Trade, Politics, and the Environment: Tailpipe vs. Smokestack[1]

Carol McAusland

Department of Agricultural and Resource Economics
University of Maryland
College Park, MD 20742
Phone: (301) 405-1288
fax: (301) 314-9091
email: cmcausland@arec.umd.edu

February 27, 2007

[1] Thanks are due to Larry Karp, Brian Copeland, Bob Deacon, Christopher Costello, Charlie Kolstad, Scott Taylor, and two very helpful anonymous referees for comments on earlier drafts of this paper. My thanks also to seminar participants at the Universities of Rochester, Central Florida, and Maryland, and at the 2003 NBER Summer Institute Environmental Economics workshop, the 13th Annual Meeting of Canadian Resource and Environmental Economists, the 7th Occasional Conference on Environmental Economics, and the 2005 ASSA meetings for comments.

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

Abstract: The vast majority of economic research on environmental regulation in open economies focuses on producer generated—"smokestack"—pollution; we instead consider consumer generated—"tailpipe"—pollution. We examine how political opposition to environmental regulation varies with a country's trade regime, and find that openness' impact on environmental policy can depend critically on who ultimately generates pollution, producers or consumers. We find that openness may raise industry opposition to smokestack regulation, but reduce its opposition to strict tailpipe policy.

JEL Classifications: F180, D720

JEL Keywords: trade, environment, political economy

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, and 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 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.

Economists have devoted much attention to the impact of globalization on the environment. Overwhelmingly the focus of this literature has been on producer-generated pollution, which we label "smokestack" pollution. The problem of consumer- generated pollution—hereafter referred to as "tailpipe" pollution—has received considerably less attention.[1] This omission is not trivial. As noted above, consumption behavior has contributed to many past and ongoing environmental problems. Consider, for example, air pollution. In the United States motor vehicles are responsible for up to half of the emissions of 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).[2]

[1] As Copeland and Taylor (2004) write in their survey, "[m]odels with consumption-generated pollution have been somewhat neglected in the trade literature." (p.11) Indeed, of the hundreds of published and unpublished papers on trade and the environment, fewer than a dozen consider tailpipe pollution.

[2] Automobiles are not the only source of tailpipe pollution. Residential waste constitutes between 55 and 65 percent of municipal solid waste (EPA 2002), and accounts for approximately a third of waste deposited in landfill. Accelerated depletion of stratospheric ozone has been linked to the use of Chlorofluorocarbons, 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 2000).

Nevertheless, ignoring consumer-generated pollution is not a problem if regulating tailpipe and smokestack pollution is effectively equivalent, i.e. if regulation has identical effects regardless of the pollution source. However the opposite is often true. We examine the effects of openness on political opposition to environmental regulation, and find that trade's impacts can depend critically on the type of pollution regulated.[3]

The conventional wisdom is that openness makes industry oppose environmental regulation more fiercely because openness exposes them to "unfair' competition from overseas firms. The logic is as follows. In a closed economy, every firm producing for the domestic market must comply with the same regulations. In turn, a portion of the compliance costs can be passed along to consumers via higher prices. In short, producers and consumers share the incidence of pollution policy in a closed economy. Compare this to an open economy. Sovereignty ensures that countries may regulate pollution generated within their borders. For example, governments may apply product standards limiting emissions arising during local *use* of dirty goods. They may also impose process restrictions limiting emissions generated during domestic *production* of goods. However governments do not have the authority to regulate externalities generated abroad; their jurisdictions end at their own borders. This means local process restrictions don't apply to firms producing on foreign soil; similarly, goods produced for export needn't meet domestic product standards.

The scope of a country's jurisdiction has implications for the incidence of its environmental regulations. Regarding smokestack, in an open economy domestic consumers can now buy goods from overseas suppliers. This leaves local producers bearing all the burden of local smokestack regulation, intensifying industry opposition to regulation. When regulators

[3] Krutilla (1991), Copeland and Taylor (1995) and Rauscher (1997) identify additional relationships for which pollution type is critical. Among other things, Krutilla (1991) shows that a dirty-good exporter wishing to manipulate environmental policy for terms-of-trade purposes will set inefficiently high smokestack taxes (so as to curtail world supply) but inefficiently low tailpipe taxes (so as to bolster world demand). We discuss the reversals observed by Copeland and Taylor (1995) and Rauscher (1997) in Section 3.3.

are captured by dirty industry, they will respond by weakening smokestack regulations.

Conversely, when consumers generate pollution, openness shifts the incidence of environmental policy *away* from firms. This is because tailpipe regulations apply to all goods sold in the market, regardless of where they are produced—foreign firms are awarded no special advantage. Moreover, because local firms can now sell their wares abroad too, openness effectively grants local producers (firms) an outside option, rendering domestic product standards less onerous than in autarky. This suggests that openness will lead tailpipe industry to scale back the pressure it exerts on regulators to set weak environmental regulations.

We use a simple small open economy model to verify these conjectures. In our model, pollution policy is set by a politically motivated regulator. This regulator is influenced by agents whose endowments of capacity to produce dirty goods are different from the average endowment. We consider two separate instruments: a cap on per unit emissions and an emission tax. We find that the regulator's preferred level of stringency depends on the general price level and on the sensitivity of prices, profits, and pollution levels to changes in local regulation. As does McAusland (2003), we find that openness makes firm profits more, and domestic prices less, sensitive to smokestack regulation; this can lead a regulator who is unduly influenced (i.e. *captured* by dirty industry to prefer weaker smokestack regulation when the economy is open than when closed to trade. However we find that the opposite occurs with tailpipe pollution. Because trade insulates profits from local tailpipe regulations, we find that openness makes profits less responsive, and local prices more sensitive, to tailpipe regulation than in autarky. As a result, openness may lead a captured regulator to set *stricter* tailpipe regulation in an open economy.

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 (2005) consider consumption-related pollution[4], and only McAusland (2003) and Gulati (2003) examine the impact of opening up a closed economy.[5] We follow McAusland (2005) in using a standardized treatment of political economy, and show that the effect of openness on political opposition to environmental policy can depend critically on the type of pollution being regulated.

The remainder of the paper is laid out as follows. Section 2 gives the basic setup and solves for the political agent's preferred level of smokestack and tailpipe regulation in the closed economy. Section 3 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 and then show how considering tailpipe regulation instead can reverse some key results. Section 4 revisits the impact of openness on regulation when emission taxes are used instead of direct emission caps. Section 5 addresses the roles played in our analysis by supply and demand elasticities, country size, factor mobility, and the form of trade liberalization. Section 6 concludes.

2 Model

The country considered, 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 and e is non-negative. For simplicity we

[4] Treating emissions as one for one with production, Schleich (1999) examines a small open economy and 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. Schleich and Orden (2000) re-consider this question in a large economy context and find governments will exploit trade taxes in the presence of each type of pollution. McAusland (2005) shows how harmonizing tailpipe policy across identical countries may reduce welfare and environmental quality.

[5] McAusland (2003) 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. Gulati (2003) finds that whether trade liberalization weakens environmental policy depends in part on the fraction of dirty goods that are consumed by citizens not represented by lobby groups.

assume f is iso-elastic with elasticity $\sigma \equiv \frac{f'(e)e}{f(e)} > 0$.

We assume pollution Z is purely local; there is no transboundary component to pollution. In the case of tailpipe pollution, e is the emissions generated per unit of the dirty good consumed; for smokestack e is emissions per unit produced. Defining q_i as the amount of dirty goods consumed by citizen i and N as the number of Home citizens, then $Z = e\sum_i^N q_i$ when pollution is tailpipe and $Z = eQ$ when pollution is smokestack. Regarding tailpipe pollution, it is implicit in this structure that the pollution intensity of 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 for example. It is straightforward to show, however, that the analytics would be unchanged if we instead considered abatement undertaken by consumers directly. Finally, we assume producing multiple product lines imposes no fixed costs: retooling costs are zero. This production function carries several implicit assumptions. Firstly, abatement costs are given by $f'(e)X$, which measures output foregone when emissions are reduced. Secondly, the iso-elasticity of f with respect to e implies the marginal cost of achieving zero emissions is infinite, and that society could, if it wanted, pollute itself to infinite consumption. These are standard Inada conditions that rule out boundary solutions, and in this model the regulator will never pursue any of these extreme outcomes.

So as to round out the model, we assume there is also a numéraire clean good for which productive capacity, Y, equals output. All capacity is owned by Home's N citizens, with X_i, Y_i denoting 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. Thus, 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 $I_i = \pi X_i + Y_i$

where

$$\pi = Pf(e) \tag{1}$$

is the return paid to a unit of dirty capacity. We assume that N is large and that all consumers and producers are price-takers.

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 and β is the marginal disutility from pollution. Note that this utility function rules out income effects in household demand for environmental quality.

Consumer optimization yields

$$P = v'(q) \tag{2}$$

and $y_i = I_i - Pq$, where we drop the individual subscripts on q from here forward.[6] For future reference define $\epsilon = -\frac{dq}{dP}\frac{P}{q}$ as the price elasticity of demand for dirty goods. So as to facilitate future comparisons, we assume from here forward that the price elasticity of demand for dirty goods, ϵ, is a constant. We further assume $\epsilon > 1$; this assumption's importance will become apparent in section 2.2.

Using expressions for q and y_i we rewrite i's individual welfare as

$$W_i = C + I_i - \beta Z \tag{3}$$

where $C = v(q) - Pq$ is individual consumer surplus, which depends on e only indirectly

[6] By dropping the i subscripts on q we implicitly assume each citizen i has a sufficiently large endowment Y_i to afford dirty good consumption at level q.

via P:

$$\frac{dC}{de} = \frac{dC}{dP}\frac{dP}{de} = -q\frac{dP}{de}. \tag{4}$$

Now consider the emission cap preferred by citizen i. Differentiating eq. 3 with respect to e gives

$$\frac{dW_i}{de/e} = -qP\frac{\hat{P}}{\hat{e}} + X_i\pi\frac{\hat{\pi}}{\hat{e}} - \beta Z\frac{\hat{Z}}{\hat{e}} \tag{5}$$

where ˆ indicates percentage change, for example $\hat{P} = \frac{dP}{P}$. Because expressions for $\frac{\hat{P}}{\hat{e}}$, etc. depend on pollution type and the trade regime, their derivations are deferred to later sections. Since eq. 3 is twice continuously differentiable and locally concave in e—see Appendix—then $i's$ preferences over e are single peaked. From eq. 5 we see that i's preferred emission cap balances the impacts of environmental regulation on i's consumer surplus from consuming dirty goods, i's income, and the disutility i suffers from pollution. In the sections to follow we analyze how openness and pollution type alter the size of these impacts. We do so by showing how the sensitivity of prices, factor returns, and total pollution to environmental regulation—measured by $\frac{\hat{P}}{\hat{e}}$, $\frac{\hat{\pi}}{\hat{e}}$ and $\frac{\hat{Z}}{\hat{e}}$ respectively—vary with the trade regime and the type of pollution regulated. We then show how changes in sensitivity feed through to affect the stringency of environmental policy itself.

2.1 Politics

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. 3 when evaluated at "represented" endowments X_D, Y_D.[7] 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. 3 when evaluated at X_D, Y_D. Thus e_D solves

$$\frac{dW_D}{de/e} = -Pq\frac{\hat{P}}{\hat{e}} + \pi X_D \frac{\hat{\pi}}{\hat{e}} - \beta Z \frac{\hat{Z}}{\hat{e}} \tag{6}$$

when set equal to zero.

When $X_D > X/N$, then D is unduly influenced by dirty industry. In keeping with the literature on environmental politics, we will refer to such an agent as a *captured regulator*. In contrast, when D has an exactly average endowment of dirty capacity, i.e. $X_D = X/N$, we will refer to D as *unbiased*. Note that, even though we focus our attention on cases in which $X_D \geq X/N$, the tools of our analysis are equally valid when the decision maker's constituents are linked to the dirty good sector predominately as consumers, i.e. when $X_D < \frac{X}{N}$.

2.2 Autarky

We now characterize the political agent's preferred policy level in the closed economy; in order to facilitate later comparisons, denote all values for autarky by a superscript a. Goods market clearance requires domestic supply and demand for dirty goods be equal; this implies

[7] For example, in a majority rules framework with costless voting X_D is simply the endowment of the median voter; when policy is set by an uncontested minority elite with $M < N$ members as in Deacon (1999) then $X_D = \frac{\sum_{m=1}^{M} X_m}{M}$ where X_m is the endowment of member m of the elite; when policy is set by an incumbent government that maximizes a weighted sum of local Utilitarian welfare and contributions from a single lobby group—a simplification of the Grossman and Helpman (1994) model—then $X_D = \frac{X+\gamma\sum_{l=1}^{L} X_l}{N+\gamma L}$ where L is the (exogenously determined) number of members in the lobby group, X_l represents the endowment of lobby group member l, and γ is the weight assigned by the government to contributions. These values are derived in McAusland (2005). Notably, the endowment represented by the political agent, X_D, is independent of the trade regime and the size of the emission cap.

$q^a = \frac{f(e)X}{N}$. Differentiating equations 1 and 2 and converting to percentage changes gives

$$\frac{\hat{P}^a}{\hat{e}} = -\frac{\sigma}{\epsilon} \quad (7)$$

$$\frac{\hat{\pi}^a}{\hat{e}} = \frac{\sigma[\epsilon - 1]}{\epsilon}. \quad (8)$$

Notably, profits are increasing in e if and only if demand is elastic, i.e. $\epsilon > 1$. This is because tighter regulation serves as a collusive device—raising prices faster than it curtails productivity—when demand is price inelastic in our model. The possibility that environmental regulation may be *beneficial* to the polluting industry is not new. See, for example, Buchanan and Tullock (1975) and Leidy and Hoekman (1993), who analyze regulation in the absence of taxes or permit auctions (where rents from emissions accrue to polluters). Because we are interested in the conventional scenario in which regulating pollution *harms* producers of dirty goods, we maintain the assumption that $\epsilon > 1$. Section 5.1 addresses cases in which demand is inelastic.

Because Home is closed to trade all goods produced locally are also consumed locally, and so the amount of pollution created locally, $Z^a = ef(e)X$, is identical regardless of whether pollution is a by-product of production or consumption. The sensitivity of pollution to regulation is similarly identical across the pollution types:

$$\frac{\hat{Z}^a}{\hat{e}} = 1 + \sigma. \quad (9)$$

Substitute these values into eq. 6 to get

$$\frac{dW_D^a}{de/e} = P^a q^a \frac{\sigma}{\epsilon} + P^a f(e) X_D \frac{\sigma[\epsilon - 1]}{\epsilon} - \beta e f(e) X[1 + \sigma]. \quad (10)$$

When set equal to zero, eq. 10 implicitly defines e_D^a, D's preferred emission cap in autarky.

3 The Small Open Economy

Next we examine regulation in 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. Denote values for the Rest of the World (ROW) by asterisks. So as to focus our study we restrict our attention to the case of a small open economy; accordingly, Home treats ROW values as exogenous.

We begin our analysis with the case of smokestack pollution, since most prior research on trade and environment interactions has focused on this type of pollution.

3.1 Trade and Smokestack Regulation

Let superscript ^{s} denote values when Home is open and pollution is smokestack. Because Home is small, the local price of dirty goods P^s equals the fixed world price P^*, and so individual consumption is independent of e. Define by E Home's net exports of dirty goods; with smokestack regulation $E^s = f(e)X - Nq^s$.

Proposition 1 *Stricter smokestack regulation reduces Home's exports of dirty goods.*

Proof. Differentiating gives $\frac{dE^s}{de/e} = f(e)X\sigma > 0$. ■

Even though Home's capacity for smokestack production is unchanged, raising e renders that capacity more productive, increasing Home supply of dirty goods. Since consumer prices are fixed, quantities demanded locally are unchanged and so exports necessarily rise. Proposition 1 replicates the well known result that weak smokestack regulation promotes dirty good exports; see, for example, Siebert (1979).[8]

[8] Chua (2003) shows that strict smokestack regulation doesn't always hurt dirty good exports. High smokestack taxes make sectors providing abatement service more profitable, altering relative input demand. If the relative cost of factors used intensively in dirty industry *falls* as a result, high pollution taxes can confer a comparative advantage in dirty goods.

3.2 Openness and Smokestack Politics

In order to address how openness affects the preferences of the political agent, we must first derive $\frac{\hat{P}}{\hat{e}}^s$, $\frac{\hat{\pi}}{\hat{e}}^s$ and $\frac{\hat{Z}}{\hat{e}}^s$ in the open economy. Since prices in the small open economy are, by definition, independent of Home behavior then

$$\frac{\hat{P}}{\hat{e}}^s = 0 \tag{11}$$

and so

$$\frac{\hat{\pi}}{\hat{e}}^s = \sigma. \tag{12}$$

Furthermore, because capacity is immobile, the only channel through which e affects the level of polluting activity is via changes in productivity. As a consequence

$$\frac{\hat{Z}}{\hat{e}}^s = 1 + \sigma \tag{13}$$

exactly as in autarky.

A graph is useful for interpreting these sensitivity measures and the manner in which they change with the trade regime. Figure 1 depicts consumer demand for dirty goods, as well as the marginal social cost (MSC) associated with Q units of dirty Home *activity*. Because all increases in Home's smokestack output come via increased emissions, the MSC curve is upward sloping. If $\sigma < 1$ then MSC is convex as drawn; if instead $\sigma > 1$ the curve is concave. As a starting point, suppose the emission cap is originally set at e^o, corresponding to output Q^o (where $Q^o \equiv f(e^0)X$). This generates autarky price P^o and pollution damages equal to the area under the MSC curve from zero to Q^o. Now consider the distributional consequences of reducing the cap to e^1, which permits production of only $Q^1 \equiv f(e^1)X$. In autarky Home's price would rise to P^1, causing consumer surplus to fall by area P^1EBP^o, producer rents to fall by area $Q^1FBQ^o - P^1EFP^o$, and pollution damages to decline by area Q^1DAQ^o. Compare these changes to those arising if Home is instead open before and after the policy change; for simplicity assume $P^* = P^o$. Reducing the smokestack cap from e^o to e^1 still lowers pollution damages by area Q^1DAQ^o. However consumer surplus is unaffected since prices are pegged on the international market and consumers now import $Q^1 - Q^0$ units of the good. Producer rents, in contrast, bear the full brunt of the regulatory change: producer rents fall by area Q^1FBQ^o.

Because openness shifts incidence away from consumers and onto producers, openness should leave industry less sanguine about smokestack regulation. To see this mathematically, substitute expressions (11)-(13) into eq. 6 to characterize the decision maker's preferred cap on smokestack emissions, e_D^s, in the open economy; e_D^s solves

$$\frac{dW_D^s}{de/e} = P^* f(e) X_D \sigma - \beta Z^s [1 + \sigma] \tag{14}$$

when set equal to zero. The local concavity of W_D^s in e is confirmed in Appendix A.

Proposition 2 *The impact of openness on the smokestack emission cap is unambiguous if* $(P^* - P^a)\left(X_D - \frac{X}{N}\right) > 0$. *In particular,*

1. *if* $P^* \geq P^a$ *and* $X_D > \frac{X}{N}$ *then* $e_D^a < e_D^s$;
2. *if* $P^* \leq P^a$ *and* $X_D < \frac{X}{N}$ *then* $e_D^a > e_D^s$.

Proof. Evaluate $\frac{dW_D^s}{de/e}$ at $e = e_D^a$; if this expression is positive then the single-peakedness of W_D^s in e indicates that D perceives e_D^a as too strict in the open economy and so chooses $e_D^s > e_D^a$; if instead $\left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a} < 0$ then, again by the single-peakedness of W_D^s in the emission cap, $e_D^s < e_D^a$. Subtract $\frac{dW_D^a}{de/e}$ from $\frac{dW_D^s}{de/e}$ and evaluate the entire expression at $e = e_D^a$ (recall $\left.\frac{dW_D^a}{de/e}\right|_{e=e_D^a} = 0$ by construction). This gives

$$\begin{aligned}
\left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a} &= P^* f(e_D^a) X_D \sigma - \beta Z^s \frac{\hat{Z}^s}{\hat{e}} - \left.\frac{dW_D^a}{de/e}\right|_{e=e_D^a} \\
&= q^a \sigma \left[(P^* - P^a) \frac{X_D/X}{1/N} + \frac{P^a}{\epsilon} \left[\frac{X_D/X}{1/N} - 1 \right] \right].
\end{aligned} \tag{15}$$

When $P^* \geq P^a$ and $X_D > \frac{X}{N}$ the bracketed terms in eq. 15 are each non-negative and eq. 15 is positive; if instead $P^* \leq P^a$ and $X_D < \frac{X}{N}$ then eq. 15 is negative. ∎

Corollary 1 *If* $X_D = X/N$ *then* $e_D^s > e_D^a$ *if and only if* $P^* > P^a$.

Corollary 2 *If openness leaves the price of dirty goods unchanged and the regulator is captured by dirty industry, then openness induces a weaker cap on smokestack emissions: if* $P^s = P^a$ *and* $X_D > \frac{X}{N}$ *then* $e_D^s > e_D^a$.

When a country opens to trade, it may be exposed to a ROW price for dirty goods different from its own autarky price. This will have a *level* effect on D's preferences. For example, if P^* is higher than P^a, then the output sacrificed in pursuit of low emissions is more valuable. This translates to a higher opportunity cost of abatement, rendering strict regulation less attractive.

With smokestack goods, level effects fully determine how an unbiased regulator will respond to openness. Following Corollary 1, whenever openness raises the opportunity cost of abatement—i.e. whenever $P^* > P^a$—an unbiased regulator will set weaker smokestack policy.

However, openness also affects the incidence of regulation, which matters when D is unduly influenced by a subset of voters. As discussed above, by exposing producers to unlimited competition at fixed world prices, openness renders profits more sensitive to smokestack regulation while leaving consumer prices completely *in*-sensitive. When D is linked to the dirty good predominately as a producer, these *sensitivity* effects of openness make strict e less attractive, *ceteris paribus*. Proposition 2 gives conditions under which the level and sensitivity effects of openness work in the same direction. Corollary 2 confirms that, if openness has *no* level effects—i.e., in the event that ROW and autarky prices are the same—then whether openness leads D to prefer weaker or stricter tailpipe policy depends entirely on whether she has above- or below-average vested interests in smokestack industry.

The level effects active in Proposition 2 mirror those in Fredriksson (1997), who shows dirty industry will increase its bid for weak environmental regulation in response to an exogenous price increase. This contrasts outcomes in Bommer and Schulze (1999), who argue that price hikes pacify dirty industry, enabling the government to favor its environmental lobby with more environmental quality via stricter regulation.

The sensitivity effects present in Proposition 2 and Corollary 2 echo those identified in McAusland (2003) and Gulati (2005), each of whom finds dirty industry profits more responsive to smokestack regulation in the open economy than autarky. In McAusland (2003), whether this sensitivity effect leads to weaker policy depends on the median voter's *relative* endowments of capacity to produce dirty and clean goods; in Gulati (2005), the policy response depends on the share of dirty goods consumed by citizens not represented by lobby groups.

3.3 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.

Sovereignty entitles governments to regulate all domestic sources of pollution; General Agreement on Tariffs and Trade (GATT) rules stipulate that such regulations may 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 citizens, regardless of where the goods 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^*. 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. Define by X_E Home capacity allocated to production of goods for export; if net exports are negative, i.e. Home imports dirty goods, then $X_E < 0$. This implies then $q^t = \frac{f(e)[X - X_E]}{N}$. Arbitrage and free trade in goods implies in turn that the return, π^*, paid to a unit of capacity employed in the production of goods for export be the same as paid for a unit producing goods for domestic consumption: $\pi^* \equiv P^* f(e^*) = P^t f(e)$, where P^t solves eq. 2 when evaluated at q^t. We take special care to point out that e^* may be lower or higher than e: the arbitrage condition holds regardless of whether ROW standards are weaker or stricter than Home's. Moreover, because there are no retooling costs, the goods supplied to a market will never over-comply with that country's product standards.

In order to track how X_E changes with e, differentiate the condition $P^t f(e) = \pi^*$ using eq. 2 and the definition of q^t; this gives

$$\frac{dX_E}{de/e} = -\sigma[\epsilon - 1][X - X_E], \tag{16}$$

which is negative under our maintained assumption that $\epsilon > 1$. Equation 16 reveals 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 so long as demand for dirty goods is elastic. This has implications for the effect of tailpipe regulation on the volume of Home exports.

Proposition 3 *When dirty good demand is price elastic, stricter tailpipe regulation raises exports of the dirty good:* $\frac{dE^t}{de} < 0$ *if* $\epsilon > 1$.

Proof: When $X_E \geq 0$ then Home's exports are $E^t = f(e^*)X_E$ and so $\frac{dE^t}{de} = f(e^*)\frac{dX_E}{de} < 0$. 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.

When Home demand for dirty goods is elastic, stricter tailpipe regulation lowers returns paid to capacity employed producing dirty goods for the Home market, regardless of where production is located. Accordingly, as the tailpipe cap is tightened, firms in both Home and abroad respond by utilizing more of their capacity to produce goods for the ROW market (recall $\frac{dX_E}{de/e} < 0$). Consequently, Home's dirty good exports rise as Home tightens its tailpipe cap. Proposition 3 confirms findings in Copeland and Taylor (1995) and Rauscher (1997) that tailpipe regulation can promote dirty good exports. Copeland and Taylor (1995) show that rich Northern countries will have higher tailpipe taxes as well as export dirty consumer goods, while Rauscher (1997) shows that "an increase of environmental concern leads to a comparative price advantage" (p.131) for tailpipe goods. Viewed in contrast to Proposition 1, Proposition 3 illustrates that environmental regulation's impact on dirty good exports may be qualitatively *opposite* when we consider tailpipe instead of smokestack pollution.

Together, Propositions 1 and 3 have implications for empirical tests of trade and environment relationships. Consider, for example, the ongoing debate surrounding the pollution haven hypothesis—the proposition that polluting behavior migrates to regions with weak environmental regulation. This is an hypothesis with much intuitive appeal but until recently only scant empirical support. Proposition 3 may provide an explanation. The principle tenet of the pollution haven hypothesis still holds with tailpipe pollution: by inadvertently promoting exports of dirty consumer goods, strict tailpipe regulation syphons off Home polluting activity. However, the link between exports and polluting activity—whereby strong export competitiveness identifies a country as a pollution haven—that is so often presumed in the pollution haven literature falls apart.

Moreover, there is a precedence of using general indices of environmental policy stringency and performance as a proxy for stringency in smokestack regulation. For example, several authors[9] use Dasgupta et al.'s (1995) composite environmental index; this index is based on country surveys of environmental policy and performance along four environ-

[9] See, e.g., Eliste and Fredriksson (2002) and Ederington, Levinson and Minier (2005).

mental dimensions—Air, Water, Land and Living Resources—and five Sectors/Activities—Agriculture, Industry, Energy, Transport, and Urban—but does not appear to distinguish between the tailpipe and smokestack regulations involved. Proposition 3 suggests that tests bundling evidence of tailpipe and smokestack regulation would either fail to find or misestimate the extent to which environmental regulation affects trade flows, simply because different types of regulation should have opposing effects on trade volumes to begin with. Studies that instead restrict attention to only one type of regulation—either smokestack or tailpipe—will avoid this problem. Indeed, recent studies that have restricted attention to smokestack regulation only—as proxied by compliance cost expenditures as measured by the U.S. Census Bureau's Pollution Abatement and Control Expenditures (PACE) survey—do find statistically and economic significant impacts of regulation on patterns of US exports; see for example Levinson and Taylor (2003).

3.3.1 Openness and Tailpipe Politics

Next we focus on our central question of how openness affects the decision maker's preferred emission cap. For this we again examine how local prices and factor returns respond to changes in e. Substitute the expression for q^t into eq. 2, differentiate employing eq. 16, and convert to percentage changes:

$$\frac{\hat{P}^t}{\hat{e}} = -\sigma \tag{17}$$

while

$$\frac{\hat{\pi}^t}{\hat{e}} = 0. \tag{18}$$

Comparing equations 7 to 17 and 8 to 18 reveals that prices are more sensitive to tailpipe regulation in the open economy than in autarky, but factor returns less so. 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 3 indicates, strictly regulating tailpipe pollution also expands Home's exports, reducing the number of goods sold in Home which further raises 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 is 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:

$$Z^t = eNq^t = ef(e)[X - X_E]. \tag{19}$$

Because X_E is endogenous, raising e^t raises Home's tailpipe activity through two channels. As in autarky, raising e makes capacity more productive. But in the open economy, raising e also attracts additional capacity to produce for the Home market. Differentiating, making use of eq. 16, and converting to percentage changes gives

$$\frac{\hat{Z}^t}{\hat{e}} = 1 + \sigma\epsilon > 0\,, \tag{20}$$

revealing a more sensitive tailpipe pollution base in the open economy than in autarky.

Figure 2 plots demand and MSC as a function of Home consumption. For purposes of the graph, again consider a reduction in Home's emission cap from some initial level e^0 to e^1 and assume $\pi^* = P^o f(e^o)$. When Home is open, international markets guarantee Home's producers a fixed rate of return. This means consumer prices will have to rise enough in order to ensure $Pf(e^1)$ maintains equality with π^*; define $X_E(e^1)$ as the amount of Home capacity reassigned to export production that guarantees this. As a result, in the open economy domestic consumption falls to $Q^2 \equiv f(e^1)[X - X^E(e^1)]$ and Home's consumer prices rise to $P^2 \equiv v'(Q^2/N)$. In terms of areas labeled on Figure 2, reducing the tailpipe cap from e^0 to e^1 causes consumer surplus to fall by area P^2HBP^o and pollution damages to decline by area Q^2GAQ^o. Producer rents (revenues earned in Home plus in ROW), in contrast, are unchanged be construction.

In terms of incidence, openness shifts the regulatory burden away from producers and onto consumers. This will impact tastes for regulation. Substituting (17)-(20) into eq. 6 and rearranging indicates that e^t_D solves

$$\frac{dW^t_D}{de/e} = q^t \left[P^t\sigma - \beta N e[1+\sigma\epsilon]\right] \tag{21}$$

when set equal to zero.

Proposition 4 *Assume $\epsilon > 1$; then the impact of openness on the tailpipe emission cap is unambiguous if $\left(\frac{X_D/X}{1/N} - \frac{1}{1+\sigma\epsilon}\right)(\pi^a - \pi^*) \geq 0$. In particular,*

1. *if $\frac{X_D/X}{1/N} \geq \frac{1}{1+\sigma\epsilon}$ and $\pi^a \geq \pi^*$ then $e^a_D \geq e^t_D$; while*
2. *if $\frac{X_D/X}{1/N} \leq \frac{1}{1+\sigma\epsilon}$ and $\pi^a \leq \pi^*$ then $e^a_D \leq e^t_D$.*

Proof. By definition, $\pi^a \equiv P^a f(e^a_D)$. Substituting this definition into eq. 10 and employing the functional form $f(e) = e^\sigma$ to solve for e^a_D as a function of π^a gives $e^a_D(\pi^a) = \left[\frac{\pi^a\sigma[1+\frac{X_D/X}{1/N}[\epsilon-1]]}{\beta N\epsilon[1+\sigma]}\right]^{\frac{1}{1+\sigma}}$. Similarly, use $\pi^* = P^t f(e^t_D)$ to solve for e^t_D as a function of π^* using (21): $e^t_D(\pi^*) = \left[\frac{\pi^*\sigma}{\beta N[1+\sigma\epsilon]}\right]^{\frac{1}{1+\sigma}}$. Comparing the two terms we see $e^a_D > e^t_D$ if and only if $\frac{1+\sigma\epsilon}{\epsilon[1+\sigma]}[1 + \frac{X_D/X}{1/N}[\epsilon-1]] > \frac{\pi^*}{\pi^a}$. Assuming $\epsilon > 1$, then if and only if $\frac{X_D/X}{1/N} > 1/[1+\sigma\epsilon]$ the left hand term is greater than unity; if and only if $\pi^* < \pi^a$ then the right hand term is less than unity. ■

Corollary 3 *Assume $\epsilon > 1$. If $\pi^* = \pi^a$ then $e^t_D < e^a_D$ whenever $X_D \geq \frac{X}{N}$.*

Corollary 4 *By the proof of Proposition 4, if $X_D = X/N$ then $e^t_D > e^a_D$ if and only if $\pi^* > \pi^a\left[\frac{1+\sigma\epsilon}{1+\sigma}\right]$.*

As with smokestack regulation, when Home opens to trade in tailpipe goods, there will be multiple level and sensitivity effects. With tailpipe, level-effects arise via changes in π. If the rate of return available in ROW markets exceed π^a, then some Home capacity will be reassigned to producing for the export market. This will raise the domestic price for tailpipe goods in Home, leading to less consumption and associated tailpipe pollution. On the one hand, the reduced consumption base makes strict Home regulation more attractive to the average Home citizen, simply because there is less consumption at risk. But since there is also less Home pollution, abatement is less urgent, warranting weaker regulation.

Simultaneously, openness has sensitivity effects on D's tastes for regulation. Since π is pegged in ROW markets, openness fully insulates producers from costs associated with changing e. Consumers, on the other hand, become more exposed because now a tightening of e not only reduces the productivity of capacity devoted to producing for Home, but also drives Home capacity into production for export. This renders consumer prices more sensitive to variation in e when Home is open than closed. Finally, since pollution follows consumption, and because raising e drives capacity away from producing for Home, the pollution base itself is more sensitive to e when Home is open.

If D is unbiased, then changes in the sensitivity of P and π match one another in terms of importance, leaving D concerned only with the level effects of openness and the heightened sensitivity of pollution to regulation. By Corollary 4, unless the price increase in sufficiently large, the pollution-sensitivity effect dominates price level effects, and D wants stricter tailpipe regulation.

When D is instead captured by industry, reduced profit-sensitivity matters more than increased price-sensitivity, rendering strict tailpipe regulation less offensive to industry. This compliments the pollution-sensitivity effect in making strict tailpipe policy more attractive. As highlighted by Corollary 3, when profit rates are unchanged, a captured regulator D unambiguously prefers stricter tailpipe policy in the open economy.

Pollution Type	Unbiased Regulator ($X_D = X/N$)	Captured Regulator ($X_D > X/N$)
Smokestack	$e^s_D < e^a_D$ iff $P^* < P^a$	$e^s_D > e^a_D$ whenever $P^* \geq P^a$
Tailpipe	$e^t_D < e^a_D$ iff $\pi^* < \pi\frac{1+\sigma\epsilon}{1+\sigma}$	$e^t_D < e^a_D$ whenever $\pi^* \geq \pi\frac{1+\sigma\epsilon}{1+\sigma}$

Table 1: Impact of Openness on Regulatory Stringency in Small Open Economy

Table 1 summarizes the results of Corollaries 2-4. As the final column of Table 1 indicates, a captured regulator's response to openness in the absence of level effects depends critically on pollution type: she'll want weaker smokestack regulation, but stricter tailpipe policy. This reversal that has not previously been identified by economists, and is summarized as follows.

Corollary 5 *From Corollaries 2 and 3, if $\epsilon > 1$ and $X_D > \frac{X}{N}$, then in the open economy with $P^s = P^t = P^a$ when $e = e^a_D$, the political agent regards e^a_D as too lax if regulating tailpipe emissions but too strict if regulating smokestack.*

The intuition behind Corollary 5 is worth reiterating. By exposing Home producers to foreign competition that is exempt from home regulations, openness makes profits *more* sensitive to domestic smokestack regulation. In contrast, openness renders profits *less* sensitive to domestic tailpipe regulation by giving producers an outside option. When level effects are absent (as when $P^a = P*$ and/or $\pi^a = \pi^*$), all that is left are the sensitivity effects. Because the sensitivity effects important to industry work in opposite directions depending on pollution type, openness can have qualitatively opposite impacts on environmental policy when pollution is tailpipe rather than smokestack.[10]

Although there has been substantial empirical research into regulation's impact on trade and investment, few papers test trade's impact on regulatory stringency itself. Using data

[10] Corollary 5 has implications for the domestic politics surrounding different types of carbon taxes. If countries agree to each honor one another's "upstream" carbon taxes—taxes levied *on* smokestack emissions *at* the point of consumption—then Home's effective jurisdiction will cover all carbon-intensive goods consumed within its border, just like with tailpipe regulation. Interpreting Corollary 5 in this context suggests Home should face less opposition from domestic industry to strict carbon regulations under this mutual recognition scheme than if countries levy their smokestack taxes at the point of emission.

on pollution abatement costs, Ederington and Minier (2003) provide empirical support for treating environmental policy as dependent on trade flows. Damania, Fredriksson and List (2003) provide a theoretical model of openness' impact on industrial regulation when regulators are corrupt; using lead levels in gasoline as a proxy for (weakness in) environmental regulation, they find a negative relationship between openness and lead levels.

Corollary 5 suggests that measures of tailpipe regulation are inappropriate proxies for industrial regulation. True, it is likely that a particular government's propensity to set strict smokestack and tailpipe regulations is positively correlated; indeed, our analysis suggests pollution caps are non-decreasing in X_D regardless of pollution type. However, because openness' may impact those propensities in opposite ways, measures of regulatory stringency concerning tailpipe regulation—lead in gasoline for example—may be a poor if not outright misleading proxy for stringency in smokestack regulation in liberalizing economies.

Throughout this paper we have emphasized the emission cap that would be chosen by a political agent captured 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 sensitivity of consumer prices to environmental regulation in the open economy makes D want, ceteris paribus, *weaker* tailpipe policy. But the heightened sensitivity 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 average vested interest in the polluting industry is ambiguous.

4 Taxes

The sections above focus on a particular type of regulation: a cap on emissions per unit produced/consumed. In this section we consider an alternate instrument: an emission tax. Anticipating our results, we show that, when stringency is measured via the nominal value of the pollution tax, openness' impact on regulatory stringency depends only on the degree of the regulator's vested interests in the dirty industry.

Let τ denote the emission tax collected from firms when units are sold and so $\pi \equiv Pf(e) - \tau ef(e)$. As in Section 3 we assume Home does not engage in extraterritorial regulation: Home only taxes emissions generated within its borders. Profit maximization by price taking firms implies

$$e = \frac{P}{\tau}\frac{\sigma}{1+\sigma} \tag{22}$$

which is increasing in the price of dirty goods and decreasing in the emission tax.[11] We assume Home tax revenues are rebated lump sum to Home citizens on a per capita basis and so individual income $I_i = \pi X_i + Y_i + \frac{\tau Z}{N}$. Substituting I_i into the utility function gives

$$W_i(\tau) = v(q) + \pi X_i + Y_i + \frac{\tau Z}{N} - Pq - \beta Z. \tag{23}$$

Maximizing this with respect to τ defines $i's$ preferred tax rate τ_i on emissions:

$$\frac{dW_i}{d\tau/\tau} = \pi X_i \frac{\hat{\pi}}{\hat{\tau}} - qP\frac{\hat{P}}{\hat{\tau}} + [\tau - \beta N]\frac{Z}{N}\frac{\hat{Z}}{\hat{\tau}} + \frac{\tau Z}{N}. \tag{24}$$

To solve for τ_i explicitly, equate eq. 24 with zero, recognize that $P = e\tau[1+\sigma]/\sigma$ and $\pi = ef(e)\tau/\sigma$ by eq. 22, substitute in values for $\frac{\hat{\pi}}{\hat{\tau}}$, $\frac{\hat{P}}{\hat{\tau}}$ and $\frac{\hat{Z}}{\hat{\tau}}$ in each of the scenarios

[11] We acknowledge our emission production function $f(e) = e^{\sigma}$ on which (22) is based abstracts from the real world constraint that society cannot pollute itself to infinite material prosperity. A more reasonable construction of $f(e)$ would be $f(e) = \left\{ \begin{matrix} 0 \\ e^{\sigma} \\ \bar{e}^{\sigma} \end{matrix} \right\}$ for $e \left\{ \begin{matrix} \leq 0 \\ \in [0, \bar{e}] \\ \geq \bar{e} \end{matrix} \right\}$ for some $\bar{e} < \infty$. Under this formulation the emission tax would be non-binding whenever $\tau < \frac{P}{\bar{e}}\frac{\sigma}{1+\sigma}$ and relations $\frac{\hat{P}}{\hat{e}}$, $\frac{\hat{Z}}{\hat{e}}$ and $\frac{\hat{\pi}}{\hat{e}}$ would be piecewise. However we would be able to abstract from these difficulties if either βN were sufficiently large relative to P or $\bar{e}$ was sufficiently high to begin with.

considered[12] and rearrange to obtain the following:

$$\tau_i^a = \frac{\beta N[1+\sigma]\epsilon}{1+\epsilon\sigma+\frac{X_i/X}{1/N}[\epsilon-1]}, \tag{25}$$

$$\tau_i^s = \frac{\beta N[1+\sigma]}{\sigma+\frac{X_i/X}{1/N}}, \tag{26}$$

$$\tau_i^t = \beta N. \tag{27}$$

Note τ_i^a and τ_i^s are each positive, decreasing in X_i, and less than the Pigouvian tax rate βN whenever $X_i > X/N$. We also point out that, just as when emissions are regulated directly, tailpipe policy in the open economy (τ_i^t) is independent of X_i; this follows because local tailpipe regulation has no impact on the rate of return earned by dirty capacity since owners can always earn π^* by exporting.

Evaluating τ_i^a, τ_i^s and τ_i^t at the endowment of the political agent, X_D, we obtain the following proposition:

Proposition 5 *Assume $\epsilon > 1$. Then openness induces higher tailpipe taxes but lower smokestack taxes if and only if D has an above average endowment of dirty capacity. In particular*

1. $\tau_D^t > \tau_D^a$ *if and only if* $X_D > \frac{X}{N}$ *whenever* $\epsilon > 1$;
2. $\tau_D^s < \tau_D^a$ *if and only if* $X_D > \frac{X}{N}$.

Proof:
1. From equations 25 and 27, $\tau_D^t > \tau_D^a$ if and only if $\beta N > \frac{\beta N[1+\sigma]\epsilon}{1+\epsilon\sigma+\frac{X_D/X}{1/N}[\epsilon-1]}$. When $\epsilon - 1 > 0$, as is our maintained assumption, this is equivalent to the condition $\frac{X_D/X}{1/N} > 1$.
2. Using equations (25) and (26) $\tau_D^s < \tau_D^a$ if and only if $\frac{\beta N[1+\sigma]\epsilon}{1+\epsilon\sigma+\frac{X_D/X}{1/N}[\epsilon-1]} > \frac{\beta N[1+\sigma]}{\sigma+\frac{X_D/X}{1/N}}$, or, equivalently, $\frac{X_D/X}{1/N} > 1$.

[12] In autarky $q = \frac{fX}{N}$ yielding $\frac{\hat{P}}{\hat{\tau}}^a = \frac{\sigma}{\sigma+\epsilon}$, $\frac{\hat{e}}{\hat{\tau}}^a = -\frac{\epsilon}{\sigma+\epsilon}$, $\frac{\hat{\pi}}{\hat{\tau}}^a = -\frac{\sigma[\epsilon-1]}{\sigma+\epsilon}$, and $\frac{\hat{Z}}{\hat{\tau}}^a = -\frac{[1+\sigma]\epsilon}{\sigma+\epsilon}$ when pollution is of either type. In the small open economy with smokestack pollution, arbitrage requires $P = P^*$, implying $\frac{\hat{P}}{\hat{\tau}}^s = 0$, $\frac{\hat{e}}{\hat{\tau}}^s = -1$, $\frac{\hat{\pi}}{\hat{\tau}}^s = -\sigma$, and $\frac{\hat{Z}}{\hat{\tau}}^s = -[1+\sigma]$. Finally, when Home is small and open and faces tailpipe pollution, $q = \frac{f[X-X_E]}{N}$ and arbitrage requires $\pi = \pi^*$ where π^* is fixed abroad. This implies $\frac{\hat{P}}{\hat{\tau}}^t = \frac{\sigma}{1+\sigma}$, $\frac{\hat{e}}{\hat{\tau}}^t = -\frac{1}{1+\sigma}$, $\frac{\hat{\pi}}{\hat{\tau}}^t = 0$, $\frac{dX_E}{d\tau/\tau}^t = \frac{\sigma}{1+\sigma}[\epsilon-1][X-X_E]$, and $\frac{\hat{Z}}{\hat{\tau}}^t = -\frac{1+\sigma\epsilon}{1+\sigma}$.

Proposition 5 shows that openness' impact on the tax rate only depends on demand elasticity and direction of vested interests; this reversal has not been previously identified by the literature on environmental politics. The underlying intuition is the same as before: openness makes profits less (more) sensitive to changes in tailpipe (smokestack) policy, shifting incidence away from (toward) producers . When D is captured by industry, this leads to a higher (lower) pollution tax.

Markedly absent from Proposition 5 are caveats concerning level effects. This is because τ is a nominal instrument: it measures the tax rate independent of the price level. Recall from 26 that actual emissions, however, depend on the *real* tax rate, as τ/P measures the real opportunity cost of emissions. This means that, even though openness may have unambiguous effects on the nominal tax rate, openness' full effect on emission behavior may still be ambiguous. For example, although openness raises τ_D^s when D is captured, if openness raises P proportionately more, then by equation 26 Home's emission intensity rises, as does Home's total smokestack pollution.

5 Caveats

We close out our analysis by addressing a few of the maintained assumptions from the previous sections: demand for dirty goods is elastic, Home is small, liberalization is wholesale, and capacity is internationally immobile. Below we address how relaxing each of these assumptions would affect our results.

5.1 Inelastic demand for dirty goods

Throughout this paper we have assumed price elastic demand for dirty goods. If demand were instead price inelastic then environmental regulation would actually be beneficial to dirty industry: prices rises fast enough with reductions in e to make up for lost productivity and, by equation 8, $d\pi^a/de < 0$.

In an open economy, the high returns associated with strict regulation would attract dirty capacity into production for the Home market. By equation 16, $\frac{dX_E}{de/e} > 0$ when $\epsilon < 1$, indicating an negative correlation between exports and tailpipe regulation.

Regarding openness' impact on industry opposition to regulation, again consider tailpipe regulation. In autarky $\frac{\hat{\pi}}{\hat{e}}^a < 0$ when $\epsilon < 1$ and so a government captured by dirty industry sets excessively *strict* tailpipe policy. However in the small open economy $\frac{\hat{\pi}}{\hat{e}}^t = 0$, eliminating opportunities for government to aid its industrial constituents by manipulating environmental policy. As a result, the captured government will set weaker tailpipe policy in the open economy than autarky provided price-level effects are not sufficiently strong.[13]

In sum, in our model with firm level abatement occurring either by mandate (as when the pollution cap is set directly) or in response to emission taxes, we find that the relationship between tailpipe regulation, openness, exports and industry opposition to regulation depends critically on the price elasticity of demand. We point out though that this need not always be the case. Consider the following example in which dirty goods are supplied by an industry with variable supply $Q(P)$ with $dQ/dP > 0$ but in which abatement is not possible; i.e. the emissions to consumption (output) ratio is constant. In this case a tax on tailpipe emissions is equivalent to a consumption tax (and a tax on smokestack emissions equivalent to a production tax) and net industry profits would be decreasing in the emission tax regardless of the demand elasticity. It is straightforward to show in such a case that when government assigns industry net profits extra weight in its welfare function, that government will set stricter tailpipe policy (but weaker smokestack policy) in the open

[13] Note also that when $\epsilon < 1$ then $\frac{\hat{Z}}{\hat{e}}^t < \frac{\hat{Z}}{\hat{e}}^a$ (because $\frac{X_E}{de/e}$); this reduced sensitivity of pollution to regulation further reduces the attractiveness of strict tailpipe regulation in the open economy.

economy relative to autarky if price-level effects are small, regardless of the magnitude of ϵ.[14]

The empirical literature on consumer demand offers estimates of ϵ (reported as a negative value) for a variety of dirty goods. Regarding fuel use, Pindyck (1979) calculates the own price elasticities of residential fuel use of -1 to -1.12 for coal, -1 to -1.38 for oil, and -1.28 to -2.09 for gas (p.160). Regarding other consumer goods likely to generate tailpipe pollution, Houthakker and Taylor (1970), find, for example, that the long run price elasticities of boats, pleasure aircraft and sports equipment is -2.3889 (p.125) while for tobacco the long run price elasticity is -1.8919 (p.66). Regarding transportation, Houthakker and Taylor (1970) find that long run demand for transportation services is elastic (-1.47 to -1.57 in Canada, p.213) while Hymans (1970) calculates the short run elasticity of automobile expenditures to be between -0.78 and -1.17 and the long run elasticity of between -0.30 and -0.46 (p.181). Finally, Graham and Gleister (2002) survey the literature on gasoline demand and find long run price elasticities of demand for gasoline ranging from -0.23 in the US to -1.35 in the OECD countries; however they conclude "the overwhelming evidence ... suggests the long-run price elasticities will typically tend to fall in the -0.6 to -0.8 range." (p.22) These numbers suggest that our maintained assumption of $\epsilon > 1$ may be reasonable for a host of (potentially) dirty consumer goods, but likely not for gasoline.

5.2 Tariff liberalization and country size

Until now we've focused exclusively on a *small* economy moving from autarky to free trade. In this section, we ask how/whether our results are sensitive to Home's size and the form of trade liberalization.

[14] We thank Larry Karp for providing this example.

If Home is large, then ROW prices and profits are endogenous; they depend on Home supply and demand conditions according to Home's relative size. To this end, define the following share variables: $\lambda \equiv \frac{f(e)X}{f(e)X+f(e^*)X^*}$ gives Home's share of global smokestack output; $\xi \equiv \frac{f(e)X-E^S}{f(e)X+f(e^*)X^*}$ measures Home's share of global smokestack consumption; finally, $\psi \equiv \frac{X-X_E}{X+X^*}$ reflects the share of global tailpipe capacity allocated to producing for the Home market. We point out that restricting λ, ξ and ψ to zero describes Home when small and open.

We also introduce the parameter δ to measure barriers to *free* trade, with corresponding arbitrage conditions $P^s = \delta P^*$ when pollution is smokestack and $\pi^t = \delta\pi^*$ when pollution is tailpipe. We will focus on import tariffs with $\delta - 1$ measuring the *ad valorem* tariff rate. However this formulation may alternately be employed to analyze trade with *iceberg* transport costs, where $1/\delta$ measures the fraction of goods surviving shipment. Note that for either interpretation, a lower value of δ (for $\delta \geq 1$) corresponds to fewer trade barriers.

5.2.1 Large Open Economy

Our goal in this subsection is to confirm that key results regarding openness' impact on trade patterns and environmental politics also hold when Home is large; for a small economy, these results are summarized in Propositions 1 and 3 and Corollaries 2 and 3.

Smokestack

Arbitrage implies $P^s = \delta P^{*s}$. Using $q^s = [f(e)X - E^S]/N$ and $q^{s*} = [f(e^*)X^* + E^S]/N^*$ in (2) and differentiating with respect to e and δ respectively gives

$$\frac{dE^s}{de} = \frac{f(e)X\sigma[1-\xi]}{e} \tag{28}$$

and

$$\frac{\partial E^S}{\partial \delta} = \frac{\epsilon}{\delta}[1-\xi][f(e)X - E^S]; \tag{29}$$

observe $\frac{dE^S}{de}$ is positive, just as in Proposition 1.

Next, substitute for q^s in eq. 2 and differentiate to get

$$\frac{\hat{P}^s}{\hat{e}} = -\frac{\sigma\lambda}{\epsilon} \tag{30}$$

and so

$$\frac{\hat{\pi}^s}{\hat{e}} = \frac{\sigma[\epsilon-\lambda]}{\epsilon}. \tag{31}$$

Because 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

$$\frac{\hat{Z}^s}{\hat{e}} = 1+\sigma. \tag{32}$$

Comparing equations (30) and (31) with their small economy equivalents (7) and (8) reveals that consumer prices are more sensitive, and factor returns less sensitive, to changes in smokestack regulation the larger is Home's market share λ. This mirrors usual results regarding the terms of trade: the larger Home is, the more its regulations impact prices abroad.

Now suppose $\delta = 1$, i.e. consider only the case where Home is engaged in free trade. The counterpart to eq. 14 for smokestack in the large open economy is then

$$\frac{dW_D^s}{de/e} = Pq\frac{\sigma\lambda}{\epsilon} + X_D Pf(e)\frac{\sigma[\epsilon-\lambda]}{\epsilon} - \beta Z[1+\sigma]$$

while the counterpart to eq. 15 is

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

If $P^s = P^a$ when $e = e_D^a$ then we again see that D views e_D^a as too strict in the open economy if and only if D has above average vested interests in the polluting industry:

$$\left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a,\ P^s=P^a} = P^a q^a \frac{\sigma}{\epsilon}[1-\lambda]\left[\frac{X_D/X}{1/N} - 1\right] \tag{33}$$

the sign of which depends only on whether $X_D > \frac{X}{N}$. Equation 33 confirms Corollary 2 also holds when Home is large. This is not surprising: even though openness' sensitivity effects are muted in magnitude when Home is large rather than small, they each have the same flavor.

Tailpipe

If pollution is instead consumer generated, then the arbitrage condition is $\pi = \delta\pi^*$, or, equivalently, $v'\left(\frac{f(e)[X-X_E]}{N}\right)f(e) = \delta v'\left(\frac{f(e^*)[X^*+X_E]}{N^*}\right)f(e^*)$. Differentiating with respect to δ and e respectively yields the relationships

$$\frac{\partial X_E}{\partial \delta} = \frac{\epsilon(X - X_E)}{\delta}(1-\psi) \tag{34}$$

and $\frac{dX_E}{de} = -\frac{\sigma[\epsilon-1]}{e}[X - X_E][1-\psi]$; note $\frac{dX_E}{de}$ is negative, confirming Proposition 3 also holds when Home is large.

Use the expression for $\frac{dX_E}{de}$ to derive

$$\frac{\hat{P}^t}{\hat{e}} = -\frac{\sigma}{\epsilon}\left[1 + [\epsilon-1][1-\psi]\right] \tag{35}$$

$$\frac{\hat{\pi}^t}{\hat{e}} = \sigma\psi\frac{\epsilon-1}{\epsilon} \tag{36}$$

and

$$\frac{\hat{Z}^t}{\hat{e}} = [1+\sigma] + \sigma[\epsilon-1][1-\psi] > 0. \tag{37}$$

Comparing equations 35 and 36 with 17 and 18, respectively, confirms that, once again, the terms of trade effects of Home's regulation depend on Home's market share. With tailpipe pollution, Home's regulation has a smaller (larger) impact on consumer prices (profits) the bigger Home's consumer market is.

Setting $\delta = 1$, the rather unwieldy counterpart to eq. 21 is

$$\frac{dW_D^t}{de/e} = q^t \left[P^t \sigma \psi \frac{X_D/X}{1/N} \frac{X}{X - X_E} \frac{\epsilon - 1}{\epsilon} + P^t \sigma \frac{\epsilon[1-\psi] + \psi}{\epsilon} - \beta N e \left[1 + \sigma + \sigma(\epsilon - 1)(1 - \psi)\right] \right]. \tag{38}$$

If $P^t = P^a$ when $e = e_D^a$ then $X_E = 0$ and, from (10) (when (10) set equal to zero), $\beta e N[1+\sigma] = \frac{P\sigma}{\epsilon}\left[1 + \frac{X_D/X}{1/N}(\epsilon - 1)\right]$. Substituting these terms into (38) and collecting terms gives

$$\left.\frac{dW_D^t}{de/e}\right|_{e=e_D^a,\ P^t=P^a} = -[1-\psi] q^a \sigma [\epsilon - 1] \left[\frac{P^a}{\epsilon} \left[\frac{X_D/X}{1/N} - 1 \right] + \beta N e_D^a \right] \tag{39}$$

which is unambiguously negative if $X_D > X/N$ and $\epsilon > 1$. Equation (39) confirms that Corollary 3 also holds in the large open economy.

5.2.2 Tariff Liberalization

This paper examines the political implications of openness by comparing outcomes in a closed and an open economy. The most obvious interpretation is literal: a country formerly closed to (most) international trade now allows its goods to be freely traded on international markets; changes in the trade policies of former East-bloc countries at the end of the Soviet era are examples of such wholesale liberalizations. Because our model takes a partial equilibrium approach—we examine the politics surrounding a *single* dirty good—our approach is also useful for analyzing the political implications of eliminating trade restrictions on a single sector—e.g. removing log export bans in Thailand, Indonesia and Costa Rica—or erecting new barriers, e.g. the trade ban on ivory or Basel Convention restrictions on trade in hazardous waste. Similarly, our framework is useful for exploring the political ramifications of exogenous liberalizations. A century ago, trans-hemispheric trade in fresh produce was infeasible; improved refrigeration and shorter transit times now make such trade commonplace. Finally, our structure is also useful for comparing differences in the political incentives surrounding regulations concerning tradable dirty goods (such as cars) versus non-tradeables (such as sewage).

Often, though, trade liberalizations aren't wholesale but incremental: a country gradual dismantles its trade barriers and reduces its trade taxes, removing distortions between domestic and international markets. Over the past decades, multilateral negotiations have been very successful in reducing tariffs in industrialized countries; the average OECD tariff rate fell to less than 4% after the Uruguay Round of negotiations (OECD 2003). But as there are still many goods on which tariffs are non-negligible, analyzing this type of liberalization is important.

We examine tariff liberalization's impact on environmental politics as follows. Because $e_D^j > 0$ and W_D^j is locally concave in e for $j = s, t$, then by the envelope theorem the derivatives $\frac{de_d^j}{d\delta}$ and $\frac{\partial}{\partial\delta}\frac{dW_D^j}{de/e}$ have the same sign. Use the following decomposition to identify impacts of a change in δ on $D's$ incentives via changes in price, profit and pollution levels—the *level* effects of tariff liberalization—and via changes in the sensitivity measures $\frac{\hat{P}}{\hat{e}}$, $\frac{\hat{\pi}}{\hat{e}}$, and $\frac{\hat{Z}}{\hat{e}}$—the incidence effects.

$$\frac{\partial}{\partial\delta}\frac{dW_D^j}{de/e} = \underbrace{\left.\frac{\partial}{\partial\delta}\frac{dW_D^j}{de/e}\right|_{d\frac{\hat{P}}{\hat{e}}^j = d\frac{\hat{\pi}}{\hat{e}}^j = d\frac{\hat{Z}}{\hat{e}}^j = 0}}_{\Lambda^j \equiv \text{ level effects}} + \underbrace{\left.\frac{\partial}{\partial\delta}\frac{dW_D^j}{de/e}\right|_{d(P^j q^j) = d\pi^j = dZ^j = 0}}_{\Gamma^j \equiv \text{ incidence effects}} \tag{40}$$

for $j = s, t$ where

$$\Lambda^j = -\frac{\hat{P}}{\hat{e}}^j \frac{\partial(P^j q^j)}{\partial\delta} + X_D \frac{\hat{\pi}}{\hat{e}}^j \frac{\partial\pi^j}{\partial\delta} - \beta\frac{\hat{Z}}{\hat{e}}^j \frac{\partial Z^j}{\partial\delta}$$

and

$$\Gamma^j = P^j q^j \frac{\partial(-\frac{\hat{P}}{\hat{e}}^j)}{\partial\delta} + \pi^j X_D \frac{\partial\frac{\hat{\pi}}{\hat{e}}^j}{\partial\delta} - \beta Z^j \frac{\partial\frac{\hat{Z}}{\hat{e}}^j}{\partial\delta}.$$

Proposition 6 *When Home is small, tariff liberalization leads D to prefer*

1. *stricter tailpipe policy,*

2. stricter smokestack policy if and only if $X_D > 0$.

Proof. When Home is small, then ξ, λ and ψ are each identically equal to zero by definition; equations (30)-(32) and (35)-(37) therefore imply $\Gamma = 0$ for either pollution type. This leaves only level effects of tariff liberalization as measured by Λ^j and so sign $\left[\frac{de_D^j}{d\delta}\right]$ = sign$[\Lambda^j]$. For tailpipe pollution, $\Lambda^t = -\frac{\hat{P}}{\hat{e}}\frac{\partial(Pq)}{\partial\delta} - \beta\frac{\hat{Z}}{\hat{e}}\frac{\partial Z}{\partial\delta}$ since $\frac{\hat{\pi}}{\hat{e}} = 0$. By (34), $\frac{\partial X_E}{\partial\delta} = \frac{\epsilon(X-X_E)}{\delta}$ when Home is small, and so $\frac{\partial q}{\partial\delta} = -\epsilon q/\delta$, which in turn implies $\frac{\partial(Pq)}{\partial\delta} = [1-\epsilon]Pq/\delta$ while $\frac{\partial Z}{\partial\delta} = -\epsilon Z/\delta$; substituting in terms and noting that $\beta Ne[1+\sigma\epsilon] = P\sigma$ at e_D^t by (21) yields $\Lambda^t = \sigma Pq/\delta > 0$ when Home is small and pollution is tailpipe. For smokestack pollution, $\Lambda^s = \sigma X_D\frac{\partial\pi}{\partial\delta} = \sigma X_D P^* f(e)$ since $\frac{\hat{P}}{\hat{e}} = 0$ and $\frac{\partial Z}{\partial\delta} = 0$. Λ^s is positive if and only if $X_D > 0$. ■

Proposition 6 shows that, when Home is small, tariff liberalization has the same impact on environmental policy regardless of pollution type. This is because the ROW supply curve for smokestack goods and ROW demand curve for tailpipe goods are each perfectly horizontal when Home is small. This means that tariff liberalization leaves Home's consumers (producers) perfectly insulated from Home's smokestack (tailpipe) regulation provided tariffs are not prohibitive. Consequently tariff liberalization has no effect on the incidence of pollution regulation when Home is small. Moreover, because tariff liberalization lowers the opportunity cost of smokestack regulation to firms, and expands Home's base for tailpipe pollution (making tailpipe regulation more productive), the level effects of tariff liberalization work in a single direction for either type of pollution: D prefers stricter regulation of either sort.

Proposition 7 *When Home is large, tariff liberalization induces stricter smokestack policy if and only if the following condition holds:*

A1. $\frac{X_D/X}{1/N} > \frac{\epsilon-1}{\epsilon-\lambda}\xi$.

Proof.

Begin with Γ. From (30)-(32), each of the sensitivity measures $\frac{\hat{P}}{\hat{e}}^s$, $\frac{\hat{\pi}}{\hat{e}}^s$ and $\frac{\hat{Z}}{\hat{e}}^s$ depends on δ only indirectly via e_D^s, if at all. Thus $\frac{\partial}{\partial\delta}\frac{\hat{P}}{\hat{e}}^s = 0$, etc., yielding $\Gamma^s = 0$ even when Home is large.

Next examine Λ^s. $P^s q^s$ and π^s can each be written as a function of q^s, while smokestack pollution, on the other hand, has no direct relationship with the tariff rate: $\frac{\partial Z^s}{\partial\delta} = 0$. Rewrite Λ^s accordingly:

$$\Lambda^s = \left[-\frac{\hat{P}}{\hat{e}}^s\frac{d(P^s q^s)}{dq^s} + X_D\frac{\hat{\pi}}{\hat{e}}^s\frac{d\pi^s}{dq^s}\right]\frac{\partial q^s}{\partial\delta}.$$

Using (29), calculate the requisite derivatives $\frac{dP^s q^s}{dq} = P^s \frac{\epsilon-1}{\epsilon}$ and $\frac{d\pi^s}{dq} = -\frac{\pi^s}{\epsilon q^s}$. Substitute these derivatives into Λ^s and collect terms to get

$$\Lambda^s = \frac{\lambda \sigma P^s}{\epsilon^2} \frac{\epsilon - \lambda}{\xi} \left[\frac{\epsilon - 1}{\epsilon - \lambda} \xi - \frac{X_D/X}{1/N} \right] \frac{\partial q^s}{\partial \delta}$$

From (29), $\frac{\partial E^S}{\partial \delta} = \frac{\epsilon}{\delta}[1-\xi][f(e)X - E^S]$, implying $\frac{\partial q^s}{\partial \delta} = -\frac{\epsilon(1-\xi)q^s}{\delta} < 0$. Thus sign $\left[\frac{de^s_D}{d\delta}\right] =$ sign $[\Lambda^s] =$ sign $\left[\frac{X_D/X}{1/N} - \frac{\epsilon-1}{\epsilon-\lambda}\xi\right]$ ■

Notice the apparent contradiction between Propositions 6 and 7: tariff liberalization always breeds stricter smokestack regulation in a small economy, but in a large economy it must also be the case that the regulator isn't overwhelmingly influenced by consumers. This is because consumers aren't fully insulated from the costs of smokestack regulation when Home is large and open. And since tariff liberalization expands Home's consumption base, it also raises consumers' stakes from strict smokestack regulation: they've got more to lose. If consumers have sufficient influence on Home's regulator, then tariff liberalization leads to weaker, rather than stricter, smokestack policy when Home is large.

Proposition 8 *When Home is large, tariff liberalization induces weaker tailpipe policy whenever the following conditions both hold:*

A2. $X_D > \frac{X+X^*}{N}\left(\frac{\epsilon\psi-1}{\epsilon-1} - (1-\psi)\right)$

A3. $\psi > \frac{\sigma\epsilon+1}{2\sigma(\epsilon-1)}$.

Proof. Substitute $\frac{\hat{P}}{\hat{e}}^t$, $\frac{\hat{\pi}}{\hat{e}}^t$ and $\frac{\hat{Z}}{\hat{e}}^t$ terms from (35)-(37) into (6); partially differentiate with respect to δ using $\frac{\partial X_E}{\partial \delta} = \frac{\epsilon}{\delta}[X - X_E][1-\psi]$ (which follows from the arbitrage condition $\pi = \pi^*\delta$ and implies in turn that $\frac{\partial \psi}{\partial \delta} = -\frac{\epsilon}{\delta}[1-\psi]\psi$, $\frac{\partial \pi^t}{\partial \delta} = \frac{\pi^t[1-\psi]}{\delta}$, $\frac{\partial P^t q^t}{\partial \delta} = -\frac{P^t q^t}{\delta}(\epsilon-1)(1-\psi)$ and $\frac{\partial Z^t}{\partial \delta} = -\frac{Z^t}{\delta}\epsilon[1-\psi]$.) Again by the envelope theorem, this gives

$$\begin{aligned} \text{sign}\left[\frac{de^t_D}{d\delta}\right] = \quad & \text{sign}\left[\frac{[1-\psi]}{\delta}\left\{Pq\sigma\frac{\epsilon-1}{\epsilon}\left(\epsilon\psi - 1 - (\epsilon-1)(1-\psi)\right)\right.\right. \\ & \left.\left. - \pi X_D \psi \sigma \frac{(\epsilon-1)^2}{\epsilon} - \beta Z \epsilon[\sigma(\epsilon-1)(2\psi-1) - (1+\sigma)]\right\}\right] \end{aligned}$$

Rewriting $\pi X_D \psi$ as $Pq\frac{X_D}{[X+X^*]/N}$ and factoring out terms implies

$$\text{sign}\left[\frac{de^t_D}{d\delta}\right] = \text{sign}\left[\frac{[1-\psi]}{\delta}\left\{Pq\sigma\frac{(\epsilon-1)^2}{\epsilon}\underbrace{\left[\frac{\epsilon\psi-1}{\epsilon-1} - (1-\psi) - \frac{X_D}{[X+X^*]/N}\right]}_{\equiv A}\right.\right.$$

$$- \beta Z \epsilon \underbrace{\left[\sigma(\epsilon - 1)(2\psi - 1) - (1 + \sigma)\right]}_{\equiv B} \Bigg\} \Bigg] \tag{41}$$

When condition A2 holds, the A term in (41) is negative; when A3 holds, the B term in (41) is positive. Thus conditions A2 and A3 are jointly sufficient for $\frac{de^t_D}{d\delta} < 0$. ■

With tailpipe policy, tariff liberalization affects political incentives not just through changes in consumption and price levels, but also by altering the sensitivity of prices, profits and pollution to regulation in the first place. Tariff liberalization draws dirty goods into the Home market, increasing the share of the global market effectively governed Home's tailpipe regulation. Simply put, tariff liberalization gives Home a bigger jurisdiction. As a result, tariff liberalization renders profits more sensitive to Home's tailpipe regulations, raising industry opposition. When Home's regulator is sufficiently captured by Home industry, these sensitivity effects of liberalization outweigh liberalization's level effects, and Home chooses weaker tailpipe policy.

Corollary 6 *When Home is large, conditions A1, A2 and A3 as outlined in Propositions 7 and 8 are jointly sufficient for tariff liberalization to induce opposite policy responses depending on pollution type: tariff liberalization will lead to stricter smokestack policy but weaker tailpipe policy.*

Corollary 6 provides sufficient conditions under which tariff liberalization has qualitatively opposite impacts on environmental policy depending on pollution type. The possibility of such a reversal is the central theme of this paper.

However the reader should note that the impact of tariff liberalization on, for example, tailpipe policy, when Home's regulator is captured by industry is itself qualitatively opposite the impact of *openness* on tailpipe policy when $X_D > X/N$: moving from autarky to free trade makes a captured regulator want stricter tailpipe policy, while eliminating import tariffs makes that regulator want weaker tailpipe regulation. Is this a paradox? No. One critical channel through which liberalization affects environmental policy is the share of the market governed by Home's regulation. By giving producers an outside option, wholesale liberalization releases producers from the burden of tailpipe regulation. But tariff liberalization draws goods into the regulated market, reducing the independence of the outside option from local conditions. Because the size of the outside option is what that ultimately drives producer preferences over tailpipe regulation, it isn't surprising then that different forms of liberalization—with their different impacts on producers' outside options—can have opposing impacts on industry support for tailpipe regulations.

5.3 Endogenous capacity supply

In this sub-section we relax our maintained assumption that Home's productive capacity, X, is fixed. In particular, suppose the stock of raw capacity X is acquired at cost $C(X)$ with $C' > 0$. Let $\rho \equiv Pf(e)$ denote the *effective* price for dirty capacity, and denote the supply elasticity as $\varphi \equiv \frac{dX}{d\rho}\frac{\rho}{X}$. Thus total industry profits are given by $\Pi = \rho X - C(X)$, the supply curve for productive capacity is upward sloping in ρ, and the marginal private cost of dirty goods is no longer zero (as it was in Figures 1 and 2).

Because X is no longer a fixed actor, we redefine our measure of vested interests as $\alpha_i \Pi$, where α_i measures i's share of the dirty industry's profits. Accordingly, we rewrite the objective function for the political agent as

$$\max_e C + \alpha_i \Pi + y_i - \beta Z$$

and the equivalent to equation 5 is

$$\frac{dW_i}{de/e} = -pq\frac{\hat{P}}{\hat{e}} + \alpha_i \frac{d\Pi}{de/e} - \beta Z\frac{\hat{Z}}{\hat{e}}. \tag{42}$$

	$j=s$	$j=a$	$j=t$
$\frac{\hat{P}}{\hat{e}}^j$	0	$-\sigma\frac{1+\varphi}{\epsilon+\varphi}$	$-\sigma$
$\frac{d\Pi^j}{de/e}$	$X\rho\sigma$	$X\rho\sigma\frac{\epsilon-1}{\epsilon+\varphi}$	0
$\frac{\hat{Z}}{\hat{e}}^j$	$1+\sigma[1+\varphi]$	$1+\sigma\epsilon\frac{1+\varphi}{\epsilon+\varphi}$	$1+\sigma\epsilon$

Table 2: Price and Pollution Responses when X Endogenous

Table 2 provides the corresponding response measures when Home is closed or small and open. From this table we see endogenizing X does not alter the incidence impacts of openness; opening to trade still shifts the incidence of tailpipe policy to consumers and the incidence of smokestack policy to producers: $\left|\frac{\hat{P}}{\hat{e}}^t\right| > \left|\frac{\hat{P}}{\hat{e}}^a\right| > \left|\frac{\hat{P}}{\hat{e}}^s\right|$ and $\frac{d\Pi^s}{de/e} > \frac{d\Pi^a}{de/e} > \frac{d\Pi^t}{de/e}$.

What is qualitatively different with endogenous X is how opening to trade impacts regulatory productivity. From the final row of Table 2 we see that opening to trade renders environmental regulation more productive regardless of pollution type. For tailpipe, the explanation is as before: in an open economy tightening pollution policy induces some capacity to shift into export production. With smokestack production, the domestic supply response is responsible. When Home is open, domestic prices won't adjust to partially compensate producers for lost production potential, and so the supply response in X is larger than it would be in autarky. As a result, smokestack regulation is more productive when the economy is open instead of closed. Other things equal, this makes strict smokestack regulation more attractive. Conlfirm this by substituting terms into equation 42 to obtain the counterpart to equation 15, evaluated here absent any level effects:

$$\left.\frac{dW_D^s}{de/e}\right|_{e=e_D^a, P^*=P^a} = \underbrace{P^* f(e) X^a \sigma \frac{1+\varphi}{\epsilon+\varphi}\left[\alpha - \frac{1}{N}\right]}_{\text{incidence shifting}} - \underbrace{\beta Z^a \sigma \frac{\varphi[1+\varphi]}{\epsilon+\varphi}}_{\text{regulatory productivity}} . \tag{43}$$

Unlike when X was fixed, from equation 43 we see that when $\alpha_i = 1/N$ the regulator prefers stricter smokestack policy in the open economy purely for regulatory productivity reasons. It follows then that openness will *not* induce weaker smokestack policy if the political distortion (i.e. the gap between α_i and $1/N$) is small. Moreover, inspecting equation 43 suggests that the size of the political distortion necessary to outweigh the regulatory productivity effect is larger the more elastic capacity supply is: as $\varphi \to 0$, the regulatory productivity term in (43) goes to zero; as $\varphi \to \infty$, the term reflecting incidence effects disappears.

What does all this mean? Recall that we have repeatedly stressed that openness can have qualitatively different impacts on environmental policy depending on pollution type. This sub-section suggests that this qualitative reversal requires any political distortion be non-trivial. In particular, if the regulator represents interests that vary only slightly from average, then the regulatory productivity effect of openness makes strict environmental regulation more attractive, irrespective of pollution type. If instead the political distortion is strong, then the incidence shifting effect dominates and type becomes pivotal. And finally, the more flexible pollution supply is, the stronger this political distortion must be in order for a reversal to occur.

5.4 Internationally mobile capacity

Since this paper focuses on goods trade, we have assumed throughout that production capacity is internationally immobile. How would our results change if instead production capacity were free to move across countries?

For tailpipe regulation this question is essentially moot since factor returns depend on where goods are sold, not where they are produced.

Conversely, factor mobility is important for smokestack goods. In our simple model all capacity would flee from Home unless $e^s \geq e^*$ (where e^* is the overseas emission cap) and sensitivity measures $\frac{\hat{\pi}}{\hat{e}}$, etc would be discontinuous. Moreover, Home's capacity owners would be indifferent to small variations in e^s if $e^s < e^*$, because they would already be producing dirty goods abroad and shipping them back to Home for sale.

This indifference of footloose industry to variations in e^s is sensitive, however, to the assumption that capacity productivity is constant for given e. Consider the following variation on the production function: $Q = f(e)g(X - x)$ 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, π^*, available abroad. Differentiating the arbitrage condition $f(e)g'(X - x) = \pi^*$ gives $\frac{dx}{\hat{e}} = \frac{\sigma}{g''/g'} < 0$, where $g'(*) = g'(X^* + x)$ etcetera. In this setup, domestic prices and profits in the small open economy respond to changes in e exactly as when there is no capital mobility: $\frac{\hat{P}}{\hat{e}}^s = 0$ while $\frac{\hat{\pi^s}}{\hat{e}} = \sigma$.

Just as with endogenous domestic capacity, Home's pollution Z would, however, be rendered more sensitive to changes in e if capacity were footloose: tightening e^s will induce some Home capacity to emigrate, reducing Home's polluting activity on two counts—capacity in Home becomes less productive, and there is less of it. Mathematically, $\frac{\hat{Z}}{\hat{e}}^s = 1 + \sigma - \frac{\sigma g'}{g\left[\frac{g''}{g'}\right]} > 1 + \sigma$. This again renders the impact of openness on smokestack policy ambiguous: as with endogenous X, when capacity if footloose the regulatory productivity effect of openness dominates if the political distortion is trivial, while for marked industry influence the incidence effect wins out.

6 Conclusions

This paper examines the relationship between politics, openness to free trade in goods, and environmental regulation when pollution arises as a by-product from consuming, instead of producing, dirty goods. We show that a common presumption—that producers of dirty goods are more opposed to environmental regulation in the open economy—can be reversed in the case of consumption-related pollution.

The simple explanation for this reversal is that openness' impact on the incidence of environmental regulation is different for tailpipe and smokestack pollutants. In the open economy, prices are less sensitive, and factor rents more responsive, to local smokestack regulation than in autarky. As a result, producers bear a larger share of the regulatory burden from smokestack regulation when the economy is open rather than closed. In contrast, with tailpipe regulation it is local consumer prices that are more sensitive, and factor rents less responsive, in the open economy than in autarky. Holding the price level constant, this incidence-shifting induces governments that are captured by dirty industry to set weaker caps on smokestack emissions, but stricter caps on tailpipe emissions, in the open economy than in autarky.

Of course openness does more than simply change the incidence of pollution policy. It can also raise or lower the price of dirty goods, with implications for the opportunity cost of environmental protection. When government regulates pollution via an emissions cap, this price-level effect may offset or compliment the incidence-effects, rendering the overall impact of openness on regulatory stringency ambiguous. This ambiguity is not present in our model, however, when we measure stringency via nominal emission taxes. We find openness unambiguously raises the nominal smokestack tax but lowers the nominal tax on tailpipe when government is captured by dirty industry and demand is elastic.

The wider implication of this and previous research on consumer-generated pollution is that trade and environment relationships may depend critically on pollution type. 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. We have focused on the relationship between openness and environmental politics, and under reasonable assumptions find that the traditional relationship can be reversed. Our model also confirms that strict environmental regulation may promote rather than hinder exports. Finally, we have interpreted our results in terms of their implications for empirical testing. Because relationships between trade patterns, politics, and environmental regulation may vary qualitatively with the type of externality being regulated, we believe it is imperative that empiricists not bundle together data on smokestack and tailpipe regulation/outcomes as a generic proxy for regulatory stringency.

References

Bommer, Rolf and Gunther G. Schulze. 1999. "Environmental improvement with trade liberalization," *European Journal of Political Economy* 15: 639-661.

Buchanan, J. and G. Tullock. 1975. "Polluters' profits and political response: direct controls versus taxes," *American Economic Review* 65: 139-147.

Chua, Swee. 2003. "Does tighter environmental policy lead to a comparative advantage in less polluting goods?" *Oxford Economic Papers* 55: 25-35.

Copeland, Brian R. and M. Scott Taylor. 1995. "Trade and the Environment: A Partial Synthesis" *American Journal of Agricultural Economics* 77: 765-771.

Copeland, Brian R. And M. Scott Taylor. 2004. "Trade, Growth, and the Environment," *Journal of Economic Literature* 42(1): 7-71.

Damania, Richard, Per G. Fredriksson and John A. List. 2003. "Trade liberalization, corruption, and environmental policy formation: theory and evidence." *Journal of Environmental Economics and Management* 46(3): 490-512.

Dasgupta, Susmita, Ashoka Mody, Subhendu Roy and David Wheeler. 1995. "Environmental Regulation and Development: A Cross-Country Empirical Analysis," *World Bank Policy Research Working Paper* No. 1448.

Deacon, Robert T. 1999. "The Political Economy of Environment-Development Relationships: A Preliminary Framework." Department of Economics, University of California at Santa Barbara, Departmental Working Paper 11-99.

Ederington, Josh, Arik Levinson and Jenny Minier. 2005. "Footloose and Pollution-Free," *Review of Economics and Statistics* 87: 92-99.

Eliste, Paavo and Per G. Fredriksson. 2002. "Environmental regulations, transfers, and trade: Theory and evidence," *Journal of Environmental Economics and Management* 43(2):

234-250.

EPA. 1993. "Plain English Guide to the Clean Air Act." United States Environmental Protection Agency Document EPA-400-K-93-001.

EPA. 2000. "EPA announces elimination of all indoor uses of widely-used pesticide Diazinon; begins phase-out of lawn and garden use," United States Environmental Protection Agency Headquarters Press Release 12/05/2000.

EPA. 2002. "Municipal Solid Waste in the United States: 2000 Facts and Figures," United States Environmental Protection Agency Document EPA530-R-02-001.

Fredriksson, Per. 1997. "The Political Economy of Pollution Taxes in a Small Open Economy," *Journal of Environmental Economics and Management* 33: 44-58.

Graham, Daniel J. and Stephen Gleister. 2002. "The Demand for Automobile Fuel: A Survey of Elasticities," *Journal of Transport Economics and Policy* 36(1): 1-25.

Grossman, Gene and Elhanen Helpman. 1994. "Protection for Sale," *American Economic Review* 84(4):833-850.

Gulati, Sumeet. 2003. "The effect of choosing free trade on pollution policy and welfare," *mimeo*, University of British Columbia.

Houthakker, H.S. and Lester D. Taylor. 1970. *Consumer Demand in the United States: Analyses and Projections.* Cambridge, MA: Harvard University Press.

Hymans, Saul H. 1970. "Consumer Durable Spending: Explanation and Prediction," *Brookings Papers on Economic Activity* 2: 173-206.

Krutilla, Kerry. 1991. "Environmental Regulation in an Open Economy," *Journal of Environmental Economics and Management* 20: 127-142.

Leidy, M.P. and B.M. Hoekman. 1993. "'Cleaning up' while cleaning up? Pollution abatement, interest groups, and contingent trade policies," *Public Choice* 78: 241-258.

Levinson, Arik and M. Scott Taylor. 2003. "Unmasking the Pollution Haven Effect," *mimeo*, University of Wisconsin.

McAusland, Carol. 2003. "Voting for Pollution Policy: The Importance of Income Inequality and Openness to Trade," *Journal of International Economics* 61(2): 425-451.

McAusland, Carol. (2005). "Harmonizing Emissions Policy in Symmetric Countries: Improve the Environment, Improve Welfare?" *Journal of Environmental Economics and Management* 50(2): 229-251.

OECD. 2003. "The Road to Cancun," *OECD in Washington* 45.

Pethig, R. "Pollution, Welfare, and Environmental Policy in the Theory of Comparative Advantage," *Journal of Environmental Economics and Management* 2: 160-169.

Pindyck, Robert S. 1979. *The Structure of World Energy Demand.* Cambridge, MA: MIT

Press.

Rauscher, Michael. 1997. *International Trade, Factor Movements, and the Environment.* Oxford: Clarendon Press.

Schleich, Joachim. 1999. "Environmental Quality with Endogenous Domestic and Trade Policies," *European Journal of Political Economy* 15: 53-71.

Schleich, Joachim and David Orden. 2000. "Environmental Quality and Industry Protection with Noncooperative Versus Cooperative Domestic Trade Policies," *Review of International Economics* 8: 681-697.

Siebert, Horst. 1979. "Environmental Policy in the Two-Country Case," *Zietschrift für Nationalökonomie* 39(3-4): 259-274.

Appendix: Second order conditions

The second order conditions—$\frac{d^2W_D}{de^2} < 0$—in autarky and the small open economy are confirmed as follows. Since $\frac{d^2W_D}{de^2} = -\frac{1}{e^2}\frac{dW_D}{de/e} + \frac{1}{e}\frac{d}{de}\frac{dW_D}{de/e}$ then at e_D for each scenario satisfying the second order condition requires $\frac{d}{de}\frac{dW_D}{de/e}$ be negative. Differentiating eq. 6 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 $\frac{d}{de}\frac{dW_D^t}{de/e} = -[X - X_E]\frac{\sigma\pi^*[1+\sigma]}{N} < 0$ 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.