Free Trade and the Greening of Domestic Industry

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TECHNICAL APPENDIX

Material in this Technical Appendix is
intended for online-only publication.

It contains additional material that
accompanies the main paper and may assist
other researchers interested in our work.

A Pollution Control using Two Instruments: a Pollution Tax and a Pollution Intensity

We now consider the case where in addition to regulating the pollution tax the government also regulates pollution intensities. Any non-numéraire 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'.[1] National treatment requires that the maximum applies equally on domestic producers and importers.

The Corporate Average Fuel Efficiency (CAFE) standards in the United States are potentially an 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 important reasons to 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.[2] Secondly, 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.

B Abatement Activity Under National Treatment

The government chooses the pollution tax, and mandates a maximum pollution intensity $(T - \bar{a})$. 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

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

[1] 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.

[2] 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).

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,

$$(c^*_{a^*}(a^*) - t) \geq 0, (a^* - \bar{a}) \geq 0, (a^* - \bar{a})(c^*_{a^*}(a^*) - t) = 0. \quad (1)$$

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

$$(c_a(a) - t) \geq 0, (a - \bar{a}) \geq 0, (a - \bar{a})(c_a(a) - t) = 0. \quad (2)$$

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

Lemma 1 *If a common maximum pollution intensity is mandated by the government and the non-numéraire good is imported, domestic firms sell the non-numéraire good in the domestic market if and only if they are equally efficient or have a cost advantage at abatement.*

proof: 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 from the paper.

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.

C 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 (1) and (2).

Proposition 1 *The social planner sets the pollution tax (t_w) such that*

$$t^w = v_z, \tag{3}$$

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

$$\max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t_w. \tag{4}$$

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.[3] This policy combination is observationally equivalent to the welfare maximizing solution illustrated in the paper. As the marginal cost of reducing pollution equals the marginal social damage across all sectors, this policy maximizes aggregate welfare.

D The Political Equilibrium

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

$$\max_{t,(T-\bar{a})} G = \left\{1 + (1+\psi)\,\pi(p) + \gamma\left(q\right) + tz - v\left(z\right)\right\}, \tag{5}$$

subject to equations (1) and (2). Let the superscript o denote political equilibrium. There are three relevant outcomes for the pollution tax (t^o), and the maximal pollution intensity (or minimum abatement level $\bar{a}^o$).

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

$$\max\left\{c_a\left(\bar{a}^o\right), c^*_{a^*}\left(\bar{a}^o\right)\right\} \leq t^o. \tag{6}$$

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 $(T - \bar{a}^o)$ are such that

$$\min\left\{c_a\left(\bar{a}^o\right), c^*_{a^*}\left(\bar{a}^o\right)\right\} \leq t_o < \max\left\{c_a\left(\bar{a}^o\right), c^*_{a^*}\left(\bar{a}^o\right)\right\}. \tag{7}$$

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 $(T - \bar{a}^o)$ are such that

$$\min\left\{c_a\left(\bar{a}^o\right), c^*_{a^*}\left(\bar{a}^o\right)\right\} > t^o. \tag{8}$$

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 in the paper.

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

Lemma 2 *If the domestic industry has a cost disadvantage, or is equally efficient at abatement t^o, and $(T - \bar{a}^o)$ are such that*

$$\max\left\{c_a\left(\bar{a}^o\right), c^*_{a^*}\left(\bar{a}^o\right)\right\} \leq t^o, \tag{9}$$

and

$$t^o = v_z.$$

proof for Lemma 2. 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 $c_a\left(a'\right) = c^*_a\left(a'\right)\ \forall a' \in [0, T]$ the only outcome possible is $\max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t$. Suppose not. Then either $\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t < \max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\}$, or, $\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} > t$. We know that $\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} \leq t < \max\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\}$, as by definition $c_a\left(a'\right) = c^*_a\left(a'\right)$. Thus the only possibility is that $\min\left\{c_a\left(\bar{a}\right), c^*_{a^*}\left(\bar{a}\right)\right\} > t$. 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

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

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

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

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

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 1). 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 (6) is identical to the case in the paper where the government chooses only the pollution tax. There we saw that given a domestic producer cost advantage at abatement the pollution tax is more stringent than welfare maximizing policy (see Proposition 1 in the paper).

Next we evaluate the second outcome from equation (7). 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: $\left(\hat{a} > \bar{a}^o\right)$. Given this necessary condition (which is a stricter version of cost advantage), equation (7) can be rewritten as

$$c_a\left(\bar{a}^o\right) < t < c^*_{a^*}\left(\bar{a}^o\right). \tag{10}$$

The second condition is

$$\psi > \frac{[x(q) - \pi_p]}{\pi_p} \left[\frac{(\hat{a} - \bar{a}^o)^2 \pi_{pp} + (T - \bar{a}^o)^2 (-x_q)}{(T - \hat{a})(T - \bar{a}^o)(-x_q)} \right]. \tag{11}$$

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).[4]

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

$$t^o = v_z + \frac{\psi \pi_p (\hat{a} - \bar{a}^o)}{-\frac{dz}{dt}}, \tag{12}$$

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.[5] However it is useful to note that as $(\hat{a} > \bar{a}^o)$ 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 4 in the paper. The condition that determines the minimum (also import) abatement level is given by

$$(c_a^*(\bar{a}^o) - t^o) = \frac{\psi \pi_p (x(q) - \pi_p)}{\Delta(p^*, t^o, \hat{a}, \bar{a}^o, \psi) + [\psi \pi_p - [x(q) - \pi_p]] \frac{d\hat{a}}{dt}} (\hat{a} - \bar{a}^o), \tag{13}$$

where $\Delta(p^*, t^o, \hat{a}, \bar{a}^o, \psi) = \left[-[x(q) - \pi_p] \left[-\frac{dz}{dt} \right] + \psi \pi_p (T - \bar{a}^o)(T - \hat{a})(-x_q) \right]$. The necessary conditions discussed earlier together ensure that $(c_a^*(\bar{a}^o) - t^o) > 0$ which ensures that condition (7) holds given domestic producer cost advantage. The condition (11) ensures that the denominator of the right hand side of equation (13) is positive. And condition (10) ensures that $(\hat{a} - \bar{a}^o) > 0$. Together these two are necessary for $(c_a^*(\bar{a}^o) - t^o) > 0$. The effect is that when domestic producers have a cost advantage, pollution policy is more stringent than welfare maximizing policy.

To summarize, in the solution to this outcome 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 $((T - \hat{a}) < (T - \bar{a}^o))$. Finally, the marginal cost of abatement for both domestic producers and importers is greater than marginal social damage $(c_{a^*}^*(\bar{a}^o) > c_a(\hat{a}) > v_z)$. In other words, pollution policy is more stringent than welfare maximizing policy.

Finally consider the third outcome from equation 8. Given domestic producer advantage at abatement, and without making any other assumptions or changes, equation (8) can be expressed as

$$t < c_a(\bar{a}^o) < c_{a^*}^*(\bar{a}^o). \tag{14}$$

[4]Note that as the right hand side of equation (11) 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 (11) becomes bigger (though not infinitely bigger given interior solutions).

[5]Please see equation 13 in Sub-Section 3.3 for a discussion.

In this case the common abatement level binds for both domestic producers and importers.

This outcome also occurs only when the domestic industry has a cost advantage at abatement. We need one necessary condition for this outcome to be valid. Formally, the condition is

$$\psi > \frac{[x(q) - \pi_p]}{\pi_p}. \tag{15}$$

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

Correspondingly, the optimal pollution tax is given by

$$t_o = v_z. \tag{16}$$

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

$$(c_a(\bar{a}^o) - t) = \frac{[(1+\psi)\pi_p - x(q)]}{x(q)} [c_a^*(\bar{a}^o) - c_a(\bar{a}^o)]. \tag{17}$$

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 (15) together ensure that the right hand side of the above equation is positive and thus $(c_a(\bar{a}^o) - t) > 0$.

The condition that determines the import abatement level is given by

$$(c_a^*(\bar{a}^o) - t) = \frac{[(1+\psi)\pi_p]}{x(q)} [c_a^*(\bar{a}^o) - c_a(\bar{a}^o)]. \tag{18}$$

This condition has a similar form to the condition for domestic producers.[6] 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.

In the solution to this outcome we find that both importers and domestic producers choose the maximum pollution intensity $(T - \bar{a}^o)$, 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 ($c_{a^*}^*(\bar{a}^o) > c_a(\hat{a}) > v_z$). 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.

[6] Note that $(c_a^*(\bar{a}) - t) > (c_a(\bar{a}) - t) > 0$,implying that the condition from 14 is indeed valid.

Proposition 2 *Given (i) that the mandates a maximum pollution intensity ($T - \bar{a}^o$) 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.*

Thus assuming 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.

D.1 Closed Economy 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 ($\bar{a}^{oc}$) chosen by the government. If the minimum abatement binds then

$$\frac{dp}{d\bar{a}} = -\left[c_a - t\right] \frac{\left[-x_q\right]}{\left[\pi_{pp} - x_q\right]}. \tag{19}$$

From equation (2) 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 ($c_a\left(\bar{a}\right) - t > 0$). 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

$$t^{oc} = v_z - \psi \frac{\pi_p}{\left[T - a\right]\pi_{pp}}, \tag{20}$$

where the superscript oc distinguishes an policy chosen by a politically motivated government in a closed economy. Equation (20) 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, $c_a\left(\bar{a}^{oc}\right) \leq t$, or $c_a\left(\bar{a}^{oc}\right) > t$. If $c_a\left(\bar{a}^{oc}\right) \leq t$ the outcome is similar to the case where the government only chooses the pollution tax. We find that the minimum level required by the government in a closed economy always binds, that is $c_a\left(\bar{a}^{oc}\right) > t$. In this case the domestic firms choose the minimum abatement and do not exceed it. The optimal abatement is given by

$$\left(c_a\left(\bar{a}^{oc}\right) - t^{oc}\right) = \psi \frac{\pi_p}{\left[T - a\right]\pi_{pp}}.$$

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

$$c_a\left(\bar{a}^{oc}\right) = v_z. \tag{21}$$

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.[7]

Thus we find that as the economy opens up to trade the domestic industry turns 'green.' When the economy is closed 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.

[7]The social planner sets the pollution tax such that $t^{cw} = v_z$, where the superscript 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.