Free Trade and the Greening of Domestic Industry

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Abstract: A majority of the theoretical literature on trade and the environment supports the view that greater openness causes a weakening in environmental regulation. In this paper we argue that a domestic import-competing industry can benefit from an pollution tax borne by its consumers. We show that this pollution tax can be similar to a traditional trade barrier (such as a tariff) as it can raise the price received by the domestic industry. Given an open economy we highlight conditions under which domestic producers prefer a higher consumer-based pollution tax than is socially optimal. In contrast, when the economy is closed, we find that producers prefer an pollution tax that is lower than socially optimal. Domestic producers turn 'green,' only when faced with import competition. Our aim through this paper is not to argue that free trade is always good for pollution policy. Instead we present an example that emphasizes the importance of understanding the specific pollution problem, and policy instrument used before drawing any conclusions on the effects of free trade on pollution policy.

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1 Introduction

What makes domestic industry prefer stricter environmental regulation in the face of openness?

As countries lower trade barriers, many people believe that governments will weaken environmental regulation, and sacrifice environmental quality to remain globally competitive.[1] However, there are examples that contradict this view. In the 1980's as the European Union (EU) reduced trade barriers among member nations, Germany adopted stricter automobile emission controls than its partners. California consistently adopts stricter emission standards than the rest of the United States. Similarly in an increasing open world, South Korea raised regulatory standards on cars to match the US, the EU, and Japan (see Vogel, 1995 and 2000, for other examples).

Even more surprising are cases where import-competing industries lobby for stricter environmental regulation. Despite being amongst the world's largest producers of Chlorofluorocarbons (CFCs), DuPont famously supported the Montreal Protocol and argued for a complete ban on their use (Oye and Maxwell, 1994). In 1990, US Tuna fishermen supported dolphin-safe labeling (DeSombre, 2000). Recently, European farmers lobbied to ban genetically modified food consumption, production and imports,[2] and European carmakers such as Fiat support high gasoline taxes in Italy (Hammar et. al. 2004). In this paper we show how a domestic import-competing industry benefits from an increase in the pollution tax borne by the consumers of its product.

In our model, we assume that firms can influence the amount of pollution generated on the consumption of their product. Most goods that generate pollution on being consumed share this property. For example: the choice of vehicle fuel efficiency determines the amount of carbon dioxide per mile, the choice of material used during production determines the toxicity of household waste, and the choice of which coal seam is mined determines the sulphur content of coal and influences sulphur dioxide emissions from coal use. We also assume that consumers pay an pollution tax on the pollution they generate.[3] For example: a gas or carbon tax paid by drivers, or a tax (or the price of a permit) on sulphur dioxide emissions from a coal fired power plant.

We then employ a simple political economy model (where domestic producers influence do-

[1] The eight rounds of policy negotiations by the General Agreements on Tariffs and Trade (GATT) and the WTO, have lowered average ad-valorem tariffs on industrial goods from over 40% to below 4% (Bagwell and Staiger, 2000).

[2] For a discussion please see a BBC news report on GMO protests: http://news.bbc.co.uk/2/hi/uk_news/england/london/3186154.stm (accessed March 19th 2009).

[3] In this paper we use a pollution tax for illustration. However, the standard equivalence between price and quantity instruments holds and a pollution quota would have the same impact as the pollution tax.

mestic policy) to derive politically optimal policy under two different policy scenarios. First, the government sets only the consumer based pollution tax. Second, it sets both the pollution tax and a cap on the pollution intensity for goods sold within its borders. In both scenarios we find that the domestic industry turns 'green,' only when the economy opens up to trade. When the economy is closed, domestic producers prefer an pollution tax that is strictly lower than socially optimal. Once the domestic industry is exposed to international competition we find that the pollution tax cannot be lower than socially optimal and the cap on pollution intensity cannot be higher than socially optimal. In other words, pollution policy improves once free trade is adopted. This occurs irrespective of which firm (domestic or foreign) has a lower cost to produce the 'cleaner' good.

While our results imply so our aim is not to argue that increased international competition is always good for the environment. Instead, our aim is to emphasize political incentives previously ignored in the theoretical literature on trade and the environment. Much of this literature supports the view that greater openness causes a weakening in environmental regulation (see for example, Beghin et al., 1997, Ederington, 2001, and Gulati, 2007).[4] Their argument is fairly simple. Traditional trade barriers redistribute income to domestic industry. If the WTO requires a reduction in traditional barriers, governments substitute weak environmental policy as a means to redistribute income.

This argument derives from an assumption of independence between production and consumption. In the standard model of an open economy consumers can buy the good at a constant import price and producers can sell it at a constant export price. Thus any policy that affects production does not impact consumer surplus and similarly, any policy affecting domestic consumers does not impact domestic producer profits. Given this independence the only way a government can redistribute income to domestic producers using environmental policy is by reducing its stringency.

In this paper we illustrate that environmental policy borne by consumers links production and consumption. If producers can influence pollution produced by consumers, they also have incentives to influence the policy imposed on the consumers of their good. In our model, the pollution tax borne by consumers creates a willingness to pay for the pollution intensity of the good.[5] If domestic producers make 'cleaner' goods, a higher pollution tax increases the consumer willingness to pay for

[4] The empirical literature on trade and the environment cannot be characterized as easily, please see Copeland and Gulati (2006), and Copeland and Taylor (2004) for surveys.

[5] For this claim, no special assumptions on consumer tastes are made. Like previous models of trade and the environment, consumers gain utility purely from the consumption of goods and get disutility from pollution.

the domestic good and allows domestic producers to raise the price they charge for their product (much like a traditional trade barrier).

Now reconsider the examples discussed earlier. As DuPont could provide a CFC substitute at a lower cost than its competitors, the worldwide ban on CFC use shifted demand to DuPont (Oye and Maxwell, 1994). As Fiat historically produces a relatively high proportion of fuel efficient diesel cars, high gasoline taxes make consumer prefer their cars over gasoline based imports. Finally, as the US tuna fishing industry could provide dolphin-safe tuna at a lower cost than its competitors, the labeling initiative helped them capture a premium for their output (DeSombre, 2000).[6]

2 Relation to Earlier Literature

The assumption that producers can choose the pollution intensity of consumption is also used in models of environmental product standards (see Fischer and Serra, 2000, Copeland, 2001, and McAusland, 2004). This literature models product standards to highlight their role in raising a rival's cost in an oligopolistic market (see Salop and Scheffman, 1983). However, these models do not consider consumer based environmental policy. For this reason they do not recognize the link created by such policy between production and consumption. An additional difference is that our paper focuses on the political economy motivations for policy. These motivations have been recognized in the political science and public policy literature. Using several examples from US environmental policy, De Sombre (1995, and 2000) argues that most US attempts at internationalizing domestic environmental policy are also measures to protect domestic industry. In their aptly titled article "Self Interest and Environmental Management," Oye and Maxwell (1994) discuss the benefits to industry from environmental policy. Finally, David Vogel (1995, and 2000) highlights the link between environmental and industrial interests in the making of environmental policy.

This research also contributes to the growing literature on consumption based pollution. Krutilla (1991), Copeland, and Taylor (1995), and Rauscher (1997) all analyze the effects of trade on the environment given consumption generated pollution and a welfare maximizing government. McAusland (2005, and 2008) discuss consumption based pollution in a political economy context. McAusland (2005) shows that harmonizing pollution regulation across symmetric countries

[6] The tuna example involves process rather than product standards. While the paper explicitly considers product standards the intuition presented carries over to cases involving process standards as well.

can worsen pollution and lower welfare. While exploring the effect of openness on environmental regulation, McAusland (2008) shows that domestic producers are indifferent to increases in the consumption based pollution taxes in an open economy. In contrast, by recognizing the link between production and consumption we can go further than indifference. We argue that in an open economy, producers of the polluting good can prefer an increase in the consumer pollution tax.

3 The Model

We consider a small economy producing one *numeraire* (price normalized to one) good and one non-numeraire good. Both goods are produced under the assumption of constant returns to scale and perfect competition. Consumption of the non-numeraire good produces pollution.[7] Production of either good does not generate pollution. However, the per-unit pollution intensity from consumption of the non-numeraire good can be altered during the production of the good.

3.1 The Production-Pollution Linkage

Production of the numeraire good (y_0) is linear in labor (l_0) (the production function is $y_0 = l_0$). The world and domestic price for good y_0 is normalized to one, and we assume that the stock of labor is large enough to ensure positive production throughout (this ensures that the wage rate, w equals one). Good y_0 does not produce any pollution and its consumption is denoted x_0.

Domestic production of the non-numeraire good is denoted y and uses two inputs, sector specific capital k and labor l. Consumption of the non-numeraire good generates pollution (z). For simplicity we separate production into two stages. The first is the production of the *raw* good - that has not been altered to influence its per-unit pollution intensity. If one unit of the raw good is consumed T units of pollution (z) are emitted. The raw good is produced using a standard production function $f(k, l)$ that is twice differentiable, homogenous of degree one, increasing, and concave in its inputs. The second stage determines the per-unit pollution intensity of this good in consumption. Let $a \in (0, T)$ represent the level of abatement per-unit. If $c(a)$ amounts of labor are combined with each unit of the 'raw' product the final product has a per-unit pollution intensity of $(T - a)$ on consumption. Thus a higher level of abatement implies a lower pollution intensity

[7] Pollution generated during consumption is an important source of ozone depletion, solid waste accumulation, climate change, and many broad measures of air and water pollution (please see McAusland 2008 for a more detailed discussion).

of consumption. With $w = 1$, $c(a)$ can also be interpreted as the per-unit pollution abatement cost function. We assume that $c(.)$ is strictly increasing and convex with $c(0) = 0$ and the overall production function is

$$y = \min\left\{ f(k,l), \frac{l_a}{c(a)} \right\}. \tag{1}$$

Let $\bar{p}$ denote the price producers receive per unit of the good and let p denote the producer price net of abatement costs $c(a)$. Also let the return to specific factor k be represented by a restricted profit function $\pi(p) = \widetilde{\pi}(p, w; k)$.[8]

A process similar to that for domestic production is required to determine the pollution intensity of imports. Let $a^* \in (0, T)$ denote the level of abatement associated with imports and let $c^*(a^*)$ denote the per-unit abatement cost function for imports ($c^*(.)$ is strictly increasing and convex with $c^*(0) = 0$ and need not be the same as that for domestic production). Let m_I denote raw imports of the non-numeraire good. Imports sold in the domestic market are given by

$$m = \min\left\{ m_I, \frac{l_a^*}{c^*(a^*)} \right\}. \tag{2}$$

Equations (1) and (2) illustrate the assumption that abatement technologies are specific to the particular good (domestic or import). Given this specificity the raw product cannot be treated like an intermediate good. If the good is imported, equation (2) implies that a labor cost of $c^*(.)$ per unit is required for abatement while if it is produced at home a labor cost of $c(.)$ is required per unit. Equations (1) and (2) also imply that differences in the cost of abatement derive from differences in appropriate technologies across competitors.[9]

Let us now formally define cost advantage at abatement.

[8] The restricted profit function is defined as $\widetilde{\pi}(p, w; k) = \max_l \{pf(k,l) - wl\}$. Restricted profit functions are positively linearly homogeneous, and convex in prices (p, w) (Diewert, 1974). They also satisfy Hotelling's lemma. Output equals the partial derivative of the restricted profit function with respect to output price ($y = \pi_p(.)$, where subcripts on functions denote partial derivatives).

[9] Some examples are: due to its development of a new kind of gasoline (EC-X), ARCO, a leading gasoline refiner in California, provided cleaner gasoline (with low levels of carbon monoxide and ozone precursor emissions) at a lower cost than its competitors (Innes and Bial, 2002). Due to its development of hydroflurocarbons (HFCs), DuPont provided a substitute for ozone depleting chloroflurocarbons (CFCs) at a lower cost than its competitors (Oye and Maxwell, 1994). And finally, due to its development of genetically engineered Bt crop varieties (Bt varieties produce insecticidal toxins derived from the bacterium Bacillus Thuringiensis), Monsanto provides seeds that require a smaller dose of pesticides than its competitors. A difference in cost can also derive from a difference in endowments. For example, coal producers in the western United States have an endowment of coal that has a lower sulphur content than the endowment of their counterparts in the mid-western region. This difference in endowment allows western coal producers to provide coal that produces lower sulhpur dioxide emissions at a lower price than their competitors (Carlson et. al, 2000). We do not explicitly model the difference in endowments in this paper, however the main intuition presented here carries over even in that case.

Definition 1 *(i) The domestic industry has a cost advantage at abatement if* $c_a(a') < c_a^*(a')$ $\forall a' \in (0,T]$. *(ii) The domestic industry has a cost disadvantage at abatement if* $c_a(a') > c_a^*(a')$ $\forall a' \in (0,T]$. *(iii) Domestic producers and importers are equally efficient at abatement if* $c_a(a') = c_a^*(a')$ $\forall a' \in [0,T]$.

The domestic industry has a cost advantage at abatement if its marginal cost for any feasible level of abatement is lower than that for the importers. The opposite holds true when importers have a cost advantage. An equal marginal cost implies that domestic producers and importers are equally efficient.[10]

Pollution is given by

$$z = (T-a)y + (T-a^*)(x-y),$$

where $(x-y) = m$ (imports). Overall pollution is a weighted sum of domestic production and imports, where the weights are the respective pollution intensities. Pollution adversely effects the utility of all consumers in the economy. The representative consumer's utility is

$$U(x_0, x) = x_0 + u(x) - v(z),$$

where the sub-utility function $u(.)$ is assumed to be strictly increasing and concave, and the damage from pollution $v(z)$ is assumed to be strictly increasing and convex. Maximization of this utility function implies that the demand for the non-numeraire good $(x(q))$ is solely a function of the consumer price (q). Consumer surplus is denoted $\gamma(q) = [u(x(q)) - qx(q)]$.

3.2 Pollution Policy and Domestic Prices

The government regulates pollution by a per unit pollution tax (t). Consumers pay tax for pollution generated during consumption. Consuming one unit of the imported good implies a tax payment of $t(T-a^*)$. Similarly, consuming one unit of the domestically produced good implies a tax payment of $t(T-a)$. Given that importers are perfectly competitive and that the non-numeraire good is always imported, the effective consumer price for one unit of the imported good (q) is

$$q = p^* + c^*(a^*) + t(T-a^*). \tag{3}$$

The effective consumer price includes the world price for the raw good (p^*), the abatement cost for importers $(c^*(a^*))$, and the associated pollution tax outlay $(t(T-a^*))$.

[10] For simplicity we only consider those cost functions that do not cross in the relevant range.

The consumer buys the domestically produced good only if it has an effective price no greater than that of the imported good. This implies that the maximum price the domestic producer can charge the consumers ($\bar{p}$) is given by the following equation

$$\bar{p} + t\,(T - a) = p^{*} + c^{*}\,(a^{*}) + t\,(T - a^{*})\,,$$

where the left hand side is the effective consumer price for the domestic good. This implies that the net price (p) received by domestic producers for producing the raw good is

$$p = p^{*} + c^{*}\,(a^{*}) - c\,(a) + t\,(a - a^{*})\,. \tag{4}$$

The net domestic producer price equals the world price (p^{*}) for the raw good, plus the difference in per-unit costs of abatement ($c^{*}\,(a^{*}) - c\,(a)$), and the difference in pollution tax outlays from consuming the two goods ($t(a - a^{*})$). Further, as the economy is open, domestic producers sell their good at home if and only if

$$p \geq p^{*}.$$

If the domestic price for the raw good is lower than the world price, domestic producers are better off selling in the world market.

In most previous models of trade and environment the two sectors of production and consumption are independent of each other. Equation (4) demonstrates a departure from this independence. If producers can influence the pollution intensity on consumption of the good they produce and consumers face a cost for pollution produced, production and consumption are linked even in a small open economy. Equation (4) demonstrates that a pollution tax paid by consumers alters the price gained by the domestic producer. Once we recognize this link it becomes easy to explain why domestic producers might prefer a higher pollution tax. If the domestic good has a lower pollution intensity ($(a - a^{*}) > 0$), domestic producers can charge a higher price for the domestic raw good. Moreover, the pollution tax amplifies the premium on the domestic good ($t\,(a - a^{*})$) and given a relative cost advantage at abatement, it may be beneficial to produce a cleaner good and lobby for a higher pollution tax.

4 The Optimal Pollution Tax

Assume that the government regulates the pollution tax alone. Once the pollution tax is set, competitive interactions determine the pollution intensities of the imported and domestic good.

4.1 Abatement Activity

The consumer prefers the good with abatement levels that minimize her effective price (from equation 3) thus the preferred level of import abatement ($\hat{a}^*$) is given by

$$c^*_{a^*}(\hat{a}^*) = t. \tag{5}$$

We assume that the preferred level of abatement is feasible, that is, $\hat{a}^* \in (0, T)$. Given feasibility, in a perfectly competitive market importers abate to the preferred level. This is because, any importer who sells a good with abatement different from $\hat{a}^*$ loses her market to the producer who sells the good with the preferred level of abatement. The effective price paid for the imported good is thus given by

$$q = p^* + c^*(\hat{a}^*) + t(T - \hat{a}^*).$$

Import-competing producers of the non-numeraire good abate at the level that maximizes their net price (p from equation 4). This level of abatement is denoted $\hat{a}$ and is defined by,

$$c_a(\hat{a}) = t. \tag{6}$$

The net price is thus given by

$$p = p^* + c^*(\hat{a}^*) - c(\hat{a}) + t(\hat{a} - \hat{a}^*). \tag{7}$$

The domestic producer price equals the world price (p^*), plus the difference in per-unit costs of abatement ($c^*(\hat{a}^*) - c(\hat{a})$), and the difference in pollution tax outlays from consuming the two goods ($t(\hat{a} - \hat{a}^*)$). Consider next two results on pollution intensities.

Lemma 1 *If* $c_a(\hat{a}') \lesseqgtr c^*_a(\hat{a}')$ $\forall \hat{a}' \in [0, T]$ *then domestic and import pollution intensities satisfy* $(T - \hat{a}) \lesseqgtr (T - \hat{a}^*)$.

Proof. Please see Appendix A.1. ■

This lemma compares pollution intensities under three possibilities listed in Definition 1. If the domestic industry has a cost advantage, domestic producers undertake greater abatement and correspondingly the pollution intensity of the domestic good is lower than that of the imported good. Similarly, if importers have a cost advantage, the imported good has a lower pollution intensity. Finally, when the domestic producers and importers have equal marginal costs, pollution intensities are equal.

Recall that domestic producers sell their product at home if and only if $p \geq p^*$. This implies that

$$c^*(\hat{a}^*) - c(\hat{a}) \geq t(\hat{a}^* - \hat{a}). \tag{8}$$

This allows us to rule out one of the possibilities discussed above.

Lemma 2 *If the non-numeraire good is imported, domestic firms sell the non-numeraire good in the domestic market if and only if they are equally efficient or have a cost advantage at abatement.*

Proof. Please see Appendix A.1. ■

Domestic firms operate in the domestic market if and only if they are at least as good as importers at abatement. If domestic firms have a cost disadvantage at abatement they are better off selling their raw product in the world market, as the maximum the price they can get at home for the raw good is lower than the world price.

Lemma 2 implies that domestic producers do not sell in the domestic market when they have a cost disadvantage. Thus they do not incur any costs for abatement and receive the world price for their raw output,

$$p = p^*. \tag{9}$$

This also implies that given a cost disadvantage at abatement, domestic producers are indifferent to the level of the pollution tax.

4.2 The Social Planner's Benchmark

The social planner's objective is to choose the pollution tax to maximize aggregate welfare, given the utility and profit maximizing behavior of its agents. Assume that the mass of labor in the economy equals 1. Aggregate welfare is a sum of wage income (given that wage equals 1), producer profits, consumer surplus, tax revenue and social damage from pollution. Formally the problem is

$$\max_t W = \{1 + \pi(p) + \gamma(q) + tz - v(z)\}. \tag{10}$$

The welfare maximizing pollution tax is given by

$$t_w = v_z, \tag{11}$$

where the subscript w denotes the welfare maximizing policy. In other words, the welfare maximizing pollution tax equals marginal social damage from pollution.

Using equation (5) the importers choose the following level of abatement,

$$c_a(\hat{a}_w^*) = v_z. \tag{12}$$

And if domestic producers operate in the domestic market, using equation, 6 their abatement level is given by

$$c_a(\hat{a}_w) = v_z. \tag{13}$$

Equations (11-13) define the optimal welfare maximizing policy for regulating pollution. At the optimum the marginal cost of reducing pollution is set equal to the marginal social damage from pollution across all sectors. When domestic producers operate in the domestic market these conditions also imply that $(T - \hat{a}_w) \leq (T - \hat{a}_w^*)$. However, when domestic firms do not operate in the domestic market (under a cost disadvantage), the two equations (11) and (12) define welfare maximizing policy and equation (13) ceases to be relevant.

These results also demonstrate that given perfect competition in the product market, just regulating the pollution tax can lead to a maximization of aggregate welfare. The planner sets the pollution tax equal to marginal social damage from pollution. Given perfect competition the marginal cost of abatement equals the pollution tax (which equals the marginal social damage from pollution). This combination of pollution tax and abatement levels maximizes aggregate welfare in society.

4.3 Politically Optimal Pollution Tax under Domestic Producer Influence

We now consider pollution policy in a model where domestic producers influence policy making. We choose the simplest model possible in order to capture producer influence. We assume that the government maximizes a weighted welfare function. In this weighted welfare function, the profits of domestic producers of the non-numeraire good get a higher weight than the rest of society. Formally, the government's welfare function is

$$\max_t G = \{1 + (1 + \psi)\pi(p) + \gamma(q) + tz - v(z)\}, \tag{14}$$

where $\psi > 0$ is the additional weight attached to domestic producer profits.[11]

[11] Please see Grossman and Helpman (1994) for the micro-foundations for this weighted welfare function. The authors show that government policy obtained from maximizing the above weighted welfare function is equivalent to

There are two possibilities to consider. In the first possibility domestic producers have a cost disadvantage at abatement.

Corollary to Lemma 2 *Given a domestic firm cost disadvantage at abatement, the optimal pollution tax maximizes aggregate welfare in the economy.*

As explained earlier, given a cost disadvantage, domestic producers disengage from the domestic market and the level of pollution tax makes no difference to their profits (as $p = p^*$). The government essentially functions like an aggregate welfare maximizer and the pollution tax chosen equals marginal social damage (from equation, 11). The corresponding level of abatement chosen by importers also equals that observed under a welfare maximizing government (see equation, 12).

Next we consider the case where domestic producers are at least as good as the importers at abatement (that is equation, **??**, holds). The optimal pollution tax gained from maximizing the weighted welfare function in equation (14) is

$$t_o = v_z + \frac{\psi\left(\hat{a}_o - \hat{a}_o^*\right)\pi_p}{-\frac{dz}{dt}}, \tag{15}$$

where the subscript o implies the optimal tax under political influence. The above equation illustrates the governments trade-off between special interest profits and aggregate welfare. The first term on the right hand side is marginal social damage. The second term reflects the government's policy compromise. The numerator of the second term is the weighted gain to domestic producers from an increase in the pollution tax ($\psi\left(\hat{a}_o - \hat{a}_o^*\right)\pi_p$) (recall that $\hat{a}_o - \hat{a}_o^* \geq 0$). The denominator is the responsiveness of pollution to pollution tax.

By substituting $\frac{d\hat{a}_o^*}{dt}$, and $\frac{d\hat{a}_o}{dt}$ (gained by differentiating equations 5 and 6) equation (15) can be re-expressed as

$$t_o = v_z + \frac{\psi\left(\hat{a}_o - \hat{a}_o^*\right)\pi_p}{\left(\hat{a}_o^* - \hat{a}_o\right)^2\pi_{pp} - \left(T - \hat{a}_o^*\right)^2 x_q + \pi_p\frac{1}{c_{aa}} + \left[x\left(q\right) - \pi_p\right]\frac{1}{c_{aa}^*}}. \tag{16}$$

Given a strict cost advantage at abatement the domestic producer prefers the pollution tax to be higher than socially optimal. The intuition is fairly simple. Due to the cost advantage, domestic producers produce a good that has a lower pollution intensity than the imported good (Lemma 1). This in turn implies that the consumer is willing to pay a higher price for the domestic good

government policy chosen under the following conditions: a) The government collects political contributions. b) The producers of the non-numeraire good are organized as a political lobby, and c) the contribution function offered by the producers is differentiable.

than the imported good and to amplify this willingness to pay domestic producers prefer a higher pollution tax than socially optimal.

Using equation (6), the level of abatement (a_o) adopted by domestic firms is given by

$$c_a(\hat{a}_o) = v_z + \frac{\psi(\hat{a}_o - \hat{a}_o^*)\pi_p}{(\hat{a}_o^* - \hat{a}_o)^2 \pi_{pp} - (T - \hat{a}_o^*)^2 x_q + \pi_p \frac{1}{c_{aa}} + [x(q) - \pi_p]\frac{1}{c_{aa}^*}}. \tag{17}$$

Similarly, using equation (6), importers choose the abatement level (a_o^*) given by

$$c_a(\hat{a}_o^*) = v_z + \frac{\psi(\hat{a}_o - \hat{a}_o^*)\pi_p}{(\hat{a}_o^* - \hat{a}_o)^2 \pi_{pp} - (T - \hat{a}_o^*)^2 x_q + \pi_p \frac{1}{c_{aa}} + [x(q) - \pi_p]\frac{1}{c_{aa}^*}}. \tag{18}$$

As explained earlier, abatement levels chosen equate the marginal cost of abatement to the pollution tax. As the optimal pollution tax exceeds marginal social damage, the marginal cost of abatement also exceeds marginal social damage.

Proposition 1 *Given (i) the non-numeraire good is imported and (ii) policy is influenced by domestic producers, the pollution tax is at least as strict as that under a welfare maximizing government. Further, if domestic producers have a strict cost advantage at abatement, the pollution tax is stricter than socially optimal.*

This proposition summarizes the results discussed above. When domestic producers have a cost disadvantage at abatement environmental policy mimics that under a welfare maximizing government. The pollution tax is set equal to marginal social damage ($t_o = v_z$) and importers abate the same amount as under a welfare maximizing government ($c_a^*(\hat{a}_o^*) = v_z$). Even when marginal costs of abatement are equal across the domestic producer and importer, environmental policy equals that under a welfare maximizing government (this can be seen by substituting $\hat{a} - \hat{a}^* = 0$ in equations, 16-18 above). Only when the domestic industry has a cost advantage at abatement do we observe environmental policy different from the welfare maximizing norm. The pollution tax chosen by the government is strictly higher than marginal social damage ($t_o > v_z$). In addition, abatement levels chosen by the importers and domestic producers are also higher than those under a welfare maximizing pollution tax ($c_a(\hat{a}_o) > v_z$, and $c_a^*(\hat{a}_o^*) > v_z$).

These results have two interesting implications. Firstly, if we assume an exogenous world price, all else being equal, a small open economy governed by a politically motivated government favoring domestic producers cannot have higher pollution (or equivalently lower pollution taxes) than a similar economy governed by a welfare maximizing government. This implication is counterintuitive when considered in the context of previous analyses of trade and environment. In those analyses political influence in the hands of import-competing industries usually implied weaker environmental policy and higher pollution in free trade (see for example Aidt 1996, Fredriksson, 1997, and McAusland, 2003). This result highlights the importance of understanding the exact nature of the pollution considered, the policy instruments used and the links between producer profits and environmental policy.

The second implication is that once the economy opens up to trade the domestic industry turns 'green.' The domestic industry's preference for relatively stringent pollution taxes in an open economy is in sharp contrast to their preferences when the economy is closed. When the economy is closed (please see Appendix A.3 for a full description of the closed economy case and derivations for the following results), the pollution tax chosen under influence of domestic producers is lower than the marginal social damage from pollution ($t_o < v_z$). This is because in a closed economy the pollution tax lowers consumer demand and subsequently lowers producer price. A lower pollution tax implies the level of abatement chosen by domestic producers is also lower than socially optimal ($c_a(\hat{a}_o) < v_z$).

When the economy is closed the domestic industry prefers low pollution taxes and chooses abatement levels below socially optimal. However, on being exposed to foreign competition the domestic industry is either indifferent to environmental policy and allows the resumption of welfare maximizing policy (given a cost disadvantage and equal efficiency), or prefers higher pollution taxes and chooses abatement levels that are higher than socially optimal (the case of a cost advantage).[12] This change in heart occurs as the domestic industry recognizes the ability of a pollution tax to shift demand towards its own product even in free trade. In other words even in a setting where the government favors domestic producers, freer trade can raise the pollution tax.[13]

[12] In addition to a comparision between autarky and free trade, a similar argument can be made for declining trade barriers. While an analytical exposition of this case is beyond the scope of this paper consider the underlying intuition. Assume that θ is the tariff imposed on imports of the raw good. This implies that the producer price for a unit of raw good produced at home (previously equation 4) now becomes

$$p = p^* + \theta + t(a - a^*) + c^*(a^*) - c(a).$$

In the presence of a cost advantage at abatement, the tariff and the emissions tax are linear substitutes for raising the producer price. Thus, if the tariff (θ) is lowered, the government can compensate domestic producers for the lower tariff by raising the emissions tax (t).

[13] This statement ignores the fact that under these conditions, free trade also worsens aggregate welfare.

5 The Optimal Pollution Tax and Pollution Intensity

We now consider the case where in addition to regulating the pollution tax the government also regulates pollution intensities. Any non-numeraire good sold in the economy must not exceed a maximum pollution intensity ($T - \bar{a}$) specified by the government (note that this is equivalent to specifying a minimum abatement level $\bar{a}$). We assume that while setting this maximum the government adheres to 'National Treatment'.[14] National treatment requires that the maximum applies equally on domestic producers and importers.

The Corporate Average Fuel Efficiency (CAFE) standards in the United States provide a good example. In addition to setting gasoline taxes, there is a minimum sales weighted average fuel efficiency required for cars sold in the United States (please see Goldberg, 1996, and the National Highway Traffic and Safety Administration website for a description of CAFE). This minimum applies equally to domestic and foreign manufacturers.

Despite the fact that the government can maximize aggregate welfare by regulating only the pollution tax (as shown in the previous section) there are several reasons why we model government control over pollution intensities. Firstly, while competitively chosen pollution intensities can maximize aggregate welfare they need not maximize the government's political welfare. The reason is fairly straightforward. Consumer willingness to pay for the domestic good is determined by the pollution tax, and relative pollution intensities. When the government only controls the pollution tax it does not have the ability to fully influence consumer willingness to pay. Expanded control over the pollution intensity can raise the government's political welfare.[15] Secondly, our analysis adds significantly to earlier models of environmental product standards. In those models (see Copeland 2001, Fischer and Serra 2000, and Battigalli and Maggi 2003) the market does not induce pollution intensities (recall that a product standard is similar to a pollution intensity in our model). Due to this difference, our model allows the possibility that governments can set caps

[14] The *National Treatment* principle (Article 3 of the General Agreement on Tariffs and Trade, now the World Trade Organization) requires equal applications of regulations to domestic and imported products, with Article 1 ensuring equal treatment of goods from all members. Exceptions apply, the most important of which are contained in Article 20 (Sanitary and Phytosanitary Measures) permitting import restrictions necessary to protect human, animal, or plant health.

[15] Note that this motive for the government to control abatement activity is different from that proposed in earlier papers considering environmental product standards. So far, the government control over product standards was justified by the presence of imperfect information (Chen and Mattoo, 2008), strategic incentives (Copeland, 2001, Ganslandt and Markusen, 2001, and McAusland, 2004), and the absence of a pollution tax (Gulati and Roy, 2008).

on pollution intensity that bind for the importer but do not impact the domestic producer. It is often argued that the CAFE standard has such an impact. Vogel 1998 argues that data on CAFE related fines in the US suggests that the standard does not bind for domestic producers but binds for German car manufacturers who pay a majority of the fines. Finally, government's across the world do indeed mandate the cleanliness of their products (several examples of recycling requirements, automobile emissions standards, and packaging requirements are listed in Vogel 2000, and DeSombre 2000) and this section captures this reality.

5.1 Abatement Activity Under National Treatment

The government chooses the pollution tax, and mandates a maximum pollution intensity $(T - \bar{a})$ (which is mathematically equivalent to setting a minimum abatement level $\bar{a}$). Importers and domestic producers take the pollution tax, and the maximum as given and choose to either produce a good that is either cleaner than allowed, or has the maximum pollution intensity. Consider the importing firm's choice. If the maximum pollution intensity (or minimum abatement level) and and pollution tax are such that

$$c^*_{a^*}(\bar{a}) \leq t,$$

the importer chooses its abatement (a^*) such that

$$c^*_{a^*}(a^*) = t.$$

Thus, if the required minimum abatement is less than that preferred by the consumer, the preferred level is chosen. In other words, the firm provides a good that is cleaner than mandated. However, if the minimum required is such that

$$c^*_{a^*}(\bar{a}) > t,$$

the importer sets $a^* = \bar{a}$. In other words, the maximum pollution intensity binds on the importing firm.

Correspondingly, the level of abatement chosen by the importer (a^*) can be represented by the following complementary slackness condition,

$$\left(c^*_{a^*}(a^*) - t\right) \geq 0, \left(a^* - \bar{a}\right) \geq 0, \left(a^* - \bar{a}\right)\left(c^*_{a^*}(a^*) - t\right) = 0. \tag{19}$$

Similarly the domestic abatement level (a) can be represented by a complementary slackness condition,

$$(c_a(a) - t) \geq 0, (a - \bar{a}) \geq 0, (a - \bar{a})(c_a(a) - t) = 0. \tag{20}$$

We find that even when the government mandates a cap on pollution intensity under national treatment, a result similar to Lemma 2 applies.

Lemma 3 *If a common maximum pollution intensity is mandated by the government and the non-numeraire good is imported, domestic firms sell the non-numeraire good in the domestic market if and only if they are equally efficient or have a cost advantage at abatement.*

Proof. Please see Appendix A.1. ■

Similar to the previous sub-section, if domestic producers have a cost disadvantage at abatement they do not sell in the domestic market. This also implies that given a cost disadvantage domestic producers are indifferent to both the pollution tax and the maximal pollution intensity mandated.

5.2 The Social Planners Benchmark

Now consider the social planner's choice of the pollution tax and the maximum pollution intensity. The formal problem is

$$\max_{t,(T-\bar{a})} W = \{1 + \pi(p) + \gamma(q) + tz - v(z)\},$$

subject to equations (19) and (20).

Proposition 2 *The social planner sets the pollution tax (t_w) such that*

$$t_w = v_z, \tag{21}$$

and chooses a maximum pollution intensity ($T - \bar{a}$) such that

$$\max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t_w. \tag{22}$$

This policy maximizes aggregate welfare in the economy.

The principle behind the above proposition is simple. The government sets the pollution tax equal to marginal social damage. It also sets the maximum pollution intensity to be at least as high as the maximum of the two chosen competitively in the presence of the welfare maximizing pollution tax.[16] This policy combination is observationally equivalent to the market solution (from conditions, 11-13). As the marginal cost of reducing pollution equals the marginal social damage across all sectors, this policy maximizes aggregate welfare.

5.3 Politically Optimal Policy Under Domestic Producer Influence

We now reconsider the effect of domestic producer influence on policy making. The government maximizes a weighted welfare function where the profits of the domestic producers get a higher weight than the rest of society. Formally, the government's problem is

$$\max_{t,(T-\bar{a})} G = \{1 + (1+\psi)\,\pi(p) + \gamma\,(q) + tz - v\,(z)\}\,, \tag{23}$$

subject to equations (19) and (20). Let the subscript o denote optimal political policy. There are three relevant outcomes for the pollution tax (t_o), and the maximal pollution intensity (or minimum abatement level $\bar{a}$).

In the first outcome, t_o, and $(T-\bar{a})$ are such that

$$\max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t_o. \tag{24}$$

In this outcome the mandated maximum pollution intensity does not bind either for domestic producers or importers. Both groups produce goods that are cleaner than mandated.

In the second outcome t_o, and $(T-\bar{a})$ are such that

$$\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t_o < \max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\}. \tag{25}$$

In this outcome the mandated maximum binds for one group, either domestic producers or importers. The other group chooses their preferred level.

In the third and final outcome, t_o, and $(T-\bar{a})$ are such that

$$\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} > t_o. \tag{26}$$

In this outcome the mandated maximum pollution intensity binds for both domestic producers and importers.

We now evaluate these outcomes under the different possibilities for cost advantage from Definition 1.

[16] Or equivalently, the highest marginal cost of meeting the minimum abatement level is no higher than the pollution tax.

Lemma 4 *If the domestic industry has a cost disadvantage, or is equally efficient at abatement t_o, and $(T - \bar{a})$ are such that*

$$\max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t_o, \tag{27}$$

and

$$t_o = v_z.$$

Proof. Please see Appendix A.1. ■

When the domestic industry has a cost disadvantage or is equally efficient as importers at abatement the maximum does not bind. When the domestic industry has a cost disadvantage, it does not sell at home and there is no incentive for the government to distort environmental policy. Thus the pollution tax equals marginal social damage and the importers marginal cost of abatement equals the pollution tax. Similarly, when the domestic industry is equally efficient as importers at abatement there are no gains from distorting pollution policy and welfare maximizing policy results (welfare maximizing policy is given in Proposition 2). In contrast, when the domestic industry has a strict cost advantage at abatement all three outcomes are possible. Let us consider each potential outcome in detail.

Policy in the first outcome from equation (24) is identical to the case where the government chooses only the pollution tax (please see sub-section 4.3 for the solution). There we saw that given a domestic producer cost advantage at abatement the pollution tax is more stringent than welfare maximizing policy (Proposition 1).

Next we evaluate the second outcome from equation (25). Given a domestic producer cost advantage, equation (25) can be rewritten as

$$c_a(\bar{a}) \leq t_o < c^*_{a^*}(\bar{a}). \tag{28}$$

In other words, the common maximum binds for the importer but does not bind for domestic producers. It is often argued that the CAFE standard has a similar impact. Data on CAFE related fines in the US suggests that the standard does not bind for domestic producers but binds for German car manufacturers who pay a majority of the fines (Vogel, 1998). In the solution to this outcome (given in Appendix A.2) we find that the pollution tax is set higher than marginal social damage (that is $t_o > v_z$), importers set their pollution intensity to equal the maximum mandated and domestic producers produce a good that is cleaner than mandated ($(T - \hat{a}) < (T - \bar{a})$). Finally, the marginal cost of abatement for both domestic producers and importers is greater than marginal social damage ($c^*_{a^*}(\bar{a}) > c_a(\hat{a}) > v_z$). In other words, pollution policy is more stringent than welfare maximizing policy.

Finally consider the third outcome from equation 26. Given domestic producer advantage at abatement, equation (26) can be expressed as

$$t_o < c_a(\bar{a}) < c^*_{a^*}(\bar{a}). \tag{29}$$

In this case the maximum binds for both domestic producers and importers. In the solution to this outcome (given in Appendix A.2) we find that both importers and domestic producers choose the maximum pollution intensity ($T - \bar{a}$), and the pollution tax equals marginal social damage (that is $t_o = v_z$). The pollution tax is not distorted as pollution intensities do not differ and so cannot be used to alter the domestic producer price. However, the maximum pollution intensity is still distorted and the marginal cost of abatement is greater than marginal social damage ($c^*_{a^*}(\bar{a}) > c_a(\hat{a}) > v_z$). Note that in this special case the outcome from our model mimics the raising rival's cost hypothesis demonstrated in earlier models of environmental standards (Fischer and Serra, 2000, Copeland, 2001, and McAusland, 2004). In those models given a domestic producer cost advantage the government raises the standard to be higher than socially optimal to shift profits to the domestic industry. In our model of competitive markets this particular outcome illustrates essentially the same logic. The only difference is that instead of shifting profits, lowering the required pollution intensity below socially optimal increases rents accruing to the specific factor in the domestic industry.

We summarize these results in the following proposition.

Proposition 3 *Given (i) that the mandates a maximum pollution intensity ($T - \bar{a}$) for all goods sold at home, (ii) the government observes national treatment, and (iii) policy is influenced by domestic producers, pollution policy is at least as strict as that observed under a welfare maximizing government. Further, if domestic producers have a cost advantage at abatement, pollution policy is stricter than welfare maximizing policy.*

For reasons similar to the government only chose the pollution taxes this result has two interesting implications. Firstly, if we assume an exogenous world price, all else being equal, a small open economy governed by a politically motivated government favoring domestic producers cannot have higher pollution (or equivalently less stringent pollution policy) than a similar economy governed by a welfare maximizing government. Secondly, as the economy opens up to trade the domestic industry turns 'green.' When the economy is closed (please see Appendix A.3 for derivation of the following results), the pollution tax chosen under influence of domestic producers is lower than the marginal social damage from pollution ($t_o < v_z$) and the marginal cost of abatement mandated by the government equals marginal social damage ($c_a(\bar{a}_o) = v_z$). In contrast, on being exposed to foreign competition the domestic industry is either indifferent to environmental policy and allows the resumption of welfare maximizing policy (when the domestic industry has a cost disadvantage, or is equally efficient at abatement), or prefers higher pollution taxes and/or produces goods that are cleaner than socially optimal.

6 Conclusion

In this paper we show how free trade can alter the incentives for domestic producers to influence policy. In a closed economy, domestic producers desire pollution policy that is less stringent than that chosen by a social planner. However, on facing import competition, and given a cost advantage at abatement, our results indicate that even though the firm has no regard for the environment, it is likely to influence the government to raise pollution policy over what is socially optimal. However, we do not wish to convey that freer trade will always be good for environmental policy. Depending on the special case analyzed, free trade can worsen environmental policy. Our aim through this paper is to emphasize the importance of understanding the specific pollution problem, and policy instrument used before drawing any conclusions on the effect of free trade on pollution policy.

In this paper we present an example where pollution taxes and pollution intensities are used to influence consumer preferences for domestically produced goods. However the underlying intuition applies beyond these specific instruments. Consumer preferences can be influenced by instruments other than consumer based taxes. One possibility is the use of information campaigns on the environmental attributes of different products. The British government rating for cars based on their CO2 pollution (please see http://news.bbc.co.uk/2/hi/uk_news/4252359.stm, last accessed March 19th 2009), and dolphin-safe tuna labelling campaigns are good examples of such instruments.

We believe that this model has potential for some interesting extensions exploring why firms might have different costs of abatement. Some authors argue that a comparative advantage at abatement derives from pre-existing domestic regulation (DeSombre, 2000 and Schreurs and Economy, 1997). Pre-existing domestic regulation allows domestic industry to develop cost effective means for abatement (similar to a learning by doing argument). Subsequently once this domestic regulation is internationalized through a multilateral (or similar bilateral) agreement domestic producers do better in a world with international trade. Another useful extension would investigate the optimal design of pollution intensities. Given national treatment a government is likely to design its requirements on industry in such a way that the domestic industry has a natural advantage. This argument is often used by the critics of the CAFE standard in the United States (Vogel 1998). A model that allows the government to design its requirements in a broader manner than allowed in this paper is likely to explain the proliferation of different product standards across the world. It might also be a good starting point to study why harmonizing existing product standards is a good idea.

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A Appendix

A.1 Proofs

Proof. for Lemma 1. The proof follows from equations (12) and (13) and from our assumptions on the two cost functions that $c(0) = 0$, $c_a > 0$, and $c_{aa} > 0$, and similarly $c^*(0) = 0$, $c^*_{a^*} > 0$, and $c^*_{a^*a^*} > 0$. ■

Proof. for Lemma 2. For the if statement. Assume $c_a(\bar{a}) \leq c^*_a(\bar{a})\ \forall \bar{a} \in [0, T]$. Given that firms choose their abatement levels $c_a(\hat{a}) = c^*_a(\hat{a}^*) = t$. This implies $(\hat{a} - \hat{a}^*) \geq 0$. From our definition of the cost function we know that

$$c(\hat{a}) - c^*(\hat{a}^*) = \int_0^{\hat{a}} c_a(z)\,dz - \int_0^{\hat{a}^*} c^*_a(z)\,dz = \int_0^{\hat{a}} c_a(z)\,dz - \left[\int_0^{\hat{a}^*} c_a(z)\,dz + \int_0^{\hat{a}^*} \left[c^*_a(z) - c_a(z)\right] dz\right].$$

Thus

$$c(\hat{a}) - c^*(\hat{a}^*) \leq \int_0^{\hat{a}} c_a(z)\,dz - \int_0^{\hat{a}^*} c_a(z)\,dz = \int_{\hat{a}^*}^{\hat{a}} c_a(z)\,dz \leq (\hat{a} - \hat{a}^*)\,c_a(\hat{a}) = t(\hat{a} - \hat{a}^*).$$

Rearranging

$$c^*(\hat{a}^*) - c(\hat{a}) \geq t(\hat{a}^* - \hat{a}),$$

and condition (8) is met.

For the only if statement. Assume that the domestic industry has a cost disadvantage at meeting abatement, thus $c_a(\bar{a}) > c^*_a(\bar{a})\ \forall \bar{a} \in [0, T]$. Given that firms choose their abatement levels $c_a(\hat{a}) = c^*_a(\hat{a}^*) = t$ and thus $(\hat{a} - \hat{a}^*) < 0$. We know that

$$\begin{aligned} t(\hat{a}^* - \hat{a}) &= (\hat{a}^* - \hat{a})\,c^*_a(\hat{a}^*) > \int_{\hat{a}}^{\hat{a}^*} c^*_a(z)\,dz = \int_0^{\hat{a}^*} c^*_a(z)\,dz - \int_0^{\hat{a}} c^*_a(z)\,dz \\ &> \int_0^{\hat{a}^*} c^*_a(z)\,dz - \left[\int_0^{\hat{a}} c^*_a(z)\,dz + \int_0^{\hat{a}} \left[c_a(z) - c^*_a(z)\right] dz\right] \\ &= \int_0^{\hat{a}^*} c^*_a(z)\,dz - \int_0^{\hat{a}} c_a(z)\,dz = c^*(\hat{a}^*) - c_a(\hat{a}). \end{aligned}$$

Thus we get

$$t(\hat{a}^* - \hat{a}) > c^*(\hat{a}^*) - c(\hat{a}),$$

and condition (8) is violated. ■

Proof. for Lemma 3. When the government sets the minimum abatement level there are three relevant outcomes for outcomes for the pollution tax (t), and the minimum abatement level ($\bar{a}$).

First, $\max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t$. Second, $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t < \max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\}$, and third, $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} > t$. In all three outcomes one can construct a proof based on the same logic as illustrated in the proof for Lemma 2. ■

Proof. for Lemma 4. The proof for the case where the domestic industry has a cost disadvantage at abatement is fairly obvious and is not provided here. We prove that if $c_a(a') = c^*_a(a')$ $\forall a' \in [0, T]$ the only outcome possible is $\max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t$. Suppose not. Then either $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t < \max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\}$, or, $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} > t$. We know that $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t < \max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\}$, as by definition $c_a(a') = c^*_a(a')$. Thus the only possibility is that $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} > t$. In this case the common abatement level binds for both domestic producers and importers. Thus, the optimal pollution tax is given by $t_o = v_z$. The condition that determines the domestic abatement level is given by

$$(c_a(\bar{a}) - t) = \frac{[(1+\psi)\pi_p - x(q)]}{x(q)}[c^*_a(\bar{a}) - c_a(\bar{a})].$$

Given $c_a(a') = c^*_a(a')$, the right hand side equals zero. Thus this condition reduces to $(c_a(\bar{a}) - t) = 0$. The condition that determines the import abatement level is given by

$$(c^*_a(\bar{a}) - t) = \frac{[(1+\psi)\pi_p]}{x(q)}[c^*_a(\bar{a}) - c_a(\bar{a})].$$

This condition has a similar form to the condition for domestic producers, and reduces to $(c^*_a(\bar{a}) - t) = 0$. Both these above conditions violate our starting supposition that $\min\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} > t$. Thus the only possibility is $\max\{c_a(\bar{a}), c^*_{a^*}(\bar{a})\} \leq t$. ■

A.2 Solution to the Government's Maximization for the Choice of the Abatement Level

In this appendix we only analyze the two additional outcomes (given Lemma 4) that occur when domestic producers have a cost advantage at abatement.

Consider the outcome from equation (25). Given a cost advantage there are two necessary conditions for this outcome to occur. The first condition is that the preferred abatement level for domestic producers should be higher than the minimum: $(\hat{a} > \bar{a})$. Given this necessary condition (which is a stricter version of cost advantage), equation (25) can be rewritten as

$$c_a(\bar{a}) < t < c^*_{a^*}(\bar{a}). \tag{30}$$

The second condition is

$$\psi > \frac{[x(q) - \pi_p]}{\pi_p} \left[\frac{(\hat{a} - \bar{a}_o)^2 \pi_{pp} + (T - \bar{a}_o)^2 (-x_q)}{(T - \hat{a})(T - \bar{a}_o)(-x_q)} \right]. \tag{31}$$

Domestic producers should have sufficiently high political influence. At the minimum, this condition requires that the extra weight assigned by the government on producer welfare must be at least as large as the ratio of imports to domestic production (thus $\psi > \frac{[x(q)-\pi_p]}{\pi_p}$ is necessary).[17]

In this outcome, the expression for the optimal pollution tax is,

$$t_o = v_z + \frac{\psi \pi_p (\hat{a} - \bar{a}_o)}{-\frac{dz}{dt}}, \tag{32}$$

where $\hat{a}$ is the domestic producer's preferred abatement level. As the pollution tax has a form similar to chosen by a politically motivated government when abatement levels were chosen autonomously, we do not repeat a discussion of its components.[18] However it is useful to note that as $(\hat{a} > \bar{a})$ the pollution tax is set higher than marginal social damage (that is $t_o > v_z$).

As discussed earlier, the condition that determines the domestic abatement level is equation 6. The condition that determines the minimum (also import) abatement level is given by

$$(c_a^*(\bar{a}) - t_o) = \frac{\psi \pi_p (x(q) - \pi_p)}{\Delta(p^*, t_o, \hat{a}, \bar{a}_o, \psi) + [\psi \pi_p - [x(q) - \pi_p]] \frac{d\hat{a}}{dt}} (\hat{a} - \bar{a}_o), \tag{33}$$

where

$$\Delta(p^*, t_o, \hat{a}, a_o^*, \psi) = \left[-[x(q) - \pi_p] \left[-\frac{dz}{dt} \right] + \psi \pi_p (T - \bar{a}_o)(T - \hat{a})(-x_q) \right].$$

The necessary conditions discussed earlier together ensure that $(c_a^*(\bar{a}) - t_o) > 0$ which ensures that condition (25) holds given domestic producer cost advantage. The condition (31) ensures that the denominator of the right hand side of equation (33) is positive. And condition (30) ensures that $(\hat{a} - \bar{a}_o) > 0$. Together these two are necessary for $(c_a^*(\bar{a}) - t_o) > 0$. The effect is that when domestic producers have a cost advantage, pollution policy is more stringent than welfare maximizing policy.

Finally consider the third outcome (from equation 26). This outcome also occurs only when the domestic industry has a cost advantage at abatement. We need one necessary condition for this

[17] Note that as the right hand side of equation (31) is endogenous, we cannot fix a unique lower bound for the weight. However we can consider a limiting value. Assume that π_p, and $[x(q) - \pi_p]$ are finite. We know that as $(\hat{a} - \bar{a}_o) \to 0$, the condition tends to $\psi > \frac{[x(q)-\pi_p]}{\pi_p}$. However, as $\hat{a}, \bar{a}_o$ diverge the right hand side of equation (31) becomes bigger (though not infinitely bigger given interior solutions).

[18] Please see equation (15) in Sub-Section 4.3 for a discussion.

outcome to be valid. Formally, the condition is

$$\psi > \frac{[x(q) - \pi_p]}{\pi_p}. \tag{34}$$

In other words, the extra weight on domestic producer profits should be higher than the ratio of imports to domestic production.

Given domestic producer advantage at abatement, and without making any other assumptions or changes, equation (26) can be expressed as

$$t < c_a(\bar{a}) < c^*_{a^*}(\bar{a}). \tag{35}$$

In this case the common abatement level binds for both domestic producers and importers. Correspondingly, the optimal pollution tax is given by

$$t_o = v_z. \tag{36}$$

As both domestic producers and importers choose the same abatement level (neither exceed the prescribed minium) the optimal pollution tax equals marginal social damage from pollution. The condition that determines the domestic abatement level is given by

$$(c_a(\bar{a}) - t) = \frac{[(1+\psi)\pi_p - x(q)]}{x(q)} [c^*_a(\bar{a}) - c_a(\bar{a})]. \tag{37}$$

The marginal cost for the minimum level of abatement for domestic producers should be higher than the pollution tax. The extent that the marginal cost is higher depends on the difference of the marginal cost of abatement between importers and domestic producers. The assumption of domestic cost advantage and condition (34) together ensure that the right hand side of the above equation is positive and thus $(c_a(\bar{a}) - t) > 0$.

The condition that determines the import abatement level is given by

$$(c^*_a(\bar{a}) - t) = \frac{[(1+\psi)\pi_p]}{x(q)} [c^*_a(\bar{a}) - c_a(\bar{a})]. \tag{38}$$

This condition has a similar form to the condition for domestic producers.[19] To summarize this case, the domestic abatement equals abatement chosen by importers. The pollution tax equals marginal social damage from pollution. And the marginal cost of either import or domestic abatement is higher than the marginal social damage from pollution. In other words, pollution policy is more stringent than welfare maximizing policy.

[19] Note that $(c^*_a(\bar{a}) - t) > (c_a(\bar{a}) - t) > 0$,implying that the condition from 35 is indeed valid.

A.3 A Closed Economy Version

A.3.1 Government Chooses only the pollution Tax

Assume there is no international trade. The non-numeraire good is produced under perfect competition, and consumers pay a per unit pollution tax (denoted t). The effective consumer price (denoted q) equals

$$q = p + c(a) + t\,(T - a)\,,$$

where p is the producer price for the raw good. Consumers prefer to buy the good with an abatement level that minimizes this effective price. The consumer's preferred abatement level ($\hat{a}$) is given by the condition

$$c_a\,(\hat{a}) = t. \tag{39}$$

As earlier we assume that the preferred abatement level is feasible, that is, $\hat{a} \in (0, T)$ and the only good supplied competitively is the one that meets the preferred abatement level. As there are no imports, pollution produced in this economy is

$$z = (T - \hat{a})\,x\,(q)\,.$$

The producer price in the economy is determined by equating domestic demand and supply. Formally,

$$\pi_p\,(p) = x\,(p + c(\hat{a}) + t\,(T - \hat{a}))\,. \tag{40}$$

In other words, the supply of the good at price p, is equal to the demand of the good at its effective price q.

In a closed economy, any change in the pollution tax alters the domestic demand and thus alters the price of the non-numeraire good. From equation (40) we can derive the relationship between the domestic producer price and the pollution tax. This relationship is given by

$$\frac{dp}{dt} = -\,[T - \hat{a}]\,\frac{[-x_q]}{[\pi_{pp} - x_q]} < 0. \tag{41}$$

As the pollution tax rises, the demand for the polluting good falls. In order to restore equilibrium, the price for the non-numeraire good falls.[20]

[20] Due to the concavity of the sub-utility function, $x_q < 0$, due to the convexity of the profit function $\pi_{pp} > 0$. Finally, by the assumption of an interior solution $[T - \hat{a}] > 0$.

The Optimal Tax when Domestic Producers Influence Policy The first order condition (for the problem in equation (14)) with respect to the pollution tax t can be expressed as

$$t_o = v_z - \frac{\psi \pi_p \left[-\frac{dp}{dt}\right]}{\left[-\frac{dz}{dt}\right]} \tag{42}$$

where the superscript o distinguishes an optimal policy chosen by the politically motivated government. The above equation can be re-expressed as

$$t_o = v_z - \frac{\psi \pi_p}{[T - \hat{a}]\,\pi_{pp}}. \tag{43}$$

In other words, as the government weighs producer profits higher than the rest of the economy's welfare it sets the optimal pollution tax lower than marginal social damage. Equations (43), and (39) imply that the abatement level chosen under a politically motivated government is given by

$$c_a(\hat{a}_o) = v_z - \psi \frac{\pi_p}{[T - \hat{a}]\,\pi_{pp}}.$$

Thus the abatement level chosen is lower than that adopted by domestic industry in a welfare maximizing economy.[21]

A.3.2 Minimum Abatement Mandated By the Government

In a closed economy model, we need to include the relationship between domestic price and any binding minimum abatement level ($\bar{a}$) chosen by the government. If the minimum abatement binds then

$$\frac{dp}{d\bar{a}} = -\left[c_a - t\right] \frac{[-x_q]}{[\pi_{pp} - x_q]}. \tag{44}$$

From equation (20) we know that $c_a - t \geq 0$ is always true. Thus given a binding abatement level the marginal cost of meeting the minimum is higher than the pollution tax ($c_a(\bar{a}) - t > 0$). This implies that an increase in the domestic abatement level lowers producer price.

Optimal Pollution Policy when Domestic Producers Influence Policy The optimal pollution tax is given by

$$t_{oc} = v_z - \psi \frac{\pi_p}{[T - a]\,\pi_{pp}}, \tag{45}$$

[21] The first order condition for the problem in equation (10) with respect to the pollution tax t is $t_w = v_z$,where the subscript w denotes the welfare maximizing policy. In other words, the welfare maximizing pollution tax equals marginal social damage from pollution. Using equation (39) we find that the abatement level chosen is given by $c_a(\hat{a}_w) = v_z$. In other words, the abatement level chosen by domestic producers is such that the marginal cost of abatement equals the marginal social damage from pollution.

where the superscript *oc* distinguishes an policy chosen by a politically motivated government in a closed economy. Equation (45) implies that the pollution tax is always set lower than the marginal damage from pollution. An increase in the pollution tax lowers the domestic price, which in turn lowers producer profits. As the government weighs these profits higher than the rest of the societies welfare the pollution tax is lowered by a term that captures this trade-off.

There are two options for the minimum abatement level in a closed economy. Either, $c_a(\bar{a}) \leq t$, or $c_a(\bar{a}) > t$. If $c_a(\bar{a}) \leq t$ the outcome is similar to the case where the government only chooses the pollution tax (see previous subsection). We find that the minimum level required by the government in a closed economy always binds, that is $c_a(\bar{a}) > t$. In this case the domestic firms choose the minimum abatement and do not exceed it. The optimal abatement is given by

$$(c_a(\bar{a}) - t_{oc}) = \psi \frac{\pi_p}{[T - a]\, \pi_{pp}}.$$

In other words, the marginal cost of abatement is higher than the pollution tax. Substitute the expression for the optimal pollution tax in the above equation to obtain

$$c_a(a_{oc}) = v_z. \tag{46}$$

The marginal cost of abatement equals marginal social damage. In contrast to the case where abatement levels are chosen competitively, in this equilibrium there is no distortion in the optimal abatement level.

However, note that the pollution tax is still distorted downwards. This is because the pollution tax is a more efficient instrument for transferring welfare to domestic producers. Due to the presence of an associated revenue component in pollution tax, the aggregate welfare costs from a distortion in pollution tax are lower than the corresponding costs from a distortion in the abatement level.[22]

[22] The social planner sets the pollution tax such that $t_{cw} = v_z$, where the subscript *cw* denotes welfare maximizing policy in a closed economy. The social planner sets any minimum abatement level such that $c_a(\bar{a}) \leq v_z$.This combination ensures that the marginal cost of abatement also equals the marginal social damage from pollution.