Trade, Politics, and the Environment: Tailpipe vs. Smokestack

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Preliminary, Comments Welcome

Abstract: Economists interested in the interaction between trade, politics and the environment have restricted their attention almost exclusively to the problem of production related—"smokestack"—pollution. We instead consider consumption related—"tailpipe"—pollution and show that this reverses a number of core results. For example, we show that the impact of regulation on a trade patterns depends on the type of pollution being regulated: while strict smokestack regulation dampens exports of pollution intensive goods, tailpipe regulation promotes these exports. Similarly, we show that pollution type may fundamentally alter the impact of openness on political opposition to environmental regulation: while openness may make dirty industry oppose smokestack regulation more vociferously, it will make industry a less ardent enemy of tailpipe regulation.

1 Introduction

Consider a list of pressing environmental problems in both the industrialized and developing world: air pollution, solid waste accumulation, climate change, ozone depletion, acidic deposition. Each can be linked to the production or consumption of dirty goods, goods that are often traded. Accordingly, concern for the environment has played a significant role in recent debates over trade liberalization: former U.S. President Bill Clinton declared that he would not support the North American Free Trade Agreement without a side-agreement protecting the environment; environmentalists and other protesters at the 1999 World Trade Organization meetings in Seattle toppled talks to initiate a new round of trade negotiations.

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Economists have devoted much attention to the impact of globalization on the environment, establishing along the way several rules of thumb concerning interactions between trade, politics, and environmental quality. Yet the literature on trade and the environment is markedly incomplete. With few exceptions, this literature has focused exclusively on cases of production-related pollution, which we will call "smokestack" pollution; the problem of consumer related pollution—hereafter referred to as "tailpipe" pollution—has been almost entirely ignored.[3] This omission is not trivial. As noted above, consumption behavior has contributed to many past and ongoing environmental problems[4]. Perhaps the most compelling example is air pollution arising from use of passenger vehicles. In the United States motor vehicles are responsible for up to half of the smog-forming volatile organic compounds (VOCs) and nitrogen oxides (NO_x); passenger vehicles also release more than 50 percent of the hazardous air pollutants and up to 90 percent of the carbon monoxide found in U.S. urban air (EPA 1993). Nevertheless, excluding consumer generated pollution in analyses of trade and environment interactions would not be a problem if tailpipe and smokestack pollution were effectively equivalent, i.e. if regulating either had an identical effect on political incentives and on trade patterns. However we find that the opposite is true: we show that simply considering a different source of pollution—consumers instead of producers—reverses several core results on the relationship between politics, environmental

[3] Exceptions include Krutilla (1991), Copeland and Taylor (1995), Rauscher (1997), Haupt (2000), Schleich (1999), Schleich and Orden (2000), Copeland (2001) and McAusland (2003). Copeland (2001) examines strategic incentives to manipulate environmentally related product standards when cost structures vary for domestic and overseas firms or where producing a variety of product types imposes a re-tooling cost at the firm level. Haupt (2000) examines how firms in open economies choose expenditures on research and development to reduce the pollution intensity of consumption goods. The remaining works are discussed elsewhere in this paper.

[4] Consumption behavior can impact a variety of environmental media. Residential waste constitutes between 55 and 65 percent of municipal solid waste (EPA 2002), and accounts for approximately a third of waste deposited in landfills. Accelerated depletion of stratospheric ozone has been linked to the use of Chlorofluorocarbons (CFCs), which, prior to regulation, were ubiquitous in home refrigeration units and household aerosol products. And prior to the phase-out mandated by the US EPA, residential applications of the pesticide Diazinon accounted for approximately three quarters of its use; Diazinon was one of the leading causes of acute insecticide poisoning for humans and wildlife and one of the top causes of bird kill incidents (EPA 2001).

regulation and international trade.

The rules of thumb from the trade and environment literature in which we are interested are as follows. Firstly, strict domestic environmental regulation will reduce the competitiveness of pollution intensive industries and thereby hurt a country's exports of dirty goods. Secondly, and following from the first, there is an expectation that producers of dirty goods will oppose strict environmental regulation more vociferously when exposed to overseas competition than when protected by trade barriers. And thirdly, governments without access to tariffs have incentives to distort local environmental policies so as to manipulate the terms of international trade. As Krutilla (1991) provides an extensive analysis of the (mis-)use of environmental policy for terms of trade objectives[5], we focus only on the first two rules of thumb: the relationship between policy stringency and the pattern of trade, and the effect of openness on the policy preferences of a political agent who is captured by dirty industry. As mentioned previously, we find that each of these rules of thumb is reversed when we consider tailpipe pollution in lieu of smokestack.

Regarding the relationship between exports and the stringency of environmental policy, the reason for the reversal is straightforward. Strict smokestack regulation in the Home country lowers the productivity of all Home firms, reducing Home's supply of dirty goods, or, alternately, the attractiveness of Home goods abroad: Home's exports fall. But with tailpipe pollution, strict regulation in the Home country makes the Home market a less attractive place to sell goods. This encourages all producers (including Home's dirty goods producers) to sell their wares elsewhere: Home exports rise. This intuition is borne out in

[5] If a country cannot use tariffs to manipulate its terms of trade—i.e. raise the world price of its exports and lower the world price of its imports—it has an incentive to distort local environmental policy for this objective. Krutilla (1991) finds that considering consumption taxes (aimed at consumption related externalities) instead of production taxes (aimed at production related externalities) reverses these incentives. For example, a country exporting dirty goods wants inefficiently high environmental taxes on production related externalities (so as to curtail world supply) but inefficiently low tax on consumption related externalities (so as to bolster world demand).

our model. We find that strict smokestack regulation unambiguously decreases both capacity allocated to production of goods for export and the volume of exports, whereas strict tailpipe regulation unambiguously raises the value of both these variables. In sum, stricter tailpipe regulation raises a country's exports of dirty goods, while stricter smokestack regulation reduces them. This result has not previously been recognized explicitly. However similar results are implicit in Copeland and Taylor (1995) and Rauscher (1997), who each assume emission taxes are set so as to maximize the welfare of representative agents. In Copeland and Taylor (1995), stricter regulation in the North induces its consumers to demand relatively less of the dirty good and so North, the country with stricter regulation, exports the dirty good. Rauscher (1997) finds that countries with higher degrees of environmental concern will have lower producer prices for dirty (consumption) goods, and so have an advantage in export markets.

Similarly, the type of pollution being regulated also affects how responsive goods prices are to regulatory stringency. This follows from General Agreement on Tariffs and Trade (GATT) prohibitions on extraterritorial pollution regulation: governments may not regulate activities that generate pollution overseas. For smokestack, the GATT ban on extraterritoriality means that governments may regulate only local production processes; for tailpipe, it means that governments may regulate the attributes of all goods consumed within their country[6]. The responsiveness of prices to environmental regulation varies strikingly with the territorial restrictions allowed: smokestack regulation may be levied only on a fraction of the firms producing goods sold on the world market, and so prices are less responsive to

[6] With respect to product regulation, GATT rules also require that regulations satisfy the principle of National Treatment—product rules must not vary across goods depending on their country of origin—and that the regulations have scientific foundation. One controversial case of a product standard satisfying the National Treatment clause but failing to meet the burden of scientific proof is the European Union ban on beef from hormone treated cows. The World Trade Organization sided with the United States in its complaint against the ban on the grounds that there exists no scientific evidence that the health of humans consuming said beef is adversely affected.

one country's regulation in the open economy than they would be if that country were closed to trade. However tailpipe regulation applies to all goods sold within a country's market, whether that country is open to trade or not. Moreover, because immobile production capacity can escape local tailpipe regulation by producing goods for overseas consumers, in the open economy tightening tailpipe regulation drives goods out of the Home market. The end result is that the prices of dirty goods are more responsive to local tailpipe regulation in the open than the closed economy.

Price responsiveness is closely related to the incidence of pollution policy, which in turn influences political opposition to environmental regulation. For example, if prices are very responsive to supply, then producers are better compensated for any curtailment in their output arising from compliance with environmental regulation. If instead prices are invariant to changes in domestic supply, then producers' bear the burden of environmental protection without any compensation. Consequently, the extent to which producers of dirty goods—and any regulators under their influence—tolerate strict environmental regulation is directly related to how prices respond to local regulation. We find that openness makes local prices less responsive to smokestack regulation but more responsive to tailpipe regulation. This means openness may make producers of dirty goods more fervent opponents of smokestack regulation but less ardent enemies of tailpipe regulation than they would be in autarky. These results contribute to the growing literature on the political economy of environmental regulation in open economies. In this literature, only Schleich (1999), Schleich and Orden (2000) and McAusland (2003) consider consumption related pollution[7], and

[7] Treating emissions as one for one with production, Schleich (1999) shows that government will not use trade taxes to transfer rents to firms when pollution is production related, but will when it is consumption related, when the economy in question is small. Schleich and Orden (2000) consider the large open economy and find the influenced government will exploit trade taxes in both these cases. McAusland (2003) examines how harmonizing producer- and consumer-generated pollution policies affects the welfare of identical countries.

only McAusland (*forthcoming*) examines the impact of opening up a closed economy.[8] We follow McAusland (2003) in using a standardized treatment of political economy, and show that the effect of openness on political opposition to environmental policy depends critically on the type of pollution being regulated.

The paper is laid out as follows. Section 2 gives the basic setup while sections 3 solves for the political agent's preferred level of smokestack and tailpipe regulation in the closed economy. Section 4 examines the agent's preferred emission cap when the economy is small and open to free trade; we begin with the standard case of smokestack regulation (Section 4.1) and then show in Section 4.2 how considering tailpipe regulation instead reverses some key results. Section 5 offers conclusions while Appendices B and C offer companion analyses of smokestack and tailpipe regulation in a large open economy.

2 Model

The country under consideration, Home, is endowed with gross capacity X to produce dirty goods Q, with net output increasing in the emissions, e, associated with a unit of the good: $Q = f(e)X$ where f is increasing and concave. For simplicity we assume f is iso-elastic with elasticity $\sigma \equiv \frac{f'(e)e}{f(e)} > 0$. In the case of tailpipe pollution, e is the emissions created per unit of the dirty good consumed; for smokestack e is emissions per unit produced. Regarding tailpipe pollution, it is implicit in this structure that the pollution intensity of

[8] Fredriksson (1997) and Bommer and Schulze (1999) each model small open economies and consider the effect of an exogenous increase in the price of dirty goods, obtaining opposite results. In Fredriksson (1997) the price increase raises the opportunity cost of abatement, thereby inducing dirty industry to increase its bid for weak environmental regulation; hence the price increase reduces the pollution tax and raises total pollution. In Bommer and Schulze (1999) the price increase pacifies dirty industry, thereby allowing the government to increase transfers to its environmental lobby by imposing stricter regulation; the price increase thus induces a tightening of the cap on total emissions and so raises environmental quality. McAusland (*forthcoming*) compares policy preferences in a small open economy with their autarkic equivalent, and finds that producers of dirty goods want weaker smokestack regulation in the small open economy provided the world price of dirty goods is not sufficiently low.

goods is determined *at the factory*, as would be the case with the installation of catalytic converters or more fuel efficient engines in passenger vehicles. Note, however, that the analytics would be essentially unchanged if we instead considered abatement undertaken by consumers directly.[9]

So as to round out the model, we assume there is also a numeraire clean good for which productive capacity, Y, equals output. All capacity is owned by citizens; then X_i, Y_i denotes the endowment portfolio of some citizen i. We assume that a citizen's entire consumption must be financed out of earnings from her factor endowments, and that factor markets are perfectly competitive such that, if the retail price of a unit of dirty goods is P, then citizen i's income and budget for financing her own consumption is $I_i = Pf(e)X_i + Y_i$.

We assume that pollution has no transboundary component: the externality is purely local. We further assume that each citizen's utility is quasi-linear in the dirty and clean goods, and linear in local pollution:

$$U_i = v(q_i) + y_i - \beta Z$$

where q_i and y_i are individual consumptions of dirty and clean goods, Z is local pollution, β is the marginal disutility from pollution and v is positive, increasing, and strictly concave; for simplicity we also assume v is iso-elastic. For the case of tailpipe $Z = e\sum_i^N q_i$; for smokestack $Z = eQ$. When buying goods consumers take prices as given and so q_i, y_i satisfy

$$P = v'(q_i) \tag{1}$$

and $y_i = Pf(e)X_i + Y_i - Pq_i$. We assume Y_i is large enough for each i to afford the desired level of dirty good consumption; accordingly we drop the subscripts on q from here forward.

[9] See footnote 21.

We can rewrite the utility function for each citizen as

$$W_i(e) = v(q) + Pf(e)X_i + Y_i - Pq - \beta Z \,. \tag{2}$$

Now consider the emission cap preferred by an individual citizen. Differentiating eq. 2 with respect to e, canceling terms using eq. 1, and rearranging gives

$$\frac{dW_i}{de/e} = PE_i\frac{\hat{P}}{\hat{e}} + Pf(e)X_i\sigma - \beta Z\frac{\hat{Z}}{\hat{e}} = 0, \tag{3}$$

where $\hat{}$ indicates the percentage change, for example $\hat{P} = \frac{dP}{P}$, and

$$E_i \equiv f(e)X_i - q \tag{4}$$

can be interpreted as i's net exports of dirty goods to the rest of the market. Since eq. 3 is twice continuously differentiable and locally concave in e—this is confirmed in Appendix A—then $i's$ preferences over e are single peaked.

We can interpret eq. 3 as follows. The last two terms represent the direct costs and benefits of pollution regulation. The term $Pf(e)X_i\sigma$ indicates the value of extra output that can be produced when the emission cap is loosened; the $-\beta Z\frac{\hat{Z}}{\hat{e}}$ term gives disutility from pollution moderated by the responsiveness of the pollution base to regulation.

The remaining term reflects an indirect cost/benefit of regulation. The term is the product of the responsiveness of prices to regulation, $\frac{\hat{P}}{\hat{e}}$, and the value of (net) dirty good exports from citizen i to the rest of the market, PE_i. For example, if citizen i is a net seller of dirty goods—i.e. $E_i > 0$—then the price rise that accompanies tightened regulation provides an indirect benefit to i, making strict policy less unattractive. If instead i is a net importer of the dirty good, then the price rise represents an indirect cost of strict regulation.

Combined, these competing considerations define the instrument level preferred by an individual citizen of Home. Notably, i's preferred level of stringency depends on X_i both directly and indirectly (via E_i).

So far we have examined only the preferences of individual Home citizens; we now specify how policy is actually set. Given that we assume individual preferences are quasi-linear in private goods and linear in pollution, then in a variety of political economy models—majority rules, an incumbent government influenced by contributions from a single lobby group, or a political elite—the objective function for the decision maker is a monotonic transformation of eq. 2 when evaluated at "represented" endowments X_D, Y_D.[10] Furthermore, these represented endowments are invariant in the model to both the instrument level and the trade regime and so can be treated as parameters of political economy. With this in mind, we define a politically motivated decision maker D and assume that D sets Home's emission cap e_D so as to maximize eq. 2 when evaluated at X_D, Y_D. Thus e_D solves

$$\frac{dW_D}{de/e} = PE_D\frac{\hat{P}}{\hat{e}} + Pf(e)X_D\sigma - \beta Z\frac{\hat{Z}}{\hat{e}} = 0\,. \qquad (5)$$

For the sake of variety we will alternately refer to D as Home's political agent and to X_D as the dirty capacity represented by D or as the vested interests of D's constituents. Treatments of political economy in the literature on environmental policy commonly assume that representatives of dirty industry unduly influence environmental policy; in our framework this is consistent with a decision maker who has an above average interest in the polluting industry, i.e. $X_D > \frac{X}{N}$. However, the tools of our analysis are equally valid when $X_D < \frac{X}{N}$, that is, for a decision maker with constituents who are linked to the dirty good sector predominately as consumers.

We anticipate results from sections below by pointing out here that $\frac{de_D}{dX_D} \geq 0$. This is precisely as one would expect from most stories of political economy: for a given trade regime and pollution type, as D's vested interests in the dirty industry rises, she (weakly) prefers more lenient environmental policy. This is confirmed by partially differentiating

[10] See McAusland (2003).

$\frac{dW_D}{de}$ and invoking the envelope theorem to get

$$\text{sign}\left[\frac{de_D}{dX_D}\right] = \text{sign}\left[\frac{\partial}{\partial X_D}\frac{dW_D}{de}\right] = \text{sign}\left[Pef(e)\left[\sigma + \frac{\hat{P}}{\hat{e}}\right]\right].$$

Equations 9, 11 and 21 below confirm, respectively, that this is non-negative for each of the cases considered.

3 Autarky

We now characterize the political agent's preferred policy level in the closed economy. Goods market clearance requires domestic supply and demand for dirty goods be equal. This implies $q = \frac{f(e)X}{N}$, where N is the size of Home's population. Differentiating eq. 1 and converting to percentage changes gives

$$\frac{\hat{P}}{\hat{e}} = -\frac{\sigma}{\epsilon} < 0 \tag{6}$$

where $\epsilon \equiv -\frac{dq}{dP}\frac{P}{q}$ is the price elasticity of dirty goods demand. Since v is iso-elastic and concave then $\epsilon > 1$. Additionally, $E_D = X_D f(e) - \frac{X}{N} f(e)$ or, equivalently, $E_D = \left[X_D - \frac{X}{N}\right] f(e)$. Since the country is closed to trade then all goods produced locally are also consumed locally, and so the amount of pollution created locally,

$$Z = ef(e)X\ ,$$

is identical regardless of whether it is a by-product of production or consumption. The responsiveness of pollution to regulation is similarly identical across the pollution types:

$$\frac{\hat{Z}}{\hat{e}} = 1 + \sigma. \tag{7}$$

Substitute these values into eq. 5 and define $P^a = v'\left(\frac{f(e_D^a)X}{N}\right)$. Then D chooses autarkic emission cap, e_D^a, to solve

$$\frac{dW_D}{de/e} = -P^a\left[X_D - \frac{X}{N}\right] f(e_D^a)\frac{\sigma}{\epsilon} + P^a f(e_D^a) X_D \sigma - \beta e_D^a f(e_D^a) X [1+\sigma] = 0\ . \tag{8}$$

As advertised, partially differentiating eq. 8 and invoking the envelope theorem gives

$$\text{sgn}\ \left[\frac{de_D}{dX_D}\right] = \text{sgn}\left[P^a e f(e)\sigma\left[1 - \frac{1}{\epsilon}\right]\right] \tag{9}$$

which is positive. This confirms that in autarky a decision maker with a larger vested interest in the polluting sector wants weaker environmental policy.

4 The Small Open Economy

Next we consider the open economy. We focus on two things: how strict environmental regulation affects exports, and how openness affects each of the competing concerns dictating the decision maker's choice of e. So as to focus our analysis we restrict our attention to the case of a small open economy; analyses of smokestack and tailpipe regulation in the large open economy are provided in Appendices B and C.

From here forward autarkic values are denoted by a superscript a; denote values in the Rest of the World (ROW) by asterisks. We begin our analysis with the case of smokestack pollution, since this is the type of pollution studied by the majority of research on trade and environment interactions. Section 4.2 provides comparable analysis for the case of tailpipe pollution.

4.1 Trade and Smokestack Regulation

Denote Home values in the open economy with smokestack regulation by a superscript s; since Home is small then the price of dirty goods is the fixed world price P^*, and so individual consumption is independent of e. Define by E Home's net exports of dirty goods; then $E^s = f(e)X - Nq^s$ and

$$\frac{dE^s}{de} = \frac{f(e)X\sigma}{e} > 0\,. \tag{10}$$

Equation 10 replicates the result, common in the literature on trade and environment interactions, that weaker smokestack regulation promotes exports of dirty goods. This result arises because an increase in the emission cap raises the productivity of Home firms, thereby increasing their supply. Since consumer prices are fixed their demand is unchanged and so exports necessarily rise.[11]

Next we examine how openness affects the preferences of the political agent; this requires derivation of $\frac{\hat{P}}{\hat{e}}^s$ and $\frac{\hat{Z}}{\hat{e}}^s$ in the open economy. Since prices in the small open economy are, by construction, independent of Home behavior then $\frac{\hat{P}}{\hat{e}}^s = 0$.[12] And since pollution derives from production of goods, then regardless of the pattern and volume of trade $Z^s = ef(e)X$ and so $\frac{\hat{Z}}{\hat{e}}^s = 1 + \sigma$, exactly as in autarky.[13]

Substituting these values into eq. 5 yields the following characterization of the decision maker's preferred cap on smokestack emissions, e^s_D, in the open economy. It solves

$$\frac{dW^s_D}{de/e} = P^* f(e^s_D) X_D \sigma - \beta Z^s [1 + \sigma] \, ; \tag{12}$$

the local concavity of W^s_D in e is confirmed in Appendix A.

The easiest way to compare the political agent's preferred emission caps in autarky and the open economy is to evaluate $\frac{dW^s_D}{de/e}$ at $e = e^a_D$. If this is positive then the concavity of W^s_D in e indicates that D perceives e^a_D as too strict in the open economy; if instead $\left.\frac{dW^s_D}{de/e}\right|_{e=e^a_D} < 0$ then she perceives e^a_D as too weak. We use eq. 8 to make this evaluation:

$$\left.\frac{dW^s_D}{de/e}\right|_{e=e^a_D} = P^* f(e^a_D) X_D \sigma - \beta Z^s \frac{\hat{Z}}{\hat{e}}^s - \left.\frac{W^a_D}{de/e}\right|_{e=e^a_D}$$

[11] If Home were instead large then the increase in Home supply would lower the world price. Equation 22 in Appendix B confirms that the resulting increase in demand would be smaller than the expansion of Home supply.

[12] This implies

$$\text{sgn}\left[\frac{de^s_D}{dX_D}\right] = \text{sgn}\left[Pef(e)\left[\sigma + \frac{\hat{P}}{\hat{e}}^s\right]\right] = \text{sgn}[Pef(e)\sigma] \tag{11}$$

which is positive.

[13] If instead production capacity were internationally mobile, $\frac{\hat{Z}}{\hat{e}}^s$ would no longer be identical in autarky and the open economy. This is addressed in Appendix D.

since $\frac{W_D^a}{de/e}\Big|_{e=e_D^a}$ is zero by construction. Recognizing that $Z^s \frac{\hat{Z}}{\hat{e}}^s = Z^a \frac{\hat{Z}}{\hat{e}}^a$ gives

$$\frac{dW_D^s}{de/e}\Big|_{e=e_D^a} = P^a E_D^a \frac{\hat{P}}{\hat{e}}^a + [P^* - P^a] f(e_D^a) X_D \sigma \tag{13}$$

which is of ambiguous sign. However it is easy to derive cases in which openness' affect on D's choice is unambiguous.

Consider the case where D is a representative agent and so domestic politics do not come into play. Then $X_D = \frac{X}{N}$ and $E_D^a = 0$ and so D wants weaker (stricter) smokestack regulation in the open economy than in autarky whenever the world price is higher (lower) than the autarkic price. This is because openness affects policy preferences by changing the price level and so alters the direct opportunity cost of abatement. Accordingly, when openness raises, for example, that opportunity cost by offering $P^* > P^a$ then D wants less abatement and sets a higher e.

But if Home's political agent does not represent average interests then there is a confounding factor. To see this, recognize that in the closed economy any decrease in e causes a curtailment in supply, thereby raising the price of dirty goods. This price rise partially compensates the producers of dirty goods for the stricter regulation they face, and so the incidence of pollution policy in the closed economy is shared by both consumers and producers. By contrast, when Home is small and open then consumer prices are fixed in the world market and so producers bear all the incidence of local smokestack regulation. Thus openness, simply by changing the way that prices respond to local regulation, alters the policy level preferred by a politically motivated decision maker. If openness leaves the price level unchanged, i.e. $P^* = P^a$, then this shift in incidence is all that matters, and by eq. 13 D wants weaker smokestack regulation in the open economy if and only if her constituents have an above average interest in the polluting industry, i.e. if $X_D > \frac{X}{N}$.[14] The next section

[14] More generally, eq. 13 generates the following predictions: If $P^* > P^a$ and $X_D > \frac{X}{N}$ then D perceives

shows the opposite is true if the type of pollution regulated is instead tailpipe.

4.2 Trade and Tailpipe Regulation

We now turn our attention to tailpipe pollution, pollution generated as a by-product of the consumption of dirty goods. Open economy values when tailpipe pollution is regulated are denoted by a superscript t.

Governments bound by GATT rules are entitled to regulate all domestic sources of pollution, provided that regulations do not discriminate between goods based on country of origin. When pollution is a by-product of consumption, this means that Home may regulate the pollution intensity of all goods consumed within its borders—i.e. Home's emission cap applies to all goods consumed by Home consumers, regardless of where they were produced. Similarly, the pollution intensity of goods produced by Home firms but consumed in the Rest of the World must meet the overseas emission cap e^*.[15] Accordingly, goods sold in Home and ROW may differ in their emission intensity and so in equilibrium consumer prices will be different in Home and ROW. Free trade in goods instead implies that the return, r^*, to a unit of capacity employed in the production of goods for export be the same as in the production of goods for domestic consumption: $r^* \equiv P^* f(e^*) = P^t f(e)$, where P^t solves eq. 1 when evaluated at q^t. [16] Define by X_E Home capacity allocated to production of goods for export; then $q^t = \frac{f(e)[X-X_E]}{N}$. Note that when $X_E < 0$ then Home imports dirty goods.

e_D^a as too strict a cap on smokestack emissions when Home is a small open economy; if instead $P^* < P^a$ and $X_D < \frac{X}{N}$ then D views e_D^a as too weak; if sgn $\left[\left(X_D - \frac{X}{N}\right)[P^* - P^a]\right]$ is negative then openness has an ambiguous effect on the decision maker's choice of a cap on smokestack emissions. This mirrors results in McAusland (*forthcoming*), derived there in the context of income inequality.

[15] In our model the unit cost of production is falling in the pollution intensity of output, and firms face no re-tooling costs when producing goods with different pollution intensities. As a result, firms will not over-comply with regulation.

[16] This equilibrium condition allows us to represent D's optimization problem as the maximization of eq. 2 even though in the open economy she may use some of her capacity to produce exports.

Consider then how X_E changes with e. Differentiating the condition $P^t f(e) = r^*$ using eq. 1 gives

$$\frac{dX_E}{de/e} = -\sigma[\epsilon - 1][X - X_E] < 0, \tag{14}$$

revealing that strict tailpipe regulation leads Home firms to reallocate dirty capacity away from the production of goods for domestic consumption and toward production for export. This has implications for the effect of tailpipe regulation on the volume of Home exports.

Proposition 1 *Stricter regulation of tailpipe pollution raises exports of the dirty good:* $\frac{dE^t}{de} < 0$*. Stricter regulation of smokestack regulation instead decreases exports of the dirty good:* $\frac{dE^s}{de} > 0$.

Proof: When $X_E \geq 0$ then Home's exports are $E^t = f(e^*)X_E$ and so $\frac{dE^t}{de} = f(e^*)\frac{dX_E}{dde} < 0$. When $X_E \leq 0$ then $E^t = f(e)X_E < 0$ and so $\frac{dE^t}{de/e} = f(e)\left[\sigma X_E + \frac{dX_E}{de/e}\right]$ which is again negative. The sign of $\frac{dE^s}{de}$ is given by eq. 10.

Proposition 1 confirms that strict tailpipe regulation encourages, rather than hinders, a country's exports of dirty goods. This is because stricter tailpipe regulation makes sales in the Home market less attractive to every firm, regardless of where they are located. As a result firms both in Home and abroad elect to utilize more of their capacity to produce goods for the ROW market, causing Home's exports to rise.

4.2.1 Openness and the emission cap

Next we focus on the broader question of how openness affects the decision maker's preferred emission cap. For this we start by examining the responsiveness of local prices to changes in e. Substitute the expression for q^t into the eq. 1, differentiate employing eq. 26, and convert to percentage changes:

$$\frac{\hat{P}^t}{\hat{e}} = -\sigma\,. \tag{15}$$

Comparing equations 15 and 6 reveals that prices are more responsive to tailpipe regulation in the open economy than in autarky. This arises in part because Home is able to regulate the characteristics of all goods consumed in its borders, and so has effective jurisdiction over its entire consumer market just as it did in autarky. But, as Proposition 1 indicates, weak regulation of tailpipe pollution also expands Home's imports, raising the number of goods sold in Home and so further reducing the price. As we discuss below, this has implications for how the incidence of pollution policy is distributed in the open economy, and so alters the emission cap favored by a politically motivated decision maker.

Also different in the open economy are the pollution base Z and how it responds to tailpipe regulation. Home's total tailpipe pollution depends on the pollution intensity of goods consumed there:

$$Z^t = eNq^t = ef(e)[X - X_E]. \tag{16}$$

Differentiating, making use of eq. 14, and converting to percentage changes gives

$$\frac{\hat{Z}^t}{\hat{e}} = 1 + \sigma\epsilon > 0\,. \tag{17}$$

These values are discussed in greater detail below.

We are now able to characterize D's preferred emission cap in the open economy. Substitute expressions 15, 16 and 17 into eq. 5, letting $E_D^t = \left[X_D - \frac{X}{N} + \frac{X_E}{N}\right] f(e)$,[17] to get the following expression:

$$\frac{dW_D^t}{de/e} = -P^t \left[X_D - \frac{X}{N} + \frac{X_E}{N}\right] f(e)\sigma + P^t f(e) X_D \sigma - \beta f(e) e [X - X_E][1 + \sigma\epsilon] = 0\,. \tag{18}$$

Again, to see whether D wants stricter or weaker tailpipe regulation in the open economy evaluate eq. 18 at e_D^a using eq. 8, recognizing that $\frac{\hat{P}}{\hat{e}}^t = \frac{\hat{P}}{\hat{e}}^a - \frac{\sigma}{\epsilon}[\epsilon - 1]$ from equations 6 and 15 while $\frac{\hat{Z}}{\hat{e}} = \frac{\hat{Z}}{\hat{e}}^a + \sigma[\epsilon - 1]$ from equations 7 and 17; collecting terms yields

$$\begin{aligned} \left.\frac{dW_D}{de/e}^t\right|_{e=e_D^a} &= [P^t E_D^t - P^a E_D^a]\,\frac{\hat{P}}{\hat{e}}^a + [P^t - P^a] f(e_D^a) X_D \sigma - \beta [Z^t - Z^a] \frac{\hat{Z}}{\hat{e}}^a \\ &\qquad - \left[\frac{P^t E_D^t}{\epsilon} + \beta Z^t\right] \sigma[\epsilon - 1]\,. \end{aligned} \tag{19}$$

[17] Since D is indifferent between allocating capacity to the production of goods for domestic or overseas sale, when $X_E > 0$ then E_D as defined by eq. 4 describes *potential* individual exports by D.

As with eq. 13, the sign of eq. 19 is ambiguous. Unlike with eq. 13, we cannot offer a general rule for the sign of eq. 19 depending on P^t versus P^a in the absence of domestic politics.[18] However, in the absence of price *level* changes—i.e. if $P^t = P^a$—the effect of openness on D's preferences is clearer, as is shown below.

Setting $P^t = P^a$, and so $X_E = 0$, in eq. 19 yields

$$\left.\frac{dW_D^t}{de/e}\right|_{e=e_D^a,\ P^t=P^a} = -\left[\frac{P^t}{\epsilon} f(e_D^a)\left[X_D - \frac{X}{N}\right] + \beta Z^t\right]\sigma[\epsilon - 1] \tag{20}$$

revealing that when $X_D > \frac{X}{N}$ and $P^t = P^a$ then D wants stricter tailpipe regulation in the open economy than in autarky. This is qualitatively opposite the response when smokestack is instead regulated and proves the following proposition:

Proposition 2 *If $X_D > \frac{X}{N}$, then in the open economy with $P^t = P^a$ when $e = e_D^a$, the political agent regards e_D^a as too lax if regulating tailpipe emissions but too strict if regulating smokestack.*

Again the reason why openness affects D's policy preference even when openness does not alter the price level is because it alters how prices respond to local regulation and so openness alters the distribution of incidence across consumers and producers. As stated earlier, the more responsive are the prices of dirty goods to Home's emission cap then the greater the indirect compensation Home firms receive for undertaking abatement, and so the smaller the fraction of incidence borne by producers. Since openness makes prices more responsive to tailpipe regulation, but less responsive to smokestack regulation, it isn't surprising then that a political agent representing dirty industry would want a stricter cap on tailpipe emissions but a weaker cap on smokestack. Indeed, when Home is small then openness shifts all the incidence of local regulation to a single group[19]: with smokestack

[18] For example, if $P^t > P^a$ and $X_D = \frac{X}{N}$ then it follows that $X_E > 0$ and so the first and fourth terms of eq. 19 are negative while the second and third terms are both positive; even if $X_D = \frac{X}{N}$ and so $X_D^t = X_E/N$, terms in eq. 19 do not cancel to yield an expression of unambiguous sign.

[19] If Home is instead large then neither group is completely insulated by openness, although the shifting of incidence retains the same flavor: compare eq. 6 with equations 23 and 27, the smokestack and tailpipe counterparts in the large open economy.

regulation consumers are completely insulated in the small open economy because they can always buy goods from abroad at a fixed price; with tailpipe regulation firms are instead completely insulated because they can always avoid regulation by producing for overseas consumers.[20,21]

And in the case of tailpipe pollution this is complemented by the heightened sensitivity of the pollution base to regulation in the open economy. Because tailpipe regulation drives out imports, it is more productive in the open economy than in autarky, making tailpipe regulation more attractive to all Home citizens.

Throughout this paper we have emphasized the policy that would be chosen by a political agent influence by the *producers* of dirty goods. However it is conceivable that Home's decision maker may instead represent constituents with below average vested interests in the polluting industry. In that case, the greater responsiveness of consumer prices to environmental regulation in the open economy makes D want, ceteris paribus, *weaker* environmental policy. But the heightened responsiveness of the pollution base to regulation works on D's preferences in the opposite direction. Thus, unlike in the case of smokestack regulation, the net impact of openness on the tailpipe policy preferred by a decision maker with below

[20] Notably, when Home is small then e^t_D is independent of D's dirty capacity endowment:

$$\text{sgn}\left[\frac{de^t_D}{dX_D}\right] = \text{sgn}\left[Pef(e)\left[\sigma - \sigma\right]\right] \tag{21}$$

which is zero. If Home instead had any influence on the world return to dirty capacity then $\frac{de^t_D}{dX_D}$ would be positive. See eq. 29 in Appendix C.

[21] Note that the results of this section would be essentially unchanged if we instead modeled abatement of consumer-generated pollution as occuring at the household instead of at the factory (again by government mandate). Household abatement could be modeled as follows. Consumer i buys "raw" consumer goods x_i from sellers at price s, and employs these raw goods in a domestic production function, generating private value $v(f(e)x_i)$ which is increasing in the pollution intensity of use. Atomistic behavior by consumers implies $v'(f(e)x_i)f(e) = s$ for all i in equilibrium (and so drop the i subscript here forward). Individual preferences over e would then be given by $\frac{dW_i}{de/e} = s\sigma x + \chi_i s\frac{\hat{s}}{\hat{e}} - \beta Z\frac{\hat{Z}}{\hat{e}}$ where $\chi = X_i - x$ is i's net exports of dirty capacity; this expression is the equivalent of eq. 3. In the small open economy s is fixed on international markets and so $\frac{\hat{s}}{\hat{e}} = 0$ while $\frac{dX_E}{de/e} = -\sigma[\epsilon - 1][X - X_E]$ (exactly as in eq. 14) and $\frac{dZ^t}{de/e} = 1 + \epsilon\sigma$ (exactly as in eq. 17), where X_E is now interpreted as Home's exports of "raw" dirty goods. Combining these gives $\frac{dW^s_D}{de/e} = s\sigma\frac{X - X_E}{N} - \beta Z[1 + \epsilon\sigma]$ which is equivalent to eq. 18. Propositions 1 and 2 would remain unchanged.

average vested interest in the polluting industry is ambiguous even when $P^t = P^a$.

5 Conclusions

This paper re-examines the relationship between politics, openness to free trade in goods, and environmental regulation when pollution arises as a by-product of consumption, instead of production, of dirty goods. We find that the two commonly accepted rules of thumb—that strict pollution policy reduces exports and that producers of dirty goods are more opposed to environmental regulation in the open economy—are reversed in the case of consumption related pollution.

The reason why tailpipe regulation promotes rather than hinders the export of dirty goods is simple. Tailpipe regulation reduces profits from sales in the regulated market, encouraging producers to shift their supply to other markets.

The interaction between openness and politics is more complicated. Several of the effects of openness on policy preferences are invariant to the type of pollution regulation. For example the effect of high world prices on the opportunity cost of abatement and terms of trade objectives are the same for either smokestack or tailpipe regulation. But the way that openness affects the responsiveness of prices to regulation, and hence alters the incidence of pollution policy, is qualitatively opposite. With smokestack regulation, prices are less responsive in the open economy, and so, ceteris paribus, openness raises producers' share of the burden of regulation and so they oppose it more. But prices are instead more responsive to tailpipe regulation in the open than the closed economy, so that openness shifts incidence away from producers. Holding the price level constant, producers of dirty goods are less opposed to tailpipe regulation in the open economy than in autarky.

The wider implications of this research are that several key aspects of the relationship between openness, politics and environmental regulation are fundamentally different for consumption related externalities. In terms of theory, this means that propositions derived from analyses of production related pollution in open economies need to be re-evaluated before assumed true for consumption related pollution as well. There are also implications for empirical tests of trade end environment relationships. Our results suggest that empirical tests that bundle data on tailpipe and smokestack regulation will either fail to find or mis-estimate the extent to which environmental regulation affects trade flows, simply because regulation of these different types of pollution should have opposing effects on trade volumes to begin with.

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Appendix A: Second order conditions

The second order conditions—$\frac{d^2 W_D}{de^2} < 0$—in autarky and the small open economy are confirmed as follows. Since $\frac{d^2 W_D}{de^2} = -\frac{1}{e^2}\frac{dW_D}{de/e} + \frac{1}{e}\frac{d}{de}\frac{dW_D}{de/e}$ then at e_D for each scenario satisfaction of the second order condition requires $\frac{d}{de}\frac{dW_D}{de/e}$ be negative. Differentiating eq. 5 in each scenario gives $\frac{d}{de}\frac{dW_D^a}{de/e}^a = -\frac{Z^a}{e}\frac{1+\sigma}{e}[\sigma + \epsilon] < 0$ in autarky, and in the small open economy $\frac{d}{de}\frac{dW_D^t}{de/e} = -[X - X_E]\frac{\sigma r^*[1+\sigma]}{N} < 0$ for tailpipe pollution while for smokestack pollution $\frac{d}{de}\frac{dW_D^s}{de/e} = Pf''(e)X_D - [1+\sigma] - [1+\sigma]^2\frac{Z^s}{e}$ which is negative by concavity of f.

Appendix B: Smokestack Regulation in a Large Open Economy

This appendix presents the comparison case of smokestack pollution when Home is large; Home as a small open economy is a limiting case of this and values for it are obtained by setting Home's share of the world population and dirty good output, defined as $n \equiv \frac{N}{N+N^*}$ and $\lambda \equiv \frac{f(e)X}{f(e)X+f(e^*)X^*}$, equal to zero in what follows.

Free trade in goods implies $P^s = P^{*s}$ and so $q^s = q^{*s} = \frac{Xf(e)+f(e^*)X^*}{N+N^*}$. With smokestack regulation $E^s = f(e)X - Nq^s$; substituting in for q^s gives $E^s = f(e)X\left[1 - \frac{n}{\lambda}\right]$. Differentiating gives

$$\frac{dE^s}{de} = \frac{f(e)X\sigma[1-n]}{e} > 0\,, \qquad (22)$$

which is opposite in sign to Proposition 1 and eq. 26.

To find $\frac{\hat{P}^s}{\hat{e}}$ substitute for q^s in eq. 1 and differentiate to get

$$\frac{\hat{P}^s}{\hat{e}} = -\frac{\sigma\lambda}{\epsilon}. \tag{23}$$

Since pollution arises from production, even if $X_E \neq 0$ then Z^s and $\frac{\hat{Z}^s}{\hat{e}}$ have the same form as in autarky: $Z^s = ef(e)X$ with $\frac{\hat{Z}^s}{\hat{e}} = 1 + \sigma$.

The counterpart to eq. 12 for smokestack in the large open economy is then

$$\begin{aligned} \left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a} &= [P^s E_D^s - P^a E_D^a]\frac{\hat{P}^a}{\hat{e}} + [P^s - P^a]f(e)X_D\sigma - \beta[Z^s - Z^a]\frac{\hat{Z}^a}{\hat{e}} \\ &+\frac{P^s E_D^s[1-\lambda]\sigma}{\epsilon}. \end{aligned} \tag{24}$$

The first, second and third terms of eq. 24 have the same form as in eq. 19. The difference lies in the final term, which here depends only on the sign of E_D^s. Assuming $P^s = P^a$ when $e = e_D^a$ gives an equivalent to eq. 20:

$$\left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a,\ P^s=P^a} = P^s f(e)\left[X_D - \frac{X}{N}\right]\frac{\sigma[1-\lambda]}{\epsilon}, \tag{25}$$

the sign of which depends only on whether $X_D > \frac{X}{N}$.

Appendix C: Tailpipe Regulation in a Large Open Economy

This appendix examines tailpipe regulation when Home is large; values when Home is small are found by setting the share of world capacity allocated to production of dirty goods for the Home market, defined as $\psi \equiv \frac{X - X_E}{X + X^*}$, equal to zero in what follows.

When Home is large then returns to exports depend on local regulation and equilibrium is defined by $v'\left(\frac{f(e)[X-X_E]}{N}\right)f(e) = v'\left(\frac{f(e^*)[X^*+X_E]}{N^*}\right)f(e^*)$. Differentiating gives the condition

$$\frac{dX_E}{de} = -\frac{\sigma[\epsilon-1]}{e}[X - X_E][1-\psi] < 0 \tag{26}$$

as in Proposition 1. This is used to derive

$$\frac{\hat{P}^t}{\hat{e}} = -\frac{\sigma}{\epsilon}\left[1 + [\epsilon - 1][1 - \psi]\right] \tag{27}$$

and

$$\frac{\hat{Z}^t}{\hat{e}} = [1 + \sigma] + \sigma[\epsilon - 1][1 - \psi] > 0\,. \tag{28}$$

Equation 27 implies

$$\text{sgn}\left[\frac{de_D^t}{dX_D}\right] = \text{sgn}\left[\sigma[\epsilon - 1]\psi\right] \tag{29}$$

which is positive provided $\psi > 0$.

The rather unwieldy counterpart to eq. 18 is

$$\begin{aligned}\frac{dW_D^t}{de/e} &= -P^t\left[X_D - \frac{X}{N} + \frac{X_E}{N}\right] f(e)\frac{\sigma}{\epsilon}\left[1 + [\epsilon - 1][1 - \psi]\right] + P^t f(e) X_D \sigma \\ &\quad -\beta f(e) e[X - X_E][1 + \sigma] - \beta f(e) e\sigma[\epsilon - 1][X - X_E][1 - \psi] = 0 \end{aligned} \tag{30}$$

and the counterpart to eq. 19 is

$$\begin{aligned}\left.\frac{dW_D^t}{de/e}\right|_{e=e_D^a} &= \left[P^t E_D^t - P^a E_D^a\right] \frac{\hat{P}}{\hat{e}}^a + [P^t - P^a] f(e_D^a) X_D \sigma - \beta[Z^t - Z^a]\frac{\hat{Z}}{\hat{e}}^a \\ &\quad - \left[\frac{P^t E_D^t}{\epsilon} + \beta Z^t\right]\sigma[\epsilon - 1][1 - \psi]\,. \end{aligned} \tag{31}$$

If $P^t = P^a$ when $e = e_D^a$ then

$$\left.\frac{dW_D^t}{de/e}\right|_{e=e_D^a,\ P^t=P^a} = -\left[\frac{P^t}{\epsilon} f(e_D^a)\left[X_D - \frac{X}{N}\right] + \beta Z^t\right]\sigma[\epsilon - 1][1 - \psi] \tag{32}$$

which is eq. 20 multiplied by the share term $1 - \psi$.

Appendix D: Regulation with Internationally Mobile Capacity

Since this paper focuses on goods trade, we have assumed throughout that production capacity is internationally immobile. For tailpipe regulation this question is essentially moot since factor returns depend on where goods are sold, not where they are produced;

the same is not true for smokestack regulation. In fact, in our simple model all capacity would move to a single country unless $e^s = e^*$ (where e^* is the overseas emission cap) and both p and Z would respond discontinuously to changes in local smokestack regulation. However the following variation on the production function would generate finite movements of productive capacity: $Q = f(e)g(X - x)$ where x is Home capacity installed in ROW and $g' > 0$, $g'' < 0$. Using this specification, equilibrium in international factor markets would require $f(e)g'(X - x)$ equal some fixed rate, r^*, available abroad if Home is small, and equal $r^* = f(e^*)g'(X^* + x)$ where X^* is overseas production capacity if Home were instead large. Differentiating the arbitrage condition $f(e)g'(X - x) = r^*$ gives $\frac{dx}{\hat{e}} = \frac{\sigma}{g''/g'} < 0$ if Home is small and $\frac{dx}{\hat{e}} = \frac{\sigma}{\frac{g''}{g'} + \frac{g''(*)}{g'(*)}} < 0$ if Home is instead large, where $g'(*) = g'(X^* + x)$ etcetera. In this setup, market prices to changes in e exactly as when there is no capital mobility: $\frac{\hat{P}}{\hat{e}}^s = 0$ when Home is small and $\frac{\hat{P}}{\hat{e}}^s = -\frac{\sigma\lambda}{\epsilon}$ if Home is large, where λ is the share of dirty good production occuring in Home; this is identical to eq. 23 for the large open economy case without factor mobility.

This does not mean, however, that the stringency level preferred by a politically motivated decision maker is also unaffected by factor mobility. For example, when capacity is mobile, Home's government has an extra incentive to set stringent policy because this drives polluting behavior abroad, effectively raising $\hat{Z}/\hat{e}$ relative to the immobile capacity case. In particular, when capacity is internationally mobile then $Z = ef(e)g(X - x)$ while $\frac{\hat{Z}}{\hat{e}}^s = 1 + \sigma - \frac{\sigma g'}{g\left[\frac{g''}{g'}\right]} > 1 + \sigma$ if Home is small and $\frac{\hat{Z}}{\hat{e}}^s = 1 + \sigma - \frac{\sigma g'}{g\left[\frac{g''}{g'} + \frac{g''(*)}{g'(*)}\right]} > 1 + \sigma$ if Home is large.

Because $\frac{\hat{Z}}{\hat{e}}^s > \frac{\hat{Z}}{\hat{e}}^a$ when pollution is mobile, eq. 13 is no longer a valid evaluation of how e^a_D and e^s_D compare. In particular, although openness continues to make prices less responsive to smokestack regulation in the open than in the closed economy, since openness also makes pollution more responsive, even when $X_D > \frac{X}{N}$ and $P^* = P^a$ we cannot be certain whether e_D^s is greater or less than e_D^a if capacity is internationally mobile.