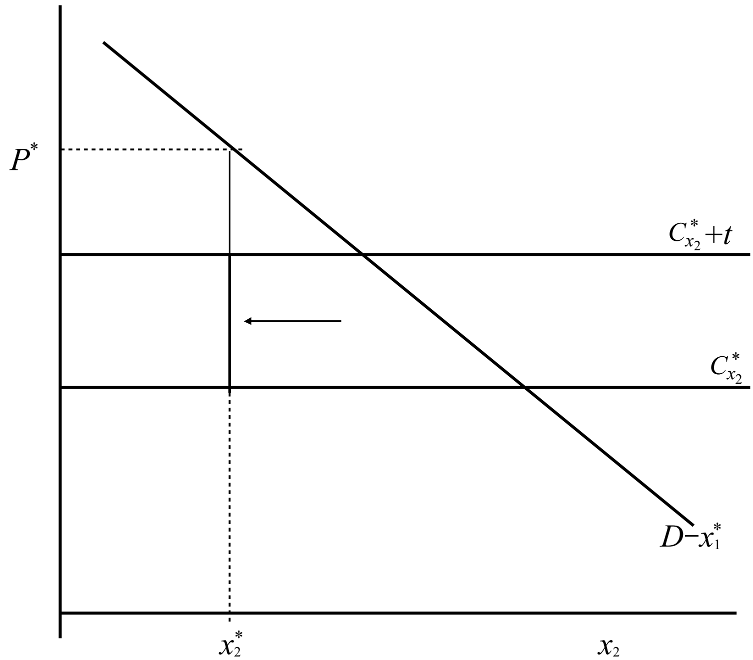

Figure 1. An Increase in Marginal Rent from An Increase of Foreign Output

Note: The vertical bolded segment indicates the marginal rent earned by the domestic country from an increase of foreign output. The domestic output is taken as fixed and is not shown on the graph.

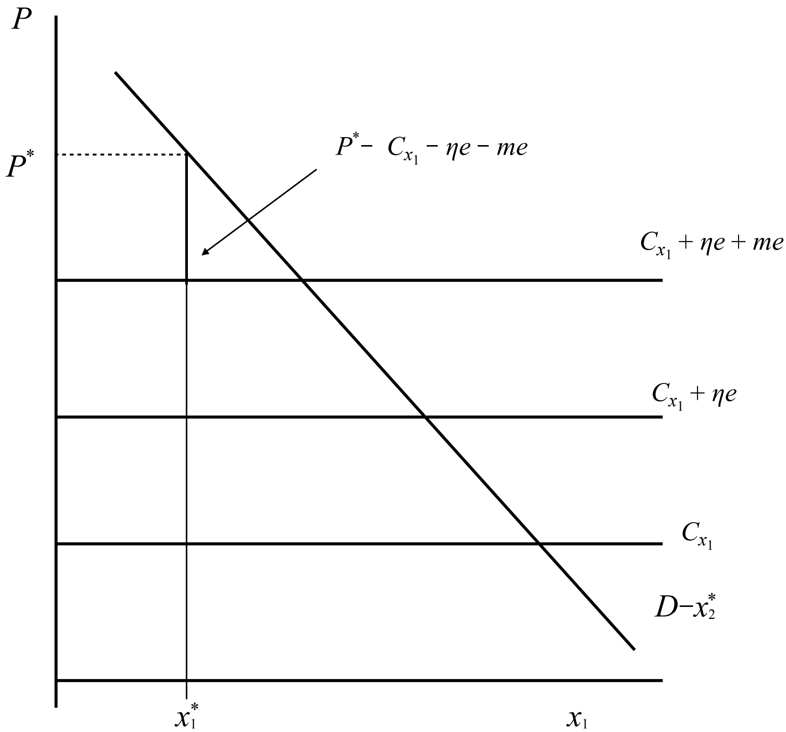

Figure 2. An Increase in Marginal Rent from An Increase of Domestic Output

Note: The vertical bolded line segment indicates the marginal rent earned by the domestic country when domestic output increases. The private and public abatement costs are indicated as ηe and me, respectively. The foreign output is taken as fixed and is not shown on the graph.

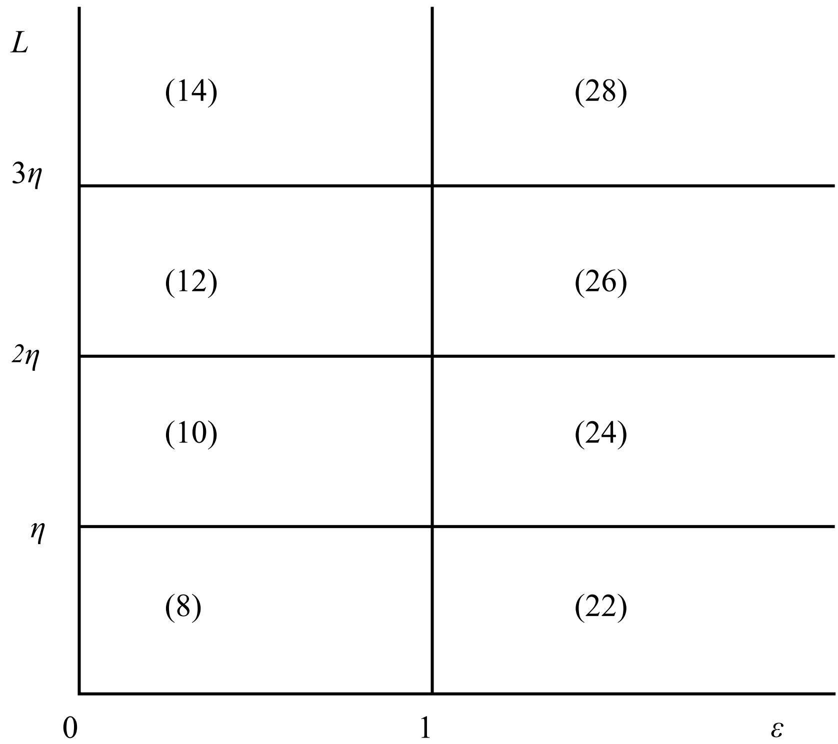

Figure 3. Multiple Policy Regions

Note: The numbered policy regions on this graph correspond to the same numbered regions on Table 1. Other numbered policy regions are located on the bolded line. These policy regions are surrounded by critical policy lines $\varepsilon=0$, $\varepsilon=1$, $L=\eta$, $L=2\eta$, and $L=3\eta$.

	$\varepsilon = 0$	$0 < \varepsilon < 1$	$\varepsilon = 1$	$\varepsilon > 1$
$L < \eta$	(1)	(8)	(15)	(22)
$L = \eta$	(2)	(9)	(16)	(23)
$\eta < L < 2\eta$	(3)	(10)	(17)	(24)
$L = 2\eta$	(4)	(11)	(18)	(25)
$2\eta < L < 3\eta$	(5)	(12)	(19)	(26)
$L = 3\eta$	(6)	(13)	(20)	(27)
$L > 3\eta$	(7)	(14)	(21)	(28)

Table 1. Multiple Policy Regions

Note: The policy regions in the second row stands for the optimal rule in environmental economics. Policy regions in the fourth row do not have environmental benefits and costs. In the sixth row, the policy regions do not depend on the optimized demand factor. On the third column, the policy regions do not depend on the marginal cost of firm 2. The first column can be considered as the case of linear cost. Other in-between policy regions will have similar interpretations.

Appendix A

This Appendix contains the derivation of equation 19. We start from writing down the first order conditions at the government level:

$$W_t = -XP_t + tx_{2t} + x_2 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1t} + x_1 P_t = 0 \tag{12}$$

$$W_e = -XP_e + tx_{2e} + Sx_1 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1e} + x_1 P_e = 0 \tag{13}$$

where $S = \dfrac{N_e - A_e}{x_1}$

Define $(A_{x_1} - N_{x_1})$ as $w(e)$, we can derive equations (A-1) and (A-2) from equations 12 and 13 simply by moving terms to the LHS:

$$t = -\frac{(1 - P_t)x_2 + [P - C_{x_1} - w(e)]x_{1t}}{x_{2t}} \tag{A-1}$$

$$w(e) = \frac{-P_e x_2 + tx_{2e} + Sx_1 + (P - C_{x_1})x_{1e}}{x_{1e}} \tag{A-2}$$

Solving equations (A-1) and (A-2) simultaneously, the following equations can be derived:

$$t = (1 - K)^{-1}[-\frac{(1 - P_t)x_2}{x_{2t}} - \frac{P_e x_2 K}{x_{2e}} + \frac{Sx_1 K}{x_{2e}}] \tag{A-3}$$

$$w(e)=(1-K)^{-1}[-\frac{(1-P_t)x_2K}{x_{1t}}-\frac{P_ex_2}{x_{1e}}+\frac{Sx_1}{x_{1e}}]+(P-C_{x_1}) \quad \text{(A-4)}$$

where $K=\frac{x_{1t}x_{2e}}{x_{2t}x_{1e}}$, and $0<K<1$

Equations (A-3) and (A-4) will imply the following relationships:

$$t>0 \text{ if } Sx_1>\frac{(1-P_t)x_2x_{2e}}{Kx_{2t}}+P_ex_2=\frac{(1-P_t)x_2x_{1e}}{x_{1t}}+P_ex_2 \quad \text{(A-5)}$$

$$w(e)>0 \text{ if } \frac{Sx_1}{x_{1e}}>\frac{(1-P_t)x_2K}{x_{1t}}+\frac{P_ex_2}{x_{1e}}-(1-K)(P-C_{x_1})$$

$$\Rightarrow \quad Sx_1<\frac{(1-P_t)x_2x_{1e}K}{x_{1t}}+P_ex_2-(1-K)(P-C_{x_1})x_{1e}$$

$$\Rightarrow \quad Sx_1<\frac{(1-P_t)x_2x_{2e}}{x_{2t}}+P_ex_2-(1-K)(P-C_{x_1})x_{1e} \quad \text{(A-6)}$$

Assume the following relationship holds:

$$\frac{x_{1e}}{x_{1t}}<\frac{x_{2e}}{x_{2t}} \quad \text{(A-7)}$$

Inequalities (A-5) and (A-6) together imply equation 19:

$$x_2P_e+\frac{(1-P_t)x_2x_{1e}}{x_{1t}}<Sx_1<x_2P_e+\frac{(1-P_t)x_2x_{2e}}{x_{2t}}-(1-K)(P-C_{x_1})x_{1e} \quad (19)$$

It remains to show that (A-7) holds. To show that, we start with the following two inequalities:

$$P_{XX}x_2 + 2P_X - C^*_{x_2x_2} < P_{XX}x_2 + P_X \tag{A-8}$$

$$P_{XX}x_1 + 2P_X - C_{x_1x_1} - A_{x_1x_1} < P_{XX}x_1 + P_X \tag{A-9}$$

These two inequalities follow directly from the stability conditions and we also know expressions on both sides of the inequalities are negative. Thus, it follows that:

$$\frac{P_{XX}x_2 + 2P_X - C^*_{x_2x_2}}{P_{XX}x_1 + P_X} > \frac{P_{XX}x_1 + P_X}{P_{XX} + 2P_X - C_{x_1x_1} - A_{x_1x_1}} \tag{A-10}$$

Multiply both side of (A-10) by $-A_{x_1e}$:

$$-\frac{A_{x_1e}(P_{XX}x_2 + 2P_X - C^*_{x_2x_2})}{P_{XX}x_1 + P_X} < -\frac{A_{x_1e}(P_{XX}x_1 + P_X)}{P_{XX} + 2P_X - C_{x_1x_1} - A_{x_1x_1}} \tag{A-11}$$

This is just another expression of (A-7).

Appendix B

This Appendix contains the derivation of equation 21. Consider the following first order conditions, equations 12 and 13 from the government's maximization problem:

$$W_t = -XP_t + tx_{2t} + x_2 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1t} + x_1 P_t = 0 \quad (12)$$

$$W_e = -XP_e + tx_{2e} + Sx_1 + (P - C_{x_1} + N_{x_1} - A_{x_1})x_{1e} + x_1 P_e = 0 \quad (13)$$

where $S = \dfrac{N_e - A_e}{x_1}$

As defined in equation 20 $h(e) = P - C_{x_1} + N_{x_1} - A_{x_1}$, we can rewrite the equations 12 and 13 as B-1 and B-2:

$$-x_2 P_t + tx_{2t} + h(e)x_{1t} + x_2 = 0 \quad \text{(B-1)}$$

$$-x_2 P_e + tx_{2e} + h(e)x_{1e} + Sx_1 = 0 \quad \text{(B-2)}$$

Moving the first and fourth terms of the above two equations to the RHS:

$$tx_{2t} + h(e)x_{1t} = x_2 P_t - x_2 = A \quad \text{(B-3)}$$

$$tx_{2e} + h(e)x_{1e} = x_2 P_e - Sx_1 = B \quad \text{(B-4)}$$

(B-3) $\times x_{1e} -$ (B-4) x_{1t}

$$\Rightarrow (x_{1e}x_{2t} - x_{1t}x_{2e})t = Ax_{1e} - Bx_{1t} \quad \text{(B-5)}$$

(B-3)$\times x_{2e}$ – (B-4)x_{2t}

$$\Rightarrow (x_{1t}x_{2e} - x_{1e}x_{2t})h(e) = Ax_{2e} - Bx_{2t} \qquad \text{(B-6)}$$

Let $K = x_{1e}x_{2t} - x_{1t}x_{2e}$, we have:

$$Kt = x_2 P_X K + Sx_1 x_{1t} - x_2 x_{1e} \qquad \text{(B-7)}$$

$$Kh(e) = x_2 P_X K + x_2 x_{2e} - Sx_1 x_{2t} \qquad \text{(B-8)}$$

Thus, we can solve t and as the following:

$$t = x_2 P_X + \frac{Sx_1 x_{1t} - x_2 x_{1e}}{K} = x_2 P_X + \frac{\dfrac{-Sx_1 \pi^1_{x_1x_2}}{D} - \dfrac{A_{x_1e} x_2 \pi^2_{x_2x_2}}{D}}{\dfrac{A_{x_1e}}{D^2}(\pi^2_{x_2x_2}\pi^1_{x_1x_1} - \pi^1_{x_1x_2}\pi^2_{x_2x_1})}$$

$$= x_2 P_X - \frac{S}{A_{x_1e}} x_1 \pi^1_{x_1x_2} - x_2 \pi^2_{x_2x_2}$$

$$= x_2 P_X - \frac{S}{A_{x_1e}} x_1 (P_{XX} x_1 + P_X) - x_2 (P_{XX} x_2 + 2P_X - C^*_{x_2x_2})$$

$$= -x_2 (P_X - C^*_{x_2x_2}) - P_{XX} (\frac{S}{A_{x_1e}} x_1^2 + x_2^2) - \frac{S}{A_{x_1e}} P_x x_1 \qquad (16)$$

Similarly, we can derive *h(e)* as:

$$h(e) = x_2 P_X + \frac{x_{2e}x_2 - Sx_1 x_{2t}}{K} = x_2 P_X + \frac{-\dfrac{A_{x_1e} x_2 \pi^2_{x_2x_1}}{D} - \dfrac{Sx_1 \pi^1_{x_1x_1}}{D}}{\dfrac{A_{x_1e}}{D}}$$

$$= x_2 P_X - x_2 \pi^2_{x_2 x_1} - \frac{S}{A_{x_1 e}} x_1 \pi^1_{x_1 x_1}$$

$$= x_2 P_X - x_2 (P_{XX} x_2 + P_X) - \frac{S}{A_{x_1 e}} x_1 (P_{XX} x_1 + 2P_X - C_{x_1 x_1} - A_{x_1 x_1})$$

$$= -\frac{S}{A_{x_1 e}} x_1 (P_X - C_{x_1 x_1} - A_{x_1 x_1}) - P_{XX} (\frac{S}{A_{x_1 e}} x_1^2 + x_2^2) - \frac{S}{A_{x_1 e}} P_X x_1 \quad (20)$$

According to the definition of *h(e)*, we can rewrite equation 20 as:

$$A_{x_1} - N_{x_1} = \frac{S}{A_{x_1 e}} x_1 (P_X - C_{x_1 x_1} - A_{x_1 x_1}) + P_{XX} (\frac{S}{A_{x_1 e}} x_1^2 + x_2^2) + \frac{S}{A_{x_1 e}} P_X x_1 + (P - C_{x_1}) \quad (17)$$

Adding up equations 16 and 17 and use first order conditions at the firms' level to substitute for $x_1 P_X$ and $x_2 P_X$, we can derive equation 21:

$$t + A_{x_1} - N_{x_1} = \frac{S}{A_{x_1 e}} x_1 (P_X - C_{x_1 x_1} - A_{x_1 x_1}) - x_2 (P_X - C^*_{x_2 x_2}) + (P - C_{x_1})$$

$$= \frac{S}{A_{x_1 e}} (C_{x_1} + A_{x_1} - P) - \frac{S}{A_{x_1 e}} x_1 C_{x_1 x_1} - \frac{S}{A_{x_1 e}} x_1 A_{x_1 x_1} - (t + C_{x_2} - P) + x_2 C^*_{x_2 x_2} + (P - C_{x_1})$$

$$\Rightarrow 2t - (\frac{S}{A_{x_1 e}} A_{x_1} - A_{x_1} + N_{x_1})$$

$$= -C^*_{x_2} (1 - \frac{x_2 C^*_{x_2 x_2}}{C^*_{x_2}}) + \frac{S}{A_{x_1 e}} C_{x_1} (1 - \frac{x_1 C_{x_1 x_1}}{C_{x_1}}) - C_{x_1} (1 - \frac{S x_1 A_{x_1 x_1}}{A_{x_1 e} C_{x_1}}) + 2P - \frac{S}{A_{x_1 e}} P \quad (21)$$

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