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The Effects of Choosing Free Trade on Endogenous Environmental Regulation and Welfare: A Model of Common Agency Government*

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Abstract

Several studies hypothesize exogeneous environmental regulation as the primary motive for trade between two regions, often predicting a lower welfare for the region with incomplete environmental protection. Such analyses do not allow the region to adjust its environmental policy in response to a shift in the trade regime. Further, they do not allow the region to refuse free trade in the face of a welfare loss. As an alternative I propose a common agency model of government to endogenize environmental policy and the choice of trade regime. Conditions for the incomplete internalization of an environmental externality are specified, and the pollution tax in autarky is compared to that under free trade. The paper finds that moving to free trade induces a tightening of pollution policy, and reduces the deadweight loss from incomplete environmental regulation. In contrast to the predictions from earlier articles, the adoption of free trade increases aggregate welfare. This gain occurs even when the country with incomplete environmental protection exports the pollution intensive good.

Keywords: Trade and environment, common agency, political economy, pollution policy, lobbying

JEL Classification: F18, Q01

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1 Introduction

Chichilinsky(1994) demonstrated how differences in property rights can create a motive for trade amongst otherwise identical regions. In the model the "South" (a region with ill defined property rights) can lose welfare by trading with the "North" (a region with well defined property rights). Subsequently, a series of papers using the Ricardian model for trade (Brander and Taylor ((1997a), (1997b) and (1998)) explored the Chichilinsky hypothesis in greater detail. Their findings are summarized in this quote from Brander and Taylor (1998): "[T]he diversified resource exporting country necessarily suffers a decline in steady state utility resulting from trade, and may lose along the entire transition path". More recently, Karp, Sacheti and Zhao (2001) argued that both, an increase, or a decline in steady state utility is possible, conditional on the resilience of the environmental stock present in the trading country. Like Chichilinsky (1994), these analyses assumed exogenously specified differences in property rights across trading regions.

The basic concept underlying these articles is that of a negative externality. Due to ill defined property rights (a market failure), the South does not internalize the negative externality from extraction of the resource (or production of pollution). This imparts an apparent comparative advantage in the production of the resource intensive (or pollution producing) good, which is exported upon opening up to trade. Free trade exacerbates the negative externality associated with the production of the resource intensive good in the South, and the increased externality outweighs the gains from specialization, resulting in a net welfare loss.

These articles provided important insights into the interaction of trade and the environment, but left a fair amount unexplained. The driving force behind their results were the property rights, or pollution policies that were exogenously given. The reason why property rights were so defined was not explained. Property rights, pollution policies, and the choice of trade regime are all outcomes of a political process. Such outcomes are usually efficient (see Becker (1983) and Dixit et. al. (1997)), and respond optimally to changes in their associated costs and benefits.

Thus, if free trade exacerbates the negative externality from production of pollution, and increases social damages, pollution policy should adjust in response. Further, if free trade reduces welfare in the "South" the region should be allowed to stay in economic isolation, but such a choice was not allowed in the literature. The articles failed to specify any mechanism for choosing the trade regime.

In this article I attempt a more complete analysis of the choice of free trade and its effects on environmental regulation and welfare. The analytical framework is a political model that endogenizes both the environmental and trade policy of the economy. An incorporation of special interest politics results in the incomplete internalization of the negative externality from pollution conforming with the assumptions for the "South" above. Such a model asks a question more relevant than those addressed before. If a country, where the negative externality from pollution is incompletely internalized, chooses free trade, what are the changes in environmental policy and aggregate welfare that accompany this move?

In contrast to the studies cited above, the adoption of free trade encourages the government to tighten its environmental regulation, and despite special interest politics, free trade brings about an increase in aggregate welfare even when the country exports the pollution producing good.

In the analysis pollution is generated in the production of an intermediate good, which is used in the production of a high end consumer good, the majority of which is consumed by the affluent. Only the affluent lobby in the pollution tax game. Two trade regimes, autarky and free trade are compared. This model extends the Grossman and Helpman (1994) paper to incorporate general equilibrium price effects from lobbying activity. Since most political economy models have ignored general equilibrium price effects, this analysis reveals an effect of trade on environmental policy neglected by the literature so far. The adoption of free trade, prevents the producers of pollution from transferring the incidence of pollution tax to the consumers of their good, which increases the responsiveness of pollution to pollution tax. Increased responsiveness encourages greater lobbying for environmental protection, reduces the influence of the polluting minority, and induces the government to tighten its environmental regulation.

The improvement in pollution policy is demonstrated theoretically when prices are constant. A numerical simulation of the theory investigates, possible price movements, the questions of why and when free trade is chosen, and the impact of this choice on aggregate welfare. I find that the adoption of free trade raises aggregate welfare, even if the country with incomplete environmental protection exports the pollution intensive good. In free trade the negative externality from pollution is still not fully internalized, nevertheless an improvement in environmental policy, coupled with the standard gains from trade provide a gain in aggregate welfare. This gain in aggregate welfare is in sharp contrast to the predictions from Chichilinsky (1994), and Brander and Taylor (1997a, 1997b, and 1998).

Robustness of the theoretical result is tested by altering the crucial assumptions in the model. At first, pollution from consumption of the high end consumer good is allowed. The adoption of free trade forces the producers of pollution (both intermediate good producers and consumers of the polluting good) to bear the entire burden of the pollution tax themselves. As before, this induces a tightening in environmental regulation. As a second variation, the poor and unorganized are assumed to consume a majority of the high end consumer good. Here the change in environmental policy when free trade is chosen is ambiguous. Finally, the presence of several organized lobbies for and against pollution is replaced with the assumption of a single lobbyist (the polluting industry). The adoption of free trade gives the polluting lobby greater political influence, and the government actually reduces the pollution tax in free trade. This result is not surprising, since previously the improvement in environmental policy was based on increased incentives for lobbying against pollution in free trade, the assumption of a single polluting lobbyist nullifies these incentives. Robustness of the numerical result is tested by varying all parameters within their feasible limits (see Appendix A.3.2). The adoption of free trade brings about an increase in aggregate welfare over the autarkic level for all tested parameter values.

There exists some empirical evidence in support of this study. Vukina et al. (1999) examined the relationship between policy reforms and composition of pollution in output in the former Centrally Planned Economies (CPE), they found, "policy reforms affecting price liberalization, trade and the foreign exchange system had a beneficial effect on the composition of manufacturing output steering it towards less-polluting sectors." The authors linked this improvement in composition to environmental policy reforms that accompanied trade reforms. In the CPE sample, markets and regulations are being developed as the economy opens up to trade, i.e., moving from autarky to free trade is leading to an improvement in environmental regulation, and in this case, an improvement in the composition of output. Such countries come the closest to the no regulation case (due to the almost total disregard of environmental issues in the centrally planned framework), and in these countries opening up to trade has had a favorable effect on pollution. Antweiler et al. (2001) estimated the scale, composition and technique effect from trade and found that freer trade appears to reduce pollution. Allowing endogenous environmental policy in their model, the authors demonstrated that freer trade brings about an adjustment of environmental policy, and contrary to the theoretical studies cited earlier, free trade may actually improve the environment.

This article is not the first to model politically determined environmental policy. Fredriksson (1997) explicitly modelled special interest politics in the context of environmental regulation and free trade. The effect of freer trade on politically determined environmental policy was first systematically analyzed by Bommer and Schulze (1999). The authors showed that increased environmental protection is compatible with trade liberalization.

Independently of the current analysis, at least two other articles incorporated general equilibrium price effects in politically determined pollution policy. Yu (1999) investigated the success of environmental groups competing with polluting industries to influence environmental policy. In his analysis of the effects of free trade on environmental protection, the author argued: "the less open an economy, the greater the likelihood that free trade will increase domestic environmental protection". McAusland (2000) studied the interaction of income inequality and free trade in a median voter setup. The author showed that openness to trade alters the incidence of pollution policy.

McAusland (2000) did not incorporate special interest politics in her analysis, and environmental policy is determined by majority preferences. When compared with the welfare maximizing policy, the equilibrium pollution policy from this set up over-corrects the pollution externality if the majority is biased towards the clean industry, and under-corrects the externality when it is biased towards the dirty industry. Consequently the article finds that free trade makes pollution policy more stringent when the majority is biased towards the clean industry, and makes policy less stringent when it is biased towards the dirty industry. In both cases the adoption of free trade moves pollution policy further away from the welfare maximizing ideal, i.e., free trade worsens the inefficiency in pollution policy. In Yu (1999) one can find a similar result: the emission standard chosen by the government in free trade, is further away from the median voters preferred policy, than in autarky. Upon moving to free trade, the polluting minority gains greater leverage over pollution policy, making environmental policy less representative of voters preferences.

In this model one finds exactly the opposite result, the adoption of free trade brings pollution policy closer to the welfare maximizing ideal, and improves efficiency. The choice of free trade induces the government to better represent aggregate preferences, and reduces the influence of polluting special interests. Finally, in all the analyses so far (including the above two) the negative welfare effects of adopting freer trade were not refuted, also, free trade was always exogenously given, never endogenously chosen.

The remainder of the paper is structured as follows. Section 2 describes the economy and the lobbying game for pollution policy. Section 3 compares the welfare maximizing with the special interest tax rates in both autarky and free trade. Section 4 analyzes the choice of free trade and contains the numerical simulation of the model. Section 5 revisits the effect of adopting free trade on environmental regulation under assumptions distinct from Section 2, and finally Section 6 concludes the paper.

2 Framework for Analysis

The model proposed in this paper is a variant of the Grossman and Helpman (1994) model of common agency government. The original political framework is extended to include domestic price effects from lobbying activity, and applied to endogenize the pollution tax and the choice of trade regime for a small open economy.

The economy is assumed to be small relative to the rest of the world, i.e., autarky prices are determined endogenously and free trade prices are given exogenously. There is a polluting intermediate good (m), and three final goods in this economy ($y_i : i \in \{0, 1, 2\}$). Pollution is generated during the production of the intermediate good,[1] and negatively affects the utility of all individuals in the economy. This intermediate good is used in the production of a high end consumer good, a majority of which is consumed by the affluent.

2.1 Production

Production of good m produces pollution (z) as a by-product. The outputs m and z are jointly produced by a convex technology using two inputs: polluting capital (k), and labor (l_m) (labor used in sector i is denoted l_i), the input requirement set for this technology is $V^m(m, z) = \{(k, l_m) : (k, l_m) \text{ can produce } (m, z)\}$.

Polluting capital (k) is used for the production of good m alone. The return to owners of polluting capital (k) can be represented by a restricted profit function, $\pi^k(q, t) = \widetilde{\pi}^k(q, t, w; k)$ where q is the price (not quantity) for good m, w is the wage rate, and t is the tax on pollution. Restricted profit functions are positively linearly homogeneous, convex in prices (q, t, w), and satisfy Shephard's Lemma, i.e., for sector m output is (subscripts denote partial derivatives) $\pi^k_q(.) = m$, and the production of pollution is given by $-\pi^k_t(q, t) = z$. Good m is a pure intermediate good, i.e., there is no direct consumption of good m, and it is used as an input into

[1] A majority of the most pollution intensive industries (based on International Standard Industrial Classification (ISIC)), are intermediate good industries. For example: chemicals, metals, mining, leather finishing, tanneries etc. (see Hettige et al.(92), (95), and Stern et al.(97) for evidence).

the production of good 2, described below.

Good 0 is the numeraire good (price is normalized to unity) produced by a constant returns to scale technology using a single input labor (l_0). The input requirement set for good 0 is $V^0(y_0) = \{l_0 : l_0 = y_0\}$. Note that in any equilibrium that involves production of good 0, wage $w = 1$.

Good 1 is produced by a convex technology using two inputs: non-polluting capital (h), and labor (l_1). The input requirement set is $V^1(y_1) = \{(h, l_1) : (h, l_1) \text{ can produce } y_1\}$. The return to owners of h is $\pi^h(p_1) = \widetilde{\pi}^h(p_1, w; h)$ where p_1 is the price for good 1 (note $\pi^i_p(.) = y_i \, \forall i$). For interpretation, good 1 is comprised of final goods and services that use negligible amounts of polluting intermediates in their production (e.g. service industries, apparel etc.).

Good 2 is produced by a convex technology using three inputs: consumer goods producing capital (s), intermediate input of good m (m_2) and labor (l_2). The input requirement set is $V^2(y_2) = \{(s, m_2, l_2) : (s, m_2, l_2) \text{ can produce } y_2\}$. The return to owners of s is $\pi^s(p_2, q) = \widetilde{\pi}^s(p_2, q, w; s)$ where p_2 is the price for good 2. The demand for good m as an intermediate input is: $m_2 = -\pi^s_q(p_2, q)$. Good 2 is interpreted as an aggregate high end consumer good in this economy, a majority of which is consumed by the affluent.

2.2 Utility

Let x_i denote the consumption of good $i \in \{0, 1, 2\}$. Individuals who own only an endowment of labor (the non-affluent) have a utility function of the form

$$u(x_0, x_1; z) = x_0 + u^1(x_1) - v(z) \tag{1}$$

Individuals who own a share of any of the afore-mentioned types of capital (the affluent), consume the high end consumer good as well. Their utility function has the form

$$u(x_0, x_1, x_2; z) = x_0 + u^1(x_1) + u^2(x_2) - v(z). \tag{2}$$

Assume that $u_x^i(.) > 0$, $u_{xx}^i(.) < 0$, $v_z(.) > 0$ and $v_{zz}(.) > 0$. Utility maximization (in case of an interior solution) provides the demand for non numeraire goods i, $x_i = x^i(p_i)$.

2.3 Income and Political Organization

The total mass of individuals in the economy is normalized to 1, and each individual is endowed with a single unit of labor. The government rebates tax revenue back proportionately to all individuals. Total tax revenue is $R = tz$, and consumer surplus from consumption of good i is denoted by $\gamma^i(p) = \left[u^i\left(x^i(p_i)\right) - p_i x^i(p_i)\right]$. There are four types of individuals in this economy.

We start with individuals who own an endowment of labor alone (members of group l). They are in proportion n_l, their joint income is $n_l(1+tz)$ (as $w = 1$), and their welfare is

$$W^l = n_l\left(1 + tz + \gamma^1(p_1) - v(z)\right) \tag{3}$$

Assume that members of group l do not organize to form a contributing lobby.[2]

The remaining individuals who own an endowment of either polluting and non polluting capital are organized into three lobby groups. The groups are denoted h, k, s after their respective capital ownership. Each group has proportion n_j, where $j \in \{h, k, s\}$. These individuals form a lobby group (maybe they are geographically concentrated, and fewer in number), and offer the government contributions in order to influence policy. Their welfare (gross of contributions) is

$$W^j = n_j\left(1 + tz + \gamma^1(p_1) + \frac{\gamma^2(p_2)}{(1-n_l)} - v(z)\right) + \pi^j,\ j \in \{h, k, s\} \tag{4}$$

Where $\pi^j, j \in \{h, k, s\}$ is the restricted profit or marginal return function for the owners of capital. Each group's welfare net of contributions is $\Omega^j = W^j - C^j$, where C^j is the contribution paid by lobby group $j \in \{h, k, s\}$ to the government.

This analytical framework attempts to model the regulation of pollution intensive intermediate industries such as mining, chemicals, metals etc. The assumption that the rich consume a majority of the intermediate using good is motivated by conditions in third world countries with wide income

[2] This could be because the size of the group is very large, and/or they are geographically dispersed raising the cost of forming a group, and/or their low level of income makes the fixed cost needed to form a lobby unaffordable.

inequalities (like some countries in South Asia). In these countries the rich consume a majority of manufactured products, while the poor depend upon, clay and mud housing, hand-spun clothing and have very basic demands on transportation.

Note that in the analysis all members of the society that own any form of capital (human or otherwise) are organized in the environmental policy game. This assumption is motivated by the following. Environmental support is strongly, and positively correlated with education (Jones and Dunlap (1992)), and with per capita income (Elliot et. al.(1995)). And, lobbying in environmental policy has a broader base than for example, lobbying in trade policy, i.e., the state of the environment is likely to find greater activism among the masses, than the level of tariff on sugar imports.[3]

2.4 Goods Prices

This subsection adds general equilibrium price effects from lobbying to the common agency model in Grossman and Helpman (1994). In a closed economy, lobbying activity that affects t affects the prices of goods m, and 2. Any group lobbying for a change in t will foresee these price changes and incorporate them in its incentives to lobby.

Goods market equilibrium conditions in autarky are

$$-\pi_q^s(p_2, q) = \pi_q^k(q, t) \quad (5)$$

$$x^1(p_1) = \pi_p^h(p_1) \quad (6)$$

$$x^2(p_2) = \pi_p^s(p_2, q) \quad (7)$$

Equation (5), (6), and (7) are the equilibrium conditions for the intermediate good, good 1, and for good 2 respectively (all conditions equate demand and supply in the economy).

[3] As an example of the broad base of environmental concern consider Lowe and Goyder (1983). While highlighting the influence of environmental groups in British politics the authors write "[T]here is widespread appreciation of the environment and the threats it faces. Of the British adult population, approximately one person in ten belongs to an environmental group".

Since 1983 and through the 90's the environmental movement has strengthened and expanded (Vig and Kraft (1997)). It is now easier than ever, for an individual to express support for the environment either by purchasing products that support the environment, or share its profits with environmental groups, or by making contributions through the internet. One can even contribute to environmental organizations solely by viewing advertizements (e.g. http://www.therainforestsite.org, htp://www.ecologyfund.com).

The effect of an increase in the pollution tax on prices, is found by totally differentiating the above system of equations (5 and 7). Equation (7) gives (note q is the price for m)

$$dp_2 = \frac{-\pi^s_{pq}(p_2, q)}{\left[\pi^s_{pp}(p_2, q) - x^2_p(p_2)\right]} dq \tag{8}$$

Note that $x^2_p(p_2)$ is negative, due to the concavity of the utility function, and $\pi^s_{pp}(p_2, q)$ is positive, due to the convexity of the restricted profit function in prices, thus the denominator is positive. The sign of the derivative is the same as the sign of $\left[-\pi^s_{pq}(p_2, q)\right]$; recall that $m_2 = \left[-\pi^s_q(p_2, q)\right]$ and $\frac{\partial m_2}{\partial p_2} = \left[-\pi^s_{qp}(p_2, q)\right]$, which is, the change in intermediate input demand when the final good price rises, and we expect this to be positive.[4]

Using the result from equation (8), and totally differentiating equation (5) we get (arguments of the functions are suppressed),

$$\frac{dq}{dt} = \frac{\left[-\pi^k_{qt}\right]}{\Delta} > 0 \tag{9}$$

where $\Delta = \left[\pi^k_{qq} + \pi^s_{qq} - \frac{\left(\pi^s_{qp}\right)^2}{\left[\pi^s_{pp} - x^2_p\right]}\right] > 0$,[5] and $\left[-\pi^k_{qt}\right]$ is positive using logic similar to that used to explain equation (8). Thus, in the closed economy, an increase in the pollution tax (t) causes the price of the intermediate good (q) to rise and subsequently this causes the price of high end consumer good 2 (p_2), to rise. Meanwhile, note that the price of good 1 is unaffected by the pollution tax.

2.5 Environmental Taxes in a Political Equilibrium

The government can choose the pollution tax (t) and trade regime $R \in \{I, F\}$ (I is short-form for Isolation, F is short-form for Free trade). The government's objective function is $G = \sum_{j \in J} C^j(t, R) + aW(t, R)$, where $J = \{h, k, s\}$ is the set of lobby groups. $C^j(t, R)$ is lobby group j's contribution schedule (a function of policy variables $\{t, R\}$),[6] $W(t, R) = \sum_{g \in \{h,k,l,s\}} W^g$

[4] As long as m_2 is a normal input this assumption will hold. For all homothetic technologies, e.g. a Constant Elasticity of Scale (CES), or a Cobb-Douglas form for production of good 2, this assumption holds automatically.

[5] This term can be re-expressed as $\left[\pi^k_{qq} + \frac{\left[\pi^s_{qq}\pi^s_{pp} - \left(\pi^s_{qp}\right)^2\right]}{\left[\pi^s_{pp} - x^2_p\right]} + \frac{-\pi^s_{pp}x^2_p}{\left[\pi^s_{pp} - x^2_p\right]}\right]$ which is positive due to the convexity of the π function, and concavity of the utility function.

[6] $C^j(t) \geq 0$ to ensure that lobby groups cannot use this function to extract payments from the government.

is aggregate (gross of contributions) welfare in the economy, and a is the weight attached to aggregate welfare by the government. Policy is set as a sub-game perfect outcome of a two stage noncooperative game. In the first stage, lobbies simultaneously choose their political contribution schedules (a mapping from the policy to payments) so as to maximize their group utility. In the second stage, the government takes contribution schedules as given, and sets policy in order to maximize its own welfare.

The conditions for an equilibrium to such a game were provided by Bernheim and Whinston (1986). A detailed derivation of the equilibrium in the current game is given in Appendix A.1. An equilibrium is denoted as $\left(\left\{C^{j0}(t)\right\}_{j\in J}, t^0, R^0\right)$. The following condition (derived in Appendix A.1) determines the optimal pollution tax in each optimal trade regime for this economy.

$$\frac{d}{dt}\left[\sum_{j\in J} W^j\left(t^0, R^0\right) + aW\left(t^0, R^0\right)\right] = 0 \tag{10}$$

This implies that the optimal tax maximizes a weighted welfare function where lobby groups get a higher weight than unorganized citizens. Given a binary choice between autarky and free trade this allows an easy comparison of the tax rates across trade regimes.

The choice of trade regime is determined by the following equation (also equation (29) in the appendix).

$$\sum_{j\in J} C^{j0}\left(t^0, R^0\right) + aW\left(t^0, R^0\right) \geq \sum_{j\in J} C^{j0}(t, R) + aW(t, R) \;\; \forall t \in \tau, R \in \{I, F\}$$

In this model there are only two differences between autarky and free trade. In autarky the general equilibrium price effect from lobbying influence incentives to lobby for pollution tax. In free trade these effects disappear. Thus the free trade tax policy is different from that in autarky. Further, the free trade price vector is likely to be different from that in autarky. Any organized group will lobby the government for or against free trade based on the price vector prevalent in the world market, and the pollution tax schedule expected in free trade. A more detailed discussion of the choice of free trade is postponed until Section 4.

3 Equilibrium Tax Schedules

Consider the welfare maximizing tax schedule as a benchmark. Aggregate welfare (gross of contributions) in this economy is $W(t, R) = \sum_{j\in\{l,h,k,s\}} W^j$. The tax schedule that maximizes aggregate welfare is

$$t^* = v_z(z) \tag{11}$$

i.e. the optimal tax rate is equal the marginal damage from pollution in society (in both free trade and autarky).

3.1 The Special Interest Tax Schedule in a Closed Economy

This sub-section characterizes the politically determined pollution policy, when the trade regime chosen by the government is Autarky ($R^0 = I$ in equation (29)).

Following are the lobbying incentives in the pollution tax game. For group l (labor owners), differentiate equation (3), use the Shephard's lemma, and the definition for $\gamma^i(p_i)$ to get

$$\frac{dW^l}{dt} = n_l\left[-\pi_t^k + [v_z - t]\left[\pi_{tq}^k\frac{dq}{dt} + \pi_{tt}^k\right]\right]. \tag{12}$$

The owners of labor gain increased transfers with an increase in tax ($-\pi_t^h$), they gain from the decrease in pollution ($v_z\left[\pi_{tq}^k\frac{dq}{dt} + \pi_{tt}^k\right] > 0$)[7] but lose from the drop in transfers that accompany this decrease in pollution ($[-t]\left[\pi_{tq}^k\frac{dq}{dt} + \pi_{tt}^k\right]$). For all $t \leq v_z$ this group unambiguously gains from an increase in pollution tax.

The following equation describes the gains and losses from pollution tax for group h (owners of non-polluting capital).

$$\frac{dW^h}{dt} = n_h\left[-\pi_t^k + [v_z - t]\left[\pi_{tq}^k\frac{dq}{dt} + \pi_{tt}^k\right] - \frac{p_2x^2(p_2)\frac{dp_2}{dt}}{(1-n_l)}\right]. \tag{13}$$

In addition to the effect for group l, this group has to pay a higher price for their consumption of the high end consumer good 2 (note that all owners of capital have to pay this higher price).

[7] The overall effect of an increase in the tax is to reduce pollution, i.e., this term can be proved positive despite the increase in pollution associated with the rise in prices ($\pi_{tq}^m\frac{dq}{dt}$). See the appendix.

Consider group s (producers of the high end consumer good), in addition to the consumption price increase, their restricted profit is altered due to the pollution tax. This can be seen in the following equation.

$$\frac{dW^s}{dt} = n_s \left[-\pi_t^k + [v_z - t] \left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k \right] - \frac{p_2 x^2 (p_2) \frac{dp_2}{dt}}{(1 - n_l)} \right] + \left[\pi_p^s \frac{dp_2}{dt} + \pi_q^s \frac{dq}{dt} \right] \tag{14}$$

The price of the intermediate input $(m_2 : (q))$, and, the price of good 2 (p_2) both rise when the pollution tax is increased.[8]

For group k (intermediate good producers) we have the following equation.

$$\frac{dW^k}{dt} = n_k \left[-\pi_t^k + [v_z - t] \left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k \right] - \frac{p_2 x^2 (p_2) \frac{dp_2}{dt}}{(1 - n_l)} \right] + \left[\pi_q^k \frac{dq}{dt} + \pi_t^k \right] \tag{15}$$

The owners of polluting capital have changes similar to group h (equation (13)). Additionally, they have an associated loss in profits due to the rise in taxes (i.e. $\left[\pi_q^k \frac{dq}{dt} + \pi_t^k \right] < 0$)[9] .

General equilibrium goods price effects dampen the incentives of groups h, and s to lobby for a higher pollution tax. As group k has to pay the pollution tax it lobbies the government for its reduction. Unlike groups h and s the price effect is beneficial for group k; an increase in taxes increases the price of good m causes a gain in profits: $\pi_q^k \frac{dq}{dt}$. This price effect reduces the incentive of group k to lobby for a reduction in the pollution tax. The outcome of this lobbying exercise is given by the following lemma.

Lemma 1 The Special Interest Tax Schedule in a Closed Economy can be expressed as:

$$t_I^0 = v_z (z) + \frac{n_l}{(n_h + n_s + n_k + a)} \left[\frac{\left[\pi_t^k \right]}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k \right]} \right]. \tag{16}$$

Proof. Substitute equations (12, 13, 14, and 15) into equation (10), rearrange and get

$$t_I^0 = v_z (z) + \frac{n_l}{(n_h + n_s + n_k + a)} \left[\frac{\left[\pi_t^k \right] + \left[\pi_q^k + \pi_q^s \right] \frac{dq}{dt} + \left[\pi_p^s - x_p^2 \right] \frac{dp_2}{dt}}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k \right]} \right]. \tag{17}$$

[8] It seems quite realistic to assume that the gain in profits from the rise in prices of good 2, is not enough to compensate producers for loss in profits from the rise in intermediate input prices. In other words assume that $\left[\pi_p^s \frac{dp_2}{dt} + \pi_q^s \frac{dq}{dt} \right] \leq 0$.

[9] This term is assumed negative, which implies that the gain in profits from the rise in price of good 1 ($\pi_q^k \frac{dq}{dt}$) is not enough to nullify the direct loss in profits ($-\pi_t^q$) from the higher pollution tax. See the appendix for a explanation.

Now substitute the goods market equilibrium conditions (5 and 7) into equation (17) above to get the expression in equation (16). ■

Lemma (1) expresses the special interest tax as the solution to a fixed point problem ($t_I^0 = v_z\left(-\pi_t^k\left(q, t_I^0\right)\right) + \frac{n_l}{(n_h+n_s+n_k+a)}\left[\frac{\pi_t^k\left(q,t_I^0\right)}{\pi_{tq}^k\left(q,t_I^0\right)\frac{dq}{dt}+\pi_{tt}^k\left(q,t_I^0\right)}\right]$). Whether the special interest tax is greater than or less than the marginal social damage depends on the sign of the extra term on the right hand side of equation (16). Note that $\left[\pi_t^k\right] < 0$, the denominator is positive as shown in Appendix A.2.1. The implication of this result is stated in the following corollary.

Corollary 1 Incomplete Internalization of the Pollution Externality: The special interest pollution tax in autarky does not completely internalize the negative externality from pollution, i.e., $t_I^0 <$ Marginal Social Damage.

The producers of good m equate marginal benefit from pollution to tax, and the special interest tax is lower than the social marginal damage from pollution ($v_z(z)$). Thus at equilibrium, marginal benefits from pollution are lower than the marginal social cost, which implies, there is a deadweight loss associated with the special interest tax.

The cause of this incomplete internalization of the negative externality is special interest politics. Due to their lobbying activity, the government assigns a higher weight to the welfare of the producers of pollution than that assigned to losses from pollution to members of group l (labor owning group). Since a part of the externality is the disutility from pollution on this group, and this group is not organized, the special interest tax schedule never fully reflects their losses, implying an incomplete internalization of the pollution externality.[10]

[10] Due to special interest politics the government's maximization implicitly assigns a weight $(1+a)$ on the welfare of the special interests, and a weight of (a) on the welfare of the unorganized. This implies that the government assigns a weight of $(n_h + n_s + n_k + a)$ on the negative consumption externality net of transfers generated by pollution (i.e. on the term $[v_z - t]\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]$), and assigns an extra weight of $(n_l = (1+a) - (n_h + n_s + n_k + a))$ on the change in aggregate special interest returns from the tax(i.e. on all restricted profit funcitons, and consumer surplus from good 2). In other words the government in its welfare maximization trades off social damages with gains/losses in special interest welfare. This tradeoff is seen in this term where special interest gains or losses from pollution tax ($\left[\pi_t^k\right]$) are divided by the responsiveness of pollution to pollution tax. Thus if responsiveness of pollution to pollution tax is very high (i.e. $\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right] \to \infty$) then the losses from any deviation in tax from the social optimal are very large and this term tends to zero. Conversely, in case the special interest gains/losses (losses in our case) from pollution tax are non-negligble ($\left[\pi_t^k\right] < 0$) there is reason for the government to set pollution taxes different from the social optimal.

3.2 The Special Interest Tax Schedule in Free Trade

This sub-section characterizes the pollution policy when the government chooses Free Trade as the optimal trade regime ($R^0 = F$ in equation (29)).

In a small open economy, there are no final, or intermediate good price changes associated with a change in the pollution tax. In this scenario the effect of an increase in pollution tax on the welfare of groups l, s, and h, in free trade is $\frac{dW^i}{dt} = n_i \left[-\pi_t^k + [v_z - t] \left[\pi_{tt}^k \right] \right] : i \in \{l, s, h\}$. Compare this expression with those in equation (12), (13), (14), and (15). In free trade groups l, h and s gain unambiguously from an increase in the pollution tax. These groups gain from the increased transfer due an increase in the pollution tax $\left[-\pi_t^k \right]$, and as pollution tax is less than social damage, they also gain from a reduction in pollution net of the second order reduction in transfers, i.e., $[v_z - t] \left[\pi_{tt}^k \right] > 0$. Capital owning groups no longer pay a higher price for the consumption of the high end consumer good 2 when the pollution tax is raised. Further, group s no longer faces a reduction in its profit from an increase in t (the price of the intermediate good (q) does not rise when pollution tax is increased). Thus both groups h and s have an incentive to lobby harder for higher environmental protection in free trade.

Now consider group k (intermediate good producers), their change in welfare associated with a change in pollution tax is $\frac{dW^k}{dt} = n_k \left[-\pi_t^k + [v_z - t] \left[\pi_{tt}^k \right] \right] + \left[\pi_t^k \right]$. This group has an associated loss in profits due to the rise in taxes (i.e. $\left[\pi_t^k \right] < 0$). In contrast with the closed economy, group k can no longer transfer a part of the pollution tax to the consumers of its good (loss from pollution tax in autarky: $-\left[\pi_q^k \frac{dq}{dt} + \pi_t^k \right]$ is less than the loss from pollution tax in free trade: $-\left[\pi_t^k \right]$). In the open economy group k has to bear the entire burden of taxes alone, encouraging this group to lobby harder for a lower pollution tax.

Meanwhile all groups gain from the increased responsiveness of pollution to pollution tax (at constant prices $[v_z - t] \left[\pi_{tt}^k \right] > [v_z - t] \left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k \right] > 0$) which implies higher gains for all lobby groups from an increase in the pollution tax. These new lobbying incentives result in a new pollution tax characterized by the following lemma.

Lemma 2 The Special Interest Tax under Free Trade can be expressed as

$$t_F^0 = v_z(z) + \frac{n_l}{(n_h + n_s + n_k + a)} \left[\frac{\pi_t^k}{\pi_{tt}^k}\right] \tag{18}$$

Like lemma (1), lemma (2) expresses the special interest tax under free trade as a solution to a fixed point problem ($t_F^0 = v_z\left(-\pi_t^k\left(q, t_F^0\right)\right) + \frac{n_l}{(n_h+n_s+n_k+a)}\left[\frac{\pi_t^k\left(q,t_F^0\right)}{\pi_{tt}^k\left(q,t_F^0\right)}\right]$).

Corollary 2 Incomplete Internalization of the Pollution Externality: The special interest pollution tax in free trade does not completely internalize the negative externality from pollution, i.e., $t_F^0 <$ Marginal Social Damage.

The above result is evident from equation (18), the special interest tax in free trade has a smaller value than the marginal damage from pollution, which implies that the externality from pollution is not completely internalized even in free trade. The relation between the special interest tax in free trade with the welfare maximizing and the special interest tax in autarky is established in the following proposition.

Proposition 1 At a constant price for good m (q), the special interest tax in free trade has a higher value than the corresponding special interest tax in autarky but has a smaller value than the corresponding welfare maximizing tax.

Proof. I present a graphical proof for this proposition. Assuming a fixed price q three fixed point solutions are graphed in t space (see Figure 1). These are $t^* = \xi(q, t^*)$, $t_F^0 = \Theta\left(q, t_F^0\right)$, and $t_I^0 = \zeta\left(q, t_I^0\right)$, where $\xi(q, t^*) = v_z\left(-\pi_t^k(q, t^*)\right)$, $\Theta\left(q, t_F^0\right) = v_z\left(-\pi_t^k\left(q, t_F^0\right)\right) + \frac{n_l}{(n_h+n_s+n_k+a)}\left[\frac{\pi_t^k\left(q,t_F^0\right)}{\pi_{tt}^k\left(q,t_F^0\right)}\right]$, and $\zeta\left(q, t_I^0\right) = v_z\left(-\pi_t^m\left(q, t_I^0\right)\right) + \frac{n_l}{(n_h+n_s+n_k+a)}\left[\frac{\pi_t^k\left(q,t_I^0\right)}{\pi_{tq}^k\left(q,t_I^0\right)\frac{dq}{dt} + \pi_{tt}^k\left(q,t_I^0\right)}\right]$. At constant prices (q, t) the following relation between the three holds true: $\xi(q,t) > \Theta(q,t) > \zeta(q,t)$, i.e., at every t the function $\xi(.)$ lies above $\Theta(.)$ which lies above $\zeta(.)$. Second order conditions guarantee that the curves intersect the 45^0 line t from above.[11]

Figure 1 illustrates the relation between the three tax rates. The special interest tax in free trade is smaller in value than the welfare maximizing tax, but is greater than the special interest tax in autarky. ■

[11] In addition to the second order conditions we can verify that $\frac{d}{dt}\left[\xi(q,t)\right] = -\pi_{tt}^k v_{zz} < 0$, thus all three curves are downward sloping as drawn in the graph.

Adoption of free trade (when the price of the polluting good is constant) reduces the divergence of the special interest tax from the socially optimal tax rate. This improvement can be traced to a price effect associated with an increase in t, that occurs in autarky. This price effect raises the price of the intermediate good, thus reducing the benefits (losses) of the consumer good (intermediate) industry from an increase in the pollution tax. It also raises the price of the good using the polluting intermediate in production, reducing the benefits of all special interest groups from an increase in taxes. The increase in the price of good 2 also reduces the loss to group s from an increase in the price of the intermediate good. Lastly, due to the increase in the price of good m the responsiveness of pollution to the environmental tax is reduced.

In free trade, group s has a greater incentive to lobby for higher pollution taxes (as the price of the intermediate good no longer increases). This increased lobbying is countered equally, by increased lobbying for lower taxes by group k. These opposing lobbying incentives have exactly the same magnitude, since they come from the same price effect.[12] The effect of taxes on the price of good m causes no change in the tax schedule.

In free trade the price of the high end consumer good 2 does not get affected by the pollution tax. This price effect too created opposing and equal lobbying incentives,[13] (as a majority of good 2 is consumed by the special interests[14]). Apart from these gains and losses, every group organized or not, gains from the increased responsiveness of pollution in free trade ($[v_z - t]\left[\pi^k_{tt}\right] > [v_z - t]\left[\pi^k_{tq}\frac{dq}{dt} + \pi^k_{tt}\right] > 0$). It is this uncountered increased benefit, that influences the government to set a higher environmental tax in the open economy.

[12] Recall the aggregate special interest benefits from pollution tax in autarky. The price effect of increased taxes on good m is: $\left[\pi^k_q + \pi^s_q\right]\frac{dq}{dt}$. This term demonstrates why this effect is not the cause of the improvement in policy.

[13] In the aggregate special interest benefits in autarky, the effect of taxes on the price of good 2 is $\left[\pi^s_p - x^2_p\right]\frac{dp_2}{dt}$. Here too one can see why this effect does not cause the improvement in policy.

[14] This assumption is relaxed later in the paper.

4 The Welfare Effects of Choosing Free Trade: A Numerical Exercise

The analysis so far demonstrates that the adoption of free trade can improve pollution policy when prices are constant. An explanation of why free trade is chosen, and the impact of choosing free trade with prices different from autarky prices on pollution policy, and aggregate welfare has been ignored. This section addresses these issues.

4.1 Framework for Numerical Analysis

4.1.1 The Choice of Free Trade

The government's choice of free trade is determined by the equation (29) (see Appendix A.1). In order to test this in a numerical model one has to specify the contribution schedules. I assume globally truthful contribution schedules (Bernheim and Whinston (1986)); formally defined as $C^{Tj}(t, R; B_j) = \max\left\{0, W^j(t, R) - B_j\right\}$. Assuming positive contributions, equation (29) can be re-written as

$$\sum_{j \in J} W^j\left(t^0, R^0\right) + aW\left(t^0, R^0\right) \geq \sum_{j \in J} W^j\left(t, R\right) + aW\left(t, R\right)\ \forall t \in \tau, R \in \{I, F\}. \tag{19}$$

This implies that the government in its choice of trade regime, prefers the regime with a higher weighted sum of special interest and aggregate welfare. Since the two special interest tax schedules (equation (16), and (18)) maximize this weighted sum in each of the two trade regimes, the government will choose free trade if and only if $\sum_{j \in J}[W^j\left(t_F^0, F\right) - W^j\left(t_I^0, I\right)] + a[W\left(t_F^0, F\right) - W\left(t_I^0, I\right)] \geq 0$.[15] The sign of this inequality is determined by the pollution tax schedules, and by the prices available in the world market.

4.1.2 Functional Forms and Parameter Values

All specific factors are normalized to 1, i.e. $h, s, k = 1$. The specific factor for good 1 (h) has the return $\pi^h\left(p_1\right) = \eta_0 + \frac{\eta_1}{2}\left[p_1\right]^2 - \eta_2\left[p_1\right]$. The specific factor in the production of good 2 (s) has the

[15] For a comprehensive analysis of the choice of trade regime by a common agency government, see Grossman and Helpman (1995).

return $\pi^s(p_2, q) = \alpha_0 + \frac{\alpha_1}{2}[p_2]^2 - \alpha_2[p_2] + \frac{\alpha_3}{2}[q]^2 - \alpha_4[q] - \alpha_5[p_2 q]$, and finally the specific factor in intermediate good production (k) has a marginal return $\pi^k(q, t) = \beta_0 + \frac{\beta_1}{2}[q]^2 - \beta_2[q] + \frac{\beta_3}{2}[t]^2 - \beta_4[t] - \beta_5[qt]$. The sub-utility functions are, for good 1 : $u^1(x_1) = \delta + \frac{\delta_o}{\delta_1}[x_1] - \frac{1}{2\delta_1}[x_1]^2$, for good 2 : $u^2(x_2) = \theta + \frac{\theta_o}{\theta_1}[x_2] - \frac{1}{2\theta_1}[x_2]^2$, and damage from pollution is given by $v(z) = v_0[z] + \frac{v_1}{2}[z]^2$.

In order to solve this model several parameters need to be specified. These values are detailed in Table 1. These values are specified to guarantee convexity of the restricted profit functions in prices, and to ensure positive quantities and prices. Besides the parameters in Table 1, the number n_l (size of the labor owning group) is assumed equal to 0.9, i.e., 90% of the population is not organized in the environmental policy game (estimate based on Lowe and Goyder (1983)). The parameter a (the weight given to aggregate welfare in the governments utility function) is set equal to 32.33.[16]

In a numerical analysis it is important to know how the results vary with a change in the parameters. For this reason sensitivity of this analysis to parameter values is studied in the Appendix A.3.2. I find that the results presented in this section are unaffected by the choice amongst feasible parameter values.

4.2 World Prices, the Choice of Free Trade, and Aggregate Welfare

Initially the model is solved for the case of autarky. Two government types are assumed: special interest, and the standard welfare maximizing. Each solution yields a tax rate for pollution and corresponding goods prices. These results are outlined in Table 2. Next, assuming price taking behavior (small open economy), the model is simulated with a continuous variation in free trade prices. The corresponding tax rate and aggregate welfare is calculated. Initially only the price q (price for the polluting intermediate good m) is allowed to differ from its value in autarky.

Figure 2 graphs the gains or losses in government and aggregate welfare as q is varied. The

[16] Goldberg and Maggi (99) empirically verify the Grossman and Helpman (94) model for US data. They estimate the government's welfare function of the form $G = (1-\beta)\sum_{j\in J} C^j(t, R) + \beta W(t, R)$ and provide an 95% confidence interval for $\beta \in [0.97, 0.99]$. The relation between a in this model and β is $a = \frac{\beta}{(1-\beta)}$, thus the value in this paper corresponds to the lower limit $\beta = 0.97$.

curve ΔG

$$\Delta G = \sum_{j \in J} [W^j \left(t_F^0, F\right) - W^j \left(t_I^0, I\right)] + a[W \left(t_F^0, F\right) - W \left(t_I^0, I\right)] \tag{20}$$

is the gain/loss in government welfare from adopting free trade, and the curve ΔAW

$$\Delta AW = [W \left(t_F^0, F\right) - W \left(t_I^0, I\right)] \tag{21}$$

is the gain/loss in aggregate welfare from adopting free trade. ΔG drops below zero for the interval $[0.536039, 0.637693]$ implying that the government loses welfare from adopting free trade in this region. For these values of q free trade is rejected. The curve ΔAW never drops below zero, this implies that aggregate welfare in free trade is always above the aggregate welfare in autarky even in the region where free trade is rejected by the government. This curve attains its minimum at $q = 0.582304$ at a value of 0.0128266.

Allowing all Prices to Vary Next allow the price of the polluting intermediate, and the price of the high end consumer good 2 in free trade to be different from their autarky values. This region of rejection for free trade is illustrated in Figure 3. The figure contains a curve in (p_2, q) space, at all points to the left of the curve the function ΔG (see equation(20)) becomes negative, and the government rejects free trade. Contained in this region is the price point corresponding to the welfare maximizing autarky tax rate (see Table 2).[17]

Meanwhile if free trade were accepted in this region aggregate welfare would be higher than that attained in autarky. Figure 4 plots the difference in aggregate welfare in free trade and autarky (the function ΔAW, see equation (21)) in (p_2, q) space. The function never falls below zero, i.e., aggregate welfare in free trade is always higher than that attained in autarky. This

[17] All else being equal a tax rate maps into a price q and p_2. The horizontal line drawn at $q = 0.581964$ denotes the autarky welfare maximizing price for m, now consider the point $p_2 = 0.940915$ (welfare maximizing price for good 2) on this line. The point $(0.582, 0.941)$ lies to the left of the curve and in the region where free trade is rejected by the special interest government.

This point corresponds to the situation where the South faces the prospect of free trade with a world that internalizes the pollution externality completely but is similar in all other respects. This situation is similar to that analyzed in Brander and Taylor (97b) where the South and the North differ only in their degree of internalization of the pollution externality. I find that while aggregate welfare would have been higher if free trade was adopted, special interest groups prevent the government from choosing free trade ($R = I$).

function attains a minimum at ($p_2 = 0.940937, q = 0.582498$) with a value of $\Delta AW = 0.0127468$.

Finally, consider the case where all free trade prices can be different from autarky prices. The function ΔAW achieves its minimum at ($p_1 = 0.916667, p_2 = 0.940937, q = 0.582498$) with a value of $\Delta AW = 0.0127468$. Note that this minimum has the same value as the minimum where only (p_2, q) are different from autarky values, also note that the minimizing value for p_1 is equal to its autarky price.[18]

The analysis of this section is summed up below.

Summary 1 The adoption of free trade increases aggregate welfare from its corresponding value in autarky. In the price region where the special interest government rejects free trade, aggregate welfare could potentially be higher if free trade was adopted.

Regardless of the free trade price vector, this economy gains aggregate welfare when it adopts free trade. This gain in welfare exists even when the world price of the polluting intermediate (q) is higher than that prevalent in autarky, and the polluting intermediate good is exported. Note that this export is feasible in part due to the incomplete environmental regulation present in this economy.

A gain in aggregate welfare is in sharp contrast to the predictions from Chichilinsky (1994), and Brander and Taylor (1997a, 1997b, and 1998). These articles predicted that a country with incomplete environmental regulation would lose welfare if it exported the polluting good. In this model the improvement in pollution policy reduces the deadweight loss from pollution. Thus, while the polluting good may be exported, and overall pollution may be higher in free trade (see Appendix A.3.1), gains from an improved pollution policy, and increased specialization imply an overall gain in welfare from adopting free trade.

[18] The production and consumption of good 1 has no link to the negative externality from pollution. Any variation in the price of this good from autarky price gives us the standard gains from trade, and raises aggregate welfare. This is verified when the minimum for the function ΔAW over all prices is calculated.

5 Some Alternative Specifications

In order to highlight the robustness of the result discussed in Section 3.2 this section reconsiders the effect of free trade on environmental policy after relaxing some basic assumptions in Section 2.

5.1 Pollution Generated by Consumption

In addition to the pollution created in the production of the intermediate good assume that consumption of good 2 (the high end consumer good) also generates pollution. This assumption reflects a consensus amongst environmentalists (see Kates (2000)), that affluence based consumption is amongst the primary sources of environmental degradation.

Assume that consumption of one unit of good 2 produces a constant ψ units of pollution. The total level of pollution in the economy is $z = z_m + z_2$, where z_m denotes the pollution generated in the production of good m and $z_2 = \psi x^2(\tilde{p}_2)$ denotes the pollution generated from the consumption of the high end consumer good 2. As earlier the externality from pollution is still corrected using a pollution tax. The effective consumer price for good 2 is $\tilde{p}_2 = (p_2 + \psi t)$, and an increase in pollution tax has a direct effect on the consumer price of good 2. Further, in autarky an increase in t has an effect on the producer price p_2 as well. This effect on the producer price comes from the increase in the price of the intermediate good, and from a reduction in demand for good 2.

The change in price of the intermediate good due to an increase in pollution tax t is given by $\frac{dq}{dt} = \frac{\left[-\pi^k_{qt}\right] - x^2_p \frac{\left[\psi\pi^s_{qp} - \pi^k_{qt}\right]}{\left[\pi^s_{pp}\right]}}{\Delta}$ (where the denominator $\Delta = \frac{\left[\left[\pi^s_{pp}\pi^s_{qq} - \left(\pi^s_{qp}\right)^2\right] - x^2_p\pi^s_{qq} + \pi^k_{qq}\left[\pi^s_{pp} - x^2_p\right]\right]}{\left[\pi^s_{pp}\right]}$ is positive due to the convexity of profit, and concavity of utility functions). The sign for the price effect above depends upon the strength of two counteracting effects. The first $\left[-\pi^k_{qt}\right]$ is the direct positive effect from the complementarity of pollution and output. The second $-x^2_p\frac{\left[\psi\pi^s_{qp} - \pi^k_{qt}\right]}{\left[\pi^s_{pp}\right]}$ comes from the effect of an increase in t on the demand for good 2, which in turn influences the demand for good m. The second term is ambiguous depending upon the relative elasticities of input demand in both industries and the constant ψ. We shall assume that the direct effect $\left[-\pi^k_{qt}\right]$

prevails and $\frac{dq}{dt} > 0$.

The change in price of final good 2, also depends on the relative magnitude of two factors ($\frac{dp_2}{dt} = \frac{\psi x_p^2 \frac{\left[\pi_{pp}^s + \pi_{qq}^s\right]}{\left[\pi_{pp}^s\right]} + \frac{\left[\pi_{qp}^s \pi_{qt}^k\right]}{\left[\pi_{pp}^s\right]}}{\Delta}$). An increase in tax causes a reduction of demand for good 2, the first component ($\psi x_p^2 \frac{\left[\pi_{pp}^s + \pi_{qq}^s\right]}{\left[\pi_{pp}^s\right]}$) captures this negative effect, the second component ($\frac{\left[\pi_{qp}^s \pi_{qt}^k\right]}{\left[\pi_{pp}^s\right]}$) captures the impact of an increase in price of the intermediate input. As above assume that the direct effect dominates and the final impact of an increase in tax t is to reduce producer price p_2, i.e. $\frac{dp_2}{dt} < 0$. This new framework yields the following tax rates.

The optimal special interest tax in Autarky for this economy can be expressed as

$$\hat{t}_I^0 = v_z(z) + \frac{n_l}{(n_h + n_s + n_k + a)} \left[\frac{\left[\pi_t^k - \psi x^2\right]}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k - \psi x_p^2 \left[\frac{dp_2}{dt} + \psi\right]\right]} \right]. \tag{22}$$

The optimal special interest tax in Free Trade for this economy can be expressed as

$$\hat{t}_F^0 = v_z(z) + \frac{n_l}{(n_h + n_s + n_k + a)} \left[\frac{\left[\pi_t^k - \psi x^2\right]}{\left[\pi_{tt}^k - (\psi)^2 x_p^2\right]} \right]. \tag{23}$$

A graphical proof similar to proposition (1) yields the following proposition.

Proposition 2 At a constant price for good m (q) and good 2 (p_2), the special interest tax in free trade has a higher value than the corresponding special interest tax in autarky, and a smaller value than the corresponding welfare maximizing tax.

Once more the gain in responsiveness of pollution to pollution tax drives the improvement of environmental regulation. In free trade, the price of intermediate good does not rise, this prevents the producers of pollution from transferring a portion of the pollution tax onto the consumers of their good. Responsiveness of production pollution (z_m) to tax increases. Further, in free trade the producer price of the polluting consumer good 2 does not decline when the pollution tax is increased. This ensures that consumers have to bear the entire burden of the pollution tax that is imposed upon them. Consumption of good 2 declines faster in free trade due to an increase in tax, than in did in autarky. The increased responsiveness induces the government to set a higher tax in free trade than it did in autarky.

5.2 Consumption of Good 2 by all agents

So far good 2 is consumed only by the rich, now assume that good 2 was consumed by all agents in the economy. The utility function for every individual is $u(x_0, x_1, x_2; z) = x_0 + u^1(x_1) + u^2(x_2) - v(z)$ where x_i is the consumption of good $i \in \{0, 1, 2\}$, $u_x^i(.) > 0$, $u_{xx}^i(.) < 0$, $v_z(.) > 0$ and $v_{zz}(.) > 0$, and goods price conditions do not change.

If autarky is the preferred trade regime, the special interest tax (denoted $\tilde{t}_I$) can be expressed as

$$\tilde{t}_I = v_z(z) + \frac{n_l}{((1-n_l)+a)} \frac{\pi_t^k + \left[x_p^2\right] \frac{dp_2}{dt}}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]}. \tag{24}$$

An increase in tax increases the burden of group k by $n_l\left(-\pi_t^k\right)$ encouraging it to lobby for a lower tax. Like Section 3.1, the effect from an increase in price of the intermediate good m is nullified by an increase in the price of the intermediate input for good 2 (see equation (17)). But unlike Section 3.1 the increase in the price of good 2 is not nullified completely. Good 2 is primarily consumed by the unorganized in the pollution tax game (i.e. group l), and an increase in p_2 multiplied by group l's share of consumption of good 2 $[\left[x_p^2\right] \frac{dp_2}{dt}]$ is a net increase in aggregate profits for the lobbyists. Thus group s has an uncountered incentive to lobby the government for a higher tax in autarky. This incentive comes from a second order effect on prices, an increase in tax t effects the price of an intermediate input (q), which in turn effects the price of the final good (p_2) (i.e. $\frac{dp_2}{dt} = \frac{dp_2}{dq}\frac{dq}{dt}$).

If free trade is the preferred trade regime the special interest tax (denoted $\tilde{t}_F$) can be expressed as

$$\tilde{t}_F = v_z(z) + \frac{n_l}{((1-n_l)+a)} \left[\frac{\pi_t^k}{\pi_{tt}^k}\right]. \tag{25}$$

This schedule is the same as in Section 3.2. The incentive to lobby in order to benefit from an increase in the price of good 2 disappears. Further, the responsiveness of pollution is higher in free trade compared to that in autarky, promising greater benefits from an increase in the pollution tax in free trade ($[v_z - t]\left[\pi_{tt}^k\right] > [v_z - t]\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right] > 0$).

In this case, the effect of adopting free trade on pollution tax is not as easy to determine as it was in Section 3.2. As discussed earlier the comparison of the two tax schedules depends on the extra term in the schedules, and in this case the comparison between $\frac{\pi_t^k + \left[x_p^2\right]\frac{dp_2}{dt}}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]}$ and $\left[\frac{\pi_t^k}{\pi_{tt}^k}\right]$ depends on the relative magnitude of $\left[x_p^2\right]\frac{dp_2}{dt}$ and $\pi_{tq}^k \frac{dq}{dt}$. If the price effect ($\frac{dp_2}{dt}$) is significant in magnitude a comparison of the two tax schedules is not possible without determining their relative magnitudes. If we have reason to believe that $\frac{dp_2}{dt}$ is very small,[19] the analysis is exactly the same as it was in Section 3 and the adoption of free trade is accompanied by an improvement of the pollution tax.

5.3 A Single Lobbyist: Owners of Polluting Capital

Consider the case where the only lobbyists in the economy are the owners of polluting capital, the case considered by López and Mitra (2000). The government's welfare function is: $G = C^k(t,R) + aW(t,R)$. In the absence of any contributions the government chooses free trade (F), and the welfare maximizing tax schedule (equation (11)) as its policy pair. Thus group k solves $\max_{C^k,t,R}\left\{W^k(t,R) - C^k(t,R) : C^k(t,R) + aW(t,R) \geq aW(t^*,F)\right\}$. This problem can be re-expressed as $\max_{t,R}\left\{W^k(t,R) - a\left[W(t^*,F) - W(t,R)\right]\right\}$, which implies that the optimal tax is determined by the condition: $\frac{d}{dt}\left[W^k\left(t^0,R^0\right) + aW\left(t^0,R^0\right)\right] = 0$.

If the chosen trade regime is autarky the tax (denoted t_I^k) can be expressed as

$$t_I^k = v_z(z) + \frac{(1-n_k)\left[\pi_t^k\right] + \left[\left[\pi_q^k\right]\frac{dq}{dt} - \frac{n_k}{(1-n_l)}\left[x_p^2\right]\frac{dp_2}{dt}\right]}{(n_k + a)\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]}. \tag{26}$$

An increase in the pollution tax raises the tax burden (net of transfers) of group k by $-(1-n_k)\left[\pi_t^k\right]$, it also raises the cost of consuming the high end consumer good 2 by $\frac{n_k}{(1-n_l)}\left[x_p^2\right]\frac{dp_2}{dt}$, some of this burden is reduced by transferring tax through an increase in the price of good of the intermediate good m ($\left[\pi_q^k\right]\frac{dq}{dt}$). The net effect of a tax is likely to be negative (see Appendix A.2.2).

[19] This price effect is small if there is high substitutability between the intermediate input and other factors of production, or if the share of the intermediate good in production of good 2 is small.

If the chosen trade regime is free trade, the accompanying tax (denoted t_F^k) can be expressed as

$$t_F^k = v_z(z) + \frac{(1-n_k)}{(n_k+a)}\left[\frac{\pi_t^k}{\pi_{tt}^k}\right]. \tag{27}$$

A transfer of the pollution tax to consumers is no longer possible, also there is no increase in the cost of consuming good 2.

A comparison of the two tax schedules above is possible only if group k is a negligible part of the population (i.e. $n_k \approx 0$). The tax schedule (t_I^k) in equation (26) reduces to $t_I^k = v_z(z) + \frac{1}{a}\frac{\left[\pi_t^k + \pi_q^k \frac{dq}{dt}\right]}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]}$, and the free trade tax schedule becomes $t_F^k = v_z(z) + \frac{1}{a}\left[\frac{\pi_t^k}{\pi_{tt}^k}\right]$. Group k can transfer some of the pollution tax to consumers in autarky $\left[\pi_q^k \frac{dq}{dt}\right]$ but has to bear the pollution tax completely in free trade encouraging it to lobby harder for a lower pollution tax. As earlier, pollution is more responsive to pollution tax in free trade, and all groups gain from this increased responsiveness ($[v_z - t]\left[\pi_{tt}^k\right] > [v_z - t]\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right] > 0$).

The effect of adopting free trade on pollution tax is quite different from that in Section 3.2. Following the logic of the proof from proposition 1, the autarky tax rate (t_I^k) will be greater than the free trade tax rate (t_F^k) if at constant prices $\left[\frac{\pi_t^k}{\pi_{tt}^k}\right] \leq \frac{\left[\pi_t^k + \pi_q^k \frac{dq}{dt}\right]}{\left[\pi_{tq}^k \frac{dq}{dt} + \pi_{tt}^k\right]} \leq 0$. We can express this term as $\frac{\varepsilon_{z,t}}{\varepsilon_{m,t}} \geq 1$ where $\varepsilon_{z,t} = \frac{-\pi_{tt}^k t}{\pi_{tt}^k}$ is the partial equilibrium elasticity of pollution with pollution tax t and $\varepsilon_{m,t} = -\frac{\pi_{q,t}^k t}{\pi_{p_1}^h}$ is the partial equilibrium elasticity of output in industry m with pollution tax t. In other words if the own price elasticity of pollution with respect to (w.r.t.) t is greater than the cross price elasticity of output m w.r.t. t then the open economy tax schedule is likely to exacerbate the deadweight loss associated with the incomplete internalization of the pollution externality. In most cases, one expects pollution to be more responsive to its own price than output in industry m. It seems plausible that the choice of free trade would worsen pollution policy for this economy.

Proposition 3 Suppose the only lobby in an economy is the polluting industry. At a constant price for good m (q), the special interest tax in free trade is likely to have a lower value than the corresponding special interest tax in autarky. Both tax rates have values lower than that of the welfare maximizing tax rate.

6 Conclusion

This paper shows that a move to free trade can prevent the producers of pollution from shifting the burden of a pollution tax to the consumers of their good, and makes pollution more responsive to a change in the pollution tax. Increased responsiveness promises greater benefits to all groups hurt by pollution when the pollution tax is increased, and encourages greater lobbying for environmental protection in free trade. This induces the government to improve its pollution policy in free trade, bringing it closer to the welfare maximizing ideal. Thus a move to free trade encourages the government to better represent aggregate preferences, and reduces the influence of polluting special interests.

The welfare effects from a move to free trade are determined through a simulation of the model. Simple functional forms and minimal restrictions on the parameters are employed. The numerical solutions show a gain in aggregate welfare from the adoption of free trade. This gain occurs even when the price for the polluting good in free trade is higher than the autarky price. A higher price for the polluting good can increase pollution and the damages from pollution, but it also increases the pollution tax. Higher prices also increase income in the economy, which combined with a better internalization of the pollution externality more than makes up for the increased damage. Free trade raises aggregate welfare even if the country with incomplete environmental protection exports the pollution intensive good. Unlike the models in Chichilinsky (1994), and Brander and Taylor (1997a, 1997b, and 1998) where environmental policy is assumed to be inflexible, this paper demonstrates that free trade can improve pollution policy to an extent where an increase in welfare from adopting free trade is possible. This increase in welfare occurs despite the existence of incomplete environmental regulation in the country exporting the pollution intensive good.

The above results are generated using a setup where pollution is produced from a production process alone. To allow greater generality, the model is extended to include the production of pollution from consumption (consumption of a high end consumer good generates pollution). Tax is levied directly on pollution generated. In addition to preventing the producers of pollution from transferring the incidence of pollution tax, a move to free trade prevents the consumers of the high end consumer good from transferring this tax to the producers of this good. As a result the responsiveness of pollution to pollution tax increases and in this case too a move to free trade improves pollution policy.

This improvement in pollution policy depends critically on the existence of environmental lobby groups. This result is reversed if the economy had a single lobby group representing the interests of the owners of polluting capital alone. Owners of polluting capital lose more from an increase in the pollution tax in free trade. This encourages them to lobby harder for a lax pollution policy in free trade. Eventually, if there is no organized group to counter their lobbying the government is induced to lower pollution taxes in free trade.

The analysis provides an interesting hypotheses for empirical verification. Ceteris paribus, in a given country environmental regulation should be more stringent for traded goods than for non-traded goods. A cross country variant of this hypothesis would be: ceteris paribus, countries trading pollution intensive goods should have more stringent environmental regulation than countries that impose barriers on the trade of such goods. In contrast to previous empirical analyses which tested the effect of pollution policy on the export of pollution intensive good, this paper suggests a reversal of the causation to test the effect of freer trade on pollution policy. Analyses testing the effect of pollution policy on the export of pollution intensive goods have not been entirely conclusive in their results (see Jaffe et. al. (1995) for a survey), an incorporation of the reverse causality may improve their predictive power.

A Appendix

A.1 Conditions and Characteristics of The Political Equilibrium

Define $\tau = \left[\underline{t}, \overline{t}\right]$ as the interval of feasible pollution tax levels and restrict attention to equilibria that lie in the interior of τ. The equilibrium to this policy game satisfies the following conditions.

Conditions for a political equilibrium.(Bernheim and Whinston (1986) & Grossman and Helpman(1994)): $\left(\left\{C^{j0}\left(t\right)\right\}_{j\in J}, t^0, R^0\right)$ is a sub-game perfect Nash equilibrium of the environmental policy game if and only if

C1. $C^{j0}\left(t, R\right)$ is feasible for all $j \in J$.

C2. $\left(t^0, R^0\right) = \arg\max\left\{\sum_{j\in J} C^{j0}\left(t, R\right) + aW\left(t, R\right)\right\}$ with $t \in \tau, R \in \{I, F\}$.

C3. $\left(t^0, R^0\right) = \arg\max\left\{W^r\left(t, R\right) - C^{r0}\left(t, R\right) + \sum_{j\in J} C^{j0}\left(t, R\right) + aW\left(t, R\right)\right\}$ with $t \in \tau, R \in \{I, F\}$ for every $r \in J$.

C4. $\forall r \in J, \exists\ t^r \in \tau \& R^r \in \{I, F\} : \left(t^r, R^r\right) = \arg\max\left\{\sum_{j\in J,\ j\neq r} C^{j0}\left(t, R\right) + aW\left(t, R\right)\right\}$

Condition (C1) stipulates feasible contribution schedules (non-negative, and no greater than aggregate income available with lobby members). Condition (C2) states that the government sets pollution policy to maximize its own welfare. Condition (C3) stipulates efficiency in the relation between the government, and each lobby involved in the political process, it requires the optimal tax to maximize their joint welfare. Condition (C4) requires that there exist a alternate tax schedule, and choice of trade regime; the next best option for the government, in case it wishes to cut out any particular lobby from the political process.[20]

Assume that lobbies offer differentiable contribution schedules. Condition (C2) implies

$$\frac{d}{dt}\left[\sum_{j\in J} C^{j0}\left(t^0, R^0\right) + aW\left(t^0, R^0\right)\right] = 0 \tag{A.28}$$

and

$$\sum_{j\in J} C^{j0}\left(t^0, R^0\right) + aW\left(t^0, R^0\right) \geq \sum_{j\in J} C^{j0}\left(t, R\right) + aW\left(t, R\right)\ \ \forall t \in \tau, R \in \{I, F\}. \tag{A.29}$$

These imply that the pollution tax is chosen to maximize the government's welfare in the equilibrium trade regime. Also the governments welfare in the equilibrium trade regime with the optimal pollution tax is the highest feasible.

[20] See Grossman and Helpman (1994) for a more detailed explanation and discussion of these conditions.

From condition (C3) we get

$$\forall r \in \{h,k,s\}: \frac{d}{dt}\left[W^{r}\left(t^{0},R^{0}\right)-C^{r0}\left(t^{0},R^{0}\right)+\sum_{j\in J}C^{j0}\left(t^{0},R^{0}\right)+aW\left(t^{0},R^{0}\right)\right]=0 \quad \text{(A.30)}$$

and

$$\begin{aligned} & W^{r}\left(t^{0},R^{0}\right)-C^{r0}\left(t^{0},R^{0}\right)+\sum_{j\in J}C^{j0}\left(t^{0},R^{0}\right)+aW\left(t^{0},R^{0}\right) \\ \geq\ & W^{r}\left(t,R\right)-C^{r0}\left(t,R\right)+\sum_{j\in J}C^{j0}\left(t,R\right)+aW\left(t,R\right)\ \ \forall t\in\tau, R\in\{I,F\} \end{aligned} \quad \text{(A.31)}$$

Equation (29) and equation (31) jointly imply that there exists no lobby group whose losses are large enough to eclipse the gains in government welfare from the choosing the equilibrium trade regime.[21]

These first order conditions allow a simple interpretation for the nature of the contribution schedules. Substituting equation (28) into equation (30) we get

$$\forall r \in \{h,k,s\}: \frac{d}{dt}\left[C^{r0}\left(t^{0},R^{0}\right)\right]=\frac{d}{dt}\left[W^{r}\left(t^{0},R^{0}\right)\right] \quad \text{(A.32)}$$

This implies that lobbies offer locally truthful contributions around the equilibrium. Further if we sum equation (32) for all $r\in\{h,k,s\}$ we get $\sum_{r\in\{h,k,s\}}\frac{d}{dt}\left[C^{r0}\left(t^{0},R^{0}\right)\right]=\sum_{r\in\{h,k,s\}}\frac{d}{dt}\left[W^{r}\left(t^{0},R^{0}\right)\right]$. Substituting this result into equation (28) yields

$$\frac{d}{dt}\left[\sum_{j\in J}W^{j}\left(t^{0},R^{0}\right)+aW\left(t^{0},R^{0}\right)\right]=0 \quad \text{(A.33)}$$

The optimal political tax maximizes a weighted welfare function where lobby groups get a higher weight than unorganized citizens.

A.2 The Effects of a Pollution Tax

A.2.1 Pollution Tax and Output of Pollution (Autarky)

Pollution in this economy is $z=-\pi_{t}^{k}\left(q,t\right)$. In a closed economy the change in pollution due to an increase in the pollution tax includes the change caused by an increase in q (price of

[21] If such a group existed it could influence the government to choose another trade regime, and this regime would not be an equilibrium. The group could offer the government a payment marginally higher than the government's gains but lower than its own losses. This would induce the government to choose the group's preferred equilibrium and increase joint welfare.

m) from t. The change is: $\frac{dz}{dt} = -\left[\pi^k_{qt}\frac{dq}{dt} + \pi^k_{tt}\right]$. From equation (9) we can substitute the value of $\frac{dq}{dt}$ and get $\frac{dz}{dt} = -\left[\pi^k_{tt} - \frac{\left[\pi^k_{tq}\right]^2}{\left[\pi^k_{qq} + \frac{\left[\pi^s_{qq}\pi^s_{pp} - \left(\pi^s_{qp}\right)^2\right]}{\left[\pi^s_{pp} - x^2_p\right]} + \frac{-\pi^s_{pp}x^2_p}{\left[\pi^s_{pp} - x^2_p\right]}\right]}\right]$. This term is re-arranged $\frac{dz}{dt} = -\left[\frac{\left[\pi^k_{tt}\pi^k_{qq} - \left[\pi^k_{tq}\right]^2\right]\left[\pi^s_{pp} - x^2_p\right] + \pi^k_{tt}\left[\left[\pi^s_{qq}\pi^s_{pp} - \left(\pi^s_{qp}\right)^2\right] + -\pi^s_{pp}x^2_p\right]}{\left[\pi^k_{qq}\left[\pi^s_{pp} - x^2_p\right] + \left[\pi^s_{qq}\pi^s_{pp} - \left(\pi^s_{qp}\right)^2\right] + -\pi^s_{pp}x^2_p\right]}\right] < 0$. All terms inside the brackets in the numerator and denominator are positive due to the convexity of the restricted profit functions, or due to the concavity of the utility function. Thus despite the increase in q when the pollution tax is increased pollution declines in a closed economy.

A.2.2 Pollution Tax and the Marginal Return to Polluting Capital (Autarky)

The return to polluting capital is $\pi^k_t(q,t)$, one would expect this return to decrease when the tax on pollution is increased. The effect of increased pollution tax on return to polluting capital in a closed economy is: $\frac{d}{dt}\left[\pi^k_t(q,t)\right] = \pi^k_q\frac{dq}{dt} + \pi^k_t$. Since $\frac{dq}{dt} > 0$ the first term is positive and the second term is negative. Using the definition of $\frac{dq}{dt}$ from equation (9) and rearranging we can express this effect as $\frac{d}{dt}\left[\pi^k_t(q,t)\right] = \left[\left[-\pi^k_{qt}\pi^k_q + \pi^k_{qq}\pi^k_t\right] + \frac{\pi^k_t}{\left[\pi^s_{pp} - x^2_p\right]}\left[\pi^s_{qq}\pi^s_{pp} - \left(\pi^s_{qp}\right)^2\right] + -\pi^s_{pp}x^2_p\right]$. The third term in the numerator is negative, as $\pi^k_t < 0$ thus if the sum of the first two terms is negative then $\frac{d}{dt}\left[\pi^k_t(q,t)\right] < 0$, investigate these two terms next. We need $\left[-\pi^k_{qt}\pi^k_q + \pi^k_{qq}\pi^k_t\right] \leq 0$. Re-arrange these two terms, use Young's theorem on the equality of cross partials, and multiply by a positive number q which preserves the sign, thus the inequality can be expressed as $\frac{-\pi^k_{tq}q}{-\pi^k_t} \leq \frac{\pi^k_{qq}q}{\pi^k_q}$. This inequality can be interpreted as the $\varepsilon_{z,q} \leq \varepsilon_{m,q}$ where $\varepsilon_{z,q} = \frac{-\pi^k_{tq}q}{-\pi^k_t}$ is the partial equilibrium elasticity of pollution with price of the intermediate good m: q, and $\varepsilon_{m,q} = \frac{\pi^k_{qq}q}{\pi^k_q}$ is the partial equilibrium elasticity of output in industry m with its own price q. Good m is likely to be more responsive to its own price, than pollution is to the price of good m. Thus the returns to polluting capital are likely to fall when the pollution tax is increased even in the closed economy.[22]

[22] The assumption that returns to polluting capital rise when the tax on pollution rises is quite counter-intuitive and would involve the polluting industry lobbying for higher pollution taxes.

A.3 Numerical Exercise

A.3.1 Tax Rates and Pollution Levels

The variation in tax rates when q is varied is illustrated in Figure 5. The horizontal line t_I is the tax rate prevalent in the special interest autarky equilibrium. The dashed curves t_o, and t_F are welfare maximizing and special interest free trade taxes respectively. We see that the free trade tax rate lies above the autarky tax rate at all prices of $q > 0.0764505$ (autarky equilibrium price 0.494876) the welfare maximizing tax rate lies above both the free trade and autarky tax rates.

The path for pollution levels is illustrated in Figure 6. From the dashed curve z_F we can see that pollution levels in free trade would have been lower than autarky levels as long as the price $q \leq 0.587871$. Recall that free trade is rejected in the region $q \in [0.536039, 0.637693]$, thus if $q \leq 0.536039$ free trade would be accepted and pollution levels would be lower in free trade. If $q \geq 0.637693$ then too free trade is accepted but pollution levels associated with free trade are higher than those in autarky. This implies that in the region $q \in [0.494876, 0.536039]$ we have a surprising situation, where the price of the polluting good m is higher, free trade is chosen, and pollution levels are lower than those prevalent in autarky.[23]

A.3.2 Improvement in Aggregate Welfare on Adopting Free Trade: A Sensitivity Analysis

Would there exist an improvement in aggregate welfare from adopting free trade if the parameter values from the model were changed? In order to test the sensitivity of this result I vary the values of: the government's weight on aggregate welfare (a), the size of the unorganized labor owning group (n_l), parameters from the social damage function, and parameters from group k's restricted profit function[24] .

Table 3 summarizes the results from these variations. Each parameter is varied from its base

[23] This situation is not so surprising when we realize that the increased tax rate in free trade reduces the production of good m for this price range. In fact the production of good m in free trade remains below autarky levels as long as $q \leq 0.566106$.

[24] These parameters determine the extent of pollution ($-\pi_t^m$), and the responsiveness of pollution to pollution tax ($\left[\pi_{tq}^m \frac{dq}{dt} + \pi_{tt}^m\right]$).

value to a maximum and minimum value. The maximum and minimum are determined as the points where either the restriction on the curvature of the function, or the restriction requiring positive prices from the model binds. The corresponding Min ΔAW is the minimum value for the function ΔAW (equation (21)) achieved under the new range of parameter values.

As an illustration, consider the effect of varying the weight attached by the government on aggregate welfare (a). This weight determines the extent of special interest influence on government policy making. As $a \rightarrow 0$ the government's policy is chosen to maximize special interest welfare, and as $a \rightarrow \infty$ government's policy is chosen to maximize aggregate welfare. As a gets larger the tax rate moves closer to the socially optimal tax and one can expect standard gains from adopting free trade, this is verified by increasing the value of a to 99. Now consider the region where $a \rightarrow 0$. As a gets smaller, autarky special interest tax falls a can be reduced from 32.33 till 11.5. At any value below 11.5 the model gives a negative tax rate for pollution. Note that the largest minimum gain in welfare is achieved when $a = 11.5$, this is also the point where the tax rate in autarky is the furthest from the welfare maximizing value.[25] Also note that despite all the parameter variations, the adoption of free trade will always give an increase in aggregate welfare. This can be verified by observing that the value of Min ΔAW is always greater than zero.

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[25] As each parameter was varied the special interest tax rate in autarky varied in the interval $[0, 1.46557]$, i.e., between zero and the socially optimal tax. The gain in aggregate welfare from adopting free trade is the largest when the autarky special interest tax is closest to zero. This is intutitively obvious given the concavity of the welfare function in t. Thus in the table above the points where Min $\Delta AW \approx 0$ are those where the autarky special interest tax was close to the welfare maximizing tax. This case corresponds to the first best gains from free trade, where there are no gains from adopting free trade is free trade prices equal autarky prices.

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Parameter	Value	Explanation
δ, θ	$\{10, 20\}$	Intercepts on Utility functions for goods 1& 2
δ_0, θ_0	$\{10, 10\}$	Intercept on demand functions for good 1, 2
δ_1, θ_1	$\{2, 2\}$	Slope on demand functions, good 1 & 2
$\eta_0, \alpha_0, \beta_0$	$\{10, 10, 10\}$	Profit parameters good 1, 2 and m
$\eta_1, \alpha_1, \beta_1$	$\{10, 10, 10\}$	Profit parameters good 1, 2 and $m : \pi^j_{pp}, \pi^k_{qq}$
$\eta_2, \alpha_2, \beta_2$	$\{1, 1, 1\}$	Profit parameters good 1, 2 and m
α_3, β_3	$\{1, 1/2\}$	Profit parameters good 2 and $m : \pi^s_{qq}, \pi^k_{tt}$
α_4, β_4	$\{2, 2\}$	Profit parameter good m
α_5, β_5	$\{1/2, 2\}$	Profit parameter good $m : \pi^s_{pq}, \pi^k_{qt}$
v_0	1/4	Social Damage Parameter: Intercept in $v_z(.)$
v_1	1/2	Social Damage Parameter: $v_{zz}(.)$

Table 1: Parameter Values for Numerical Solutions

Variable	Autarky Values		Free Trade Values (Spec. Int. Tax Schedule)	
	Special. Interest	Welfare. Maximizing	At Autarky Special Interest Prices	At Autarky Welfare Maximizing Prices
p_1 (good 1)	0.916667	0.916667	0.916667	0.916667
p_2 (good 2)	0.937286	0.940915	0.937286	0.940915
q (good m)	0.494876	0.581964	0.494876	0.581964
t (polln tax)	0.987496	1.46557	1.29184	1.35518
R (trade regime)	–	–	F (Free Trade)	I (Autarky)
W (agg. welfare)	98.1243	98.1409	98.1731	98.1371

Table 2: Preliminary Solutions

Parameter	Base Value	Min ΔAW	Min Val.	Min ΔAW	Max Val.	Min ΔAW
a	32.33	0.0128266	11.5	0.111036	99	0.00132
v_1	0.5	0.0128266	0.11	0.014	0.99	0.0110302
β_3	0.5	0.0128266	0.411	0.05123	10	0.00000001
β_1	10	0.0128266	8	0.048612	100	0.0001695
β_5	2	0.0128266	0.01	0.0000001	2.23	0.0549477
n_l	0.9	0.0128266	0.01	0.000001	.999	0.0160012

Table 3: Parameter Variations for the Numerical Solution

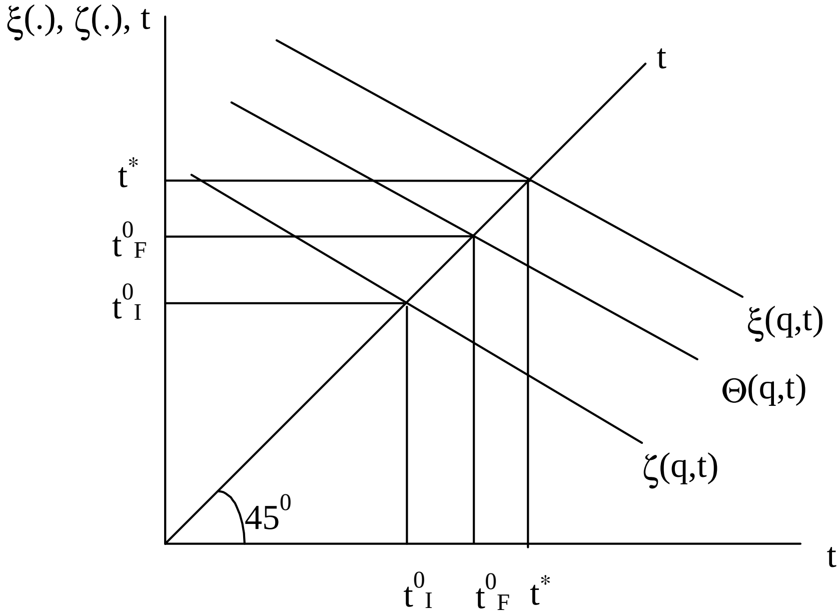

Figure 1: Special Interest and Welfare Maximizing Taxes

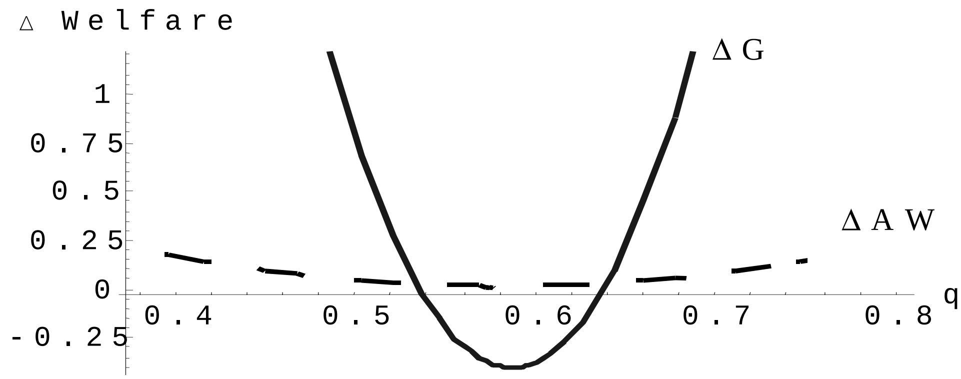

Figure 2: Government Utility and Aggregate Welfare

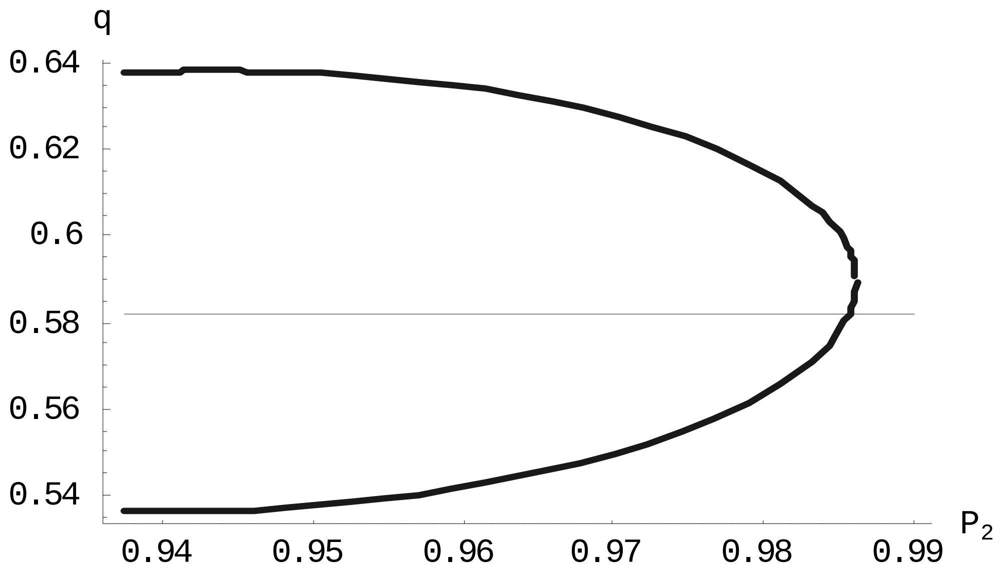

Figure 3: Rejection Region for Free Trade

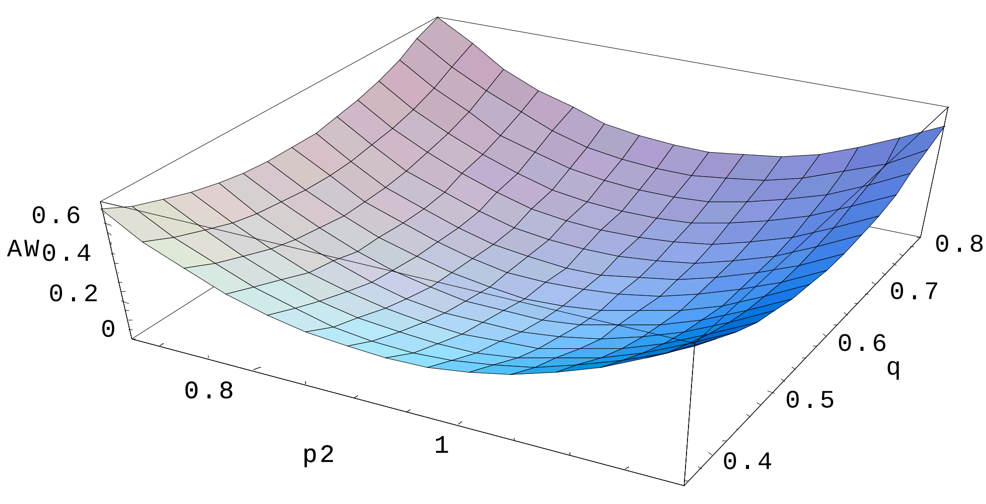

Figure 4: Gain in Aggregate Welfare when Free Trade is Adopted

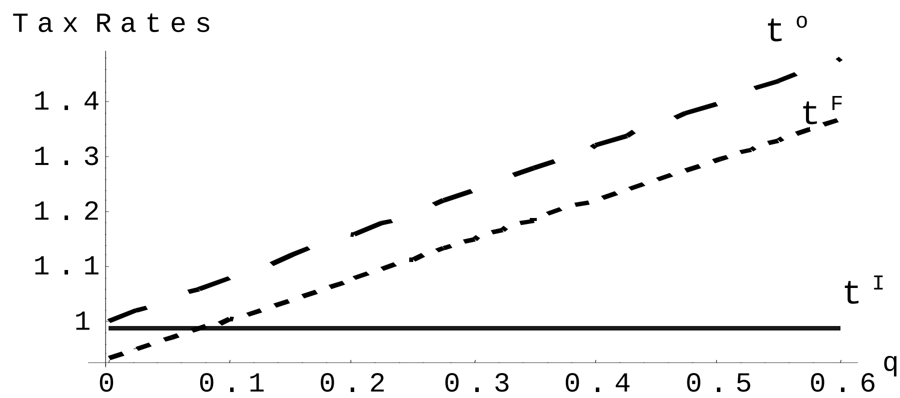

Figure 5: Tax Rates: Special Interest and Welfare Maximizing

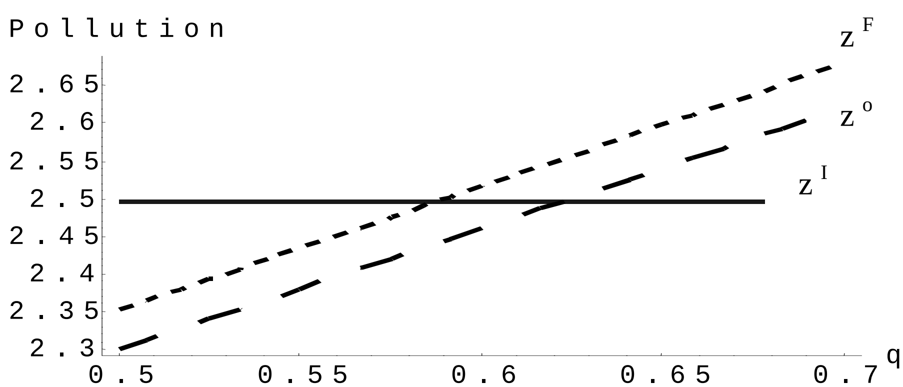

Figure 6: Pollution Emissions: Special Interest and Welfare Maximizing