Title
Harmonizing Emissions Policy in Symmetric Countries: Improve the Environment, Improve Welfare?

Author
McAusland, Carol

Publication Date
2003-10-29

Harmonizing Tailpipe Policy in Symmetric Countries: Improve the Environment, Improve Welfare?

Carol McAusland[†,‡]
University of California, Santa Barbara

October 29, 2003

Abstract: We show that harmonizing emissions policy may be bad for the environment and/or global welfare, even when pollution is transboundary and countries are identical in every way. Harmonization effectively internalizes the transboundary aspects of pollution. But it also hampers producers' ability to avoid local tailpipe regulation via exports of dirty goods and thereby redistributes incidence between producers and consumers. We develop a generic treatment of the political economy of environmental regulation to examine these competing effects. We find that whether harmonization makes politically motivated governments prefer stricter or weaker policy depends on their constituents' vested interests and the degree of transboundary pollution transmission.

JEL Classification: F18, D72

Keywords: trade, environment, harmonization, political economy

[†]Address for correspondence: Department of Economics, University of California, Santa Barbara, CA 93106. Phone: (805) 893-4823; fax: (805) 893-8830; email: mcauslan@econ.ucsb.edu.

[‡]My gratitude to Christopher Costello, Bob Deacon, and Joel Bruneau for helpful comments on previous drafts of this paper. The usual disclaimer applies.

1 Introduction

Consider some of today's most pressing environmental concerns: climate change, biodiversity loss, acidic deposition, and ozone depletion. Each has a local source but global implications. Policies to efficiently control externalities like these may require international cooperation for a variety of reasons. For example, citizens within countries do not typically direct their governments to fully internalize the utility of their foreign counterparts. And while governments may regulate local activities, they have no direct control over behavior abroad. Consequently, we may expect governments to set less stringent environmental regulations when acting unilaterally than when setting policy cooperatively. If countries are sufficiently similar, we may further expect such cooperation to improve the welfare of the countries involved.

We examine the environmental and welfare effects of a particular kind of international cooperation—policy harmonization—when governments are politically motivated. There has been substantial discussion, both in and outside of the economics profession, as to the merits of harmonizing environmental regulation internationally. Rauscher (1992) and Bhagwati and Srinivasan (1996) point out that (globally) optimal levels of environmental protection will vary from region to region depending on the tastes and incomes of citizens, as well as on the assimilative capacities of regional ecosystems. Consequently, any policy that requires instrument levels be identical across countries is inefficient when those countries are asymmetric.

We agree with assessments that, in general, dissimilar countries should have dissimilar standards.[1] However we take issue with any presumption that harmonization by similar countries is necessarily beneficial or even simply innocuous. We address harmonization[2] when the countries

[1] Others, however, have argued that harmonization may be desirable in the presence of market failures. Ulph (1997) finds that harmonization—at levels imposed by a supra-national authority—may be Pareto improving in the presence of strategic trade incentives or informational asymmetries.

[2] We focus on *de jure* harmonization, whereby regulations are equalized across jurisdictions by mandate. The term harmonization has been used elsewhere to describe one country altering its local standards so as to make them identical to those of another country, but without such equality being enforced by multilateral agreement;

in question are alike in every way. In this case the instrument levels that maximize global welfare are indeed identical across countries. Nevertheless, we show that policy harmonization by perfectly symmetric countries may be bad for the environment and global welfare if governments are politically motivated and/or pollution is less than fully transboundary.

The model we use is purposely simple. Citizens are endowed with immobile[3] capital used to produce dirty goods, while pollution policy is influenced by politics. We employ a generic treatment of the political process[4]; given our set-up we show this treatment is isomorphic to three popular models of political economy—majority rule, a political elite, and a political contributions approach.

We focus on *tailpipe* pollution: pollution that is a by-product of consuming dirty goods.[5] We find that harmonizing tailpipe policy may be bad for the environment and/or global welfare. We show this occurs because tailpipe harmonization affects policy preferences through three sometimes competing channels. The first two channels have been recognized previously in the literature on international cooperation. To begin with, a harmonized standard directly affects emissions created both locally and abroad. If the neighbor's emissions harm the decision maker's country, then this extended control makes strict environmental policy more attractive when policy is harmonized than when it is set unilaterally. Working in the opposite direction is

this would be described best as *de facto* harmonization and is not considered here.

[3] Some models of environmental regulation in the presence of internationally mobile capital also suggest—implicitly at least—that cooperation can be bad for the environment. See, e.g., Markusen, Morey and Olewiler (1995), Wilson (1997) and McAusland (2002); each describes outcomes of interjurisdictional competition whereby governments set inefficiently strict local environmental regulation so as to either extract rents from overseas investors or to drive polluting firms abroad. In such cases cooperation would eliminate these strategic incentives and so induce downward harmonization. We do not allow for interjurisdictional capital mobility in the present paper.

[4] Others examining politics and environmental policy in open economies have used specific models of political economy. Hillman and Ursprung (1992) use a political support model to examine how campaign contributions from environmental groups affect trade policy; Fredriksson (1997), Aidt (1998) and Schleich (1999) and Schleich and Orden (2000) each use the political contributions approach to examine the influence of lobby groups on production and trade taxes in small open economies; McAusland (2003a) uses a median voter framework to compare pollution standards in closed and open economies.

[5] Tailpipe pollution is distinct from producer generated pollution in that tailpipe emissions are generated when goods are consumed.

the loss of *pollution-shifting* opportunities as identified by Kennedy (1994)[6]. When countries set policy unilaterally each has an incentive to set excessively strict policy so as to shift some polluting activity overseas; when policy is instead harmonized this pollution-shifting opportunity is eliminated because overseas policy is mandated to move in lock-step with local policy.

We identify a third channel, which works via the incidence of environmental regulation. Many trade agreements permit governments to regulate polluting activity that occurs within their border but not that occuring abroad.[7] As a result local regulation completely binds local consumers while producers can avoid regulation by simply producing for export.[8] However when policy is instead harmonized, producers cannot use exports to avoid strict regulation because overseas and local policy will be identical by mandate. This shifts some of the burden of tailpipe regulation away from consumers and onto producers, with consequences for how political agents view policy.

We analyze these competing effects of harmonization in the context of perfectly symmetric countries. We derive conditions under which one or another of the three channels described above dominates, and so derive parameter values under which harmonizing tailpipe regulation across identical countries leads to weaker policy and is therefore bad for the environment.[9]

[6] Kennedy (1994) examines environmental regulation when dirty industry is oligopolistic, pollution is a by-product of production, and national policies are set so as to maximize national welfare. He shows that when pollution is less than perfectly transboundary, countries have an incentive to raise environmental taxes so as to transfer production and its associated pollution abroad. In contrast to Kennedy (1994), we examine the problem of consumer related pollution and consider political actors who may be acting on the part of only a subset of the local citizenry.

[7] For example, the World Trade Organization principle of National Treatment dictates that governments may impose the same product standards on all goods sold within their border regardless of where the goods were produced, provided the regulation has scientific foundation.

[8] An example is the export of pesticides. Between 1997 and 2000, approximately 65 million pounds of pesticides legally exported from the United States were either forbidden, severely restricted, or never-registered for use in the United States (Smith 2001).

[9] Schleich and Orden (2000) also consider cooperation by politically motivated governments; examining the environmental effects of cooperation when governments may manipulate both production and trade taxes, they declare "no general conclusions can be drawn as to whether the cooperative equilibrium policies ... result in higher or lower environmental quality than the noncooperative policies...." (p. 690) We take a different approach. Because we consider only symmetric countries, in equilibrium net trade is zero. This allows us to highlight harmonization's impact on the incidence of pollution policy, and permits us to derive specific conditions on environmental, taste and political parameters under which harmonization is unambiguously bad for either welfare or the environment.

Because environmental quality is only one factor determining individual utility, we also examine the impact of harmonization on global welfare. Again, we find that whether harmonization raises or lowers global welfare depends on parameter values. For example, if a sufficiently large component of the damages from emissions are felt only locally, and if politicians are captured by dirty industry, harmonizing tailpipe policy unambiguously *hurts* both the environment and global welfare.

2 Model

Consider Home and Foreign, large open economies exposed to tailpipe pollution[10] that (potentially) trade clean and dirty goods with one another. Each country is endowed with aggregate endowments of capital, K and K^*, which are owned heterogeneously by Home's N citizens and Foreign's N^* citizens respectively; let K_i denote the capital endowment of Home citizen i with analogous definition for K_i^*. In what follows, let asterisks denote values for Foreign. Capital can be used to produce goods for domestic consumption or for export. Define by K_E the total amount of capital employed producing dirty goods for export from Home; if $K_E < 0$ then Home is a net importer of dirty goods.

Output of dirty goods depends on the amount of capital employed and the pollution intensity of final products. Defining e as emissions per unit of consumption, then total output of dirty goods produced for the Home market is $Q = f(e)[K - K_E]$ where f is an increasing, concave function. Let q_i denote Home citizen i's dirty good consumption; in equilibrium $Q = \sum_{i=1}^{N} q_i$ and similarly for Foreign. So as to round out the model, we assume Home and Foreign citizens are also exogenously endowed with units of a clean good Y.

Citizens are assumed to have quasi-linear preferences over private goods and to suffer disu-

[10] As tailpipe emissions are generated when dirty goods are consumed, the pattern of actual emissions is determined by where the consumers of dirty goods, not the producers, are located.

tility from both local and overseas emissions. In specific, denote the utility of Home citizen i by[11]

$$U_i = v(q_i) + y_i - \beta[Z + \xi Z^*]$$

where $v(\cdot)$ is an increasing, strictly concave function, y_i is individual consumption of clean goods, Z and Z^* are emissions generated at Home and in Foreign, and $\xi \in [0,1]$ is the coefficient of transboundary transmission of emissions. For instance, if $\xi = 1$ then pollution is perfectly global: citizens of Home and Foreign suffer equally from emissions in each country; at the other extreme, if $\xi = 0$ then pollution is perfectly local. In our analysis we focus largely on cases in between these two extremes, as we believe this accurately describes most transboundary environmental problems.[12] Similarly, the utility of a Foreign citizen j is given by $U_j^* = v(q_j^*) + y_j^* - \beta[Z^* + \xi Z]$.

We assume countries are open to free trade and that output markets are perfectly competitive. Citizens choose consumptions of dirty and clean goods to maximize utility taking the price of dirty goods P and regulation as exogenous. Conditional on sufficient individual income[13] $I_i = \pi K_i + Y_i$, where

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

is the return earned by capital, this generates (quasi-) indirect utility functions

$$W_i = v(q) - Pq + \pi K_i + Y_i - \beta[Z + \xi Z^*] \tag{2}$$

[11] Income effects are notably absent in this formulation of preferences. This vastly simplifies analysis of the political economy of environmental regulation. Readers interested in the overlap between income effects and political influence in open economy models of environmental regulation are directed to McAusland (2003a).

[12] Consider, e.g., the activities responsible for the principle greenhouse gas carbon dioxide: the burning of coal, oil and natural gas. These same activities generate other pollutants with purely local effects: burning coal and gasoline creates ground level ozone, harmful to humans and plants; combusting gasoline and oil generates carbon monoxide, low concentrations of which cause dizziness; and burning any of these releases volatile organic compounds, some of which are carcinogenic. Similarly, habitat conversion is the leading cause of species extinction worldwide, and creates global losses of associated intrinsic and pharmaceutical values. However habitat conversion also reduces flood and erosion control, with purely local impacts. And finally, the long range problem of acidic deposition, which harms lakes, streams, forests and buildings, is caused by emissions of sulphur dioxide and nitrous oxides. Those same pollutants also contribute to smog, which has a more geographically limited range.

[13] We assume that all $i = 1, \ldots, N$ and $j = 1, \ldots, N^*$ have clean capacity endowments sufficiently large for this condition to be met.

in which $q = f(e)[K - K_E]/N$ (we drop the subscripts on individual consumptions from here forward), $q^* = f(e^*)[K^* + K_E]/N^*$ and so

$$Z = \bar{e}f(\bar{e})[K - K_E] \ , \quad Z^* = \bar{e}^* f(\bar{e}^*)[K^* + K_E]. \tag{3}$$

Finally, we note that in equilibrium arbitrage requires $\pi = \pi^*$ where $\pi^* \equiv P^* f(e^*)$: the rates of return earned by capital employed in producing for either market must be equal in equilibrium.

2.1 Regulation

In this model, the instrument by which Home regulates local emissions is a cap $\bar{e}$ on emissions per unit of the dirty good consumed locally.[14] That is, if a producer wants to sell the dirty good in Home, its goods must not exceed the cap $\bar{e}$, regardless of where the goods are produced.[15] Similarly, denoting by $\bar{e}^*$ the Foreign cap, if a Home producer wants to export goods to Foreign, those goods cannot generate higher per unit emissions than $\bar{e}^*$.

We assume emissions policy is set in each country via a generic political process. In particular, we introduce political agents D and D^* with endowments (K_D, Y_D), (K_D^*, Y_D^*) and define W_D as (2) and W_D^* as its parallel for Foreign when evaluated at these respective endowments. We point out that postulating a generic political objective function of this kind is consistent with three popular models of political economy—majority rules, an uncontested minority elite as in Deacon (1999), and the political contributions approach of Grossman and Helpman (1994) with a single lobby group. To confirm this, in Appendix A we show that the objective functions of the political agent(s) in each of these models of political economy is a monotonic transformation

[14] Because production exhibits constant returns to scale (i.e. there are no fixed costs associated with producing goods with different characteristics), f is increasing, and producers are atomistic, no firm will sell goods in a market that over-comply with that market's emission cap.

[15] This is consistent with the World Trade Organization's principle of National Treatment, which dictates that product rules must not vary across goods depending on their country of origin.

of (2) when (2) is evaluated at some set of "represented" endowments (K_D, Y_D). In what follows we will alternately refer to the political agents' endowments as the "vested interests" of the politician or as the endowments of her "constituents".[16]

To further simply our exposition we define $k_D = \frac{K_D/K}{1/N}$, which gives the ratio of D's capital endowment to that of a hypothetical 'average' Home citizen. k_D serves as an index of D's relative vested interest the dirty industry: if $k_D > 1$ then D has above-average vested interests in the dirty industry; if instead $k_D < 1$ then D's vested interest in the dirty industry are below her country's average.

Using this definition we can defined D's preferred emission cap $\bar{e}_D$. Using (2) when evaluated at (K_D, Y_D), differentiate W_D with respect to $\bar{e}$ to get

$$\frac{dW_D}{d\bar{e}} = -q\frac{dP}{d\bar{e}} + K_D\frac{d\pi}{d\bar{e}} - \beta\frac{d[Z + \xi Z^*]}{d\bar{e}}. \tag{4}$$

Setting (4) equal to zero defines $\bar{e}_D$; the cap preferred by D^*, denoted $\bar{e}^*_D$, is defined symmetrically. Examining the right hand side of (4) we see that when choosing $\bar{e}_D$, D balances concerns regarding higher consumptions costs and lower capital returns for her constituents versus changes in their damage from pollution. Moreover, assuming the second order condition for an interior optimum holds[17], then

$$\text{sgn}\left[\frac{d\bar{e}_D}{dK_D}\right] = \text{sgn}\left[\frac{d\pi}{d\bar{e}}\right]. \tag{5}$$

Thus whenever weakening environmental regulation (i.e. raising $\bar{e}$) raises the return to capital owners, D's preferred emission cap is larger the greater is the capital endowment of her constituents.

[16] As shown in Appendix A, under majority rules K_D is simply the capital endowment of the median voter; with a minority elite K_D is the average capital endowment of the members of the elite; in a political contributions model with a single lobby group, $K_D = \frac{K+\gamma\sum_l^L K_l}{\gamma L+N}$ where γ is the incumbent government's weight on contributions and L is the exogenously determined number of members in the lobby group.

[17] Sufficient conditions for local concavity of W_D at any extremum in $\bar{e}$ are discussed in Appendix B.

3 Decentralized Policy

We start by considering the emission caps that would be set by the political agents if countries set emission policy unilaterally. We assume that in the non-cooperative setting each policy maker takes its neighbor's emission cap as exogenous (and so we concentrate on the Nash equilibrium), and so changes in $\bar{e}$ affect π^* and Z^* only indirectly via K_E. Differentiating the arbitrage condition taking into consideration P and P^* are functions of q and q^* respectively gives[18]

$$\frac{d\pi}{d\bar{e}} = \frac{Pf'(\bar{e})\lambda[\epsilon - 1]}{\epsilon}, \quad \frac{dK_E}{d\bar{e}} = -\frac{\sigma[\epsilon - 1]}{\bar{e}}\lambda[1-\lambda]K^W \tag{7}$$

where $\lambda = \frac{K-K_E}{K^W}$ is the share of world capital $K^W = K + K^*$ devoted to producing dirty goods for the Home market, $\sigma \equiv \frac{f'e}{f}$ is the elasticity of production with respect per unit emissions and $\epsilon = -\frac{dP}{dq}\frac{q}{P}$ the price elasticity of demand. So as to simplify subsequent analysis, we assume σ and ϵ are each constant; in particular we assume $f(e) = e^\sigma$ and $v(q) = \frac{\epsilon}{\epsilon-1}q^{\frac{\epsilon-1}{\epsilon}}$ generating $P = q^{-\frac{1}{\epsilon}}$ and $P^* = q^{*-\frac{1}{\epsilon}}$.

Examining (7), we see $\frac{d\pi}{d\bar{e}}$ is positive and $\frac{dK_E}{d\bar{e}}$ negative only so long as $\epsilon > 1$. That is, stricter local environmental regulation lowers capital returns and makes Home a less attractive place to sell dirty goods only if $\epsilon > 1$ (consumer demand is elastic). This is because if demand were instead inelastic, the price rise that accompanies a reduction in $\bar{e}$ would more than offset the reduction in productivity, *raising* the profitability of the local dirty goods industry. As we are interested in the case in which pollution regulation reduces profitability of the dirty industry, we restrict our attention to the case of $\epsilon > 1$ for the remainder of this paper.[19,20]

[18] Other relations of interest are as follows:

$$\frac{dP}{d\bar{e}} = -\frac{P\sigma}{\epsilon\bar{e}}[\lambda + \epsilon[1-\lambda]], \quad \frac{d[Z+\xi Z^*]}{d\bar{e}} = f(\bar{e})[K-K_E][1+\sigma] + [\xi\bar{e}^* f(\bar{e}^*) - \bar{e}f(\bar{e})]\frac{dK_E}{d\bar{e}}. \tag{6}$$

[19] If demand for dirty goods were price inelastic then the emission cap would serve as a collusive mechanism for the dirty industry. When $\epsilon < 1$ we are unable to verify the second order condition for an interior optimum in $\bar{e}$, however if it were satisfied then D would prefer a stricter emission cap the larger is her capital endowment. Readers are directed to Leidy and Hoekman (1993) who study the potential for polluting firms to gain from environmental regulation.

[20] Given that we restrict ourselves to consider only cases in which $\epsilon - 1 > 0$, a survey of demand elasticities

We are interested in the case in which Home and Foreign are identical. This implies $K = K^*$, $N = N^*$. We now consider the non-cooperative equilibrium emission caps that would be set if both the political processes and the vested interests represented by the political agent in each country were also identical: $K_D = K_D^*$. Then by symmetry $\bar{e}_D = \bar{e}_D^*$ generating $K_E = 0$ and $\lambda = 1/2$ in equilibrium. Define the Nash equilibrium emission caps when countries are perfectly symmetric as $\bar{e}_D^N$, $\bar{e}_D^{N*}$. Substituting values for $\frac{dP}{d\bar{e}}$, $\frac{dK_E}{d\bar{e}}$, and $\frac{d[Z+\xi Z^*]}{d\bar{e}}$ from above into (4), setting $\frac{dW_D}{d\bar{e}}$ equal to zero and solving for $\bar{e}_D$ gives[21]

$$\bar{e}_D^N = \bar{e}_D^{N*} = \left\{ \frac{k_D[\epsilon - 1] + \epsilon + 1}{\Delta \frac{2\epsilon}{1+\xi} \left[1 + \frac{\sigma}{1+\sigma} \frac{\epsilon - 1}{2} [1 - \xi] \right]} \right\}^{\frac{\epsilon}{\epsilon+\sigma}} \tag{8}$$

where $\Delta \equiv \beta N \left[\frac{K}{N} \right]^{1/\epsilon} \frac{1+\sigma}{\sigma} [1 + \xi]$.

We point out that $\bar{e}_D$ depends negatively on β and positively on both K_D and ξ. The intuition underlying the first two relationships is straightforward. β measures the marginal private disutility from pollution; the more damaging is local pollution to D then the more stringent the policy she prefers. The greater is K_D then the greater D's profit base that is hurt by strict environmental regulation and so the more lenient the cap she prefers.

Finally, the negative relationship between $\bar{e}_D$ and ξ reflects a *pollution-shifting* opportunity as in Kennedy (1994). When countries set policy unilaterally, each can use its local emission cap to manage where polluting behavior occurs. Recalling $\frac{dK_E}{d\bar{e}} < 0$, Home can shift polluting

(reported as negative values) suggests our approach is relevant only for some forms of tailpipe pollution. For example, 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, while Hymans (1970) calculates the short run elasticity of automobile expenditures to be between -0.78 and -1.17. Surveying the literature, Graham and Gleister (2002) 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)

[21] If instead the political systems/decision makers differed across countries then D's preferred policy would satisfy $\bar{e}_D = \left\{ \frac{k_D[\epsilon-1]+2[1+(\epsilon-1)(1-\lambda)]}{\beta N \left[\frac{2\lambda K}{N}\right]^{\frac{1}{\epsilon}} \frac{2\epsilon}{\sigma} \left[1+\sigma+\sigma(\epsilon-1)(1-\lambda)\left[1-\xi\left(\frac{1-\lambda}{\lambda}\right)^{\frac{1+\sigma}{\sigma(\epsilon-1)}}\right]\right]} \right\}^{\frac{\epsilon}{\epsilon+\sigma}}$ which is again decreasing in β, increasing in k_D and ξ; the relationship between $\bar{e}_D$ and λ is indeterminate.

behavior abroad by making her country a less attractive place to sell dirty goods. So long as pollution is less than fully transboundary then this shifting of the *location* of polluting activity reduces total pollution suffered in Home, making D prefer stricter local policy than she would if polluting activity occured in a fixed location.

We next examine how $\bar{e}_D^N$ compares with D's preferred emission cap when governments instead harmonize policy explicitly.

4 De Jure Harmonization

As discussed earlier, there is an accepted wisdom that when countries set policy regarding transboundary emissions unilaterally, they fail to take into consideration the full impact of local policy on the global commons. One proposed solution is that countries harmonize their policies; this way governments can be assured that local emission cuts will be matched by overseas clean up and so will take into consideration transboundary aspects of pollution when electing policy. Accordingly, we ask how *de jure* harmonization of Home and Foreign's emission caps would affect the policies preferred by the respective political agents.[22]

When contemplating the emission cap that would give D her highest welfare in a harmonized setting, she again chooses $\bar{e}_D$ so as to equate $\frac{dW_D}{d\bar{e}} = 0$ using (4) but also recognizes that there are new relationships between $\bar{e}$ and P, π, K_E, Z, Z^*. In particular, D recognizes at the outset that, if countries have identical populations and aggregate capital endowments, then when $\bar{e}$ is mandated identical across countries there will be no trade ($K_E = 0$) and so equilibrium prices are given simply by $P = P^* = v'(f(\bar{e})K/N)$ where $\bar{e}$ is the uniform policy. Differentiating the demand function gives $\frac{dP}{d\bar{e}} = -\frac{P\sigma}{\epsilon e}$ and so $\frac{d\pi}{d\bar{e}} = Pf'\left[\frac{\epsilon-1}{\epsilon}\right]$.[23] Setting (4) equal to zero in this

[22] Of course when countries are symmetric in every way we find the Nash policies are already harmonized *de facto*: values for $\bar{e}_D^N$ and $\bar{e}_D^{N*}$ are equal. In this section we instead examine policy choices when governments agree at the outset to make tailpipe policies identical worldwide; that is, when they practice *de jure* harmonization.

[23] Additionally, $\frac{d[Z+\xi Z^*]}{d\bar{e}} = f(\bar{e})[1+\sigma][K+\xi K^*]$. Substituting these values into (4) and rearranging terms

setting and using specific functional forms $P = q^{-1/\epsilon}$, $f = e^{\sigma}$ to solve for $\bar{e}$ gives D's preferred emission cap, $\bar{e}^H_D$, in the harmonized setting[24]:

$$\bar{e}^H_D = \left\{ \frac{k_D[\epsilon - 1] + 1}{\Delta\epsilon} \right\}^{\frac{\epsilon}{\epsilon+\sigma}}, \tag{10}$$

which is easily compared with $\bar{e}^N_D$.

Proposition 1 *There exists ξ^H such that $\bar{e}^N_D > \bar{e}^H_D$ iff $\xi > \xi^H$, where $\xi^H \in (-1, 1)$ and ξ^H is monotonic increasing in k_D.*

Proof: see Appendix C

Proposition 1 is best viewed graphically as in Figure 1. In Figure 1 the horizontal axis indicates the relative vested interests of D's constituents: for $k_D > 1$ then $K_D > \frac{K}{N}$ and so D's constituents have above average vested interests in the dirty industry. When k_D is instead less than unity then D's constituents are linked to the dirty industry predominately as consumers. In Figure 1 the vertical axis represents the degree to which pollution is transboundary. As noted earlier, pollution becomes perfectly global as ξ approaches unity and perfectly local as ξ approaches zero. ξ^H provides a useful division of k_D, ξ space. In Figure 1, for any (k_D, ξ) pairs below/right of the ξ^H curve then harmonization leads to weaker environmental regulation (a larger emission cap); for any (k_D, ξ) pairs above/left of the ξ^H curve then harmonization leads to stricter environmental regulation (a smaller emission cap).

The easiest way to understand the intuition behind Proposition 1 is by considering the three competing effects of harmonization on D's preferred emission cap.

gives

$$\frac{dW^H_D}{d\bar{e}} = q\left[\frac{P\sigma}{\epsilon e}\left[k_D(\epsilon - 1) + 1\right] - \beta N[1 + \sigma][1 + \xi]\right] \tag{9}$$

where the H superscript signifies the harmonization constraint is in place. A sufficient condition for W^H_D to be locally concave in $\bar{e}$ at any extremum is our maintained assumption $\epsilon > 1$: $\frac{d^2W^H_D}{d\bar{e}^2} = -q\left[k_D[\epsilon - 1] + 1\right]\frac{\sigma[\epsilon+\sigma]P}{[\epsilon e]^2} + \frac{f'(\bar{e})}{f(\bar{e})}\frac{dW^H_D}{d\bar{e}}$.

[24] We assume $\bar{e}^H_D$ is indeed the emission cap set by identical Home and Foreign political agents D and D^* when Home and Foreign negotiate a harmonized standard, as would be the case in a Nash Bargaining game in which each side has equal bargaining power, for example.

Firstly, when countries practice harmonization, governments no longer need treat the pollution intensity of overseas consumption as exogenous. While the Home decision maker doesn't worry about the effect of locally generated pollution on the welfare of foreigners, she does take into consideration how changes in the harmonized emission cap alter the pollution intensity of overseas consumption and how that ultimately affects the amount of foreign pollution to which her own country is subjected. Call this the *internalization* effect of harmonization; other things equal it makes D prefer a stricter emission cap (lower $\bar{e}$) provided there is any transboundary component to pollution at all ($\xi > 0$).

Secondly, when countries harmonize, the pollution-shifting motive to set excessively strict emission caps that was present with decentralized policy setting is now absent. The reason is simple: neither country can use emission caps to drive polluting consumption abroad because regulation overseas is mandated to be equally stringent. By eliminating pollution-shifting opportunities, harmonization makes any decision maker prefer *weaker* environmental policy, other things being equal.

And finally, harmonization has an *incidence-redistributing* effect, which affects policy whenever regulators represent constituents with different-from-average vested interests in dirty industry. The logic is as follows. When governments formally harmonize their emission caps, capital owners in a country cannot escape regulation in one country by simply shifting capital into production for export, because local and overseas regulations move in lock-step. Essentially, harmonization eliminates opportunities to hide from tailpipe regulation via exports. Accordingly, capital returns are more sensitive to changes in the emission cap when policy is formally harmonized than when set unilaterally, which translates into the incidence of emissions policy being shifted away from consumers and onto producers. This is the incidence-redistributing effect of harmonization. Whether incidence-redistributing makes D want stricter or weaker emission policy depends on whether D represents predominately producers or consumers of dirty goods. When $k_D > 1$ then the capital endowment represented by D produces more dirty goods than D's constituents want to consume. As harmonization redistributes incidence to producers, D's constituents are therefore hurt and—other things being equal—D wants weaker policy. If instead $k_D < 1$ then D's constituents consume more dirty goods than their capital endowments produce and so are benefited by the shift of incidence away from consumers; other things being equal, this induces D to want stricter policy.

Putting these effects into the context of Proposition 1 and Figure 1, when $k_D > 1$ then unless the internalization effect sufficiently dominates lost pollution-shifting opportunities—i.e. unless ξ is sufficiently close to unity—then harmonization will raise D's preferred emission cap, to the detriment of the environment; this is the outcome in regions I, II and III of Figure 1. Conversely, when k_D is small, unless ξ is very low (such that the loss of pollution-shifting opportunities dominates the internalization effect) then harmonization induces D to prefer stricter policy, to the benefit of the environment; this is the outcome in regions IV, V and VI of Figure 1.

This analysis allows us to make a prediction as to what might be the outcome of current policy disputes in the international arena, such as the brewing dispute between the United States, the European Union, and Japan over fuel-economy standards. Each of these countries has complained that the others' fuel economy standards are unfairly strict.[25] Even though weaker fuel economy standards will likely induce greater emissions of the principle greenhouse gas CO_2, burning of fossil fuels also has significant local effects (recall footnote 12) and so our analysis suggests that these governments may well choose to harmonize fuel economy standards down instead of up.

[25] See Retallack and Sobhani (2001).

5 Global Welfare

The preceeding discussion focused on environmental effects of harmonization, and we derived conditions under which explicit harmonization may be bad for the global environment. But environmental quality is only one aspect of overall utility, and so far we have been silent on this issue. In this section we address the more fundamental question of how harmonization affects global welfare. For this we use a Utilitarian metric[26], defining global welfare as $W^G = \sum_i^N [v(q) - Pq + Pf(\bar{e})K_i - \beta[Z + \xi Z^*]] + \sum_j^{N^*} [v(q^*) - P^*q^* + P^*f(\bar{e}^*)K_j^* - \beta[Z^* + \xi Z]]$.

Because Home and Foreign are perfectly symmetric the emission caps that maximize W^G are identical for Home and Foreign. Denote this uniform cap as $\bar{e}^G$, which solves $\frac{dW^G}{d\bar{e}} = 0$:

$$\bar{e}^G = \left\{ \frac{1}{\Delta} \right\}^{\frac{\epsilon}{\epsilon+\sigma}}. \tag{11}$$

Comparing $\bar{e}^G$ with $\bar{e}_D^N$ and $\bar{e}_D^H$ we obtain the following propositions.

Proposition 2 *The emission caps set by symmetric decision makers D, D^* in the decentralized setting are laxer than those which maximize global welfare—i.e. $\bar{e}_D^N > \bar{e}^G$—if and only if $\xi > \xi^G$ where $\xi^G \in (-1, 1)$ and ξ^G is monotonic decreasing in k_D.*

Proof: See Appendix C.

Proposition 3 *For $\epsilon > 1$, the emission cap preferred by decision maker D in the presence of* de jure *harmonization is laxer than that which maximizes global welfare—i.e. $\bar{e}_D^H > \bar{e}^G$—if and only if $k_D > 1$.*

Proof: Proposition 3 follows directly from comparison of $\bar{e}_D^H$ and $\bar{e}^G$ using (10) and (11).

Using Proposition 2, ξ^G similarly partitions k_D, ξ space, this time into parameter pairs for which the non-cooperative policy is excessively strict or weak from a Utilitarian welfare perspective. In Figure 1, all points above/right of the ξ^G partition correspond to levels of transboundary pollution transmission and vested interests generating a non-cooperative emission cap $\bar{e}_D^N$ laxer than that which maximizes joint welfare: when $\xi > \xi^G$ then $\bar{e}_D^N > \bar{e}^G$. Similarly, all

[26] We acknowledge that there are many other possible social welfare functions that could be considered, but examine only the Utilitarian social welfare function in the interest of brevity.

k_D, ξ pairs below/left of the ξ^G partition generate excessively strict policy: when $\xi < \xi^G$ then $\bar{e}_D^N < \bar{e}^G$.

Further, Proposition 3 shows that anytime $k_D > 1$ then harmonized policy is too strict from a global welfare perspective. This allows us to further partition k_D, ξ space into parameter pairs under which harmonization helps/hurts the environment, and/or raises/lowers global welfare.

These two partitions are useful in identifying 'best' and 'worst' case scenarios in terms of the usefulness of *de jure* harmonization. For example, whenever (k_D, ξ) fall in Region VI in Figure 1, harmonization is beneficial to both the environment and global welfare: pollution is sufficiently transboundary that the internalization effect dominates the incidence-redistributing and pollution-shifting effects, inducing governments to lower $\bar{e}$ toward $\bar{e}^G$. However, when either ξ is lower and/or k_D larger, countries find themselves in Region I, in which harmonization is instead *harmful* on two counts. As $k_D > 1$ then incidence-redistributing makes weak policy more attractive politically, and because ξ is not large, the loss of pollution-shifting opportunities dominates the internalization effect: the end result is that harmonization drives $\bar{e}$ up. And as $k_D > 1$ then $\bar{e}_D^N$ was excessively weak to begin with, harmonization drives $\bar{e}$ even further away from $\bar{e}^G$, to the detriment of both the environment and global welfare.

These results bring home the central point of this paper. *De jure* harmonization by identical countries need not be beneficial to either the environment or global welfare when transboundary transmission of pollution is less than perfect and/or policy is set by political agents captured by dirty industry. When pollution is fully transboundary (i.e. $\xi = 1$), we find in this setting that the internalization effect is always sufficiently strong and so harmonization is unambiguously good for the environment. However, if there is instead there is some purely local component to pollution then outcomes in which harmonization harms either welfare and/or the environment cannot be ruled out. This suggests that harmonizing policy by similar countries regarding use of Chlorofluorocarbons (CFCs), for example, which don't generate local damages but which harm stratospheric ozone, is likely beneficial. However for environmental problems with predominately local effects—such as poisonings and ground water contamination associated with use of pesticides and insecticides—our analysis suggests that international policy harmonization may instead be bad for both aggregate welfare and the environment.

6 Additional Instruments

Sections 2 through 4 consider the use of only a single instrument. As we see there, when behaving non-cooperatively political agents use that single instrument to manage both the pollution intensity of consumption as well as its location. This raises the obvious question of whether the potentially negative environmental and welfare effects of harmonization would be undone if agent's instead had access to a second instrument to manage the location of consumption directly. In this section we consider the location tax t and emission cap $\bar{e}$ that would be set by a political agent with vested interests D when policy setting is decentralized and when it is harmonized. We anticipate the results below by pointing out here that allowing for location taxes—taxes set either unilaterally or collectively—does not eliminate the potential for harmonizing the emission cap to both harm the environment and reduce global welfare.

Consider a location tax levied on the base materials used to produce consumption goods; denote the location taxes in Home and Foreign by t and t^*.[27] In equilibrium $Pf(\bar{e}) - t = P^*f(\bar{e}^*) - t^*$ while D's utility is given by

$$W_D = v(q) - Pq + [Pf(\bar{e}) - t]K_D + \frac{t[K - K_E]}{N} - \beta[Z + \xi Z^*]. \tag{12}$$

[27] We examine a location tax rather than a direct consumption tax because the former is more direct and analytically more tractable; the direct consumption tax equivalent to the location tax is simply $\frac{t}{f(\bar{e})}$.

Maximizing with respect to t and $\bar{e}$ respectively, taking t^* and $\bar{e}^*$ as exogenous, generates[28]

$$t_D = \beta N \bar{e} f(\bar{e})[1-\xi] - [k_D - 1]\,\frac{Pf(\bar{e})}{\epsilon},$$

$$\bar{e}_D^{Nt} = \left[\frac{1+\xi}{\Delta}\right]^{\frac{\epsilon}{\epsilon+\sigma}} \tag{13}$$

where we have again assumed perfect symmetry across Home and Foreign. Notice D sets the tax at a rate equal to the local benefit of reduced Home pollution—given by $\beta N \bar{e} f(\bar{e})[1-\xi]$—plus or minus a term reflecting political economy concerns. Since t reduces returns to capital and is rebated to Home citizens on a per capita basis, if D's capital endowment is above/below average, then she sets the tax rate below/above the local social benefit of shifting pollution overseas.

Now compare $\bar{e}_D^{Nt}$ with $\bar{e}^G$.

Proposition 4 *When countries also employ location taxes, the emission caps chosen unilaterally by symmetric decision makers are weaker than the cap which maximizes global welfare—i.e.* $\bar{e}_D^{Nt} > \bar{e}^G$*—whenever* $\xi > 0$.

Proof: Comparing (11) and (13) reveals $\bar{e}_D^{Nt} > \bar{e}^G$ whenever $1 + \xi > 1$.

Proposition 4 shows that when the political agents have access to location taxes, they set excessively weak emission caps (relative to $\bar{e}^G$) *whenever* emissions are transmitted internationally. This follows because governments can use unilaterally-set location taxes to manipulate where polluting activity occurs as well as to transfer rents for political purposes. They are then unencumbered by political and pollution-shifting concerns when setting the local emission cap and so set the cap to maximize local welfare, ignoring any damage their emissions may have on pollution overseas. Consequently, when location taxes are used the non-cooperative emission cap is always too lax from a global welfare perspective.

[28] For a full derivation see Appendix D.

6.1 Comparing $\bar{e}_D^{Nt}$ with Harmonized Policy

Next consider the emission cap and tax that would be preferred by D when countries agree to harmonize policy. We consider two[29] different types of harmonization: harmonize $\bar{e}$ and fix $t = 0$, or instead harmonize $\bar{e}$ *after* location taxes have been set unilaterally. Conveniently, the harmonized emission caps that will be set in each of these two cases are identical and equal to $\bar{e}_D^H$ as defined by (10); this is verified in Appendix E.

As before, conditions under which $\bar{e}_D^H$ is less or greater than $\bar{e}_D^{Nt}$ are easily found.

Proposition 5 *There exists ξ^{Ht} such that $\bar{e}_D^{Nt} > \bar{e}_D^H$ if and only if $\xi > \xi^{Ht}$; moreover, ξ^{Ht} is monotonic increasing in k_D.*

Proof: Comparing (13) and (10) gives $\bar{e}_D^{Nt} > \bar{e}_D^H$ if and only if $\xi > [k_D - 1]\frac{\epsilon-1}{\epsilon} \equiv \xi^{Ht}$. Because $\frac{d\xi^{Ht}}{dk_D} = \frac{\epsilon-1}{\epsilon} > 0$ then ξ^{Ht} is monotonic increasing in k_D whenever $\epsilon > 1$. Additionally, for $\epsilon > 1$, $\text{sgn}[\xi^{Ht}] = \text{sgn}[k_D - 1]$.

Propositions 4 and 5 are represented graphically in Figure 2, which again plots the relative vested interests of D against the environmental parameter ξ. We see that the parameter space over which the political agent represents capitalists (i.e. $k_D > 1$) can again be divided into regions effectively representing 'best' and 'worst' case scenarios regarding the benefits of harmonizing. For example, in Region B, where the political agents are moderately captured by capital owners ($k_D > 1$) and the degree of transboundary transmission is high, then harmonization both improves the environment and raises global welfare. However when politics favor

[29] There are two alternate forms of harmonization that we could consider, however neither eliminates the potential for harmonizing the emission cap to both harm the environment and reduce global welfare.

The first alternative involves countries harmonizing both $\bar{e}$ and t (without the constraint of $t = 0$). In this case, it is easy to show that the first order condition for D's choice of $\bar{e}$ would have the same basic form as when harmonizing under the constraint of $t = t^* = 0$. However, because D would choose $t = -\infty$ if $K_D > \frac{K}{N}$—so as to extract maximum rents from below-average capital owners—then our maintained assumption that all consumers can afford their desired level of dirty good consumption would be violated.

A second alternative involves countries first harmonizing $\bar{e}$ and second setting their location taxes unilaterally. At the second stage political agents max W_D taking $\bar{e} = \bar{e}^*$ as fixed and set $t = \beta N \bar{e} f(\bar{e})[1 - \xi] - P f(\bar{e})[k_D - 1]$. In the first stage harmonizing governments recognize that the symmetry of the decision makers at the second stage will generate $t = t^*$ and $K_E = 0$ and so choose $\bar{e}$ to maximize W_D treating exports as zero. After some manipulation, this gives a maximizing argument hereafter denoted $\bar{e}' = \left[\frac{[\epsilon-1]\left[(k_D-1)^2 + k_D + \frac{1}{\epsilon-1}\right]}{\Delta\frac{\epsilon}{1+\xi}[k_D[1-\xi]+2\xi]}\right]^{\frac{\epsilon}{\epsilon+\sigma}}$. Comparing this cap with $\bar{e}_D^{Nt}$ we find that whether $\bar{e}_D^{Nt} \gtrless \bar{e}'$ depends on whether $[2 - k_D]\,\xi \gtrless [\epsilon-1]\left[(k_D - 1)^2 + k_D + \frac{1}{\epsilon-1}\right] - k_D$, revealing no simple relationship between k_D, ξ and the relative magnitudes of $\bar{e}_D^{Nt}$ and $\bar{e}'$.

capitalists but the degree of transboundary transmission is sufficiently low—as in Region A of Figure 2—then harmonization both harms the environment and reduces global welfare. Notably, when $N > \frac{2\epsilon-1}{\epsilon-1}$ then ξ 'sufficiently low' includes $\xi = 1$! That is, in this setting, when both N and k_D are sufficiently large then harmonization can hurt the environment even when pollution is perfectly global.

The explanation for the results above is much the same as in Section 4 (where location taxes were not used). In the current setting governments no longer need to manipulate their emission caps for the purposes of pollution-shifting since location taxes accomplish this. Thus whether harmonization weakens emission caps depends only on the relative magnitude of the incidence-redistributing and internalization effects, which work in opposite directions whenever $k_D > 1$. Moreover, since governments captured by dirty industry set unilateral caps that are too weak (relative to $\bar{e}^G$) then *whenever* harmonization generates weaker regulation in this setting, it also reduces global welfare.

This confirms our earlier claim that harmonization's possibly negative effects on global welfare and the environment are not merely artifacts of our previous assumption that governments do not have access to instruments capable of directly managing where polluting activity occurs. As we have shown in this section, even when location taxes are available in either the decentralized or harmonized settings the result persists that harmonization will weaken tailpipe regulation if political influence is sufficiently strong relative to the degree of transboundary pollution transmission.

7 Conclusions

We have used a purposely simple model to examine the environmental and welfare effects of policy harmonization. We consider the special case of policy setting in countries that are identical in every way—their endowments, their preferences, their technologies, and their political structures. Focusing on the problem of tailpipe pollution, we develop a generic treatment of political economy and examine three competing channels through which international policy harmonization affects the preferences of governments.

Firstly, there is an incidence-redistributing effect: by eliminating opportunities to evade local regulations via exports, harmonization shifts incidence of tailpipe regulation onto producers; whether this makes weak policy more attractive depends on whether the political agent represents constituents with above- or below-average vested interests in the dirty industry. Secondly, harmonization has an internalization effect, whereby regulators effectively internalize the transboundary component of pollution. And finally, harmonization eliminates pollution-shifting opportunities: when all governments agree outright to set identical policies, policy makers in one country cannot manipulate their policy stringency relative to that in other countries so as to drive polluting activity abroad.

We find that a 'worst case' scenario of sorts occurs when either governments are sufficiently captured by dirty industry or a sufficient component of the damages from emissions are only local. In these cases, the incidence-redistributing effect makes weak policy attractive to the captured government while lost pollution-shifting opportunities dominate the internalization effect. Moreover, since governments captured by dirty industry will set excessively weak harmonized policy to begin with, harmonization in such cases both *weakens* tailpipe regulation and drives policy even further from its global-welfare maximizing level, to the detriment of both the environment and aggregate welfare.

These results indicate that harmonizing international policy regarding some environmental problems may be far from innocuous even when the countries in question are perfectly symmetric. Our results suggest that when regulators are markedly captured by dirty industry then harmonization is likely to weaken policy and reduce aggregate welfare unless the pollutants in question have only small local-only effects; as would be the case with, for example, use of CFCs and the Montreal Protocol. However, for pollutants with significant local-only effects—pesticide use for example—our results suggest harmonization will be welfare reducing and environmentally degrading unless countries find themselves in the (likely uncommon) scenario that regulators systematically *under*-represent the interests of producers.

References

Aidt, Toke. 1998. "Political Internationalization of Economic Externalities and Environmental Policy," *Journal of Public Economics* 69: 1-16.

Antweiler, Werner, Brian Copeland and Scott Taylor. 2001. "Is Free Trade Good for the Environment?" *American Economic Review,* 91: 877-908.

Bernheim, B. Douglas and Michael D. Whinston. 1986. "Menu Auctions, Resource Allocation, and Economic Influence," *Quarterly Journal of Economics,* 101(1): 1-31.

Bhagwati, Jagdish and T.N. Srinivasan. 1996. "Trade and the Environment: Does Environmental Diversity Detract from the Case for Free Trade?" in Jagdish Bhagwati and Robert E. Hudec, eds., *Fair Trade and Harmonization: Prerequisites for Free Trade?*, Volume 1. Cambridge, MA: MIT Press.

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

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

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

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

Hillman, Ayre L. and Heinrich W. Ursprung. 1992. "The influence of environmental concerns on the political determination of trade policy," in Kym Anderson and Richard Blackhurst, eds., *The Greening of World Trade Issues.* London: Harvester Wheatsheaf.

Huizinga, Harry and Søren Bo Nielsen. 2002. "The coordination of capital income and profit taxation with cross-ownership of firms," *Regional Science and Urban Economics* 32: 1-26.

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

Kennedy, P.W. 1994. "Equilibrium Pollution Taxes in open Economies with Imperfect Competition," *Journal of Environmental Economics and Management* 27: 49-63.

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.

Markusen, James R., Edward R. Morey, and Nancy Olewiler. 1995. "Competition in regional environmental policies when plant locations are endogenous," *Journal of Public Economics* 56: 55-77.

McAusland, Carol. 2002. "Cross-Hauling of Polluting Factors," *Journal of Environmental Economics and Management* 44: 448-470.

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

McAusland, Carol. 2003b. "Trade, Politics, and the Environment: Tailpipe vs. Smokestack," mimeo, University of California, Santa Barbara.

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

Rauscher, Michael. 1992. "International economic integration and the environment: the case of Europe," in Kym Anderson and Richard Blackhurst, eds., *The Greening of World Trade Issues.* London: Harvester Wheatsheaf.

Retallack, Simon and Ladan Sobhani. 2001. "The impact of economic globalisation on global climate," *Transnational Associations* 3: 157-165.

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.

Smith, Carl. 2001. "Pesticide Exports from U.S. Ports, 1997-2000," *International Journal of Occupational and Environmental Health* 7(4): 266-274

Stokey, Nancy. 1998. "Are There Limits to Growth?" *International Economic Review* 39: 1-31.

Wilson, John D. 1997. "Capital Mobility and Environmental Standards: Is There a Theoretical Basis for a Race to the Bottom?" in Jagdish Bhagwati and Robert E. Hudec, eds., *Fair Trade and Harmonization: Prerequisites for Free Trade?*, Volume 1. Cambridge, MA: MIT Press.

Ulph, Alistair. 1997. "International environmental regulation when national governments act strategically," in John G. Braden and Stef Proost, eds., *The Economic Theory of Environmental Policy in a Federal System.* Cheltenham, UK: Edward Elgar, pp. 66-96.

Appendix A: Generic Political Model

In section 2 we introduced policy decision makers—indexed by D and D^*—for each country. Below we show that majority rule, political elite and political contributions models of political economy each generate objective functions that are monotonic transformations of (2) when evaluated at some set of represented endowments (K_D, Y_D) or (K^*_D, Y^*_D). Define W_D and W^*_D as (2) and its parallel for Foreign when evaluated at these respective endowments, and define by $\bar{e}_D$ and $\bar{e}^*_D$ the respective maximizing arguments.

Majority Rule

Consider a majority rule referendum on environmental policy in which there is full information, certainty, single peaked preferences, and costless voting. Then the voting equilibrium is defined as a value $\bar{e}_{MR}$ for which no set of voters strictly preferring a distinct alternative $\tilde{e}$ to $\bar{e}_{MR}$ has more members than the number of voters not strictly preferring $\tilde{e}$ to $\bar{e}_{MR}$. If the number of voters is odd and there are no abstentions, then policy in the majority rule equilibrium is unique and is the policy preferred by the median voter. In the present model, the median voter would be an individual with the median capital endowment(and her endowments give K_D, Y_D); because endowments are exogenous then the identity of the median voter is invariant to stringency overseas. Using (5), the smaller is the capital endowment of the median voter—perhaps reflecting concentrated ownership of capital in the hands of few—the stricter will be the equilibrium emission cap.

Political Elite

Following Deacon (1999), an uncontested minority elite with $M < N$ members that is constrained to set a single policy for all dirty production will choose $\bar{e}$ so as to solve

$$\max_{\bar{e}} \sum_{m=1}^{M} [v(q) - Pq + Pf(\bar{e})K_m + Y_m - \beta[Z + \xi Z^*]]$$

or its equivalent

$$\max_{\bar{e}} M \left[v(q) - Pq + Pf(\bar{e}) \frac{\sum_{m=1}^{M} K_m}{M} + \frac{\sum_{m=1}^{M} Y_m}{M} - \beta[\bar{e}f(\bar{e})[K - K_E] + \xi \bar{e}^* f(\bar{e}^*)[K^* + K_E]] \right]$$

which is isomorphic to the problem of a single decision maker D maximizing (2) with endowments $K_D = \frac{\sum_{m=1}^{M} K_m}{M}$, $Y_D = \frac{\sum_{m=1}^{M} Y_m}{M}$. Interpreting this in light of (5), the larger is the average capital endowment of members of the elite $\frac{\sum_{m=1}^{M} K_m}{M}$ then the weaker is the environmental policy that will be preferred (holding $\bar{e}^*$ constant).

Lobby Group Contributions

Finally, consider the case in which lobby groups influence the stringency of policy set by an incumbent local government. Using the political contributions approach of Grossman and Helpman (1994), lobby groups make policy contingent contributions similar to a menu auction as in Bernheim and Whinston (1986). The incumbent, I, then sets policy so as to maximize some linear combination of political contributions and the aggregate welfare of citizens. Defining $C_k(\bar{e})$ as the policy contingent contribution to the incumbent from lobby group g, then when the incumbent chooses policy level $\bar{e}$, she receives welfare

$$W_I = \gamma \sum_{g}^{G} C_g(\bar{e}) + \sum_{i}^{N} W_i(\bar{e}; \bar{e}^*)$$

where γ is a parameter, G is the total number of lobby groups, and $W_i(\bar{e}; \bar{e}^*)$ are the welfare functions of individual citizens as defined by (2) when evaluated at $\bar{e}, \bar{e}^*$. In this framework, each lobby group chooses its contribution schedule so as to maximize the welfare of its members subject to a participation constraint for the incumbent, and taking the contribution schedules of competing lobby groups and overseas policy stringency as exogenous. If every citizen is a member of a lobby group then the contributions offset one another and the incumbent chooses policy so as to maximize $\sum_i^N W_i$. A more interesting case is where only a subset of citizens are represented by a lobby group; given our model with only two industries, we focus on the case in which only one industry—either the dirty goods or the clean goods industry—is organized. With only one lobby group present, that group's contribution schedule would be set so as to induce the policy vector

$$e' \in \arg\max_{\bar{e}} \sum_l^L [v(q) - Pq + Pf(\bar{e})K_l + Y_l - \beta[\bar{e}f(\bar{e})[K - K_E] + \xi\bar{e}^* f(\bar{e}^*)[K^* + K_E]]] - C$$

subject to the constraint[30] $\gamma C + \sum_i^N W_i(e'; \bar{e}^*) \geq \max_{\tilde{e}} \sum_i^N W_i(\tilde{e}, \bar{e}^*)$; L is the number of members in the lobby group. Since the lobby group would not contribute more than the minimum required, the constraint can be treated as binding. This gives an expression for the lobby group's contributions C that can be substituted into the objective function above; collecting terms gives the equivalent policy vector

$$\begin{aligned} e' \in \arg\max_{\bar{e}} \frac{\gamma L + N}{\gamma}\{v(q) - Pq \quad + \quad & Pf(\bar{e})\frac{K + \gamma\sum^L K_l}{\gamma L + N} + \frac{Y + \gamma\sum^L Y_l}{\gamma L + N} \\ & -\beta[\bar{e}f(\bar{e})[K - K_E] + \xi\bar{e}^* f(\bar{e}^*)[K^* + K_E]]\} - \delta \qquad (14) \end{aligned}$$

where $\delta \equiv \max_{\tilde{e}} \sum_i^N W_i(\tilde{e}; \bar{e}^*)$ is a constant. Assuming, as is the practice in these models, that membership in the lobby group is exogenous then the objective function in (14) will be maximized by the same policy as would maximize (2) for a decision maker with endowments $K_D = \frac{K + \gamma\sum_l^L K_l}{\gamma L + N}$, $Y_D = \frac{Y + \gamma\sum_l^L Y_l}{\gamma L + N}$. Given (5) the stringency level induced by political contributions is increasing in the aggregate capital endowments of the lobby group's members. A larger

[30] The incumbent will accept contribution C only if the weighted sum of contributions plus citizen welfare given prescribed emission cap e' is at least as great as the maximum welfare the incumbent can deliver when unconstrained.

weight γ placed by the incumbent on the relative importance of lobby group contributions has an ambiguous effect on stringency:

$$\frac{d\bar{e}_D}{d\gamma} = \frac{d\bar{e}_D}{dK_D}\frac{dK_D}{d\gamma} = \frac{\frac{d\pi}{d\bar{e}}}{-W^D_{\bar{e}\bar{e}}}\left[\frac{LN\left[\frac{\sum^L K_l}{L} - \frac{K}{N}\right]}{(\gamma L + N)^2}\right].$$

For example, if the lobby group has as members all local owners of capital then $\sum^L K_l = K$; so long as $L < N$ then $\frac{d\bar{e}_D}{d\gamma} > 0$ whenever $\frac{d\pi}{d\bar{e}} > 0$. Conversely, if the mean capital endowment of lobby group members is below the Home average—i.e. $\frac{\sum^L K_l}{L} < \frac{K}{N}$, as would be the case if the lobby group instead represented only citizens without any capital holdings—then a heavier weight placed by the incumbent on contributions would generate a preference for weaker emissions policy. Given $K_D = \frac{K+\gamma\sum_l^L K_l}{\gamma L+N}$ in this case, note that $k_D > 1$ if and only if $\frac{\sum_l^L K_l}{L} > \frac{K}{N}$.

Appendix B: Local Concavity of W_i in $\bar{e}$

Using (4), (6) and (7), we can rewrite $\frac{dW}{d\bar{e}}$ in the non-cooperative setting as $\frac{dW}{d\bar{e}} = a[AB - \beta NC]$ where $A \equiv \frac{\sigma/\epsilon}{\left[\frac{K^W}{N}\right]^{1+\frac{1}{\epsilon}}\lambda^{\frac{1}{\epsilon}}\bar{e}^{\frac{\epsilon}{\epsilon+\sigma}}} > 0$, $B \equiv K_i[\epsilon-1] + \frac{K^W}{N}[1+[\epsilon-1][1-\lambda]] > 0$, $C \equiv 1+\sigma+\sigma[\epsilon-1][1-\lambda]\left[1-\xi\left[\frac{1-\lambda}{\lambda}\right]^{\frac{1+\sigma}{\sigma[\epsilon-1]}}\right]$ which is also positive at $\bar{e}_i$. Differentiating $\frac{dW_i}{d\bar{e}}$ with respect to $\bar{e}$ gives

$$\frac{d^2W_i}{d\bar{e}^2} = \frac{1}{q}\frac{dq}{d\bar{e}}\frac{dW_i}{d\bar{e}} + q\left[B\frac{dA}{d\bar{e}} + A\frac{dB}{d\bar{e}} - \beta N\frac{dC}{d\bar{e}}\right].$$

Since $\frac{dA}{d\bar{e}} = -\frac{A}{\epsilon\lambda}\frac{d\lambda}{d\bar{e}} - \frac{\epsilon+\sigma}{\epsilon}\frac{A}{\bar{e}}$ and $\frac{dB}{d\bar{e}} = -\frac{K^W[\epsilon-1]}{N}\frac{d\lambda}{d\bar{e}}$, which are both positive since $\frac{d\lambda}{d\bar{e}} = \frac{\sigma}{\bar{e}}[\epsilon-1][1-\lambda]\lambda > 0$, then a sufficient condition for $\frac{d^2W_i}{d\bar{e}^2} < 0$ at any extremum of W_i in $\bar{e}$ is that $\frac{dC}{d\bar{e}} = -\sigma[\epsilon-1]\left\{1-\xi\left[\frac{1-\lambda}{\lambda}\right]^{\frac{1+\sigma}{\sigma[\epsilon-1]}}\left[1+\frac{1+\sigma}{\sigma[\epsilon-1]}\right]\right\}\frac{d\lambda}{d\bar{e}} < 0$, or, equivalently, that $\xi\left[\frac{1-\lambda}{\lambda}\right]^{\frac{1+\sigma}{\sigma[\epsilon-1]}} > \frac{\sigma[\epsilon-1]}{\sigma[\epsilon-1]+1+\sigma}$. Note, however, that even if the above condition is violated, other sufficient conditions for the local concavity of W_i exist. For example, when $\xi = 0$, then $\left.\frac{d^2W_i}{d\bar{e}^2}\right|_{e=\bar{e}_i} < 0$ whenever $\frac{1}{\epsilon\lambda} + \frac{K^W}{N}\frac{[\epsilon-1]}{K_i[\epsilon-1]+\lambda\frac{K^W}{N}[1+[\epsilon-1][1-\lambda]]} > \frac{\sigma[\epsilon-1]}{1+\sigma\epsilon}$.

Appendix C: Proofs

Proposition 1: Comparing (8) and (10), $\bar{e}_D^N > \bar{e}_D^H$ iff $\xi > \xi^H \equiv \frac{k_D[1+\sigma\epsilon]-1}{k_D[1+\sigma\epsilon]+\left[\frac{1+\epsilon+2\sigma\epsilon}{\epsilon-1}\right]}$. Because $\frac{d\xi^H}{dk_D} = \frac{1+\sigma\epsilon}{k_D[1+\sigma\epsilon]+\left[\frac{1+\epsilon+2\sigma\epsilon}{\epsilon-1}\right]}[1-\xi^H] > 0$ then ξ^H is monotonic increasing in k_D whenever $\xi^H > -1$. As $\lim_{k_D\to 0}\xi^H = -\frac{\epsilon-1}{1+\epsilon+2\sigma\epsilon} \in (-1,0)$ and $\lim_{k_D\to N}\xi^H = \frac{1+\sigma\epsilon-\frac{1}{N}}{1+\sigma\epsilon+\frac{1}{N}\left[\frac{1+\epsilon+2\sigma\epsilon}{\epsilon-1}\right]} < 1$ then $\xi^H \in (-1,1)$. Note also $\lim_{k_D\to 1}\xi^H = \frac{[\epsilon-1]\sigma}{\sigma\epsilon+\sigma+2} > 0$.

Proposition 2: Directly comparing $\bar{e}_D^N$ and $\bar{e}^G$ using (8) and (11) gives $\xi^G \equiv \frac{1+\frac{\sigma\epsilon}{1+\sigma}-k_D}{\frac{1+\sigma+\epsilon+\epsilon^2\sigma}{[\epsilon-1][1+\sigma]}+k_D}$. Since $\frac{d\xi^G}{dk_D} = -\frac{1+\xi^G}{\frac{1+\sigma+\epsilon+\epsilon^2\sigma}{[\epsilon-1][1+\sigma]}+k_D} < 0$ then ξ^G is monotonic decreasing in k_D for $\xi^G > -1$. Furthermore, taking limits reveals $\lim_{k_D\to 0} = \frac{1+\frac{\sigma\epsilon}{1+\sigma}}{\frac{1+\sigma+\epsilon+\epsilon^2\sigma}{[\epsilon-1][1+\sigma]}} \in (0,1)$ while $\lim_{k_D\to N} = \frac{1+\frac{\sigma\epsilon}{1+\sigma}-N}{\frac{1+\sigma+\epsilon+\epsilon^2\sigma}{[\epsilon-1][1+\sigma]}+N} > -1$ and so $\xi^G \in (-1,1)$.

Appendix D: Deriving t_D and $\bar{e}_D^{Nt}$

Differentiating (12) gives

$$\frac{dW_D}{dt} = -\left[K_D - \frac{K-K_E}{N}\right]\frac{\rho_2}{\rho} - \left[\frac{t}{N} - \beta(\bar{e}f(\bar{e}) - \xi\bar{e}^* f(\bar{e}^*))\right]\frac{dK_E}{dt}$$

$$\frac{dW_D}{d\bar{e}} = \frac{Pf'(\bar{e})}{\rho}\left[[\rho_1+\rho_2/\epsilon]\frac{K-K_E}{N} + K_D\rho_2\frac{\epsilon-1}{\epsilon}\right] - \beta f(\bar{e})[K-K_E][1+\sigma] - \left[\frac{t}{N} - \beta[\bar{e}f(\bar{e}) - \xi\bar{e}^* f(\bar{e}^*)]\right]\frac{dK_E}{d\bar{e}} \tag{15}$$

where we have made use of the relations $\frac{dP}{d\bar{e}} = -\frac{Pf'(\bar{e})}{f(\bar{e})}\left[\frac{\rho_1+\rho_2/\epsilon}{\rho}\right] < 0$, $\frac{dP}{dt} = \frac{\rho_1}{f(\bar{e})\rho} > 0$, $\frac{dK_E}{d\bar{e}} = -\frac{Pf'(\bar{e})[\epsilon-1]}{\rho} < 0$, $\frac{dK_E}{dt} = \frac{\epsilon}{\rho} > 0$ where $\rho_1 = \frac{Pf(\bar{e})}{K-K_E}$, $\rho_2 = \frac{P^* f(\bar{e}^*)}{K^*+K_E}$ and $\rho = \rho_1 + \rho_2$. In the symmetric case $t_D = \beta N\bar{e}f(\bar{e})[1-\xi] - [k_D-1]\frac{Pf(\bar{e})}{\epsilon}$. Substituting into (15) and again taking into account symmetry gives $\left.\frac{dW_D}{d\bar{e}}\right|_{t=t_D} = q\left[\frac{\sigma}{\left[\frac{K}{N}\right]^{\frac{1}{\epsilon}}\bar{e}^{\frac{\epsilon+\sigma}{\epsilon}}} - \beta N[1+\sigma]\right]$. Setting this equal to zero and solving for $\bar{e}$ gives (13).

Appendix E: Harmonizing in presence of location taxes

When governments harmonize emission caps and fix their pollution taxes at $t = t^* = 0$, they face the identical problem as in (9). When governments instead first set taxes unilaterally and then harmonize emission caps then D's preferred harmonized cap solves $\max_{\bar{e}} \; v(q) - Pq + [Pf(\bar{e}) - t]K_D + \frac{t[K-K_E]}{N} - \beta\bar{e}f(\bar{e})[K - K_E + \xi[K^* + K_E]]$ taking t and t^* as exogenous. The first order condition for an interior optimum to this problem is $0 = f(\bar{e})\left[K_D - \frac{K-K_E}{N}\right]\frac{dP}{d\bar{e}} + Pf'(\bar{e})K_D - \beta f(\bar{e})[1+\sigma][K - K_E + \xi[K^* + K_E]] - \left[\frac{t}{N} - \beta\bar{e}f(\bar{e})[1-\xi]\right]\frac{dK_E}{d\bar{e}}$. To solve for $\frac{dP}{d\bar{e}}$, $\frac{dK_E}{d\bar{e}}$, differentiate the equilibrium condition $Pf(\bar{e}) - t = P^*f(\bar{e}) - t^*$ to get $\frac{dP}{d\bar{e}} = -\frac{Pf'(\bar{e})}{\epsilon f(\bar{e})} + \frac{\rho_1}{\rho}\frac{\epsilon-1}{\epsilon}\frac{f'(\bar{e})}{f(\bar{e})^2}[t^* - t]$ and $\frac{dK_E}{d\bar{e}} = \frac{\epsilon-1}{\rho}\frac{f'(\bar{e})}{f(\bar{e})}[t^* - t]$. Note however that when D and D^* have identical attributes then they will choose identical tax rates in the first stage and so at the second stage $\frac{dP}{d\bar{e}} = -\frac{Pf'(\bar{e})}{\epsilon f(\bar{e})}$ and $\frac{dK_E}{d\bar{e}} = 0$ and so each decision maker's problem reduces to choosing a cap such that $q\left[\frac{P\sigma}{\epsilon\bar{e}}[k_D[\epsilon - 1] + 1] - \beta N[1+\sigma][1+\xi]\right] = 0$, the solution to which is simply $\bar{e}_D^H$.

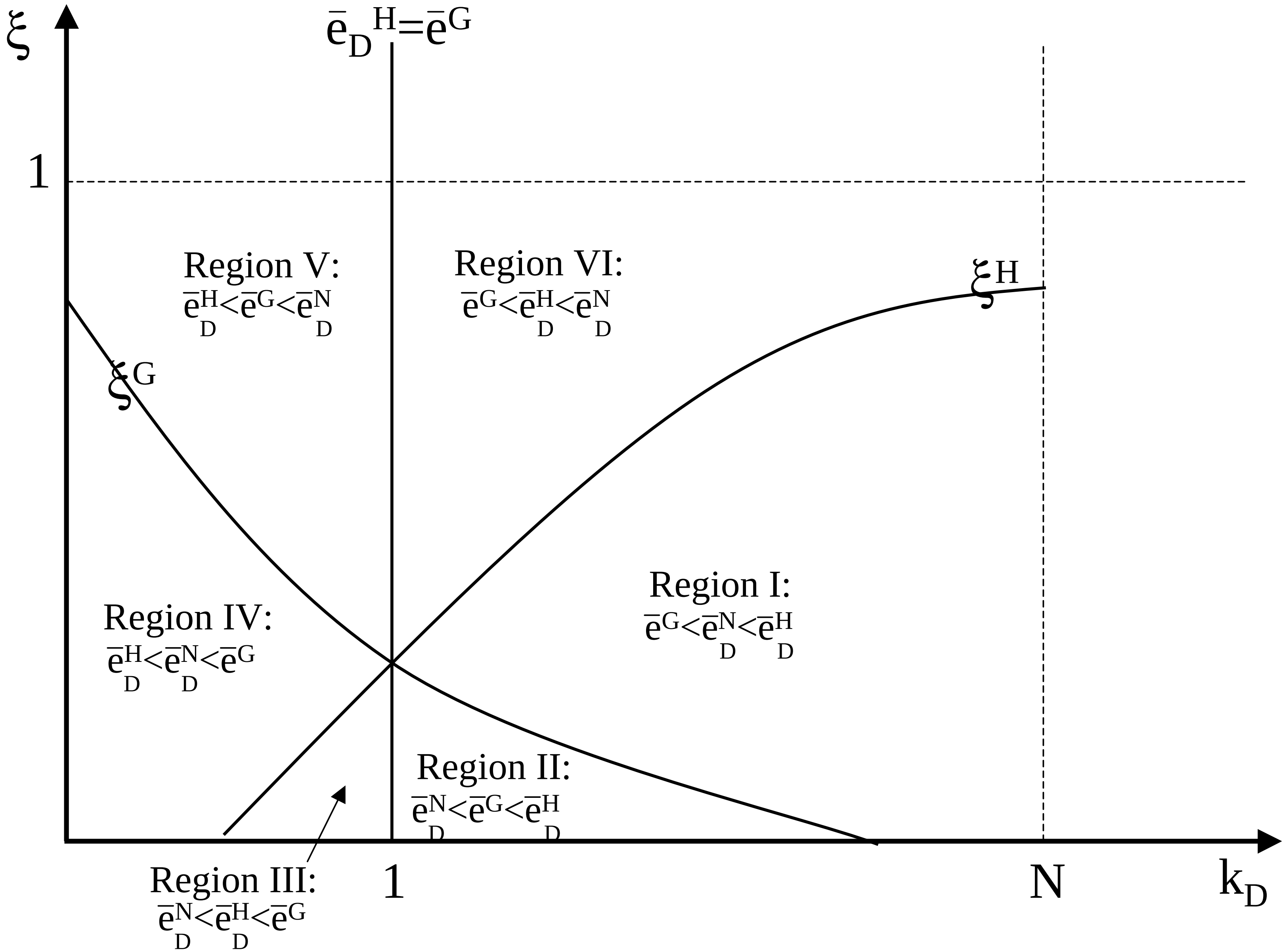

Figure 1: Harmonizing $\bar{e}$

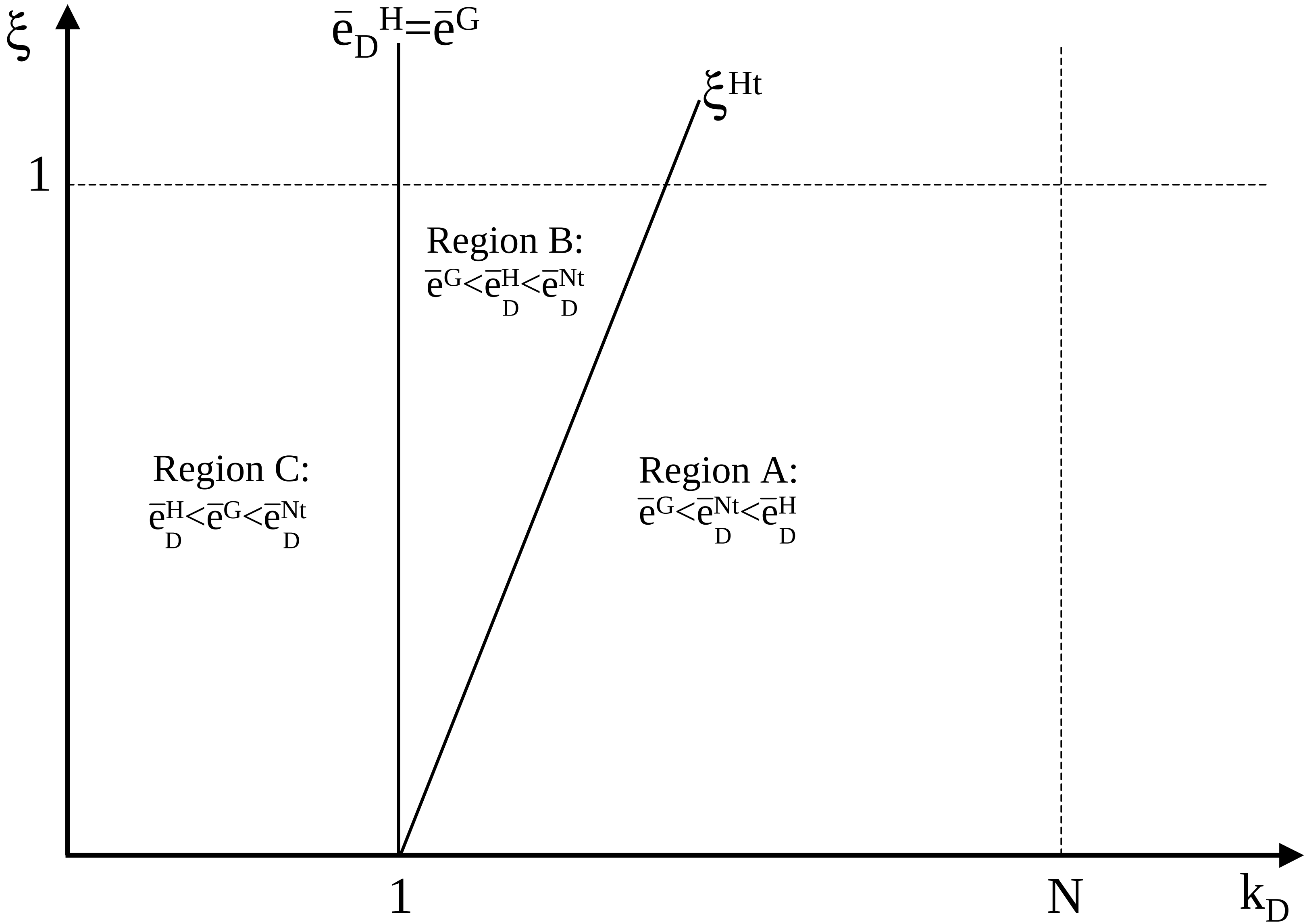

Figure 2: Harmonizing $\bar{e}$ (when non-cooperative taxes $\neq 0$)