NEIGHBORHOOD EFFECTS IN ENVIRONMENTAL POLICY INDUCED DELOCATION*

It's not easy bein' green (but it helps if your neighbors are)

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Abstract

I consider the effect of foreign environmental policy on domestic manufacturing activity using theory and empirics. In a three-country model I derive the broad conditions under which delocating manufacturing activity in response to stringent environmental policy moves to the more accessible market. In a more general many-country setting, the model yields a structural measure of multilateral foreign environmental policy and I estimate its effect on domestic manufacturing activity econometrically. I find robust evidence that stringent foreign regulation increases domestic manufacturing value added. Finally, I consider two important and largely unaddressed policy issues. Structurally estimating industry transport costs, I find that industries with *high transport costs* are *more responsive* to domestic environmental regulation. I also find that domestic environmental regulation influences the level of domestic economic activity less in stringently regulated 'neighborhoods' like Europe and North America.

Keywords: Pollution haven, Environmental regulation, Pollution haven effect, Third-country effects, Emissions intensive trade exposed

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1 Introduction

The foreign consequences of domestic environmental policy are increasingly of interest to policy makers. This is not surprising given the recent focus on transboundary pollutants, including greenhouse gases, water and air particulates and loss of biodiversity. With transboundary pollutants, the simple calculus of marginal cost versus marginal benefit or 'jobs versus the environment' is more complicated. If more stringent domestic environmental policy increases foreign pollution, the effectiveness of environmental measures is diminished. For example, carbon dioxide emitters were asked the following question during the *public consultation on state aid in the context of the amended EU Emissions Trading Scheme (ETS)* in 2011 and the answer, made by the European Container Glass Federation, is typical of respondents:

> *Q: Which non-EU countries would see the largest increase in production if the price of EU production were to rise?*
>
> *A: There is evidence of significant additional capacity due to be built just outside Europe ... in Belarus, Northern Africa, Russia and the Ukraine.*

Concern about such 'leakage' is not the only reason for increased interest. Unilaterally tightening environmental policy can also create polluting constituencies in foreign countries, rendering future policy coordination difficult. For example, responding to Germany's decision to shut down all domestic nuclear power plants in May 2011, Polish Prime Minister Donald Tusk said: *From Poland's point of view this is a good thing not a bad one ... it means coal-based power will be back on the agenda".*[1] In addition, U.S. Senator James Inhofe claims more stringent environmental policy will influence relative geopolitical strength: *If we decide as a nation to regulate greenhouse gas emissions ... then the result will be carbon leakage. By sending our jobs and basic industries to China and India, America will be weaker, and our strategic competitors will be stronger.*[2]

Importance notwithstanding, foreign environmental policy effects have received surprisingly little attention in the empirical literature. Instead, recent literature focuses overwhelmingly on the effect of *domestic* environmental policy on *domestic* economic activity. For example, Fredriksson et al. (2003), Greenstone (2002), Kellenberg (2009) and Wagner and Timmins (2008) consider

[1] Quote published at http://www.bbc.co.uk/news/business-19168574 on 9 August 2012.
[2] Quote retreived from U.S. Senate Committee on Environment and Public Works Hearing on Climate Change and National Security, 30 July, 2009.

the relationship between domestic policy and measures of economic activity, including FDI, employment and multinational affiliate value added. Another set of studies deploy multinomial choice models to estimate the effect of domestic environmental policy on plant location decisions. These include Becker and Henderson (2000), Ben Kheder and Zugravu (2012), Dean, Lovely and Wang (2009), Javorcik and Wei (2004), Keller and Levinson (2002) and List and Co (2000).

Aldy and Pizer (2012), Ederington, Levinson and Minier (2005), Ederington and Minier (2003) and Levinson and Taylor (2008) estimate the effect of U.S. environmental policy on U.S. net trade flows and all find that more stringent U.S. environmental policy increases net imports. However, these studies do not consider how U.S. policy influences levels of foreign production or pollution and, if it does, where. A paper by Eskeland and Harrison (2003) is closest in purpose to this paper. The authors find little evidence that global industry abatement costs increase FDI flows from developed to developing countries. As both Eskeland and Harrison (2003) and Kellenberg (2009) note, this study is hampered by the lack of measures of industry abatement costs outside the U.S.

The paucity of empirical evidence on the consequences of environmental policy in country A on country B is clearly not caused by a lack of interest in the subject. An enormous Computable General Equilibrium (CGE) literature on 'carbon leakage' has developed since the ratification of the Kyoto protocol, which addresses two key questions: Does domestic environmental policy influence foreign economic activity and pollution? If it does, where? Babiker (2005), Burniaux and Martins (2000), Felder and Rutherford (1993), OECD (1992) and Weyant (1999) provide examples. These analyses typically assume an increase in environmental policy stringency in some countries but not others (often simulating the Kyoto Protocol commitments) and estimate the effect on the location of production and pollution.

The shortcomings of CGE are well known. CGE complexity makes it difficult for anyone but the authors to understand what drives results. In addition, in comparison to empirical work, the assumptions tend to drive the conclusions. High sensitivity to parameter values and functional forms result in CGE carbon leakage estimates for the same international environmental agreement, which vary between 0% and over 100% depending on the assumptions adopted. In light of these challenges, empirical analysis is an important and necessary complement to existing CGE studies of foreign regulatory effects. If we plan to assume domestic policy affects foreign production then empirical evidence to support the assumption should exist.

The lack of internationally comparable data on regulatory costs is, without doubt, the main hurdle to empirical analysis. Before making restrictive assumptions necessary to avoid the use of measures of foreign environmental policy, Aldy and Pizer (2012) state: *if our data allowed us to construct a proxy measure of foreign regulation, we could ... estimate the coefficient on foreign regulation in a regression with domestic production as the regressand ... unfortunately, such data are not available.*[3] A second challenge arises because estimating foreign or 'third' country effects, unlike domestic effects, requires a detailed theoretical structure if it is to plausibly account for the heterogeneous effect of domestic environmental policy across foreign countries. Without detailed theory we cannot, for example, model the way stringent policy in Germany influences Polish and Peruvian production unevenly. This paper directly addresses these two challenges, using theory to derive a measure of foreign environmental policy for each country-industry-year triple and estimating it with a recent and well accepted cross-country data set measuring environmental policy.

Before any empirics, I solve a three-country model with environmental policy for the locus of manufacturing production. This demonstrates the broad conditions (positive transport costs, increasing returns to scale and foreign country sizes which are not too different) under which firms which delocate in response to more stringent domestic environmental policy favour the market to which they originally had greater access. This advantage of adjacency may explain the higher correlation in environmental policy changes between closer jurisdictions (see Fredriksson and Millimet (2002)).

The use of a three-country model to derive analytic expressions for firm location differentiates the present model from previous theoretical studies of 'pollution haven effect' (PHE) which, almost exclusively, adopt two-country models.[4] See Pethig (1976), Siebert (1979) and Neary (2006) for constant returns to scale (CRS) models with no transport costs, Markusen et al. (1993), Motta and Thisse (1994) and Ulph (1994) for international oligopoly models and Venables (1999) for a model with monopolistic competition and transport costs. Sturm (2003) provides an excellent summary of the theoretical literature on the PHE. The model can distinguish between near and far trading partners, enabling a spatially heterogeneous effect of environmental policy on the location of polluting activity.

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[3] Eskeland and Harrison (2003) similarly lament data shortcomings before assuming U.S. industry-level abatement costs are proxies for abatement costs in every country.

[4] The pollution haven effect implies that tightening pollution policy affects plant location and trade flows. See Copeland and Taylor (2004).

My empirical approach uses a generalized version of the theoretical model to impose structure on the way foreign policy influences domestic production. The estimating equation implies that polluting firms value environmental comparative advantage, locating where environmental policy is lax and competing firms in neighboring foreign countries face high environmental costs. This approach is standard in the literature on third country effects in a non-environmental context. For example, Anderson and van Wincoop (2003) consider third country transport costs, Head and Mayer (2004) consider market size, Redding and Venables (2004) consider supplier access and Helpman et al. (2004) consider firm productivity. Readers familiar with this literature should not be surprised that the foreign environmental policy measure derived in this paper, which I call multilateral environmental competition (MEC), closely resembles the widely-used and theoretically-derived 'market potential' measure. MEC aggregates foreign environmental policy using weights, which include country size and market access.[5] As well as justifying MEC as a measure of foreign regulation, the theoretical model yields an estimating equation which makes explicit how failure to control for foreign environmental policy can introduce bias to studies of the effect of domestic environmental policy on domestic economic activity.

Model in hand, using industry-level data on total value added for 47 countries, which together represent over 90% of world GDP, I show that foreign environmental policy matters; more stringent policy increases domestic economic activity. This result survives instrumental variable (IV) estimation, extensive controls and fixed effects specifications. This is the first study of the PHE to use total value added, rather than foreign affiliate value added, FDI or firm births, as a measure of economic activity. This more comprehensive activity variable is of interest in light of Poelhekke and van der Ploeg's (2012) evidence that FDI faces corporate social responsibility motives, which deter investment in poorly regulated countries. Weak evidence of the PHE in past studies may simply be a result of using the wrong regressand.

My results also suggest, as foreshadowed by theory, that past studies, which do not incorporate a multilateral regulatory term do contain downward bias: The estimated delocation elasticity - the negative influence of tighter domestic environmental policy on domestic manufacturing value added - increases substantially after the introduction of MEC into the empirical model.

Using interaction terms I investigate two additional policy-relevant hypotheses not related to the theory. I show that the delocation elasticity declines in the foreign policy stringency measure: Tightening environmental policy in more stringent regions like North America and Europe causes

[5] Head and Mayer (2004 and 2011) outline typical formulations of market potential used since Harris' (1954) seminal work.

less loss of manufacturing value added than in Asia, Africa or the Middle East. Finally, using a structural relationship derived from the model, I estimate a measure of transport costs for each manufacturing industry. Interacting this industry-specific transport cost with the domestic environmental policy measure I show that manufacturing industries with higher transport costs have a higher delocation elasticity. This result, the first to tie an empirically estimated measure of industry transport costs to the delocation elasticity, casts doubt over the effectiveness of legislation in the EU, North America, Australia and New Zealand, which exempts trade-exposed industries from greenhouse gas levies in an attempt to reduce international relocation.

The remainder of this paper proceeds as follows: Section 2 develops the model and derives the key theoretical results. Section 3 describes the empirical strategy and presents estimation results. Section 4 concludes the paper.

2 Theory

2.1 Assumptions

There are three countries, country 1, country 2 and country 3. Country i hosts an exogenously given number of consumers/workers L_i who each supply one unit of labour inelastically. Labour is the only factor of production and workers are internationally immobile.[6] Preferences of consumers are defined over two goods: Horizontally differentiated manufacturing and a homogeneous non-manufacturing good. The utility of a representative consumer over the two consumption goods is:

$$U = C_M^{\mu} C_N^{1-\mu}$$

$$C_M \equiv \left(\int_{i=0}^{n^w} D_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, \quad 0 < \mu < 1 < \sigma \tag{1}$$

Cobb-Douglas utility comprises C_N, which denotes consumption of the non-manufactured good, and C_M, which is a CES aggregate of all manufactured varieties. μ is the manufacturing

[6] These assumptions follow Krugman (1980), however, the the Footloose Capital (FC) model of Martin and Rogers (1995) yields almost identical properties to those presented in this section. As a consequence, neither the absence of a second factor of production, say capital, nor the inter-country immobility of labour is critical for the results that follow.

expenditure share.

D_i denotes consumption of manufactured variety i. n^w is the mass of manufactured goods varieties produced globally. σ denotes both the elasticity of demand for any particular variety and the elasticity of substitution between any two varieties. Maximizing (1) subject to a budget constraint yields the familiar CES demand function.

$$D_i = \frac{p_i^{-\sigma}E}{G_1^{1-\sigma}}$$

$$G_1^{1-\sigma} \equiv \int_0^{n^w} p_j^{1-\sigma}dj \qquad (2)$$

E is the total expenditure on the manufacturing good. Let z_i be the (inverse) productivity of labour in country i in both sectors. The non-manufacturing good is produced with constant returns to scale (CRS) and is traded between countries without cost. The cost of producing one unit of the non-manufacturing good in country i is $w_i z_i$. w_i is the wage per worker in country i. With perfect competition $p_A^i = w_i z_i$, and with free trade $p_A \equiv p_A^1 = p_A^2 = p_A^3$. Assuming that all countries produce some of the CRS good, effective wage equalization occurs such that $w_1 z_1 = w_2 z_2 = w_3 z_3$.

The manufacturing good is produced with increasing returns to scale (IRS) and is subject to iceberg transport costs, τ_{ij}, when transporting goods from country i for sale in country j. A fixed quantity of labour, fz_i, is required per manufacturing firm and z_i units of labour are required per unit of manufactures produced in country i.[7] Government in country i regulates the pollution which arises in the manufacturing process with an environmental tax equal to $t_i - 1$ per unit of pollution produced.[8] For simplicity, pollution increases linearly in the variable cost of production. The manufacturing total cost function in country i is therefore:

$$TC_i = w_i z_i \left(f + t_i x_i\right) \qquad (3)$$

[7] The inclusion of the parameter z_i allows the model to account for differences in wages internationally as a result of variations in productivity. The assumption that labour productivity in both non-manufacturing and manufacturing sectors in country i is reflected by the parameter z_i is not necessary for any of this paper's main results. The productivity ordering of countries could vary across sectors. However, this assumption is adopted as it improves focus on manufacturing productivity differences which arise from differentials in the stringency of environmental policy.

[8] Environmental policy is referred to as a tax, however, under general conditions, the same parameter could reflect a permit price to pollute, or the additional constant variable cost of adopting a method of production which is mandated by government for environmental purposes.

	1	**2**	**3**
1	1	τ_{12}	τ_{13}
2	τ_{21}	1	∞
3	τ_{31}	∞	1

Table 1: Summary of transport costs

Without loss of generality I assume that country 1 has a higher environmental tax than country 2 and country 3. To keep the model as simple as possible, I assume that the environmental tax is equal in country 2 and country 3 ($t_1 > t_2 = t_3$); this simplifying assumption allows a clearer focus on the interaction between changes in the environmental tax in country 1 and the distribution of polluting firms across countries. In considering pairs of countries with similar income per capita this assumption does not seem to be unreasonable.

Transport costs between any two countries are equal in both directions (i.e. $\tau_{ij} = \tau_{ji}$) and I adopt a hub-and-spoke trade arrangement with country 1 as the hub and $\tau_{23} = \infty$. This is the simplest trade structure which allows location choice amongst delocating firms.[9] Table 1 summarizes the structure of transport costs between the locus of production (the rows) and the locus of consumption (the columns).

2.2 Equilibrium location of firms

Assumptions of CES monopolistic competition and iceberg transport costs give rise to the standard mill pricing conditions: A given firm receives the same revenue per unit sold (after accounting for transport costs) in all markets. Firms charge a constant mark-up equal to $\tau_{ij}\sigma/(\sigma-1)$ over their (environmental tax inclusive) variable cost of production ($w_i z_i t_i$). Selecting the non-manufacturing good as numeraire ensures $w_i z_i = 1$ for all i and yields the following expression for p_{ij} :

$$p_{ij} = \tau_{ij} \frac{\sigma}{\sigma - 1} t_i \tag{4}$$

Equation (4) makes explicit the relationship between environmental policy, prices and therefore

9 Ossa (2010) adopts the same trade arranagment in the Krugman (1980) model for its simplicity. Citing the *Braess paradox* (Braess (1968)), Behrens et al. (2007) explain why complexity increases dramatically in the Krugman (1980) model with more than two countries.

the competitiveness of firms. Letting q_1 (q_2) equal the break-even output level of firms in country 1 (countries 2 and 3), in equilibrium $q_i = f(\sigma - 1)/t_i$. Countries with higher environmental tax rates host smaller firms. Market clearing conditions for manufacturing firms in countries 1, 2 and 3 enable solution for the location of manufacturing firms. These conditions are:

$$q_1 = p_1^{-\sigma} G_1^{\sigma-1} \mu Y_1 + p_1^{-\sigma} \phi_{12} G_2^{\sigma-1} \mu Y_2 + p_1^{-\sigma} \phi_{13} G_3^{\sigma-1} \mu Y_3 \tag{5}$$

$$q_2 = p_2^{-\sigma} \phi_{12} G_1^{\sigma-1} \mu Y_1 + p_2^{-\sigma} G_2^{\sigma-1} \mu Y_2 \tag{6}$$

$$q_2 = p_2^{-\sigma} \phi_{13} G_1^{\sigma-1} \mu Y_1 + p_2^{-\sigma} G_3^{\sigma-1} \mu Y_3 \tag{7}$$

$\phi_{ij} = \tau_{ij}^{1-\sigma}$ is a measure of trade 'freeness' between countries. $\phi_{ij} = 1$ implies zero transport costs while $\phi_{ij} = 0$ implies infinite transport costs. Country i GDP, denoted Y_i, equals $L_i w_i \, (= L_i/z_i)$. Equations (5), (6) and (7) can be solved for the price indexes as a function of model parameters:

$$G_1 = \left[\frac{r q_1 p_1^{\sigma} \left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\mu Y_1 \left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{8}$$

$$G_2 = \frac{q_1 p_1^{\sigma} r}{\mu Y_2} \left[\frac{r^{-\sigma}\left(1 - \phi_{12}^2 - \phi_{13}^2\right) - \phi_{12}\left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{9}$$

$$G_3 = \frac{q_1 p_1^{\sigma} r}{\mu Y_3} \left[\frac{r^{-\sigma}\left(1 - \phi_{12}^2 - \phi_{13}^2\right) - \phi_{13}\left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{10}$$

The ratio of the environmental tax parameter in country 1 to country 2 (or country 3) is denoted $r \equiv t_1/t_2 (= t_1/t_3)$. Substituting in the definition of G_i from equation (2), these can be solved for the main variable of interest, the equilibrium location of firms:

$$n_1 = \frac{r^{\sigma-1}\mu}{q_1 p_1} \left[\frac{Y_1}{\Omega} - \frac{Y_2 \phi_{21}}{\Theta - \phi_{12}\Omega} - \frac{Y_3 \phi_{31}}{\Theta - \phi_{13}\Omega} \right] \tag{11}$$

$$n_2 = \frac{\mu}{q_1 p_1}\left[\frac{Y_2\left(1-\phi_{13}^2\right)}{\Theta-\phi_{12}\Omega}+\frac{Y_3\phi_{12}\phi_{31}}{\Theta-\phi_{13}\Omega}-\frac{Y_1\phi_{12}}{\Omega}\right] \quad (12)$$

$$n_3 = \frac{\mu}{q_1 p_1}\left[\frac{Y_3\left(1-\phi_{12}^2\right)}{\Theta-\phi_{13}\Omega}+\frac{Y_2\phi_{21}\phi_{13}}{\Theta-\phi_{12}\Omega}-\frac{Y_1\phi_{13}}{\Omega}\right] \quad (13)$$

Where $\Omega \equiv r^\sigma - \phi_{12} - \phi_{13}$ and $\Theta \equiv 1 - \phi_{12}^2 - \phi_{13}^2$. Analysis of equations (11), (12) and (13) yields novel comparative static results regarding the relationship between the location of firms and the model's key parameters, the environmental tax, transport costs and GDP, which arise only in models of three regions or more. I begin with those relating to GDP. The own country effects are not surprising; countries with higher GDP host more manufacturing firms ($\partial n_i / \partial Y_i > 0$). Cross country effects are less intuitive and are stated in Lemma 1.

Lemma 1 $\frac{\partial n_1}{\partial Y_i} < 0$, $\frac{\partial n_i}{\partial Y_1} < 0$, $\frac{\partial n_i}{\partial Y_j} > 0$, *for* $i, j \in \{2, 3\}, i \neq j$

Proof. By differentiating equations (11), (12) and (13) ■

Cross country effects involving country 1 ($\frac{\partial n_1}{\partial Y_i} < 0$ and $\frac{\partial n_i}{\partial Y_1} < 0$) reflect Krugman's well-known home market effect; an increase in expenditure in country 1 decreases the number of firms in the foreign spokes while an increase in expenditure in either of the foreign spokes decreases the number of firms in country 1. The positive derivatives $\partial n_2 / \partial Y_3 > 0$ and $\partial n_3 / \partial Y_2 > 0$ imply that as Y_3 increases, country 1 produces less of the manufacturing good. This reduction in the number of domestic firms makes country 1 a less competitive market, which increases the profitability of firms in country 2. Country 2's manufacturing firms increase in number until profits are again driven to zero.[10]

I turn to this paper's key theoretical results, those which relate the location of firms to the level of the environmental tax. Lemma 2 states formally that increases in the relative environmental tax in country 1 (countries 2 and 3) decrease the number of firms in country 1 (countries 2 and 3) and increase the number of firms in countries 2 and 3 (country 1).

Lemma 2 $\frac{\partial n_1}{\partial r} < 0$, $\frac{\partial n_2}{\partial r} > 0$ *and* $\frac{\partial n_3}{\partial r} > 0$

Proof. See appendix 1. ■

[10] While this mechanism is especially stark in a model with no trade between countries 2 and 3, the mechanism holds in a case in which such trade is allowed. See Behrens et al. (2009).

This result is the standard domestic PHE to which most empirical studies turn their attention. However, the application of the theoretical model allows for a stricter definition of a pollution haven. In a three-country model, it is possible to determine which market relocating firms favour. Proposition 1 establishes the direction of delocating firms from country 1 as a function of country sizes and transport costs.

Proposition 1 $\frac{\partial n_2}{\partial r} > \frac{\partial n_3}{\partial r}$ *iff* $\frac{Y_2\left(1-\phi_{13}^2-\phi_{12}\phi_{13}\right)\phi_{12}}{(\Theta-\phi_{12}\Omega)^2} + \frac{Y_1\phi_{12}}{\Omega^2} > \frac{Y_3\left(1-\phi_{12}^2-\phi_{12}\phi_{13}\right)\phi_{13}}{(\Theta-\phi_{13}\Omega)^2} + \frac{Y_1\phi_{13}}{\Omega^2}$

Proof. See Appendix A.1 ■

Proposition 1 implies that delocating firms favour the larger market. Country 2 becomes relatively more attractive than country 3 as a destination for delocating economic activity if country 2 is larger. Larger Y_1 also encourages economic activity to delocate to country 2 in response to a higher environmental tax in country 1.

In addition to this 'size effect', there is a 'proximity effect'. Larger ϕ_{12} and smaller ϕ_{13} increase this delocation bias towards country 2. Firms which delocate in response to higher environmental taxes tend to seek out countries which are close and shun those which are far away. This arises because the improvement in competitiveness, which arises from a relative decrease in the domestic environmental tax rate is declining in transport costs.

To provide an intuitive comparison of the actual size-proximity trade-off implicit in Proposition 1, Figure 1 takes Germany in 2006 as the hub and plots country pairs for which the RHS condition in Proposition 1 approximately holds with equality.[11] As a consequence, more stringent German environmental policy will cause a roughly equal increase in the number of firms in both members of a pairing. ϕ_{ij} is approximated by d_{ij}^{-1} where d_{ij} is the population weighted distance between countries i and j in kilometers.[12]

The natural log of the ratio of the GDP of the first country in the pairing to GDP of the second country is on the x-axis. The y-axis reports trade freeness between Germany and the second country divided by trade freeness between Germany and the first country. The positive slope of the scatter plot highlights the trade-off between GDP and trade freeness implicit in Proposition

[11] In practice, it is unlikely that any country pairing will exist for which the inequality in Proposition 1 holds precisely. Instead, for those country pairs featured the left hand side is no more than 5% different than the right hand side. r is set equal to 1.

[12] According to Head and Mayer (2004), who estimate transport costs by indsutry, inverse distance rule is a 'rough but reasonable' approximation. In Section 3, I estimate bilateral trade freeness, ϕ_{ijl}, for industry l and all country pairs, (i, j) using data on exports. The estimated distance effect varies by industry, however, all effects are between $d_{ij}^{-1.05}$ and $d_{ij}^{-1.85}$.

1. Country pairs with roughly even size and roughly equal proximity to Germany such as Great Britain and France or South Africa and Thailand are in the bottom left corner. The top right corner features the country pair with the largest asymmetry in size and proximity. The USA had roughly 230 times the GDP of Morocco in 2006, however, it is more than 5000km more distant from Germany.

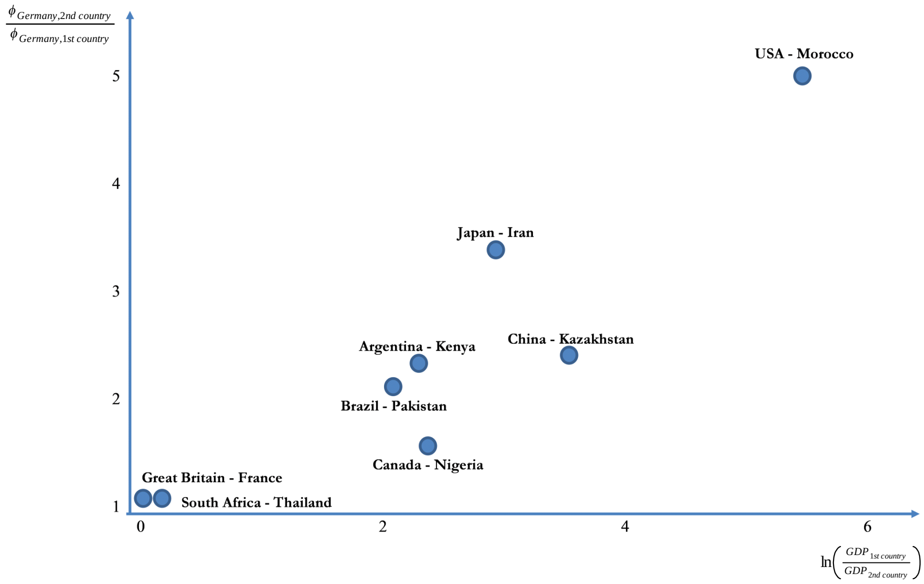

Figure 1: Spoke pairs for which $\frac{\partial n_2}{\partial r} \simeq \frac{\partial n_3}{\partial r}$ with Germany as hub.

A special case of Proposition 1, one which removes the size effect, arises with symmetric regions and asymmetric transport costs. Corollary 1 states formally that if all countries are of equal size, an increase in the level of the environmental tax in country 1 increases production in country 2 more than production in country 3.

Corollary 1 $\frac{\partial n_2}{\partial r} > \frac{\partial n_3}{\partial r}, if\, Y_2 = Y_3$

Proof. See Appendix A.2. ■

The mechanism, which causes the 'proximity effect' can be given intuition as follows: Increased environmental tax in country 1 decreases manufacturing firm profits and domestic firm numbers decline. This decline in the number of firms in country 1 reduces competition for firms in all countries, increasing profits in countries 2 and 3. Because the market in country 1 is more accessible to country 2 than to country 3, this reduction in competition raises the profitability of firms in country 2 more than those in country 3. When net profits are eventually zero again, country 2, whose manufacturing firms benefitted more from reduced competition in country 1 than those in country 3, will have increased its level of manufacturing activity more than country 3.

With no trade flows between countries 2 and 3, the simple model presented above does not allow country 1's environmental policy to affect trade flows between countries 2 and 3. Changing assumptions to allow one of the spokes, say country 3, to be the country which increases its pollution tax, such that $t_3 > t_2 = t_1$, gives rise to such effects. As above, equilibrium firm locations are:

$$n_1 = \frac{\mu}{q_1 p_1}\left[\frac{Y_1}{\Omega'} - \frac{Y_2\phi_{21}}{\Theta - \phi_{12}\Omega'} - \frac{1}{r'^{\sigma-1}}\frac{Y_3\phi_{31}}{\Theta' - \phi_{13}\Omega'}\right]$$

$$n_2 = \frac{\mu}{q_1 p_1}\left[\frac{Y_2\left(1-\phi_{13}^2\right)}{\Theta' - \phi_{12}\Omega'} + \frac{1}{r'^{\sigma-1}}\frac{Y_3\phi_{12}\phi_{31}}{\Theta' - \phi_{13}\Omega'} - \frac{Y_1\phi_{12}}{\Omega'}\right]$$

$$n_3 = \frac{\mu}{q_1 p_1}\left[\frac{Y_3\left(1-\phi_{12}^2\right)}{\Theta' - \phi_{13}\Omega'} + \frac{Y_2 r'^{\sigma-1}\phi_{21}\phi_{13}}{\Theta' - \phi_{12}\Omega'} - \frac{Y_1 r'^{\sigma-1}\phi_{13}}{\Omega'}\right]$$

Where $\Omega' \equiv \left(1 - \phi_{12} - \phi_{13} r'^{\sigma-1}\right)$, $\Theta' \equiv \left(1 - \phi_{12}^2 - \phi_{13}^2\right)$ and $r' = t_3/t_1 = t_3/t_2$. As before, the proximity effect can be isolated from the market size effect:

Proposition 2 $\frac{\partial n_1}{\partial r'} > \frac{\partial n_2}{\partial r'}$, *if* $Y_1 = Y_2 = Y_3$

Proof. See Appendix A.3 ■

Not only does country 1, which is easier to access from market 3, increase firm numbers more than country 2 in response to country 3's higher environmental tax. In addition, net exports from country 1 to country 2 increase. Third country effects of higher taxation in country 3 alter bilateral trade flows such that net exports from proximate firms (relative to the third country) to distant firms increase.

This model establishes a theoretical basis for the observation that pollution havens are defined by *foreign* as well as domestic environmental policy. More specifically, corollaries 1 and 2 isolate the effect of transport costs by assuming market size and environmental policy are equal in the two markets which do not alter their environmental tax. In doing so they show that under quite general assumptions, pollution havens, countries which specialize in the production and export of polluting goods due to comparative advantage in environmental policy, have lax environmental policy, not necessarily in absolute terms, but relative to countries with which their firms compete most fiercely. Section 3 tests this theory empirically.

3 Empirics

I set out to test whether changes in foreign environmental policy influence the domestic level of manufacturing production. Before presenting results I explain my econometric strategy.

3.1 Econometric strategy

3.1.1 Functional forms for foreign environmental policy

As Section 2 has shown, with positive transport costs, a given increase in environmental policy stringency in one country does not affect the output of all foreign countries equally. I rely on guidance from the model to construct measures of foreign environmental policy. Equations (11), (12) and (13) present an intuitive, theoretically grounded, functional form for estimating the effect of foreign environmental policy on domestic manufacturing production. However, these functions are discontinuous and non-linear as well as analytically unwieldy in many-country equivalents necessary for empirical estimation. Furthermore, such precise functional forms are unlikely to hold empirically in annual data, both because of measurement error and because they assume a time frame over which firm relocation yields zero profits.

I therefore do not attempt to estimate equations like (11), (12) and (13) in a many-country setting. Instead, taking one causal step back from firm relocation, I operationalize the theory by estimating the relationship between environmental policy, both domestic and foreign, and firm profits when firm location is fixed. This is a standard approach in the empirical literature on firm location. For examples, see Head and Mayer(2004) and Dean and Lovely (2009). Intuitively this can be thought of as estimating a 'short-run' version of the model.

Profits can be non-zero and I allow for n countries, positive transport costs between all countries and a generalization of equation (1) with many CES manufacturing industries nested within a Cobb-Douglas utility function. μ_l is the Cobb-Douglas budget share for industry l. $c(t_i, a_{il})$ is the marginal cost of production in country i industry l, which includes both environmental and non-environmental components. Fixing firm location, firm profits are:

$$\pi_{il} = \frac{\mu_l}{\sigma_l} c(t_i, a_{il})^{1-\sigma_l} \sum_{j=1}^{n} \frac{\phi_{ijl} Y_j}{\sum_{k=1}^{n} \phi_{jkl} n_{kl} c(t_k, a_{kl})^{1-\sigma_l}}, \qquad c_1(t_i, a_{il}) > 0$$

Profit in country i is equal to the sum of domestic market profits and the profit from exporting to each foreign country. The profit from exporting to country j, $\mu_l c(t_i, a_{il})^{1-\sigma_l} \phi_{ijl} Y_j / \left(\sigma_l \sum_{k=1}^{n} \phi_{jkl} n_{kl} c(t_k, a_{kl})^{1-\sigma_l}\right)$, is, according to the numerator, increasing in the market size and the freeness of trade between country j and country i and decreasing in country i's (environmental policy inclusive) marginal cost of production. According to the denominator, profit is also decreasing in the competitiveness of country j. Because this version of the model is one causal step removed from the equilibrium derived in equations (11), (12) and (13), it features third country regulatory effects on industry profits identical in sign to those firm location effects derived in corollary 1: more stringent foreign environmental policy increases domestic profitability and the effect on domestic profits is increasing in the output and proximity of the foreign country. Importantly for empirical specification, the model yields a simple linear expression in logs for the profit equation:

$$\ln(\pi_{il}) = \ln\left(\frac{\mu_l}{\sigma_l}\right) - (\sigma - 1)\ln(c(t_i, a_{il})) + \ln\left(\sum_{j=1}^{n} \frac{\phi_{ijl} Y_j}{\sum_{k=1}^{n} \phi_{jkl} n_{kl} c(t_k, a_{kl})^{1-\sigma}}\right) \tag{14}$$

Apart from the final term, equation (14) is easily interpreted. According to the first term, profits are increasing in the share of income spent on manufacturing industry l (μ_l) and decreasing in the elasticity of substitution between varieties in manufacturing industry l (σ_l). According to the second term profits are decreasing in the the environmental tax rate (t_{il}). The third term is most commonly called 'market potential'. The existence of this term implies that profits in market j are increasing in GDP (Y_j) and trade freeness from i to j (ϕ_{ijl}), while they are decreasing in the competitiveness of market j, which is equal to $\sum_{k=1}^{n} \phi_{jkl} n_{kl} (w_{kl} z_{kl} t_{kl})^{1-\sigma}$. This denominator reflects the level of competition in market j from all foreign and domestic firms and gives rise to a 'market crowding' force which decreases profits of firms which are located where there are already many firms with a low cost of production. The market crowding force is increasing in the number of foreign firms (n_{kt}) and the trade freeness with which foreign firms access market j (ϕ_{kjt}) and decreasing in the environmental and non-environmental costs of production of those firms, $c\left(t_k, a_{kl}\right)^{1-\sigma}$.

The presence of the third term makes explicit a potentially important omitted variable from past studies of the PHE, which focus purely on domestic environmental policy. If environmental policy is correlated across space, as Fredriksson and Millimet (2002) demonstrate, changes in t_i are correlated with changes in 'market potential'. Because an increase in t_i decreases profitability while an increase in market potential increases profitability, past estimates of the effect of domestic environmental policy on profitability or some measure of economic activity are likely to be biased downwards.[13]

Market potential is typically estimated as the importer fixed effects in an OLS regression of bilateral trade flows with the inclusion of a transport costs term.[14] However, in addition to correcting for this bias, my goal is to estimate the significance and magnitude of the effect of foreign environmental policy on domestic production. As environmental policy is only one (probably quite small) source of variation in the third term of equation 14, I cannot estimate it in the standard way while interpreting a significant coefficient as evidence that foreign environmental policy matters. Instead, I follow Head and Mayer (2002) and construct the third term from its constituent components while ensuring that any variation is a function only of changes in environmental policy rather than Y, n, or a. The constructed foreign policy variable, which I differentiate from market potential by calling it 'multilateral environmental competition' (MEC), is:

$$MEC^1_{ilt} = \ln\left(\sum_{j=1}^{n} \frac{\widehat{\phi_{ijl}} Y_j}{\sum_{k=1}^{n} \frac{\widehat{\phi_{jkl}} Y_k}{\widehat{t_{kt}} c}}\right)$$

I describe data sources, including derivations of a proxy for trade freeness, $\widehat{\phi_{ijl}}$, and environmental taxes, $\widehat{t_{kt}}$, in Section 3.1.2. In order to isolate the effect of foreign environmental policy, and

[13] Further evidence for this conjecture arises because the two studies of which I am aware that control for time-varying third country effects, Ben kheder and Zugravu (2012) and Kellenberg (2009), find robust evidence for the PHE.

[14] Redding and Venables (2004) is the first paper to use this approach.

due to data constraints, three deviations from the theory are required. First, Y_j is estimated as the average GDP of country j over the 6-year period considered from 1999-2004. This removes time variance in market potential as a consequence of changes in GDP. Inclusion of country and country-time fixed effects in the estimation should capture the time-variance in foreign GDP lost by this simplification. Second, I assume that firm numbers in each industry in each country are proportional to GDP. This simplification is necessary because accurate data on firm numbers at the required level of industry granularity (ISIC 3-digit, revision 2) is not readily available. This assumption appears reasonable; using data on firm numbers which is available from Mayer and Zignago (2005), the correlation coefficient between PPP GDP at current prices in international dollars and firm numbers by ISIC 3-digit (revision 2) industry for the years 1999-2004 is 0.36. The use of GDP instead of firms number means that MEC^1_{ilt} is a weighted average of foreign environmental policy, $\widehat{t_{kt}}$.

I follow Section 2 and assume that the environmental tax rate enters marginal costs multiplicatively. The final deviation from the theory removes non-environmental variance in production costs. I assume that the remaining component of costs, $c\left(a_{ilt}\right)$, does not vary by time, industry or country (i.e. $c\left(a_{ilt}\right) = c$). Head and Mayer (2002) take a slightly different approach, assuming that marginal costs are proportional to wages. However, I believe my approach is a better, yet clearly not perfect, proxy. For example, productivity adjusted wages (wages per unit of value added) are much closer to equal across countries than they are to being proportional wages.[15] Overall, this simplification retains the key features of the theory, namely that stricter foreign environmental policy increases domestic profits and that this influence is increasing in trade freeness and the number of foreign competing firms, while being estimable with available data.

Because the functional form of MEC^1_{ilt} is relatively complex, as an additional robustness check I also construct a simpler MEC variable, derived from theory, which reflects the effect of foreign environmental policy on profits in the domestic market only. This is equation (14) with only the first term from the first summation. To justify the relevance of this simpler measure, I note that on average 70% of sales for the 28 manufacturing industries considered are domestic. Therefore, I expect the multilateral environmental policy term which arises in the domestic component of the profit function to be an important determinant of domestic value added. The domestic

[15] For example, in the subest of data from Mayer and Zignago (2005), the productivity adjusted wage for a given industry, is typically 3-4 times as high in the 90th percentile as the 10th, whereas wages in USD are 15 times the size in the 90th GDP per capita percentile than in the 10th. I do not use productivity adjusted wages in constructing MEC^1_{ilt}, although this would be my prefered approach, because the data are not available for sufficient country-industry-time observations.

component of (14) is:

$$\ln\left(\pi_{il}^{D}\right)=\ln\left(\frac{\mu_{l}}{\sigma}\right)-(\sigma-1)\ln\left(c\left(t_{i},a_{il}\right)\right)+\ln\left(Y_{i}\right)+\ln\left(\phi_{ii}\right)-\ln\left(\sum_{j=1}^{n}\frac{\phi_{jil}n_{jl}}{\left(t_{j}z_{jl}w_{jl}\right)^{\sigma-1}}\right) \quad (15)$$

Following those same simplifications adopted in constructing MEC_{ilt}^{1}, the alternative MEC variable is:

$$MEC_{ilt}^{2}=\ln\left(\sum_{j=1}^{n}\frac{\widehat{\phi_{ijl}}Y_{j}}{\widehat{t_{jt}}}\right)$$

3.1.2 Estimating equation and data sources

My strategy is to estimate a model which controls all of those factors in equation (14). The basic estimating equation is:

$$\ln\left(VA_{ilt}\right)=\alpha_{i}+\alpha_{l}+\alpha_{t}+\beta_{1}\ln\left(\widehat{t}_{it}\right)+\beta_{2}\ln\left(MEC_{ilt}^{j}\right)+\sum_{o}\gamma_{o}\ln\left(X_{ilt}\right)+\varepsilon_{ilt} \quad (16)$$

I cluster errors at the country-time level. Descriptive statistics for variables used and their sources are summarized in Appendix C. VA_{ilt} is the value added in USD of industry l in country i at time t. This is largely world bank data which was used in Mayer and Zignago (2005) and is freely available from Thierry Mayer's website. Two alternative left-hand-side variables were considered, total value of production in USD and US foreign affiliate value added. Value added is superior to production as a measure of economic activity because it excludes the cost of inputs. US foreign affiliate value added, which is freely available from the US Bureau of Economic Analysis (BEA) may not respond to changes in foreign environmental policy same way as total industry value added. For example, Poelhekke and van der Ploeg (2012) suggest that Dutch FDI in certain industries may avoid countries with lax environment policy on corporate social responsibility grounds. Domestic firms are unlikely to be similarly motivated. In addition, the response of VA, which is considerably larger than US affiliate value added, is of greater policy interest. Two further benefits of using Mayer and Zignago's (2005) value added data are: First, it is disaggregated 28 manufacturing sectors yielding significantly more observations that the US Bureau of Economic Analysis' multinational affiliate value added data, which is disaggregated into 7 manufacturing sectors; second, previous studies have tended to focus on FDI, plant births or U.S. affiliate value added and this is the first PHE paper to analyze total value added by industry.

On the right hand side of the equation α_i, α_l and α_t are country, industry and year fixed effects.[16] The environmental index, $\widehat{t}_{it}$, is a proxy for environmental policy costs. It is drawn from a survey by the World Economic Forum (WEF) Global Competitiveness Report (GCR). To produce the GCR, the WEF conducts surveys of corporate executives in a large number of countries annually. In the construction of MEC^1_{ilt} and MEC^2_{ilt} I include only the 59 countries for which data is available in 1999 (150 are available in 2004). According to the Penn World Tables, these countries generated approximately 92% of global GDP in 1999. This restriction ensures that time variance in MEC^1_{ilt} and MEC^2_{ilt} is only due to changes in environmental policy and it is not due to new countries entering the summation.

I focus on two environmental measures from the GCR reported in each addition from 2000-2001 until 2005-2006.[17] The first measure reflects the stringency of environmental regulation and the second reflects the consistency with which environmental regulation is enforced.[18] Both measures are reported on a scale from 1 to 7 of increasing stringency/consistency. These measures are multiplied together to yield a composite environmental index of the stringency of environmental regulation and consistency of its enforcement for a given country in a given year, $\widehat{t}_{it}$. The environmental index is constructed in this way to incorporate regulation and enforcement, both of which are likely to influence firms' marginal environmental costs, into a single measure and to enable comparison with Kellenberg (2009) and Poelhekke and van der Ploeg (2012), both of which use the same index.

The GCR measure of environmental policy stringency provides three key advantages over the most obvious alternative, industry-level pollution abatement and control expenditure (PACE). Because I am interested in the influence of domestic environmental policy on foreign economic activity in a setting in which inter-jurisdictional collaboration is difficult, the most obvious advantage is geographic coverage. I use GCR data for 47 countries and over 90% of world

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16 More comprehensive fixed effects are introduced in section 3.2 to investigate the robustness of results.

17 Following the convention when using the GCR data, figures from the 2000-2001 GCR are matched to non-GCR data from 1999. Because most surveys are completed at the beginning of the period to which the report applies (i.e. early 2000 for the 2000-2001 edition of the GCR) respondents are likely to reference conditions in the previous year in providing their responses.

18 The stringency question is: The stringency of overall environmental regulation in your country is (1=lax compared with most other countries, 7=among the world's most stringent). The enforcement question is: Environmental regulation in your country is (1=not enforced or enforced erratically, 7=enforced consistently and fairly).

GDP, whereas PACE data is typically only collected in wealthy countries. Second, where it is collected, the collection and construction of PACE data is subject to important cross-country methodological differences making it less useful for international comparison of environmental policy stringency globally.[19] I am not aware of a cross-country study using PACE as a measure of environmental policy. The third benefit arises because the GCR's measures of environmental regulation and enforcement are likely to incorporate broader cost impacts of environmental policy than pollution abatement cost measures do. List and Co (2000) and Levinson (1996) argue that the regulation process is multidimensional and advocate the use of many measures of policy stringency to test the PHE. By surveying executives on the general stringency and enforcement of environmental policy, the GCR measures are likely to capture more dimensions of the regulatory process.

The clear drawback of the GCR data is that it is based on a survey and therefore is open to the standard criticisms of survey-based metrics. This appears to be less problematic with the GCR data than many other cross-country surveys. First, the data is widely used in the international trade literature and has repeatedly demonstrated *construct validity*, that is, its metrics behave in the way they are expected to.[20] Second, the GCR metrics demonstrate *convergent validity.* They are correlated with objective measures of similar phenomena. World Economic Forum (2000, 2001, 2002, 2003, 2004 and 2005) provide details of robustness checks performed on survey results.

$\widehat{\phi_{ijl}}$ is estimated structurally from the model using data on industry-level bilateral trade flows. The approach used is standard in the empirical international economics literature and I relegate the specific details to Appendix B.1. The first key benefit of estimating bilateral transport costs by sector is that construction of MEC^1_{ilt} and MEC^2_{ilt} follows the theory closely, ensuring that the effect of foreign environmental policy on a given sector is declining in the ease with which firms in that sector in the foreign country can sell in the domestic market. A second benefit arises because derivation of industry specific transport costs enables consideration of the important policy question of whether 'trade-exposed' industries are more likely to relocate in response to

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[19] For example, the OECD typically provide a caveat along these lines when publishing cross-country data: 'As definitions and methodologies remain diverse across member countries, comparisons across countries should be limited to orders of magnitude.'

[20] For example Carr et al. (2001) find a negative impact on FDI of an index created by aggregating survey responses to survey responses on restrictions on the ability to acquire control in a domestic company, limitations on the ability to employ foreign skilled labor, restraints on negotiating joint ventures, strict controls on hiring and firing practices, market dominance by a small number of enterprises, an absence of fair administration of justice, difficulties in acquiring local bank credit, restrictions on access to local and foreign capital markets, and inadequate protection of intellectual property. Markusen and Maskus (2002), Blonigen. et al. (2003) and Ekholm et al. (2007) also support the construct validity of GCR survey measures.

tougher environmental policy. The assumption is central to greenhouse gas legislation in the EU, Australia, New Zealand and past legislation in the US, in which trade-exposed polluters pay a lower price for polluting.[21] Despite this strong policy presence, there is scant empirical evidence that trade-exposure is an important parameter for determining the responsiveness of an industry to environmental policy.[22]

X_{ilt} contains a set of additional controls not captured by the fixed effects which potentially either are correlated with the environmental variables $\widehat{t}_{it}$, MEC^1_{ilt} and MEC^2_{ilt} or influence firm production costs. These include: a 'foreign market potential' term from Head and Mayer (2011) which controls for foreign country effects which might be correlated with MEC^1_{ilt} and MEC^2_{ilt}; GDP per capita from the Penn World Tables, which, according to Grossman and Krueger (1995), is related to environmental policy stringency; government's share of GDP from the Penn World Tables, which captures within country changes in a wide range of government policy variables. Population, USD exchange rate and tariffs should all affect the incentives to manufacture domestically. Country-industry level weighted average import tariffs from the UNCTAD TRAINS database are included to reflect industry lobbying ability in a given country. As a final set of control variables, I include indexes of voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption from the Worldwide Governance Indicators.[23]

3.1.3 Addressing potential endogeneity

Recent studies highlight the need to address potential endogeneity arising from the inclusion of a measure of domestic environmental policy in a regression with a measure of economic activity as the regressand. For example, Kellenberg (2009) finds a two-step process with IVs dramatically changes the estimated effect of domestic environmental regulation on U.S. multinational affiliate value added, while Levinson and Taylor (2008) find a similar improvement considering net imports. In contrast, Poelhekke and Van der Ploeg (2012) find little effect of instrumentation using the GCR data.

I address the econometric challenge posed by an endogenous environmental index in three main

[21] In Australia see the Clean Eneergy Bill (Feb 2011). In New Zealand see The Climate Change Response (Moderated Emissions Trading) Amendment Act (2009). For the U.S. see the Waxman Markey bill (H.R. 2454).

[22] Notably, Anderson et al. (2011) find no significant relationship between the trade intensity of a firm and a measure of 'future impact of climate policy' derived from interview responses.

[23] These are available from *www.governance.org*

ways. First, I reduce the potential for simultaneity bias by considering a large number of manufacturing industries and an environmental policy variable for the entire country. For the available 4627 country-industry-year observations of value added, the mean value added is 0.6% of GDP.[24] As a consequence, value added in a given industry is unlikely to have a noticeable influence on the environmental index in a given year. Second, to reduce the likelihood of omitted variable bias I introduce country, industry and time fixed effects to all regressions. To control for omitted variables which are not country, industry or time invariant, first I include a number of potentially important controls through the vector $X_{ilt}$and second, I introduce more comprehensive fixed effects, interacting year, industry and country fixed effects.

The third approach to address potential endogeneity involves adopting a generalized method of moments specification to estimate the model using instrumental variables (IV) as a source of exogenous variation in environmental policy. A number of candidate IVs for environmental policy have been proposed. I follow Copeland and Taylor (2003), using measures of the demand for environmental protection as IVs. Specifically, I use the UN World Development Indicators' measures of marine protected areas as a percentage of territorial waters and terrestrial protected areas as a percentage of total land area. I assume that in designating land or territorial water as protected, countries trade potential consumption from the land's use in the agriculture or fisheries industry in exchange for an environmental benefit. These two measures therefore reflect preferences over environmental goods. Because the alternative use of land or coastal water is not in the manufacturing industry, these variables are unlikely to influence the level of value added in manufacturing sectors.

3.2 Estimation results

3.2.1 Baseline estimates

Table 5 presents baseline estimates of equation (16) using four different sets of controls and both measures of MEC. Models 1 - 4 use MEC^1_{ilt}. Taken together, these first four models support the theory, showing that estimates of coefficients on foreign and domestic environmental measures are robust to the inclusion of other potential determinants of economic activity. Across all specifications the coefficient on $ln\left(MEC^1_{ilt}\right)$ is between 0.83 and 0.92, implying that more stringent foreign environmental policy increases domestic manufacturing value added. This

[24] Total manufacturing value added is roughly 17% (28 multiplied by 0.6) of total GDP for the sample.

sign is consistent with the theory. All four estimated coefficients are significant at the 5% level. Because the equation is linear in logs, coefficients can be interpreted as elasticities; a 1% increase in MEC^1_{ilt} is associated with an increase of approximately 0.9% in manufacturing value added. The coefficient on $ln\left(\widehat{t}_{it}\right)$ is negative as implied by the theory. Estimates of the impact of a 1% increase in $\widehat{t}_{it}$ range from -0.856 to -0.977. All estimates are significant at the 5% level at least.

Model 1 only includes the domestic and foreign environmental terms in addition to country, industry and year fixed effects. Model 2 also introduces the foreign market potential term from Head and Mayer (2011). The inclusion of foreign market potential as a control is important for ensuring that MEC^1_{ilt} does not capture non-environmental foreign country effects. For example, taking the theory at face value, foreign market potential reflects all of the benefits of foreign market size and the costs of foreign competition. The inclusion of the market potential term in model (2) increases the magnitude of the coefficient on $ln\left(MEC^1_{ilt}\right)$.

Models 3 controls for important non-environmental domestic market factors which have been shown to affect economic activity. The inclusion of GDP per capita, government share of GDP, population, exchange rate and weighted industry tariffs slightly changes the environmental regressors' coefficients, increases the coefficient on MEC^1_{ilt} decreases it on $\widehat{t}_{it}$. I find that high GDP per capita countries have higher value added and that higher exchange rates and tariffs decrease value added. None of these results is surprising.

Finally, in model 4, which is my preferred model, the six country-time specific governance measures are introduced. The inclusion of these variables reduces the magnitude of the coefficient on $ln\left(\widehat{t}_{it}\right)$, but not by much. Only two of the six subjective measures is significant at the 10% level. I find support for the finding of Javorcik and Wei (2004) with a positive coefficient on the regressor reflecting control of corruption.[25] The political stability coefficient is also significant at the 10% level.

Models 5 - 8 paint a very similar picture. The coefficient on the new MEC term MEC^2_{ilt} is negative, which is consistent with more stringent foreign policy decreasing MEC^2_{ilt} and increasing MEC^1_{ilt}. Estimated coefficients on all regressors in models 7 and 8 match those in 3 and 4 very closely, suggesting that the functional form used to construct MEC^1_{ilt} is not driving the results. In models 5 and 6 the index variable is significantly negative yet smaller than in models 1 and 2.

[25] Unlike Javorcik and Wei (2004), I do not find that removal of the corruption measure renders the evnironmental index insignificant.

3.2.2 Robustness tests using IVs and fixed effects

Table 6 presents 6 additional models, which expand on model 4 to consider the robustness of the results presented in Table 5 to instrumentation and the inclusion of more comprehensive fixed effects. Non-environmental variables are not shown to save space.

Model 9, presents the IV estimates obtained by two-stage GMM using the two instruments for $\widehat{t}_{it}$ described in Section 3.1.3. First stage regression results are summarized in the notes below Table 6. The estimated coefficients are very similar to those in Table 5, an observation which is supported by a Durbin-Wu-Hausman test p-value very close to 1. This implies that instrumentation is not warranted and may be significantly less efficient that OLS. Standard errors with instrumentation are approximately 50% larger, resulting in estimated effects of $\widehat{t}_{it}$ and MEC^1_{ilt}, which, despite their similarity to those in Table 5, are not significantly different than zero.

Two other diagnostic tests are conducted for the IV specification. The Hansen J-statistic rejects the null hypothesis that the instruments are invalid and the Anderson L-R statistic rejects the null hypothesis that the instruments are weak. The IV approach in model 9 therefore provides little reason to forego the efficiency of OLS estimation in favour of an IV approach.

Models 10 and 11 introduce location-year fixed effects. Before estimating model 11, which has country-year fixed effects, I estimate a model with 'region'-year fixed effects, where countries in the study are divided into 13 regions.[26] Region fixed effects are estimated for two reasons. First, because the variable of interest is MEC, this provides a way of controlling for location and time variant omitted variables at a relevant geographic scale while preserving degrees of freedom. Second, because this approach retains the flexibility to estimate the coefficient on $\widehat{t}_{it}$ which is not possible with country-year fixed effects. Model 10 yields similar estimates to model 4, its equivalent without region-year fixed effects. The significance and magnitude of the coefficients on both environmental policy variable are largely unchanged.

The message is similar for the introduction of more stringent country-year fixed effects in model 11. The coefficient on environmental policy is no longer estimable and the magnitude of the coefficient on MEC^1_{ilt} increases slightly. I conclude from models 10 and 11 that omitted country and time invariant factors do not present an omitted variable bias problem.

[26] See appendix C for the allocation for countries to regions. On average there are 3-4 countries per region.

As a further robustness test, model 12 and 13 introduce fixed effects which are location and industry specific, relying only on time variance in MEC^1_{ilt} to identify an effect. Introduction of region-industry fixed effects does not alter the coefficients on the two environmental variables much compared to model 4 while introducing the R-squared substantially from 0.842 in model 4 to 0.919.

The results of model 13 are less supportive of the theory. The inclusion of over 1000 country-industry dummy variables removes the effect of both domestic and foreign environmental policy. With at most 6 observations per country-industry pair my prior was that it was unlikely that there would be sufficient variance in MEC^1_{ilt} to establish a significant relationship with value added. The R-squared of 0.994 suggests that the fixed effects are capturing most of the variance in value added.

3.2.3 Three additional hypotheses

I turn to three important yet under-emphasized issues in the PHE literature. First, are industries with lower transport costs more responsive to stricter environmental policy? Second, is it less costly in terms of loss of economic activity to increase domestic policy levels if nearby neighbors have high environmental standards? Third, does omission of a measure of foreign policy, which is typically in PHE studies, bias estimates of the effect of domestic policy on domestic economic activity?

The first hypothesis is considered in models 14, 15 and 16 of Table 7. All three models include an interaction between $ln\left(\widehat{t}_{it}\right)$ and the variable $Bdist_l$.[27] Appendix 2 summarizes $Bdist_l$ and describes its derivation. Put concisely, $Bdist_l$ reflects the rate at which trade flows fall with distance. Industries in which $Bdist_l$ is most negative exhibit the fastest fall in trade flows with distance, and I use this as a proxy for transport costs.

Model 14 does not include a measure of MEC. While models 15 and 16 include MEC^1_{ilt} and MEC^2_{ilt} respectively. Across all specifications the interaction term is positive and significant. This implies that *less trade-exposed* industries, those with more negative $Bdist_l$ values, tend to reduce value added by more in response to tighter domestic environmental policy. For example, taking model 15, which includes my preferred measure of MEC, a 1% increase in $\widehat{t}_{it}$ reduces the value added of the very trade-exposed 'miscellaneous petroleum and coal products' industry

[27] $Bdist_l$ itself cannot be included in the models because of the presence of industry fixed effects.

($Bdist_l = -1.057$) by 0.7%.[28] In contrast, the same 1% increase in $\widehat{t}_{it}$ reduces value added in the less trade-exposed 'paper and products' industry ($Bdist_l = -1.817$) by 1.36%.[29]

This is a very surprising result in light of the high level of financial support targeted at trade-exposed industries to avoid carbon leakage in the EU, Australia and New Zealand. One plausible and theoretically grounded explanation is the presence of agglomeration forces. Using a standard New Economic Geography model, Feddersen (2012) shows theoretically that reductions in transport costs can make polluting industries less likely to relocate in response to more stringent environmental policy by strengthening the agglomeration bonds holding firms together. Alternatively, less trade-exposed industries may be more pollution intensive. This appears to be the case as the less trade-exposed right hand column of Table 2 includes petroleum refineries, paper and products, industrial and other chemicals and iron and steel, which are the four industries designated by Jaffe et al. (1995) as having 'high abatement costs'.[30] Jaffe's et al. (1995) 'low abatement cost' industries include printing and publishing, rubber and miscellaneous plastic products and machinery (except electrical), which tend to have lower transport costs in Table 2.

Turning to the second issue, models 17 and 18 both include an interaction term between $ln\left(\widehat{t}_{it}\right)$ and the log of the MEC variable adopted in the model. Model 17 uses MEC^1_{ilt} while model 18 uses MEC^2_{ilt}. The interaction term is positive in both models, however, it is only significant in model 18. This result suggests that the loss of economic activity as a consequence of tighter domestic environmental policy is lower if nearby countries have stringent environmental policy. This finding supports Fredriksson and Millimet's (2002) finding that changes in US state-level environmental policy are spatially correlated. For example, if environmental stringency in a country's neighborhood increases, this makes it both less costly to tighten environmental policy domestically and less costly to relax it.

Finally, in model 19 I consider whether the absence of an MEC term affects the estimated coefficient on $\widehat{t}_{it}$. My hypothesis is that because changes in environmental policy are spatially correlated, those studies which estimate the effect of environmental policy on economic activity capture the effect of both domestic and foreign policy changes. The downward bias arises because an increase in domestic regulation, if accompanied by an increase in foreign policy, will not alter

[28] This is calculated as $0.209 + (-1.057) \times 0.863$.
[29] This is calculated as $0.209 + (-1.817) \times 0.863$.
[30] Jaffe et al. (1995) uses PACE to determine the high abatement cost industries. The industry classification system is slightly different and the high abatement cost industries are actually: paper and allied products, chemicals and allied products, petroleum and coal products and primary metal industries.

the level of economic activity domestically, even if a unilateral tightening of environmental policy would.

Model 19 supports this hypothesis. The specification is identical to the baseline case in model 4 except for the omission of a control for MEC. The coefficient on $ln\left(\widehat{t}_{it}\right)$ declines in magnitude from -0.856 to -0.106. As a consequence, those studies which do not control for foreign country environmental policy may well understate the size of the PHE.[31]

4 Conclusion

This paper considers the influence of foreign environmental policy on domestic economic activity. Drawing on theory to appropriately account for heterogeneous foreign country effects, I derive an advantage of adjacency under broad conditions, which implies that delocating firms favour the market to which they originally had greater access. Operationalizing the model empirically, I find robust evidence that stricter domestic environmental policy reduces domestic manufacturing value added and that stricter foreign environmental policy increases it. I find three other novel results. First, failure to incorporate a foreign regulation term into estimates of the pollution haven effect leads to bias. Second, industries with *high transport costs* are *more responsive* to domestic environmental regulation. Third, domestic environmental regulation influences the level of domestic economic activity less in stringently regulated 'neighborhoods'.

As potential extensions, the inclusion of a term like MEC term to consider the spatial effects of non-environmental policies like labour laws or intellectual property rights may provide similar insights in those areas. Also, application to more detailed domestic (probably U.S.) data on environmental policy would provide an interesting extension and a useful robustness test.

There are two main policy implications. First, the results in this paper, not only fail to support, but they contradict the explicit assumption in most of the world's major greenhouse gas regulation schemes that trade exposure equates with environmental delocation elasticity. The absence of empirical evidence to justify this assumption needs consideration in the future design of these schemes. Second, given neighborhood environmental policy matters, coordination of policy is probably warranted to avoid socially inefficient environmental policy competition. I

31 Notable exceptions are Ben Kheder and Zugravu (2012) and Kellenberg (2009). The latter incorporates non-environemntal third country effects into the model, which could proxy for foreign environmental policy.

have shown that regional cooperation in environmental regulation is a close substitute for global cooperation, especially for those pollution intensive industries with higher transport costs. A global agreement on carbon dioxide emissions, which is broadly consider to be a desirable goal in greenhouse gas policy, may be closely approximated by a series of more politically feasible regional agreements.

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A Section 2 derivations

A.1 Derivation of Proposition 1

From equations (12) and (13):

$$\begin{aligned} n_2 - n_3 &= \frac{\mu}{q_1 p_1}\left[\frac{L_2\left(1-\phi_{13}^2\right)}{1-\phi_{13}^2-\phi_{12}r^{\sigma}+\phi_{12}\phi_{13}} + \frac{L_3\phi_{12}\phi_{31}}{1-\phi_{12}^2-\phi_{13}r^{\sigma}+\phi_{12}\phi_{13}} - \frac{L_1\phi_{12}}{r^{\sigma}-\phi_{12}-\phi_{13}}\right] \\ &\quad -\frac{\mu}{q_1 p_1}\left[\frac{L_3\left(1-\phi_{12}^2\right)}{1-\phi_{12}^2-\phi_{13}r^{\sigma}+\phi_{12}\phi_{13}} + \frac{L_2\phi_{21}\phi_{13}}{1-\phi_{13}^2-\phi_{12}r^{\sigma}+\phi_{12}\phi_{13}} - \frac{L_1\phi_{13}}{r^{\sigma}-\phi_{12}-\phi_{13}}\right] \end{aligned}$$

$\therefore \frac{\partial n_2 - n_3}{\partial r} > 0$ if $\frac{\partial f}{\partial r} > 0$ where $f \equiv \frac{L_2\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)}{1-\phi_{13}^2-\phi_{12}r^{\sigma}+\phi_{12}\phi_{13}} - \frac{L_3\left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)}{1-\phi_{12}^2-\phi_{13}r^{\sigma}+\phi_{12}\phi_{13}} - \frac{L_1(\phi_{12}-\phi_{13})}{r^{\sigma}-\phi_{12}-\phi_{13}}$

$\frac{\partial f}{\partial r} = \frac{L_2\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)}{\left(1-\phi_{13}^2-\phi_{12}r^{\sigma}+\phi_{12}\phi_{13}\right)^2}\sigma\phi_{12}r^{\sigma-1} - \frac{L_3\left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)}{\left(1-\phi_{12}^2-\phi_{13}r^{\sigma}+\phi_{12}\phi_{13}\right)^2}\sigma\phi_{13}r^{\sigma-1} + \frac{L_1(\phi_{12}-\phi_{13})}{(r^{\sigma}-\phi_{12}-\phi_{13})^2}\sigma t^{\sigma-1}$

$\therefore \frac{\partial f}{\partial r} > 0$ if $\sigma r^{\sigma-1}\left[\frac{L_2\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)\phi_{12}}{\left(1-\phi_{13}^2-\phi_{12}r^{\sigma}+\phi_{12}\phi_{13}\right)^2} - \frac{L_3\left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)\phi_{13}}{\left(1-\phi_{12}^2-\phi_{13}r^{\sigma}+\phi_{12}\phi_{13}\right)^2} + \frac{L_1(\phi_{12}-\phi_{13})}{(r^{\sigma}-\phi_{12}-\phi_{13})^2}\right] > 0$

This condition can be rewritten as:

$$\frac{L_2\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)\phi_{12}}{\left(\Theta-\phi_{12}\Omega\right)^2} > \frac{L_3\left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)\phi_{13}}{\left(\Theta-\phi_{13}\Omega\right)^2} - \frac{L_1\left(\phi_{12}-\phi_{13}\right)}{\Omega^2}$$

A.2 Proof of Corollary 1

From Proposition 1, the proof requires that the following inequality holds:

$$\frac{\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)\phi_{12}}{\left(\Theta-\phi_{12}\Omega\right)^2} > \frac{\left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)\phi_{13}}{\left(\Theta-\phi_{13}\Omega\right)^2} - \frac{\left(\phi_{12}-\phi_{13}\right)}{\Omega^2}$$

The second RHS term is clearly positive as $\phi_{12} > \phi_{13}$. Because $\phi_{12} > \phi_{13}$ it is also true that $\left(1-\phi_{13}^2-\phi_{21}\phi_{13}\right)\phi_{12} > \left(1-\phi_{12}^2-\phi_{12}\phi_{31}\right)\phi_{13}$. Therefore, the proposition holds if $\left(\Theta-\phi_{12}\Omega\right)^2 < \left(\Theta-\phi_{13}\Omega\right)^2$. This condition is equivalent to $\phi_{13}+\phi_{12} < r^{\sigma}$. The assumption of the existence of some manufacturing in all regions implies that this inequality holds.

To show that $\phi_{13}+\phi_{12} < r^{\sigma}$, recall that with equal country sizes, the number of firms in region 1 is determined by:

$$n_1 = \frac{r^{\sigma-1}\mu}{q_1 p_1}\left[\frac{1}{r^{\sigma} - \phi_{12} - \phi_{13}} - \frac{\phi_{21}}{1 - \phi_{13}^2 - \phi_{12}r^{\sigma} + \phi_{12}\phi_{13}} - \frac{\phi_{31}}{1 - \phi_{12}^2 - \phi_{13}r^{\sigma} + \phi_{13}\phi_{12}}\right]$$

Beginning from an equilibrium at autarky ($\phi_{12} = \phi_{13} = 0$, all three terms in the square brackets are positive and n_1 is greater than zero regardless of the tax differential. As $\phi_{13} + \phi_{12}$ increases from zero, once $\phi_{13} + \phi_{12} = r^{\sigma}$, the first term in the square brackets tends to ∞. This is not a possible equilibrium. For a small increase in $\phi_{13} + \phi_{12}$ above this, n_1 becomes negative which is precluded by assumption. Therefore $\phi_{13} + \phi_{12} < r^{\sigma}$. QED

A.3 Proof of Corollary 2

Subtracting the number of firms in country 2 from country 1 yields:

$$n_1 - n_2 = \frac{L\mu}{q_1 p_1}\left[\frac{1 + \phi_{12}}{\Omega'} - \frac{1 + \phi_{21} - \phi_{13}^2}{\Theta' - \phi_{12}\Omega'} - r^{1-\sigma}\frac{\phi_{31} + \phi_{12}\phi_{31}}{\Theta' - \phi_{13}\Omega'}\right]$$

To prove the corollary it suffices to show that the derivative of the first term in parenthesis with respect to r is positive while the derivatives of the second and third terms are negative. For $1 > \phi_{12} > \phi_{13} > 0, r > 1$ it is simple to show that this will always hold. QED

B Section 3 derivations

B.1 Derivation of industry transport costs

Trade freeness in sector l, between countries i and j, ϕ_{ijl}, is estimated from data on bilateral trade flows within each industry. Bilateral trade flows between country i and country j in industry l can be expressed as:

$$M_{ijl} = p_{ijl}q_{ijl}n_{il} = \left[\frac{\mu_l Y_j}{\sum_{k=1}^{n} n_{kl}\phi_{kjl}c_k^{1-\sigma}}\right]\left[n_{il}\phi_{ijl}c_i^{1-\sigma}\right] \quad (17)$$

Taking logs of both sides of equation (17) yields:

$$\ln\left(M_{ijl}\right) = \ln\left(\frac{n_{il}}{c_i^{\sigma-1}}\right) + \ln\left(\frac{\mu_l Y_j}{\sum_{k=1}^{n} n_{kt}\phi_{kj}c_k^{1-\sigma}}\right) + \ln\left(\phi_{ijl}\right) \tag{18}$$

The first and second right-hand terms can be estimated using exporter and importer fixed effects. The third term is estimated using three typical components of bilateral trade freeness: distance; contiguity; and common language. This yields the following estimating equation:

$$\ln\left(M_{ijl}\right) = \exp_i + imp_j + B_{1l}\ln\left(d_{ij}\right) + B_{2l}contiguous_{ij} + B_{3l}commonlanguage_{ij} \tag{19}$$

I estimate this equation using import data from Head et al. (2010)'s compilation of trade flows from the IMF's Direction of Trade Statistics (DOTS) database. Geographic data on distances, contiguity and language are obtained from CEPII's GeoDist database. With the estimates $\widehat{B}_{1l}$, $\widehat{B}_{2l}$ and $\widehat{B}_{3l}$ I construct trade freeness measures between countries i and j in country l as:

$$\widehat{\phi}_{ijl} = \left(distw_{ij}^{\widehat{B}_{1l}} \exp^{\widehat{B}_{2l}contiguous_{ij} + \widehat{B}_{3l}commonlanguage_{ij}}\right)$$

The cost of transport by industry, as measured by $\widehat{B}_{1l}$, are presented in Table 2. For industries in which $\widehat{B}_{1l}$ is more negative, bilateral export value drops more quickly with distance.

Industry	B_1	**Industry**	B_1
Misc. petroleum and coal products	-1.057	Textiles	-1.436
Professional and scientific equipment	-1.143	Wearing apparel, except footwear	-1.441
Tobacco	-1.178	Wood products, except furniture	-1.493
Footwear, except rubber or plastic	-1.178	Non-ferrous metals	-1.523
Pottery, china, earthenware	-1.195	Industrial chemicals	-1.533
Leather products	-1.255	Printing and publishing	-1.54
Transport equipment	-1.301	Glass and products	-1.541
Beverages	-1.325	Fabricated metal products	-1.555
Rubber products	-1.345	Iron and steel	-1.566
Other manufactured products	-1.356	Plastic products	-1.582
Machinery, electric	-1.385	Other chemicals	-1.597
Machinery, except electrical	-1.397	Other non-metallic mineral products	-1.604
Food products	-1.403	Petroleum refineries	-1.658
Furniture, except metal	-1.435	Paper and products	-1.817

Table 2: Industry trade freeness measures

C Data description

Table 3 summarizes the allocation of countries to regions.

Region number	Countries
1	Austria, Belgium, Switzerland, Spain, France, Great Britain, Italy, Luxembourg, Netherlands, Portugal
2	China, Hong Kong, Japan
3	Bulgaria, Hungary, Russia, Turkey
4	Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador
5	Canada, Mexico, USA
6	Mauritius, South Africa
7	Czech Republic, Poland
8	Denmark, Finland, Norway, Sweden
9	Australia, New Zealand
10	Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam
11	India
12	Costa Rica
13	Egypt, Isreal, Jordon

Table 3: Allocation of countries to regions

Table 4 provides descriptive statistics and sources for all variables used in models 1-19 as well as the countries, industries and years covered. Average manufacturing tariff rates are the average applied import tariff rates on non-agricultural and non-fuel products and are obtained from the UNCTAD TRAINS database.

D Estimation results

Estimation results are presented in Tables 5, 6 and 7.

Variable	Obs.	Mean	Std.Dev	Min	Max	Source
Value added ($US at current prices)	4627	4826478	17100000	-61720	253000000	IMF (Mayer and Zignago (2005))
Environmental index (0-49)	4627	21.16	10.05	5.28	41.6	World Economic Forum
MEC^1 (0-49)	4627	19.89	9.68	3.74	42.86	See section 3
MEC^2	4627	540.74	700.89	6.6	7135.31	See section 3
Market potential	4504	4626122	6714196	314662	44000000	Head and Mayer (2011)
GDP Per Capita (PPP) at current prices, (international $)	4627	17055	11475	1488	57785	Penn World Tables
Government Consumption Share of GDP Per Capita (PPP), (%)	4627	9.22	3.18	3.21	18.17	Penn World Tables
Population (000s)	4627	110919	261345	433	1284303	Penn World Tables
Domestic-USD exchange rate	4627	381.77	1817.62	0.42	14167.75	Penn World Tables
Industry weighted average tariff, (%)	4613	8.7	39.1	-1.8	1909.8	UNCTAD TRAINS database
Voice and accountability index (0-100)	4627	62.03	16.25	18.51	85.06	www.governance.org
Political stability index (0-100)	4627	56.57	18.65	7.49	83.26	www.governance.org
Government effectiveness index (0-100)	4627	67.71	18.34	33.1	93.87	www.governance.org
Regulatory quality index (0-100)	4627	66.19	15.74	31.43	91.7	www.governance.org
Rule of law index (0-100)	4627	64.21	18.15	28.58	89.31	www.governance.org
Control of corruption index (0-100)	4627	66.18	21.85	27.21	101.52	www.governance.org
Marine protected areas as a percentage of total land area, (%)	4122	10.34	16.02	0.04	74.87	World Development Indicators
Terrestrial protected areas as a percentage of total land area, (%)	4627	13.63	9.23	0.95	41.78	World Development Indicators

Countries: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Denmark, Ecuador, Egypt, El Salvador, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, South Korea, Luxembourg, Malaysia, Mauritius, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Russian Federation, Singapore, Slovakia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, Ukraine, United Kingdom, United States, Venezuela, Vietnam, Zimbabwe

Years: 1999-2004

Industries: See Table 2 for industries included

Table 4: Summary of data used

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: ln(value added)								
ln(MEC^1)	0.832**	0.908**	0.925**	0.917**				
	(0.391)	(0.398)	(0.421)	(0.422)				
ln(MEC^2)					-0.533***	-0.574***	-0.781***	-0.771***
					(0.198)	(0.203)	(0.254)	(0.248)
ln(environmental index)	-0.897**	-0.977***	-0.875**	-0.856**	-0.377**	-0.402**	-0.759***	-0.754***
	(0.368)	(0.373)	(0.374)	(0.363)	(0.176)	(0.179)	(0.261)	(0.260)
ln(market potential)		0.203	0.164*	0.194*		0.220	0.167*	0.200*
		(0.168)	(0.0956)	(0.113)		(0.168)	(0.0946)	(0.112)
ln(per capita GDP)			1.861***	1.615***			1.898***	1.663***
			(0.300)	(0.305)			(0.298)	(0.303)
ln(gov't share of GDP)			-0.225	-0.355			-0.199	-0.330
			(0.283)	(0.285)			(0.282)	(0.286)
ln(population)			1.077	1.057			1.239	1.250
			(1.043)	(1.040)			(1.047)	(1.023)
ln(exchange rate)			-0.326***	-0.371***			-0.320***	-0.367***
			(0.0950)	(0.0993)			(0.0934)	(0.0975)
ln(tariffs)			-0.155***	-0.156***			-0.159***	-0.160***
			(0.0223)	(0.0224)			(0.0222)	(0.0223)
ln(violence and acc.)				0.145				0.174
				(0.136)				(0.128)
ln(political stability)				0.216*				0.213*
				(0.120)				(0.118)
ln(government eff.)				0.347				0.353
				(0.438)				(0.436)
ln(regulatory quality)				-0.403				-0.404
				(0.338)				(0.342)
ln(rule of law)				0.222				0.210
				(0.480)				(0.481)
ln(corruption)				0.673*				0.663*
				(0.352)				(0.343)
Country effects	Y	Y	Y	Y	Y	Y	Y	Y
Industry effects	Y	Y	Y	Y	Y	Y	Y	Y
Year effects	Y	Y	Y	Y	Y	Y	Y	Y
R-squared	0.830	0.830	0.842	0.842	0.829	0.83	0.842	0.842
Observations	4621	4498	4233	4233	4621	4498	4233	4233

Notes: Year and country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 28 isic revision 2 3-digit manufacturing industries and for 49 countries from 1999-2004. Columns 1 - 4 use MCC^1 as a proxy for foreign regulation and columns 5 - 8 use MCC^2. *10% level, **5% level, ***1% level. See appendix TBC for more detailed variable descriptions

Table 5: OLS estimates of the effect of the environemtnal index on value added using both versions of MEC

Model	(9)	(10)	(11)	(12)	(13)
Dependent variable: ln(value added)					
ln(MEC^1)	0.762	0.956**	0.980**	0.887***	-0.158
	(0.579)	(0.448)	(0.464)	(0.331)	(0.367)
ln(environmental index)	-0.773	-0.912**		-0.879***	0.0219
	(0.652)	(0.364)		(0.292)	(0.304)
Country effects	Y	Y	Y	Y	Y
Industry effects	Y	Y	Y	Y	Y
Year effects	Y	Y	Y	Y	Y
Region-time effects		Y			
Country-time effects			Y		
Region-industry effects				Y	
Country-industry effects					Y
Durbin-Wu-Hausman test statistic	0.000				
Durbin-Wu-Hausman test p-value	0.997				
Hansen J-statistic	1.236				
Hansen J-statistic p-value	0.266				
Anderson L-R statistic	75.14				
Anderson L-R statistic p-value	4.82e-17				
R-squared	0.0240	0.842	0.843	0.919	0.994
Observations	3849	4233	4233	4233	4233

Notes: Year and country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 28 isic revision 2 3-digit manufacturing industries and for 49 countries from 1999-2004. All models include the additional controls from column 4 in Table 1. *10% level, **5% level, ***1% level. See appendix TBC for more detailed variable descriptions. In column 1, marine and terrestrial protected area as a percentage of total territorial waters and land are instruments for ln(environmental index). In the first stage regression, the coefficient and robust standard error are -0.0042 and 0.0015 for marine protected areas and -0.0019 and 0.0050 for terrestrial protected areas. The R-squared for the first stage regression is 0.74

Table 6: Robustness checks using instrumental variables and fixed effects

Model	(14)	(15)	(16)	(17)	(18)	(19)
Dependent variable: ln(value added)						
ln(MEC^1)		1.094**		1.228***		
		(0.433)		(0.471)		
ln(MEC^2)			-0.676**		-1.193***	
			(0.275)		(0.320)	
ln(environmental index)	0.960**	0.209	0.267	-1.538**	-1.774***	-0.106
	(0.428)	(0.489)	(0.532)	(0.611)	(0.522)	(0.096)
ln(environmental index)*Bdist	0.786**	0.863***	0.708**			
	(0.308)	(0.314)	(0.317)			
ln(environmental index)*ln(MEC^1)				0.132		
				(0.0869)		
ln(environmental index)*ln(MEC^2)					0.190**	
					(0.0837)	
Country effects	Y	Y	Y	Y	Y	Y
Industry effects	Y	Y	Y	Y	Y	Y
Year effects	Y	Y	Y	Y	Y	Y
R-squared	0.843	0.842	0.843	0.843	0.843	0.843
Observations	4233	4233	4233	4233	4233	4233

Notes: Year and country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 28 isic revision 2 3-digit manufacturing industries and for 49 countries from 1999-2004. All models include the additional controls from column 4 in Table 1. *10% level, **5% level, ***1% level. See appendix TBC for more detailed variable descriptions

Table 7: Estimation with index-trade cost and index-MEC interactions