Pollution Havens: Does Third Country Environmental Policy Matter?

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Abstract

I consider the influence of foreign environmental policy on domestic manufacturing activity using theory and empirics. A tractable three-country spatial model yields a theory of locational comparative advantage in the production of pollution-intensive manufactured goods: greater market access to countries with stringent environmental policy encourages output in the polluting sector. Operationalizing the model empirically, I find robust evidence that high market access to countries with stringent environmental policy increases manufacturing value added. Both the theoretical and empirical analyses suggest that estimates of the Pollution Haven Effect that ignore third country environmental policy – yet make the stable unit treatment value assumption – can be misleading.

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1 Introduction

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.

Response by The European Container Glass Federation to the public consultation on state aid in the context of the amended EU Emissions Trading Scheme (ETS), 2011

Is location a source of comparative advantage in the production of polluting goods? Owing to its excellent market access, might Poland specialize in the production and export of polluting goods that are heavily regulated – and therefore expensive to produce – in Germany?[1] I answer these questions using theory and empirics. A tractable three-country spatial model yields a theory of locational comparative advantage in the production of pollution-intensive manufactured goods: greater market access to countries with stringent environmental policy encourages output in the polluting sector. Operationalizing the model empirically, I find robust evidence that high market access to countries with stringent environmental policy increases manufacturing value added.

Cross-border environmental policy effects have received surprisingly little attention in the empirical literature, given the increasing policy focus on transboundary pollutants. 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 (so-called 'leakage'), the effectiveness of environmental measures diminishes.

Recent literature focuses overwhelmingly on the effect of *domestic* environmental policy on *domestic* economic activity.[2] Papers by Eskeland and Harrison (2003) and Hanna (2010) are

[1] 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.*

[2] For example, Fredriksson et al. (2003), Greenstone (2002), Kellenberg (2009), and Wagner and Timmins (2009) consider 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 et al. (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 and where U.S. policy influences levels of foreign production or pollution.

exceptions, which are closest in purpose to this paper as they estimate the effect of U.S. environmental policy on foreign production. Eskeland and Harrison (2003) find little evidence that pollution abatement costs increase outbound U.S. FDI flows to developing countries. Hanna (2010) finds that U.S. multinational firms significantly increase foreign output in response to more stringent environmental policy. Neither of these studies identifies which foreign jurisdictions increase production most in response to U.S. environmental policy.

The paucity of empirical evidence on the international consequences of environmental policy is clearly not due to lack of interest in the subject. An enormous Computable General Equilibrium (CGE) literature on 'carbon leakage' has developed since the adoption of the Kyoto Protocol (1997) to stabilize greenhouse gas emissions, considering how domestic environmental policy influences foreign economic activity. Babiker (2005) is a prominent example.

However, the shortcomings of CGE are well known. CGE complexity makes it difficult for anyone but the authors to understand what drives results. In comparison to empirical work, assumptions tend to drive conclusions. High sensitivity to parameter and functional form assumptions cause peer-reviewed CGE carbon leakage estimates to vary between less than 0 percent and over 100 percent when modelling identical international environmental agreements. In light of these challenges, empirical analysis is a necessary complement to existing CGE studies. If we plan to assume domestic environmental policy affects foreign production, then empirical evidence supporting this should exist.

The lack of internationally comparable data on environmental policy stringency is a major hurdle to empirical analysis.[3] A second challenge arises because estimating international effects, unlike domestic effects, requires a detailed theoretical structure if it is to plausibly account for the heterogeneous effects of domestic environmental policy across foreign countries. Without theory we cannot, for example, model the way stringent policy in Germany influences Polish and Peruvian production differently. This paper directly addresses these two challenges, using theory to derive a measure of foreign environmental policy reflecting locational comparative advantage in polluting production for each country-industry-year triple, and estimating its importance with a recent and increasingly used cross-country data set measuring environmental policy stringency.

Before any empirics, I present and solve a three-country model with environmental policy for

[3] 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.*

the locus of manufacturing production. The use of a three-country model to derive analytic expressions for the location of polluting manufacturing activity differentiates this paper from previous theoretical studies of the 'Pollution Haven Effect' (PHE)[4], which almost exclusively adopt two-country models.[5] A three-country model enables spatially heterogeneous effects of changes in environmental policy, rendering location a source of comparative advantage in pollution intensive production.[6] This motivates the empirical approach adopted.

A generalized version of the theoretical model is used for the empirical analysis. The structural estimating equation implies that polluting firms value environmental comparative advantage, locating where domestic environmental policy is lax and competitors in easily accessed foreign countries face high costs of complying with environmental policy. The estimating equation also 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.

There is a growing empirical literature on 'third country' effects at the heart of which is the idea that location – in particular, the characteristics of nearby jurisdictions – matters.[7] Anderson and van Wincoop (2003) show – both theoretically and empirically – that third country transport costs are critical determinants of bilateral trade. Head and Mayer (2004) and Redding and Venables (2004) examine the influence of third country market size and output on inbound FDI and domestic income. Helpman et al. (2004) suggest that third country firm productivity is likely to influence FDI decisions.

Model in hand, using industry-level data on total value added for 49 countries – which together represent over 90 percent of world GDP – I show that locational comparative advantage in polluting production significantly influences manufacturing activity. More stringent foreign environmental policy, appropriately structurally weighted by market size and market access, increases domestic manufacturing value added. This result survives instrumental variable (IV)

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4 The PHE implies that tightening pollution policy affects plant location and trade flows (Copeland and Taylor 2004).

5 Two-country models include: Pethig (1976), Siebert (1979) and Neary (2006), who present models with constant returns to scale (CRS) and no transport costs; Markusen et al. (1993), Motta and Thisse (1994) and Ulph (1994), who present international oligopoly models; and Venables (1999) and Feddersen (2012), who put forward models with monopolistic competition and transport costs.

6 Deardorff (2004) makes a similar point, showing that 'local comparative advantage' (which is defined as arising from prices that are low in comparison to nearby countries rather than the world as a whole) drives trade in a world with transport costs.

7 In the present paper – as in Redding and Venables (2004) – the term 'third country' could be construed as slightly misleading. Conventional use of the term applies to situations where bilateral flows (typically FDI or trade) are influenced by the characteristics of a country that is neither origin nor destination. In the present paper, the term implies the characteristics of nearby jurisdicitons influence purely domestic variables, like manufacturing value added or profits. I therefore use the terms 'third country' and 'foreign country' interchangably.

estimation, extensive controls and fixed effects specifications.

To the best of my knowledge, this is the first study of the PHE to use total value added – rather than, for example, foreign affiliate value added, FDI or firm births – as a measure of economic activity. This more comprehensive activity variable arises from the theory and is of interest in light of Poelhekke and van der Ploeg's (2012) evidence that FDI faces 'corporate social responsibility' (CSR) motives, deterring investment in countries with lax environmental policy. Weak evidence of the PHE in past studies may be a result of using the wrong regressand.

My empirical results also suggest – as foreshadowed by theory – that past studies of the PHE that do not control for foreign-country environmental policy, can contain bias on the coefficient on domestic environmental policy. The estimated delocation elasticity – the negative influence of tighter domestic environmental policy on domestic manufacturing value added – typically decreases after accounting for third country environmental policy in the empirical model.

Finally, the paper yields one key policy implication, suggesting that policy coordination with major trading partners is a powerful way to address the adverse competitiveness effects of unilateral environmental policy. With transport costs geographically segmenting markets, regional policy is extremely powerful. For example, the leakage levels of a global agreement on carbon dioxide emissions – which is widely considered to be a desirable goal in long-term greenhouse gas policy – may be very closely approximated by a series of more politically feasible regional agreements.

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

2 A model of locational comparative advantage

The theoretical model serves two purposes. First, using a three-country structure I show that location alone – specifically, proximity to a country with stringent environmental policy – can lead a country with no comparative advantage induced by factor abundance or environmental policy to specialize in polluting production. This is the central empirical hypothesis of this paper and it is a result that does not arise in a two-country model. I demonstrate the result in both a medium-run case where firm prices and quantities vary, but firm location is fixed, and a long-run case where firm location varies. Second, a more general many-country version of the theoretical model provides the structural measures of locational comparative advantage in polluting production, and transportation costs, used empirically in Section 3.

2.1 Setup

There are three countries labelled 1, 2 and 3. Country i hosts an exogenous number of consumers/workers L_i who each supply one unit of labor inelastically. Labor is the only factor of production and workers are internationally immobile.[8] Preferences of consumers are defined over horizontally differentiated manufacturing and a homogeneous non-manufactured good, with the utility of a representative consumer equal to:

$$U = C_M^{\mu} C_N^{1-\mu}, \quad C_M \equiv \left(\int_0^{n^w} D(v)^{\frac{\sigma-1}{\sigma}} dv \right)^{\frac{\sigma}{\sigma-1}}, \quad 0 < \mu < 1 < \sigma \tag{1}$$

Cobb-Douglas utility comprises consumption of the non-manufactured good (C_N) and a CES aggregate of all manufactured varieties (C_M). μ is the expenditure share for the manufactured good.

$D(v)$ denotes consumption of manufactured variety v. n^w is the mass of manufactured varieties produced globally. σ is the elasticity of substitution between manufactured goods. Maximizing (1) subject to the budget constraint yields the CES demand functions where E is the total expenditure on the manufactured good and G is the ideal manufacturing price index.

$$D(v) = \frac{p(v)^{-\sigma} E}{G^{1-\sigma}}, \quad G^{1-\sigma} \equiv \int_0^{n^w} p_j^{1-\sigma} dj \tag{2}$$

The non-manufactured good is produced with constant returns to scale (CRS) and is traded between countries without cost.[9] The cost of producing one unit of the non-manufactured good in country i is $w_i z_i$. w_i is the wage per worker in country i and z_i is the labor input per unit of

8 Assumptions regarding the location, mobility and utilization of the factor of production follow Krugman (1980) and are adopted for their analytical simplicity and their familiarity to international economists. These assumptions are not necessary. For example, the four results emphasized in this section can be derived in Martin and Rogers' (1995) Footloose Capital (FC) model and therefore, neither the absence of a second factor of production, say capital, nor the inter-country immobility of labor, is critical.

9 These assumptions yield substantial analytical tractability, but do not drive the paper's main results. As Deardorff (2004) shows, the two key assumptions giving rise to locational comparative advantage are first, transport costs and second, Ricardian comparative advantage (i.e. different levels of pollution intensity by sector).

output in both sectors in country i. With perfect competition, the price of the non-manufactured good in country i is $p_N^i = w_i z_i$, and with free trade $p_N \equiv p_N^1 = p_N^2 = p_N^3$. Assuming that all countries produce some of the non-manufactured good, unit labor cost equalization occurs: $w_1 z_1 = w_2 z_2 = w_3 z_3$.

The manufactured 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. I assume that all countries host some manufacturing firms. A fixed quantity of labor, fz_i, is required per manufacturing firm, and z_i units of labor are required for each unit of the manufactured good produced in country i. Government environmental policy, t_i, adds to firm costs such that total costs in country i are:

$$TC_i = w_i z_i \left(f + t_i x_i\right), \qquad t_i > 1 \tag{3}$$

In the theoretical literature numerous methods have been adopted to model firms' cost of government environmental policy. Environmental policy in equation (3) can most naturally be thought of as requiring firms to hire workers to abate $t_i - 1$ units of pollution per unit of output.[10] This assumption is both highly analytically tractable and plausible in a number of applications. The four results emphasized in this section apply to more general forms of environmental policy and appendices with two plausible alternative specifications are available from the author.[11]

Because the theoretical model is introduced to show how location alone can drive comparative advantage in polluting, I assume that environmental policy is identical in countries 2 and 3 ($t_1 \neq t_2 = t_3$). 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 that allows location choice for delocating production.[12]

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[10] Units of pollution are selected such that abatement of each requires z_i units of labor.

[11] One case considered is if regulation adds to fixed costs – such that $TC_i = w_i z_i \left(t_i f + x_i\right)$ or $TC_i = w_i z_i \left(f + x_i\right) + t_i$. In this case, the model is far simpler to solve and yields the four results emphasized in this section. A caveat applies when taking this approach to data because the assumptions of CES utility and a large number of firms ensure fixed mark-up pricing over variable costs (see equation (4)). Therefore, competitiveness impacts of environmental policy affecting only fixed costs are unlikely to be observed in annual data because they only affect the location of firms and have no price effect. The second case considered is environmental policy in the form of a flat tax per unit of output (such that $TC_i = w_i z_i \left(f + x_i\right) + x_i t_i$). This might be appropriate in the case of a tax on pollution that increases linearly with output and is therefore unaffected by labor costs. The model is solvable for the location of firms, however, comparative statics are analytically unwieldy. Simulation provides a high degree of confidence that the four results emphasized in this section apply in a model with a flat per unit tax.

[12] Ossa (2011) adopts the same trade arrangement in the Krugman (1980) model for its simplicity. Citing the *Braess paradox* (Braess 1968), Behrens et al. (2009) show how complexity increases dramatically in the Krugman (1980) model with trade between country 2 and country 3.

	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 $\tau_{12} < \tau_{13}$. Table 1 summarizes the structure of transport costs between the locus of production (rows) and the locus of consumption (columns).

2.2 Equilibrium location of firms

The combination of CES monopolistic competition and iceberg transport costs ensures mill pricing: 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 policy inclusive variable cost of production ($w_i z_i t_i$). Selecting the non-manufactured good as numeraire ensures $w_i z_i = 1$ for all i. The price of a manufactured variety made in country i and sold in country j is therefore:

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

Equation (4) establishes the relationship between environmental policy and prices and therefore the competitiveness of firms. Without intermediate inputs, firm revenue equals value added:

$$\text{VA}_i = \mu t_i^{1-\sigma}\sum_{j=1}^{3}\frac{\tau_{ij}^{1-\sigma}Y_j}{\sum_{k=1}^{3}\tau_{jk}^{1-\sigma}n_k t_k^{1-\sigma}}, \qquad Y_j = w_j L_j \tag{5}$$

Equation (5) represents a medium-run equilibrium with fixed firm location, appropriate for empirical estimation with annual data (the focus of Section 3). Clearly, with some trade between regions ($\tau_{ij} < \infty$, for some j) firm value added in country i declines in t_i and increases in any t_j. Because the influence of t_j is augmented by greater market access to country i, equation (5) trivially exhibits locational comparative advantage: all else equal, value added is larger if nearby jurisdictions possess stricter environmental policy.

Equation (5) provides abridge to the empirical section of the paper. In the medium-run changes in firm output and prices drive changes in value-added, yet a key question at the heart of existing pollution haven literature is whether stricter environmental policy causes dirty industries to migrate, rather than increase or decrease firm output. Therefore, prior to empirical estimation of equation (5), I prove that locational comparative advantage – with firms locating near markets with stringent environmental policy – arises in the long run.

Designating q_1 (q_2) to be the break-even output level of firms in country 1 (countries 2 and 3), in equilibrium $q_i = f(\sigma - 1)/t_i$. Using this expression for firm output, I solve market clearing conditions for manufacturing firms in countries 1, 2 and 3 for their corresponding equilibrium price indexes as a function of model parameters. Details are in Appendix A.1. Setting the definition of G_i from equation (2) equal to these expressions – equations (16), (17) and (18) in Appendix A.1 – I solve the price indexes for the main variable of interest, the equilibrium location of firms:

$$n_1 = \frac{\mu}{f\sigma} r^{\sigma-1} \left[\frac{Y_1}{\Omega} - \frac{Y_2\phi_{21}}{\Theta - \phi_{12}\Omega} - \frac{Y_3\phi_{31}}{\Theta - \phi_{13}\Omega} \right] \tag{6}$$

$$n_2 = \frac{\mu}{f\sigma} \left[\frac{Y_2\left(1 - \phi_{13}^2\right)}{\Theta - \phi_{12}\Omega} + \frac{Y_3\phi_{12}\phi_{31}}{\Theta - \phi_{13}\Omega} - \frac{Y_1\phi_{12}}{\Omega} \right] \tag{7}$$

$$n_3 = \frac{\mu}{f\sigma} \left[\frac{Y_3\left(1 - \phi_{12}^2\right)}{\Theta - \phi_{13}\Omega} + \frac{Y_2\phi_{21}\phi_{13}}{\Theta - \phi_{12}\Omega} - \frac{Y_1\phi_{13}}{\Omega} \right] \tag{8}$$

$$\Omega \equiv r^\sigma - \phi_{12} - \phi_{13}, \quad \Theta \equiv 1 - \phi_{12}^2 - \phi_{13}^2, \quad \phi_{ij} = \tau_{ij}^{1-\sigma}$$

ϕ_{ij}, which is a measure of trade 'freeness' between countries, equals one when trade has no cost and equals zero for infinitely costly trade. I denote the ratio of the environmental policy parameter in country 1 to country 2 (or country 3) $r \equiv t_1/t_2 (= t_1/t_3)$.

2.3 Comparative statics

Equations (6), (7) and (8) enable comparative static analysis of the long-run relationship between the location of firms and the model's key parameters: environmental policy (t); transport costs (ϕ); and market size (Y). First, by differentiating equations (6), (7) and (8) with respect to t_1, note that more stringent environmental policy in country 1 decreases the number of firms and the level of output in country 1 (i.e. $\partial n_1/\partial t_1 < 0$). This is the aspect of the PHE that has been the focus of most empirical analysis.

Taking the cross-partial derivatives with respect to domestic environmental policy and, respectively, industry transport costs and foreign environmental policy yields two testable predictions:

Lemma 1 *The delocation elasticity increases with trade freeness* (*i.e.* $\frac{\partial^2 n_1}{\partial t_1 \partial \phi_{12}} < 0, \frac{\partial^2 n_1}{\partial t_1 \partial \phi_{13}} < 0$)

Proof. See Appendix A.2 ■

Lemma 2 *The delocation elasticity decreases with neighborhood environmental policy stringency* $\left(i.e.\ \frac{\partial^2 n_1}{\partial t_1 \partial t_2} > 0\right)$

Proof. See Appendix A.2 ■

Lemmas 1 and 2 apply in a simpler two-country model and the real value of the three-country model arises from the stricter spatial definition of a pollution haven that it enables. Only in a model with three or more countries can the more successful pollution haven – the market favored by delocating polluting production – be identified as a function of model parameters. Proposition 1 establishes the location preferences of delocating production from country 1 as a function of country sizes and transport costs.

Proposition 1 $\frac{\partial n_2}{\partial t_1} > \frac{\partial n_3}{\partial t_1}$ *iff*

$$\overbrace{\frac{Y_2\left(1-\phi_{13}^2-\phi_{12}\phi_{13}\right)\phi_{12}}{\left(\Theta-\phi_{12}\Omega\right)^2}}^{Term\ 1}+\overbrace{\frac{Y_1\phi_{12}}{\Omega^2}}^{Term\ 2}$$
$$>$$
$$\underbrace{\frac{Y_3\left(1-\phi_{12}^2-\phi_{12}\phi_{13}\right)\phi_{13}}{\left(\Theta-\phi_{13}\Omega\right)^2}}_{Term\ 3}+\underbrace{\frac{Y_1\phi_{13}}{\Omega^2}}_{Term\ 4}$$

Proof. See Appendix A.3 ■

Inspection of Proposition 1 reveals that delocating production favors both the larger market – a 'market size' effect – and the more accessible market – a 'market access' effect. The market size effect arises because firm profits decline by less in larger markets for each additional firm that opens. This effect can be switched off in the model by setting $Y_2 = Y_3$.

The market access effect can be split into two components. The first component – which is a third country version of the market size effect – can be given intuition by comparing terms 2 and 4 in Proposition 1. Because varieties exported from country 2 incur lower transport costs than those exported from country 3, country 1 consumes a higher quantity of each country 2 variety. Country 2 is therefore better able to absorb new firms – in spite of the increased competition and decreased firm profits they cause – because the output of each additional firm is spread over the market in country 2 and the relatively high demand from country 1. This component can be switched off by setting $Y_1 = 0$ in the model.

The second component of the market access effect is similar to the export-platform motive for FDI; a comparison of terms 1 and 3 in Proposition 1 provides intuition. Tightening environmental policy in country 1 decreases domestic firm profits and firm numbers decline. This decline in firm numbers reduces competition for firms in countries 2 and 3 and increases their profits. Because the less competitive market in country 1 is more accessible to country 2 than to country 3, the reduction in competition enhances the profitability of country 2 firms more. Country 2 is the better export platform to country 1, avoiding stringent environmental policy while minimizing transport costs to the now less competitive market in country 1. This component can be switched off by setting $\phi_{12} = \phi_{13}$.

Finally, to illustrate the pure market access effect, consider a special case of Proposition 1 with $Y_2 = Y_3$ and asymmetric transport costs. In this case, with no advantage in market size or environmental policy, location is the only force creating comparative advantage for Country 2 in attracting polluting firms.

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

Proof. See Appendix A.4. ■

The market access effect demonstrates how locational comparative advantage arises simply as a consequence of positive transport costs. In Section 3 I use the model to construct a measure of locational comparative advantage in environmental policy and estimate its effect on manufacturing output.

3 Empirical evaluation of the model

3.1 Econometric strategy

3.1.1 Functional forms for foreign environmental policy

The main empirical goal is to evaluate the importance of locational comparative advantage in polluting production. In doing so, I rely on guidance from the model to construct measures of foreign environmental policy that are appropriately adjusted for foreign market size and bilateral market access.

Equations (6), (7) and (8) present an intuitive and theoretically grounded functional form for estimating the long-run effect of foreign environmental policy on domestic manufacturing production. However, these functions are discontinuous and non-linear as well as analytically unwieldy in the many-country versions necessary for empirical estimation. Furthermore, and probably more importantly, 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 estimate equations like (6), (7) and (8) in a many-country setting. Instead, I operationalize the medium-run version of the theory, estimating the relationship between environmental policy, both domestic and foreign, and firm value added when firm location is fixed.[13]

Profits can be non-zero and I allow for m 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 and $w_i z_i t_i$ is the marginal cost of production in country i. Fixing firm location, firm value added is a

[13] This is a common approach in the empirical literature on firm location. For examples, see Head and Mayer(2004) and Dean and Lovely (2009).

generalized version of equation (5):

$$\text{VA}_{ilt} = \mu_l \left(w_{it} z_{it} t_{it}\right)^{1-\sigma_l} \sum_{j=1}^{m} \frac{\phi_{ijl} Y_{jt}}{\sum_{k=1}^{m} \phi_{jkl} n_{klt} \left(w_{kt} z_{kt} t_{kt}\right)^{1-\sigma_l}} \tag{9}$$

Value added in country i is equal to the sum of domestic market value added and the value added from exporting to each foreign country. The value added from exporting to country j – which equals $\mu_l \left(w_{it} z_{it} t_{it}\right)^{1-\sigma_l} \phi_{ijl} Y_{jt} / \left(\sum_{k=1}^{m} \phi_{jkl} n_{klt} \left(w_{kt} z_{kt} t_{kt}\right)^{1-\sigma_l}\right)$ – 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, value added is also decreasing in the competitiveness of the market in country j.

Clearly, as in equation (5), more stringent foreign environmental policy increases domestic value added and the effect on domestic value added is increasing in the market access of the foreign country. Importantly for empirical specification, the model yields a simple linear expression in logs for value added:

$$\ln \text{VA}_{ilt} = \ln \mu_l - (\sigma_l - 1) \ln t_{it} - (\sigma_l - 1) \ln w_{it} z_{it} + \ln \left(\sum_{j=1}^{m} \frac{\phi_{ijl} Y_{jt}}{\sum_{k=1}^{m} \phi_{jkl} n_{klt} \left(w_{kt} z_{kt} t_{kt}\right)^{1-\sigma_l}} \right) \tag{10}$$

Apart from the final term, equation (10) makes intuitive sense. Value added (and therefore profit) is increasing in the share of income spent on manufacturing industry l (μ_l), and decreasing in the environmental policy variable (t_{it}) and unit labor costs ($w_{it} z_{it}$). Following standard terminology, I call the exponent of the final term Krugman Market Potential (KMP) and its existence implies that profits from exporting to market j are increasing in GDP (Y_{jt}) and trade freeness from i to j (ϕ_{ijl}) and decreasing in the competitiveness of market j as measured by $\sum_{k=1}^{m} \phi_{jkl} n_{klt} \left(w_{kt} z_{kt} t_{kt}\right)^{1-\sigma}$. This denominator reflects the level of competition in market j from all foreign and domestic firms, giving rise to a 'market crowding' force that decreases profits of firms 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_{klt}) and the trade freeness with which foreign firms access market j (ϕ_{jkl}), and decreasing in the environmental and non-environmental costs of production of those firms, $w_{kt}z_{kt}t_{kt}$.

The presence of the third term makes explicit a potentially important omitted variable from past studies of the PHE considering only domestic environmental policy. If environmental policy is correlated across space – as Fredriksson and Millimet (2002) find, and as suggested by the existence of several regional environmental agreements including the EU Emissions Trading Scheme and NAFTA – changes in t_{it} are correlated with changes in KMP. Because an increase in t_{it} decreases profitability while an increase in market potential increases profitability, past estimates of the effect of domestic environmental policy on measures of economic activity violate the 'non-interference' component of the Stable Unit Treatment Value Assumption (SUTVA) and may exhibit bias.[14]

KMP is typically structurally estimated using the importer fixed effects in an OLS regression with bilateral trade flows as regressand and with the inclusion of terms to control for bilateral transport costs.[15] However, in addition to correcting for potential omitted variable 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 source of variation in the third term of equation (10), I cannot estimate the third term as an importer fixed effect and interpret its effect on value added as evidence that locational comparative advantage in polluting production matters.

Instead, I follow Head and Mayer (2002), constructing the third term from its constituent parts, while ensuring that any variation is only a function of changes in environmental policy and transport costs to foreign countries, rather than Y, n, w or z. The constructed measure of locational comparative advantage in polluting production, which I distinguish from market potential by naming 'multilateral environmental competition' (MEC), is:

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

I describe data sources, including derivation of a proxy for environmental policy, $\widehat{t_{kt}}$, in Section 3.1.2. To isolate the effect of foreign environmental policy, I have made four amendments to the

[14] Without reference to a particular theoretical model, Karp (2011) outlines the practical challenge posed in estimating the effect of domestic policy on domestic polluting activity when third country environmental policy matters. Morgan and Winship (2007) provide a popular explanation of the SUTVA assumption.

[15] See Redding and Venables (2004).

structural measure of KMP from equation (10). First, Y_j is estimated as the average GDP of country j over the seven-year period considered from 1999 - 2005. This removes time variation in MEC caused by changes in GDP and avoids endogeneity arising from using domestic GDP as a regressor with industry value added as regressand. To control for time-variation in foreign GDP lost by this simplification, in econometric specifications I include either country-time fixed effects or a measure of 'foreign market potential' from Head and Mayer (2011) to control for time variation in foreign market characteristics.

Second, to account for the stylized fact that firm size varies substantially within each country, I use GDP rather than firm numbers to reflect the competitiveness of each country-industry. This amendment is based on the assumption that GDP is approximately proportional to manufacturing industry output.

Third, I remove non-environmental variation in production costs by assuming that the remaining component of costs, $w_{it}z_{it}$, does not vary by country. Time and industry variation in production costs is permitted by the specification, as these can be brought outside the summations in the third term of equation (10) where they are captured by time, industry or time-industry fixed effects.[16] This simplification retains the key features of the theory, namely that stricter foreign environmental policy increases domestic value added and that this influence is increasing in trade freeness and the level of foreign production, while remaining estimable with available data. Fourth, I remove domestic environmental policy from the summation, enabling interpretation of MEC^1_{ilt} as a measure of the environmental policy in foreign countries.[17]

$\widehat{\phi_{ijl}}$ is estimated structurally from the model using data on industry-level bilateral trade flows. The approach used is common in the empirical international economics literature and I relegate the specific details to Appendix B.1. Estimating bilateral transport costs by industry enables construction of MEC^1_{ilt} and MEC^2_{ilt} to follow the theory presented here closely.

I consider several variants of the basic specification in order to raise the level of confidence in the

[16] Head and Mayer (2002) take a slightly different approach, assuming that marginal costs are proportional to wages. I believe my approach to approximating wage differentials is more realistic: unit labor costs are better approximated as being equal across countries than being proportional to wages. Using the data from Mayer and Zignago (2005), I find that unit labor costs (in USD) for a given industry, are typically 3-4 times higher in the country representing the 90th percentile than in the 10th percentile country, while wages are 15 times higher in the 90th percentile than in the 10th. I do not use unit labor costs in constructing MEC^1_{ilt}, although this would be my preferred approach, because the data are not available for sufficient country-industry-time observations.

[17] A previous version of this paper kept the domestic policy component in the summation. This approach fits the data better (higher R-squared and more significant coefficents on MEC and the environmental index), yields similar conclusions, but coefficient estimates are far less straightforward to interpret. These domestic-inclusive versions of MEC are available in the data set accompanying this paper.

results. Because MEC^1_{ilt} is dependant on the specific functional forms adopted, as an additional robustness check, I also construct a simpler MEC variable, derived from the theoretical measure of the effect of foreign environmental policy on value added from selling in the domestic market only. Theory suggests this is an important determinant of value added. From equation (9), the natural log of value added from selling in the domestic market only is:

$$\ln \mathrm{VA}^D_{il} = \ln \mu_l - (\sigma_l - 1)\ln(t_{it}) - (\sigma_l - 1)\ln(w_{it}z_{it}) + \ln Y_i + \ln \phi_{ii} - \ln\left(\sum_{j=1}^{m} \frac{\phi_{jil}n_{jl}}{(t_j z_{jl} w_{jl})^{\sigma-1}}\right) \quad (11)$$

Following the same four amendments to the theory used in constructing MEC^1_{ilt}, the alternative MEC variable is:

$$MEC^2_{ilt} = -\ln\left(\sum_{j\neq 1}^{m} \frac{\widehat{\phi_{ijl}} Y_j}{\widehat{t_{jt}}}\right)$$

While grounded in theory, this second measure is a simple GDP and transport cost weighted aggregate of foreign environmental taxes. It is closely related to the ad-hoc market potential measure of Harris (1954), sharing the same empirical virtue of simplicity.

3.1.2 Estimating equation and data sources

I estimate a model that controls for the factors in equation (10). The basic estimating equation is:

$$\ln \mathrm{VA}_{ilt} = \alpha_i + \alpha_l + \alpha_t + \beta_1 \ln \widehat{t_{it}} + \beta_2 MEC_{ilt} + \sum_o \gamma_o \ln X_{it} + \varepsilon_{ilt} \quad (12)$$

β_2 is the main parameter of interest. It measures the elasticity of value added with respect to MEC and the theory presented suggests it should be positive. β_1 is the elasticity of value added with respect to domestic environmental policy and theory predicts a negative value.

Descriptive statistics for variables used and their sources are presented in Appendix C. VA_{ilt} is the value added in USD of ISIC revision two three-digit level industry l in country i at time t. VA_{ilt} comprises World Bank data supplemented by additional sources described in de

Sousa et al. (2012). 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, which are typically not subject to environmental regulation when purchased. 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 the same way that total industry value added does. For example, Poelhekke and van der Ploeg (2012) suggest that Dutch FDI in certain industries avoids countries with lax environment policy on CSR grounds. Domestically owned firms – which typically contribute significantly more to industry value added than foreign owned firms – are of greater policy interest and are also unlikely to be as motivated by CSR considerations.

Two further benefits of using value added data from de Sousa et al. (2005) are: first, it is disaggregated into 26 manufacturing industries, yielding significantly more observations than the US Bureau of Economic Analysis' multinational affiliate value added data, which is disaggregated into 7 manufacturing industries; second, previous studies tend to focus on FDI, plant births or U.S. affiliate value added and, to my knowledge, this is the first paper on the PHE to analyze industry total value added.

On the right hand side of equation (12) α_i, α_l and α_t are country, industry and year fixed effects. The environmental index, $\widehat{t_{it}}$, is a proxy for environmental policy costs. It is drawn from 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 are available every year from 1999 to 2004 (150 are available in 2004).[18] According to the Penn World Tables (Heston et al. 2012), these countries generated approximately 92 percent of global GDP in 1999. This restriction ensures that time variation in MEC^1_{ilt} and MEC^2_{ilt} is due only to changes in environmental policy and not new countries entering the summation.

I focus on two environmental measures from the GCR, reported in each edition from 2000 until 2006 - 2007.[19] The first measure reflects the stringency of environmental policy and the second measure reflects the consistency with which environmental policy is enforced.[20] Both

[18] Because value added data is not available for 10 of these countries between 1999 and 2005, having constructed MEC measures with 59 countries, I include 49 countries in the empirical analysis.

[19] Following the convention when using the GCR data, figures from the 2000 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 edition of the GCR) respondents are likely to reflect on conditions in the previous year in providing their responses.

[20] 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:

measures are reported on a scale from one to seven of increasing stringency/consistency. These measures are multiplied together to yield a composite environmental index of the stringency of environmental policy 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 probably influence firms' marginal environmental costs, into a single measure, and to enable direct comparison with Kellenberg (2009) and Poelhekke and van der Ploeg (2012).

The GCR measure of environmental policy stringency provides three key advantages over the most obvious alternative, industry-level pollution abatement and control expenditure (PACE). A clear advantage is geographic coverage. I am interested in the influence of foreign environmental policy on domestic economic activity in a setting in which inter-jurisdictional collaboration is difficult, therefore cross-country data are desirable. PACE data are typically only collected in developed countries. Second, where it is available, 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.[21]

The third benefit arises because the GCR's measures of environmental policy stringency and enforcement probably 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, advocating the use of many measures of policy stringency to analyze the PHE. By surveying executives on the general stringency and enforcement of environmental policy, the GCR measures capture more dimensions of the regulatory process.

The standard criticisms of survey-based metrics apply to the GCR data, although this appears to be less problematic with the GCR data than many other cross-country surveys. The data are widely used in the international trade literature and have repeatedly demonstrated *construct validity* as GCR metrics behave the way they are expected to.[22] In addition, the GCR metrics demonstrate *convergent validity*, being correlated with objective measures of similar phenomena.[23] The seven versions of the World Economic Forum Global Competitiveness Report cited

'Environmental regulation in your country is (1=not enforced or enforced erratically, 7=enforced consistently and fairly).'

[21] For example, a common caveat in OECD PACE data is: 'definitions and methodologies remain diverse across member countries. International comparisons should therefore be limited to orders of magnitude.'

[22] For example Carr et al. (2001) find a negative impact on FDI of an index created by aggregating 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.

[23] For example, survey responses on the ease of doing business across countries correlates positively with the

in this paper provide details of validity checks performed on GCR metrics.

X_{it} contains a set of additional controls not captured by the fixed effects. To remove omitted variable bias I choose controls that are correlated with the environmental variables $\widehat{t_{it}}$, MEC^1_{ilt} and MEC^2_{ilt} and influence firm profits. As discussed above, I include non-industry-specific foreign market potential from Head and Mayer (2011) to control for non-environmental foreign country effects. I also include GDP per capita, which, according to Grossman and Krueger (1995), is strongly related to environmental policy stringency. I also include government's share of GDP, which captures within country changes in a wide range of government policy variables. Population and the domestic-USD exchange rate should both affect incentives to manufacture domestically and are controlled for. As a final set of control variables, I use indexes of voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption from the World Bank's Worldwide Governance Indicators.

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 (Karp 2011). Kellenberg (2009) finds a two-step procedure with instrumental variables (IVs) dramatically changes the estimated effect of domestic environmental policy on U.S. multinational affiliate value added, and Levinson and Taylor (2008) find a similar improvement when 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 endogenous environmental policy in three main 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 6,765 country-industry-year observations, the mean industry value added is approximately 0.6 percent of GDP. As a consequence, value added in a given industry is unlikely to noticeably influence the environmental index in a given year. Second, to reduce the likelihood of omitted variable bias, I introduce country, industry and year fixed effects to all regressions. To control for omitted variables that are not country, industry or time invariant, first I include a number of potentially important controls through the vector X_{it} and second, I introduce more comprehensive fixed effects – pair-wise interacting country, industry, and year dummy variables.

actual number of days required to start a business.

The third means of addressing potential endogeneity involves adopting a generalized method of moments specification to estimate the model using IVs 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. In selecting these instruments, I assume that in designating land or territorial water protected, countries trade potential consumption from use in the agriculture or fisheries industry for an environmental benefit. Time variation in these two measures therefore reflects changing preferences over environmental goods. Because the available quantity of neither land nor territorial water influences manufacturing profitability, these variables do not affect the level of value added in manufacturing industries directly.

3.2 Estimation results

3.2.1 Baseline estimates

The main purpose of this section is to demonstrate that the theory of locational comparative advantage in polluting production explains the global distribution of manufacturing activity. The main evidence presented for this is a robustly positive and significant value of $\widehat{\beta_2}$ – the coefficient on the two proposed structural MEC measures – estimated across a broad range of model specifications.

As a preliminary step, to motivate subsequent results, I simply use GDP-weighted average foreign environmental policy in concentric circles around each observation as a reduced-form measure of MEC. This type of reduced form measure has been used previously in the spatial econometric literature (Harrigan 2010). Although this concentric circle variable doesn't exploit industry transport cost variation like the measures MEC^1_{ilt} and MEC^2_{ilt} do, its simplicity and transparency are valuable as a starting point for empirical analysis.

Table 6 presents estimation results. Models 1-4 consider all countries and Models 1 and 2 use GDP-weighted average foreign environmental policy by distance[24] tertile and Models 3 and 4 considering foreign environmental policy by distance quartile.[25] Models 2 and 4 include Head

[24] The bilateral distance measure used throughout the paper is a population-weighted measure, described in detail at http://mpra.ub.uni-muenchen.de/26469/1/noticedist_en.pdf.

[25] Tertile and quantile cutoffs are used to avoid the perception that cutoffs could have been chosen in order to

and Mayer's (2011) foreign market potential measures to control for non-environmental foreign country effects. Models 1-4 yield significant positive coefficients on foreign environmental policy. In all models the coefficient on the first quantile – which theory suggests influences domestic economic activity most – is not significant.

This absence of first-quantile significance probably arises because distance to close neighbors varies substantially by country, meaning that for many countries there are very few observations in this quantile. For example, in Europe a 4000km concentric circle captures a large number of foreign countries. In almost all directions, locations 4000km around the population centroid of the USA capture only one country (Canada or Mexico). Harrigan (2010) use a simple approach to address this: consider only one country or region. Models 5-8 therefore restrict the sample to European countries, provided striking evidence of the importance of the environmental policy of nearby neighbors in determining domestic value added: The influence of GDP-weighted foreign environmental policy declines monotonically by distance quantile.

Table 7 presents results exploiting the structural measures of MEC: MEC^1_{ilt} and MEC^2_{ilt}. In Models 9 - 16 the coefficient on MEC^1_{ilt} lies between 0.26. and 0.30, implying that more stringent foreign environmental policy increases domestic manufacturing value added. Consistent with the theory on locational comparative advantage, all four estimated coefficients are significant at least at the five percent level. Because the equation is linear in logs, coefficients can be interpreted as elasticities: a one percent increase in MEC^1_{ilt} is associated with an increase of approximately 0.28 percent in manufacturing value added. The coefficient on $\ln \widehat{t_{it}}$ is negative as implied by the theory. Estimates of the impact of a one percent increase in $\widehat{t_{it}}$ on industry value added range from -0.195 percent to -0.30 percent.

Model 9 only includes the domestic and foreign environmental policy terms in addition to country, industry and year fixed effects. In Model 10 the six governance measures are introduced. The inclusion of these variables reduces the magnitude of the coefficient on $\ln \widehat{t_{it}}$. Only two of the six subjective measures are significant at the ten percent level, with positive coefficients on the regressors reflecting control of corruption and regulatory quality.

Model 11 controls for important non-environmental domestic market factors that have been shown to influence economic activity. The inclusion of GDP per capita, government share

drive the results. The 25th distance percentile (first quartile) is calculated as the country-country bilateral distance for which 25% of country-country distance pairs in the sample are shorter. Countries with a population centroid less than 5,330km (greater than 9,436km) from the observation country belong to the first (third) tertile. Countries belonging to each quartile are delineated at distances of 4,315km, 7,616km and 10,474km.

of GDP, population and exchange rate make little difference to the environmental regressors' coefficients. I find that high GDP per capita countries have higher value added and that higher domestic-USD exchange rates and tariffs decrease manufacturing value added.

Model 12 introduces the country-time specific foreign market potential term from Head and Mayer (2011). The inclusion of foreign market potential as a control ensures that MEC^1_{ilt} is not confounded with 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. Unlike in the Models 1 - 8, the inclusion of the foreign market potential term reduces the coefficient on MEC^1_{ilt}, but it remains significantly greater than zero.

Models 13 - 16 paint a very similar picture, with a positive coefficient on MEC^2_{ilt} consistent with the theory. Estimated coefficients on all regressors in Models 9 - 12 match those in Models 13 - 16 very closely, suggesting that the functional form of MEC^1_{ilt} is not driving the results.

3.2.2 Robustness checks

In Table 8, Models 17 - 18 present the IV estimates obtained by two-stage generalized method of moments (GMM) estimation using the two instruments for $\widehat{t_{it}}$ described in Section 3.1.3. Included control variables correspond respectively to the two full models (Models 12 and 16). Table 9 presents first stage regression results. Three diagnostic tests are conducted for the IV specifications. In both cases, the Hansen J-statistic rejects the joint null hypothesis that the instruments are invalid and the Anderson likelihood ratio test rejects the null hypothesis that the equation is under-identified. The Cragg-Donald F-statistic rejects the null hypothesis of weak instruments at a five percent significance level for maximal bias levels of 0.1 of the IV estimator relative to OLS. Table 9 presents first stage regression results for Models 17 and 18.

The estimated coefficients are similar to those in Table 7, an observation supported by highly insignificant Durbin-Wu-Hausman test p-values, which fail to reject the assumed exogeneity of the environmental index. By comparison with Kellenberg's (2009) finding of endogenous environmental policy when using the GCR data, the insignificant Durbin-Wu-Hausman test statistic suggests that endogeneity bias can be addressed through the use of country-level fixed effects and disaggregated data by manufacturing industry. Instrumentation reduces efficiency relative to OLS, yielding larger standard errors. These IV results provide little reason to forego the efficiency of OLS estimation in favor of a GMM-IV approach.

Table 10 evaluates the robustness of the results presented in Table 7 to the inclusion of extensive fixed effects. Because MEC is country, industry and time varying, I expect to be able to identify an effect through variation in any of these dimensions. Models 19 - 21 include MEC^1_{ilt}, and Models 22 - 24 include MEC^2_{ilt}. I omit non-environmental control variables from the table for convenience.

Models 19 and 22 include country-year fixed effects. The coefficient on environmental policy is no longer estimable and the effect of these added regressors on MEC^1_{ilt} and MEC^2_{ilt} is small and positive, with both coefficients significant at the one percent level and equal to approximately 0.3. Potentially omitted country and time invariant factors from prior specifications do not appear problematic. This provides further reassurance that the MEC variables are not capturing non-environmental foreign country variables.

Models 20 and 23 include industry-year fixed effects with very little impact on the coefficients on the environmental policy variables. This suggests that omitted industry-time specific factors, such as innovation or global demand and supply shocks are not causing any bias in the estimated environmental policy coefficients.

Models 21 and 24 introduce country-industry fixed effects, relying on time variation in MEC^1_{ilt} to identify an effect of foreign environmental policy. The inclusion of over 1,000 country-industry dummy variables reduces the magnitude of the coefficient on the environmental policy variables and renders coefficients insignificant. The R-squared of 0.98 implies that fixed effects absorb most of the variation in value added.

Identification of environmental policy effects using only time variation in the data presents a very high hurdle.[26] With at most seven observations per country-industry pair, there is insufficient variation in MEC^1_{ilt} to establish a significant relationship with value added.

Perhaps the most plausible omitted country-industry specific variable that MEC could be capturing is industry transport cost adjusted foreign market size. For example, the foreign markets that benefit domestic firms the most vary depending on industry transport costs. Even this seems unlikely , as it would require environmental policy to be correlated with market size (a relationship that is not strong in the data). Also, results in Table 6 – which show that a

[26] This is especially the case in the WEF data. Kellenberg (2009) is unable to detect a significant effect of domestic environmental policy on domestic U.S. foreign affiliate value added with country fixed effects, and the main specification therefore uses only 'region' fixed effects. This may arise because the WEF data has little time variation when compared to other measures of environmental policy. Indeed, there should be no time trend because respondents are asked to rate environmental policy relative to the current global average.

non-industry-varying measure of foreign environmental policy influences domestic manufacturing activity – suggest that industry variation in MEC is not necessary to identify a significant positive effect.

As a further robustness check, I adopt the approach of Kellenberg (2009), taking a long-difference with a five year span between the years with the least and most stringent average environmental policy across all countries, 2001 and 2005. Results from estimating eight different models with country-industry fixed effects are presented in Table 11. Models incorporate increasingly stringent control variables from left to right, with the right-most models (28 and 32) including country-year fixed effects in addition to country-industry fixed effects. The coefficients on the environmental policy variables over this time frame are substantially larger, perhaps reflecting the fact that in the long-run environmental policy is a more potent determinant of the location of polluting activity. The MEC coefficients are significant and positive, indicating that it is possible to identify a significant effect of MEC using only its time-variation.

As a final robustness test, specifications in Table 12 control for industry pollution intensity. If the value added in pollution intensive industries responds more to environmental policy, this increases confidence that the GCR environmental policy metrics accurately reflect environmental policy stringency.

As a measure of industry pollution intensity, I use 2005 U.S. industry Pollution Abatement Operating Costs (PAOC) divided by 2005 U.S. industry value added ($\text{PAOC}_{l,US}/\text{VA}_{l,US}$).[27] The use of operating (rather than total) expenditure is standard and follows Levinson and Taylor (2008) among others. The industry pollution intensity measures are presented in Table 4, along with the concordance used between NAICS and ISIC three-digit manufacturing industries.[28]

For each of the four columns from left to right, the controls included are identical to Table 11. Model 33 includes only country, industry and time fixed effects. Model 34 adds governance controls, Model 35 adds macroeconomic controls, and finally model 36 incorporates country-time fixed effects. Across all specifications, the coefficient estimates on the three environmental policy variables change little. Clearly, the value added of more pollution intensive industries is more responsive to domestic environmental policy. Interpreting the coefficients from Model 35, a one percent increase in the level of the domestic environmental index decreases domes-

[27] Both PAOC and value added are expressed in 2005 USD and are freely available from the U.S. Census Bureau.

[28] For empirical analysis, prior to taking the log, I rescale $PAOC_{l,US}/VA_{US}$ relative to its mean so that industries with above (below) average pollution intensity have $\ln\left(PAOC_{l,US}/VA_{l,US}\right) > 0$ (< 0).

tic manufacturing value added in the manufacturing industry with average pollution[29] by 0.28 percent. The same one percent change is estimated to decreases value added by 0.75 percent in the heavily-polluting iron and steel industry and increases it by 0.37 percent in the largely pollution-free 'machinery, except electrical' industry. The positive coefficient on the least polluting manufacturing industry is not surprising, arising quite naturally in a general equilibrium model like that in Section 2, but with a continuum of polluting manufacturing industries with increasing – rather than equal – pollution intensity.

3.2.3 Policy analysis

Foreign environmental policy is of statistical significance, but is it of practical significance? To consider this question, I simulate regional environmental policy coordination scenarios assuming the structural relationship and coefficient estimates from the empirics above. The simple simulation process is as follows. First, I select three reasonably representative country-industry-year triples. I consider only the food products industry, which exhibits approximately average trade freeness and pollution intensity. As a consequence, the food products industry behaves much like the entire manufacturing industry would. I select Indonesia, Mexico and Poland as countries because they belonging to different regions, are of similar economic size and possess similar environmental indexes. The year 2000 is the latest in which value added data for the food products industry is available for all three countries.

Second, I select three policy experiments, one for each country-industry-year triple. For the Indonesian simulation, I assume that environmental indexes for all east Asian countries must at least increase to the level of Malaysia (17.63).[30] For the Mexican simulation, I assume that environmental indexes for Canada (32.45) and USA (34.16) reach Germany's level (38.19). For the Polish simulation, European countries[31] lower their environmental index to the level of Poland (17.64).

Third, I choose the coefficient estimates from Model 32 to use in the simulation. Model 32 benefits from the inclusion of a large set of controls and the measure of MEC^2_{ilt} is easier to construct and more intuitive to interpret than MEC^1_{ilt}. Model selection impacts the coefficient

[29] The average value for industry PAOC divided by industry value added is 1.37 percent.

[30] East Asian countries in the sample with environmental indexes below Malaysia in 2000 were Bangladesh (6.96), China (12.95), Philippines (7.84), Thailand (14.06) and Vietnam (8.28).

[31] These are Austria (37.62), Belgium (31.11), Switzerland (39.00), Czech Republic (18.36), Germany (38.19), Denmark (37.52), Spain (20.58), Estonia (19.27), Finland (41.6), France (34.1), United KIngdom (32.48), Hungary (19.78), Ireland (24.96), Iceland (35.34), Italy (23.94), Lativa (18.92), Neatherlands (39.53), Norway (33.48), Slovak Republic (19.2), Slovenia (20.16), Sweden (36.4).

on MEC very little provided country-industry fixed effects are not included, and simulation using the coefficient estimates from Model 29 and MEC^1_{ilt} yields almost identical results. .

Country	Scenario	Percentage change in exp(-MEC^2)	Percentage change in value added
Indonesia	East Asian countries increase environmental index at least to Malaysian level	-8.3%	2.6%
Mexico	USA and Canada increase environmental index to German level	-8.3%	2.5%
Poland	European countries reduce environmental index at least to Polish level	75.0%	-15.0%

Notes: Simulations apply to the food products industry (ISIC 311) for the year 2000.

Table 2: The practical significance of three simulated policy changes

Table 2 presents simulation results. The third column shows the effect of each policy change on the measure $\sum_{j\neq 1}^{m} \widehat{\phi_{ijl}} Y_j / \widehat{t_{jt}}$. This provides a sense of how policy changes in a few nearby countries can influence MEC.[32] The fourth column shows the simulated effect on value added in the food products industry.

Two key messages arise from the simulation exercise. First, foreign environmental policy influences domestic manufacturing value added materially. A 2.5% change in the size of the manufacturing industry for a substantial – but not implausible – environmental policy change clearly matters. Second, regional cooperation is a powerful way to offset the negative competitiveness effects of domestic environmental policy changes. For example, as $\widehat{\beta_1} \approx 0.2$ across Models 9 - 16, the negative impact of, say, a 10% increase in the domestic environmental policy index on value added is more than offset by the simulated policy proposals for Mexico and Indonesia.

[32] Because policy scenarios are regional, the same scenario would influence value added more in industries with lower trade freeness than food products.

3.2.4 Omitted variable bias

Is the estimated delocation elasticity $\widehat{\beta_1}$ biased if a measure of multilateral environmental competition is omitted from the estimating equation? The preceding results suggest a clear breach of the Stable Unit Treatment Value Assumption (SUTVA) assumption typically made in PHE studies considering the effect of domestic environmental policy on domestic polluting economic activity: I have shown that the treatment status of any unit *does* affect the outcomes of other units. However, this effect may be of little practical concern.

Table 13 provides mixed evidence of the practical importance of breaching the SUTVA assumption. Consider first the upper-half of the table, which analyzes the full sample. The specifications in left hand column control includes the standard governance and macroeconomic controls as well as country, industry and year fixed effects, the second column adds industry-year fixed effects and the third column adds country-industry fixed effects.[33] Within each column, I compare $\widehat{\beta_1}$ when estimated without controls for MEC, with estimates obtained when controlling for MEC^1_{ilt} and MEC^2_{ilt}. In all three columns, estimates of β_1 with MEC controls differ by less than three percent from $\widehat{\beta_1}$ when estimate without a MEC control. This suggests that omitted MEC does not pose a bias problem in practice.

Because environmental policy in neighboring jurisdictions is correlated through time (Fredriksson and Millimet, 2002), one might be concerned that omitting MEC is problematic if $\widehat{\beta_1}$ is estimated using only time variation in environmental policy. This hypothesis receives stronger support. In the lower-half of Table 13, I consider observations only for 2001 and 2005 – recall these are the years with the lowest and highest average level of environmental policy across countries in the sample – because time variation in environmental policy has a significant impact on value added in this sub-sample. When β_1 is estimated without country-industry fixed effects, omission of MEC from the specification causes a small change in $\widehat{\beta_1}$ ($<$ seven percent). However, with country-industry fixed effects $\widehat{\beta}_1$ declines by over 20 percent. Table 13, in its entirety, suggests exercise of some caution in applying the SUTVA to empirical studies of the PHE.

[33] β_1 cannot be estimated with country-time fixed effects.

4 Conclusion

This paper considers the influence of locational comparative advantage in polluting production on the level of domestic manufacturing activity using theory and empirics. Deploying a spatial model with increasing returns to scale and transport costs, I show how comparative advantage in the production of pollution intensive goods can arise purely from location. The theory suggests that high market access to jurisdictions with stringent environmental policy increases the size of the domestic polluting industry.

Operationalizing the model empirically, I find robust evidence that stricter foreign environmental policy increases domestic manufacturing value added and that stricter domestic environmental policy reduces it. Both the theoretical and empirical analyses suggest that estimates of the Pollution Haven Effect that ignore third country environmental policy – yet make the stable unit treatment value assumption – can be misleading.

The present paper suggests several directions for future research. The use of a multilateral policy term like MEC to consider the spatial effects of non-environmental policies like labor laws or intellectual property rights may provide similar empirical insights in those areas. Empirical results also suggest that the long-term response to environmental policy may be very different to the short-term response. Clearly future work should also ensure that estimates of the PHE are not biased because of a failure to allow for foreign country effects.

This paper provides an important and novel policy implication, suggesting that policy coordination with major trading partners is a powerful way to address the adverse competitiveness effects of unilateral environmental policy. With transport costs geographically segmenting markets, regional policy is extremely powerful. Based on Table 2, the additional benefits of global coordination over, say, European or North American coordination are likely to be small for most manufacturing industries. A global agreement on carbon dioxide emissions – which is widely considered to be a desirable goal in long-term greenhouse gas policy – may be very closely approximated by a series of more politically feasible regional agreements.

References

Aldy, Joseph E., and William A. Pizer. 2011. "The Competitiveness Impacts of Climate Change Mitigation Policies." National Bureau of Economic Research Working Paper 17705.

Anderson, James E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review*, 93(1): 170–192.

Babiker, Mustafa H. 2005. "Climate Change Policy, Market Structure, and Carbon Leakage." *Journal of International Economics*, 65(2): 421–445.

Becker, Randy, and Vernon Henderson. 2000. "Effects of Air Quality Regulations on Polluting Industries." *Journal of Political Economy*, 108(2): 379–421.

Behrens, Kristian, Andrea R. Lamorgese, Gianmarco I.P. Ottaviano, and Takatoshi Tabuchi. 2009. "Beyond the Home Market Effect: Market Size and Specialization in a Multi-Country World." *Journal of International Economics*, 79(2): 259–265.

Ben Kheder, Sonia, and Natalia Zugravu. 2012. "Environmental Regulation and French Firms Location Abroad: An Economic Geography Model in an International Comparative Study." *Ecological Economics.*

Blonigen, Bruce A., Ronald B. Davies, and Keith Head. 2003. "Estimating the Knowledge-Capital Model of the Multinational Enterprise: Comment." *The American Economic Review*, 93(3): 980–994.

Braess, Dietrich. 1968. "Über ein Paradoxon aus der Verkehrsplanung." *Mathematical Methods of Operations Research*, 12(1): 258–268.

Carr, David L., James R. Markusen, and Keith E. Maskus. 2001. "Estimating The Knowledge-Capital Model of the Multinational Enterprise." *The American Economic Review*, 91(3): 693–708.

Copeland, Brian R., and M. Scott Taylor. 2003. *Trade and the Environment: Theory and Evidence.* Princeton University Press.

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

Dean, Judith M., Mary E. Lovely, and Hua Wang. 2009. "Are Foreign Investors Attracted to Weak Environmental Regulations? Evaluating the Evidence from China." *Journal of Development Economics*, 90(1): 1–13.

Deardorff, Alan. 2004. "Local Comparative Advantage: Trade Costs and the Pattern of Trade." University of Michigan Research Seminar in International Economics Working Paper 500.

De Sousa, Jose, Thierry Mayer, and Soledad Zignago. 2012. "Market Access in Global and Regional Trade." *Regional Science and Urban Economics*, 42: 1037–1052.

Ederington, Josh, and Jenny Minier. 2003. "Is Environmental Policy a Secondary Trade Barrier? An Empirical Analysis." *Canadian Journal of Economics/Revue canadienne d'économique*, 36(1): 137–154.

Ederington, Josh, Arik Levinson, and Jenny Minier. 2005. "Footloose and Pollution-Free." *The Review of Economics and Statistics*, 87(1): pp. 92–99.

Ekholm, Karolina, Rikard Forslid, and James R. Markusen. 2007. "Export-Platform Foreign Direct Investment." *Journal of the European Economic Association*, 5(4): 776–795.

Eskeland, Gunnar S., and Ann E. Harrison. 2003. "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis." *Journal of Development Economics*, 70(1): 1–23.

Feddersen, John. 2012. "Why We Can't Confirm the Pollution Haven Hypothesis: A Model of Carbon Leakage with Agglomeration." University of Oxford Department of Economics Discussion Paper 613.

Fredriksson, Per G., and Daniel L. Millimet. 2002. "Strategic Interaction and the Determination of Environmental Policy across U.S. States." *Journal of Urban Economics*, 51(1): 101–122.

Fredriksson, Per G., John A. List, and Daniel L. Millimet. 2003. "Bureaucratic Corruption, Environmental Policy and Inbound US FDI: Theory and Evidence." *Journal of Public Economics*, 87(7-8): 1407–1430.

Greenstone, Michael. 2002. "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." *Journal of Political Economy*, 110(6): 1175–1219.

Grossman, Gene M., and Alan B. Krueger. 1995. "Economics, Growth and the Environment." *The Quarterly Journal of Economics*, 110(2): 353–377.

Hanna, Rema. 2010. "US Environmental Regulation and FDI: Evidence From a Panel of US-Based Multinational Firms." *American Economic Journal: Applied Economics*, 2(3): 158–189.

Harrigan, James. 2010. "Airplanes and Comparative Advantage." *Journal of International Economics*, 82(2): 181–194.

Harris, Chauncy D. 1954. "The Market as a Factor in the Localization of Industry in the United States." *Annals of the Association of American Geographers*, 44(4): 315–348.

Head, Keith, and Thierry Mayer. 2002. "Market Potential and the Location of Japanese Investment in the European Union." Centre for Economic Policy Research Working Paper 3455.

Head, Keith, and Thierry Mayer. 2004. "Market Potential and the Location of Japanese Investment in the European Union." *Review of Economics and Statistics*, 86(4): 959–972.

Head, Keith, and Thierry Mayer. 2011. "Gravity, Market Potential and Economic Development." *Journal of Economic Geography*, 11(2): 281–294.

Head, Keith, Thierry Mayer, and John Ries. 2010. "The Erosion of Colonial Trade Linkages After Independence." *Journal of International Economics*, 81(1): 1–14.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple. 2004. "Export Versus FDI with Heterogeneous Firms." *The American Economic Review*, 94(1): 300–316.

Heston, Alan, Robert Summers, and Bettina Aten. 2012. "Penn World Table Version 7.1." Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.

Javorcik, Beata Smarzynska, and Shang-Jin Wei. 2005. "Pollution Havens and Foreign Direct Investment, Dirty Secret or Popular Myth?" *The B.E. Journal of Economic Analysis and Policy*, 3(2): 8.

Karp, Larry. 2011. "The Environment and Trade: A Review." *Annual Reviews of Economics*, 3: 397–417.

Kellenberg, Derek. 2009. "An Empirical Investigation of the Pollution Haven Effect with Strategic Environment and Trade Policy." *Journal of International Economics*, 78(2): 242–255.

Keller, Wolfgang, and Arik Levinson. 2002. "Pollution Abatement Costs and Foreign Direct Investment Inflows to US States." *Review of Economics and Statistics*, 84(4): 691–703.

Krugman, Paul. 1980. "Scale Economies, Product Differentiation, and the Pattern of Trade." *The American Economic Review*, 70(5): 950–959.

Levinson, Arik. 1996. "Environmental Regulations and Manufacturers' Location Choices: Evidence from the Census of Manufactures." *Journal of Public Economics*, 62(1): 5–29.

Levinson, Arik, and M. Scott Taylor. 2008. "Unmasking the Pollution Haven Effect." *International Economic Review*, 49(1): 223–254.

List, John A., and Catherine Y. Co. 2000. "The Effects of Environmental Regulations on Foreign Direct Investment." *Journal of Environmental Economics and Management*, 40(1): 1–20.

Lopez-Claros, Augusto, and Klaus Schwab. 2006. *The Global Competitiveness Report 2005-2006.* Geneva: Oxford University Press.

Lopez-Claros, Augusto, Michael E. Porter, Xavier Sala-i Martin, and Klaus Schwab. 2006. *The Global Competitiveness Report 2006-2007.* London: Palgrave Macmillan.

Markusen, James R., and Keith E. Maskus. 2002. "Discriminating Among Alternative Theories of the Multinational Enterprise." *Review of International Economics*, 10(4): 694–707.

Markusen James, R., R. Morey Edward, and D. Olewiler Nancy. 1993. "Environmental Policy when Market Structure and Plant Locations Are Endogenous." *Journal of Environmental Economics and Management*, 24(1): 69–86.

Martin, Philippe, and Carol Ann Rogers. 1995. "Industrial Location and Public Infrastructure." *Journal of International Economics*, 39(3-4): 335–351.

Morgan, Stephen L., and Christopher Winship. 2007. *Counterfactuals and Causal Inference: Methods and Principles for Social Research.* Cambridge University Press.

Motta, Massimo, and Jacques-François Thisse. 1994. "Does Environmental Dumping Lead to Delocation?" *European Economic Review*, 38(3-4): 563–576.

Neary, J. Peter. 2006. "International Trade and the Environment - Theoretical and Policy Linkages." *Environment and Resource Economics*, 33(1): 95–118.

Ossa, Ralph. 2011. "A 'New Trade' Theory of GATT/WTO Negotiations." *Journal of Political Economy*, 119(1): 122–152.

Pethig, Rüdiger. 1976. "Pollution, Welfare, and Environmental Policy in the Theory of Comparative Advantage." *Journal of Environmental Economics and Management*, 2(3): 160–169.

Poelhekke, Steven, and Frederick van der Ploeg. 2012. "Green Havens and Pollution Havens." Oxford Centre for the Analysis of Resource Rich Economies Working paper 87.

Porter, Michael E., Jeffrey Sachs, Peter K. Cornelius, and John W. McArthur. 2002. *The Global Competitiveness Report, 2001-2002.* Geneva: Oxford University Press.

Porter, Michael E., Peter K. Cornelius, Jeffrey D. Sachs, Macha Levinson, Andrew M. Warner, and Klaus Schwab. 2000. *The Global Competitiveness Report 2000.* Geneva: Oxford University Press.

Redding, S., and A.J. Venables. 2004. "Economic Geography and International Inequality." *Journal of international Economics*, 62(1): 53–82.

Sala-i Martin, Xavier, and Klaus Schwab. 2004. *The Global Competitiveness Report 2003-2004.* Geneva: Oxford University Press.

Schwab, Klaus, and Michael E. Porter. 2005. *The Global Competitiveness Report 2004-2005.* Geneva: Oxford University Press.

Schwab, Klaus, Michael E. Porter, and Peter K. Cornelius. 2003. *The Global Competitiveness Report 2002-2003.* Geneva: Oxford University Press.

Siebert, Horst. 1979. "Environmental Policy in the Two-Country-Case." *Journal of Economics*, 39(3): 259–274.

Ulph, Alistair. 1994. "Economic Policy, Plant Location and Government Protection." In *Trade, Innovation, Environment.* , ed. Carlo Carraro, 123–159. Dordrecht, Boston and London: Kluwer Academic Publishers.

Venables, Anthony J. 1999. "Economic Policy and the Manufacturing Base: Hysteresis in Location." In *Dynamic Issues in Commercial Policy Analysis.* , ed. Richard Baldwin and Joseph Francois, 177–195. CEPR and Cambridge University Press.

Wagner, Ulrich, and Christopher Timmins. 2009. "Agglomeration Effects in Foreign Direct Investment and the Pollution Haven Hypothesis." *Environmental and Resource Economics*, 43: 231–256.

A Appendix to Section 2

A.1 Definition of market clearing conditions and derivation of price indexes

Market clearing conditions for manufacturing firms in countries 1, 2 and 3 allow me to solve for the location of manufacturing firms. These conditions are:

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

$$q_2 = p_2^{-\sigma} \phi_{12} G_1^{\sigma-1} \mu Y_1 + p_2^{-\sigma} G_2^{\sigma-1} \mu Y_2 \tag{14}$$

$$q_2 = p_2^{-\sigma} \phi_{13} G_1^{\sigma-1} \mu Y_1 + p_2^{-\sigma} G_3^{\sigma-1} \mu Y_3 \tag{15}$$

$\phi_{ij} = \tau_{ij}^{1-\sigma}$ 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 expenditure, denoted Y_i, equals $L_i w_i \, (= L_i/z_i)$. Equations (13), (14) and (15) can be solved for the price indexes as a function of model parameters. Note that q_i and p_i have already been determined as functions of model parameters:

$$G_1 = \left[\frac{r q_1 p_1^{\sigma} \left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\mu Y_1 \left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{16}$$

$$G_2 = \frac{q_1 p_1^{\sigma} r}{\mu Y_2} \left[\frac{r^{-\sigma}\left(1 - \phi_{12}^2 - \phi_{13}^2\right) - \phi_{12}\left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{17}$$

$$G_3 = \frac{q_1 p_1^{\sigma} r}{\mu Y_3} \left[\frac{r^{-\sigma}\left(1 - \phi_{12}^2 - \phi_{13}^2\right) - \phi_{13}\left(1 - r^{-\sigma}\phi_{12} - r^{-\sigma}\phi_{13}\right)}{\left(1 - \phi_{12}^2 - \phi_{13}^2\right)} \right]^{\frac{1}{\sigma-1}} \tag{18}$$

The ratio of the environmental policy parameter in country 1 to country 2 (or country 3) is denoted $r \equiv t_1/t_2 (= t_1/t_3)$.

A.2 Derivation of Lemmas 1 and 2

It is useful to define bounds on the parameter space. By the assumption that all countries produce both goods I have restricted the parameter space such that:

$$\phi_{13} + \phi_{12} < r^{\sigma}$$

$$r^{\sigma} < \left(1 - \phi_{13}^2 + \phi_{13}\phi_{12}\right)/\phi_{12}$$

$$r^{\sigma} < \left(1 - \phi_{12}^2 + \phi_{12}\phi_{13}\right)/\phi_{13}.$$

To see this, note from Equation (6) that when these inequalities are satisfied with equality, the number of firms in country 1 is infinitely positive or negative.

Equation (6) can be rearranged as:

$$n_1 = \frac{\mu}{f\sigma}\left(\frac{Y_1}{r - \frac{\phi_{12}+\phi_{13}}{r^{\sigma-1}}} - \frac{Y_2\phi_{21}}{\frac{1-\phi_{13}^2+\phi_{12}\phi_{13}}{r^{\sigma-1}} - \phi_{12}r} - \frac{Y_3\phi_{31}}{\frac{1-\phi_{12}^2+\phi_{13}\phi_{12}}{r^{\sigma-1}} - \phi_{13}r}\right)$$

r now only occurs in the denominator terms. Clearly, the derivatives of the first, second and third denominator terms are:

$$1 + (\phi_{12} + \phi_{13})(\sigma - 1)/r^{\sigma} > 0 \tag{19}$$

$$-\phi_{12} - (\sigma - 1)\left(1 - \phi_{13}^2 + \phi_{12}\phi_{13}\right)/r^{\sigma} < 0 \tag{20}$$

$$-\phi_{13} - (\sigma - 1)\left(1 - \phi_{12}^2 + \phi_{13}\phi_{12}\right)/r^{\sigma} < 0 \tag{21}$$

By the signs on these three terms $\partial n_1/\partial r < 0$. Given the parameter bounds established above, differentiating inequalities (19), (20) and (21) with respect to ϕ_{12} or ϕ_{13} confirms Lemma 1.

Similarly, Lemma 2, is obtained by differentiating inequalities (19), (20) and (21) with respect to t_2.

A.3 Proof of Proposition 1

From equations (7) and (8):

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

Therefore:

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

Note that:

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

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.4 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 $(\Theta-\phi_{12}\Omega)^2 < (\Theta-\phi_{13}\Omega)^2$. This condition is equivalent to $\phi_{13}+\phi_{12} < r^{\sigma}$. Therefore, the assumption of the existence of some manufacturing firms in all regions implies that this inequality holds.

B Appendix to Section 3

B.1 Derivation of industry transport costs

Trade freeness in industry l, between countries i and j, ϕ_{ijl}, is estimated from data on bilateral trade flows within each industry. Designating the variable cost of production in industry l in country i as c_{il}, bilateral trade flows between country i and country j in industry l can be expressed as:

$$M_{ijl} = p_{ijl}q_{ijl}n_{il} = \left[\frac{\mu_l Y_j}{\sum_{k=1}^{m} n_{kl}\phi_{kjl}c_{kl}^{1-\sigma}}\right]\left[n_{il}\phi_{ijl}c_{il}^{1-\sigma}\right] \tag{22}$$

Taking logs of both sides of equation (22) yields:

$$\ln M_{ijl} = \ln\left(\frac{n_{il}}{c_{il}^{\sigma-1}}\right) + \ln\left(\frac{\mu_l Y_j}{\sum_{k=1}^{m} n_{kt}\phi_{kj}c_{kl}^{1-\sigma}}\right) + \ln\phi_{ijl} \tag{23}$$

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 identical to those used in Head and Mayer (2004): (population-weighted) distance; contiguity; and common language. This yields the following estimating equation:

$$\ln M_{ijl} = \exp_i + imp_j + B_{1l}\ln d_{ij} + B_{2l}contiguous_{ij} + B_{3l}commonlanguage_{ij} \tag{24}$$

I estimate this equation using import data from a compilation of trade flows used by Head et al. (2010). Their data is taken 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 adopt Redding and Venables (2004) preferred adjustment for internal trade, constructing trade freeness measures between countries i and j in industry l as:

$$\begin{aligned} \widehat{\phi}_{ijl} &= \left(distw_{ij}^{\widehat{B_{1l}}} \exp^{\widehat{B_{2l}} contiguous_{ij} + \widehat{B_{3l}} commonlanguage_{ij}} \right) \text{ if } i \neq j \\ \widehat{\phi}_{iil} &= \left(distw_{ij}^{\widehat{B_{1l}}/2} \right) \end{aligned}$$

The costs of transport by industry, as measured by $\widehat{B_{1l}}$, are presented in Table 3. For industries in which $\widehat{B_{1l}}$ is more negative, bilateral export value drops more quickly with distance.

Industry	B_1	**Industry**	B_1
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
Machinery, electric	-1.385	Plastic products	-1.582
Machinery, except electrical	-1.397	Other chemicals	-1.597
Food products	-1.403	Other non-metallic mineral products	-1.604
Furniture, except metal	-1.435	Petroleum refineries	-1.658
Textiles	-1.436	Paper and products	-1.817

Table 3: Industry trade freeness measures

B.2 Industry pollution intensity and ISIC-NAICS concordance

ISIC Industry	**NAICS Industry**	**Pollution Abatement Operating Costs (2005) divided by VA VA (2005)**
Machinery, except electrical	Machinery	0.29%
Wearing apparel, except footwear	Textile product mills	0.32%
Professional and scientific equipment	Computer & electronic product	0.34%
Furniture, except metal	Furniture & related product	0.39%
Machinery, electric	Electrical equipment, appliance, & component	0.48%
Fabricated metal products	Fabricated metal product	0.63%
Printing and publishing	Printing & related support activities	0.64%
Transport equipment	Transportation equipment	0.70%
Rubber products	Plastics & rubber products	0.77%
Plastic products	Plastics & rubber products	0.77%
Beverages	Beverage & tobacco product	0.86%
Tobacco	Beverage & tobacco product	0.86%
Textiles	Textile mills	1.05%
Food products	Food	1.13%
Pottery, china, earthenware	Non-metallic mineral product	1.54%
Glass and products	Non-metallic mineral product	1.54%
Other non-metallic mineral products	Non-metallic mineral product	1.54%
Wood products, except furniture	Wood product	1.71%
Leather products	Leather & allied product	2.50%
Footwear, except rubber or plastic	Leather & allied product	2.50%
Petroleum refineries	Petroleum & coal products	2.69%
Industrial chemicals	Chemical	2.85%
Other chemicals	Chemical	2.85%
Paper and products	Paper	3.33%
Iron and steel	Primary metal	4.26%
Non-ferrous metals	Primary metal	4.26%

Table 4: Industry Pollution Abatement and Control Operating Experditure (PAOC) for 2005 divided by Industry Value Added (VA) for 2005

C Data description

Variable	Obs.	Mean	Std.Dev	Min	Max	Source
Value added ($US at current prices)	6765	5,422,854.00	19,200,000.00	- 1,141.12	279,000,000.00	Sousa et al. (2012)
MEC^2_{-i}	6765	42.47	71.85	0.08	1,008.39	See Section 3
MEC^1_{-i}	6765	1,052.99	3,279.77	4.82	58,840.27	See Section 3
MEC^2	6765	466.33	642.92	6.45	5,478.73	See Section 3
MEC^1	6765	20.55	9.55	3.74	42.78	See Section 3
Environmental Index (0-49)	6765	22.11	10.11	5.28	42.24	World Economic Forum
Voice and Accountability (0-100)	6765	64.00	15.73	18.51	86.51	World Bank
Political Stability (0-100)	6765	56.50	19.43	1.75	83.26	World Bank
Gov't Effectiveness (0-100)	6765	68.82	18.07	31.71	96.23	World Bank
Regulatory Quality (0-100)	6765	67.59	15.17	31.43	91.70	World Bank
Rule of Law (0-100)	6765	65.38	18.52	28.58	89.89	World Bank
Control of Corruption (0-100)	6765	67.66	21.42	27.21	101.52	World Bank
GDP per capita (PPP) at current prices (international $)	6765	18,294.08	12,048.75	1,487.55	43,111.42	Penn World Tables
Government Consumption Share of GDP	6765	8.96	3.05	3.21	18.17	Penn World Tables
Domestic-USD Exchange Rate	6765	380.21	1,679.04	0.42	14,167.75	Penn World Tables
Population (000s)	6765	91,430.56	225,303.50	277.28	1,284,303.00	Penn World Tables
Foreign Market Potential	5133	4,203,812.00	5,449,816.00	314,661.60	31,100,000.00	Head and Mayer (2011)
Marine Protected Areas (percentage of territorial waters)	6006	9.71	14.57	0.14	74.87	United Nations
Terrestrial Protected Areas (percentage of land area)	6765	13.77	8.72	0.95	41.95	United Nations

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

Years: 1999 - 2005

Industries: See Table 3 for industries included

Notes: Only observations with recorded value added are included in this table. Six observations of value added are less than zero. These are omitted prior to taking the natural log. Data used to construct the measures of MEC is included in the data files accompanying this paper.

Table 5: Summary of data used

D Estimation results

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: ln(value added)								
ln(Environmental Index - Tertile 1)	-0.0609	-0.246			2.977**	3.358***		
	(0.145)	(0.170)			(1.256)	(1.195)		
ln(Environmental Index - Tertile 2)	1.117***	1.129**			1.543*	1.301		
	(0.350)	(0.443)			(0.831)	(1.085)		
ln(Environmental Index - Tertile 3)	0.811***	0.733**			0.311	0.289		
	(0.302)	(0.316)			(0.327)	(0.297)		
ln(Environmental Index - Quartile 1)			0.245	0.221			1.477	2.680**
			(0.154)	(0.209)			(1.417)	(1.247)
ln(Environmental Index - Quartile 2)			0.265	0.433***			0.0238	0.0810
			(0.167)	(0.161)			(0.162)	(0.198)
ln(Environmental Index - Quartile 3)			0.196	0.402*			0.0672	-0.149
			(0.241)	(0.239)			(0.228)	(0.179)
ln(Environmental Index - Quartile 4)			0.144	0.403*			-0.298	-0.301
			(0.225)	(0.217)			(0.208)	(0.196)
Environmental Index	Y	Y	Y	Y	Y	Y	Y	Y
Governance controls	Y	Y	Y	Y	Y	Y	Y	Y
Macroeconomic controls	Y	Y	Y	Y	Y	Y	Y	Y
Market potential	N	Y	N	Y	N	Y	N	Y
Country fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Industry fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations considered	All	All	All	All	EU only	EU only	EU only	EU only
R-squared	0.822	0.823	0.822	0.823	0.855	0.855	0.855	0.855
Observations	6763	5131	6725	5105	2697	1947	2697	1947

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 1999 - 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions.

Table 6: Naive estimates of the effect of foreign environmental policy

Model	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent variable: ln(value added)								
ln(MEC[1])	0.293***	0.296***	0.293***	0.261**				
	(0.0974)	(0.0977)	(0.0977)	(0.109)				
ln(MEC[2])					0.273***	0.275***	0.270***	0.248**
					(0.0982)	(0.0988)	(0.0989)	(0.110)
ln(Environmental Index)	-0.298**	-0.223*	-0.193**	-0.195*	-0.295**	-0.221*	-0.192**	-0.194*
	(0.119)	(0.114)	(0.0889)	(0.101)	(0.119)	(0.114)	(0.0889)	(0.101)
ln(Voice and Accountability)		-0.146	-0.0637	0.0151		-0.148	-0.0655	0.0145
		(0.164)	(0.119)	(0.115)		(0.164)	(0.119)	(0.115)
ln(Political Stability)		0.0686	0.0332	0.0210		0.0690	0.0334	0.0207
		(0.0427)	(0.0392)	(0.0431)		(0.0425)	(0.0392)	(0.0432)
ln(Gov't Effectiveness)		0.158	0.226	0.732		0.161	0.229	0.735
		(0.486)	(0.395)	(0.455)		(0.486)	(0.394)	(0.454)
ln(Regulatory Quality)		0.661*	0.0302	0.117		0.655*	0.0273	0.119
		(0.339)	(0.253)	(0.365)		(0.340)	(0.253)	(0.365)
ln(Rule of Law)		-0.0959	-0.343	-0.762		-0.0975	-0.347	-0.771
		(0.492)	(0.369)	(0.521)		(0.493)	(0.370)	(0.522)
ln(Control of Corruption)		0.849***	0.464*	0.435		0.849***	0.463*	0.434
		(0.320)	(0.239)	(0.318)		(0.320)	(0.239)	(0.318)
ln(GDP per capita)			1.614***	1.658***			1.616***	1.662***
			(0.283)	(0.405)			(0.285)	(0.407)
ln(Gov't share of GDP)			-0.169	-0.00601			-0.166	-0.0000513
			(0.261)	(0.322)			(0.261)	(0.323)
ln(Exchange Rate)			-0.397***	-0.509***			-0.396***	-0.509***
			(0.0943)	(0.0935)			(0.0944)	(0.0935)
ln(Population)			-0.327	1.055			-0.309	1.072
			(0.747)	(1.002)			(0.751)	(1.007)
ln(Market Potential)				0.147				0.146
				(0.136)				(0.137)
Country fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Industry fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
R-squared	0.820	0.821	0.822	0.823	0.820	0.821	0.822	0.823
Observations	6763	6763	6763	5131	6763	6763	6763	5131

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 1999 - 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions

Table 7: Structural estimates of the effect of foreign environmental policy on value added with domestic policy omitted from MEC

Model	(17)	(18)
Dependent variable: ln(value added)		
$\ln(MEC^1)$	0.283**	
$\ln(MEC^2)$		0.243**
		(0.119)
ln(Environmental Index)	-0.0599	-0.0532
	(0.258)	(0.258)
ln(Voice and Accountability)	0.0616	0.0675
	(0.149)	(0.151)
ln(Political Stability)	0.0637*	0.0637*
	(0.0379)	(0.0381)
ln(Gov't Effectiveness)	1.023**	1.011**
	(0.453)	(0.456)
ln(Regulatory Quality)	-0.446	-0.435
	(0.369)	(0.369)
ln(Rule of Law)	0.272	0.273
	(0.490)	(0.490)
ln(Control of Corruption)	0.760**	0.759**
	(0.359)	(0.360)
ln(GDP per capita)	1.112***	1.107***
	(0.352)	(0.351)
ln(Gov't share of GDP)	-0.270	-0.279
	(0.309)	(0.309)
ln(Exchange Rate)	-0.505***	-0.504***
	(0.0948)	(0.0948)
ln(Population)	0.531	0.507
	(1.355)	(1.354)
ln(Market Potential)	0.359***	0.361***
	(0.129)	(0.130)
Country fixed effects	Y	Y
Industry fixed effects	Y	Y
Year fixed effects	Y	Y
Durbin-Wu-Hausman statistic	0.193	0.215
Durbin-Wu-Hausman p-value	0.660	0.643
Hansen J-statistic	0.886	0.893
Hansen J-statistic p-value	0.347	0.345
Anderson L-R statistic	135.4***	135.4***
Anderson L-R statistic p-value	4.06e-30	4.01e-30
Cragg-Donald F-statistic	68.04	68.06
R-squared	0.0112	0.0106
Observations	4510	4510

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 1999 - 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions. Marine and terrestrial protected area as a percentage of total territorial waters and land are instruments for ln(environmental index). Table 9 presents first stage regression results.

Table 8: Instrumental variable estimation

First Stage of Model	(17)	(18)
Dependent variable: ln(value added)		
ln(MEC[1])	0.0075	
	(0.0106)	
ln(MEC[2])		0.0065
		(0.0107)
ln(Voice and Accountability)	0.4286***	0.4286***
	(0.1629)	(0.1629)
ln(Political Stability)	-0.0596	-0.0596
	(0.0463)	(0.0463)
ln(Gov't Effectiveness)	-0.0513	-0.0509
	(0.3989)	(0.3989)
ln(Regulatory Quality)	0.8946**	0.8945**
	(0.3531)	(0.3532)
ln(Rule of Law)	-1.4327***	-1.433***
	(0.4348)	(0.4349)
ln(Control of Corruption)	-0.3077	-0.3077
	(0.3037)	(0.3037)
ln(GDP per capita)	0.2197	0.2198
	(0.3339)	(0.3339)
ln(Gov't share of GDP)	0.2639	0.2642
	(0.3626)	(0.3626)
ln(Exchange Rate)	0.0192	0.0191
	(0.1316)	(0.1316)
ln(Population)	3.3323***	3.3335***
	(0.7603)	(0.7605)
ln(Market Potential)	0.2535**	0.2535**
	(0.1113)	(0.1113)
Marine Protected Area (% of territorial waters)	-0.0104***	-0.0104***
	(0.0038)	(0.0038)
Terrestrial Protected Area (% of land area)	-0.0024	-0.0024
	(0.0116)	(0.0116)
Observations	4510	4510

Notes: Year-country clustered standard errors of mean in parentheses. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions.

Table 9: First stage regression results

Model	(19)	(20)	(21)	(22)	(23)	(24)
Dependent variable: ln(value added)						
ln(MEC^1)	0.311***	0.298***	0.00269			
	(0.104)	(0.0979)	(0.185)			
ln(MEC^2)				0.291***	0.275***	0.00527
				(0.106)	(0.0986)	(0.185)
ln(Environmental Index)		-0.196**	-0.134		-0.195**	-0.134
		(0.0897)	(0.0932)		(0.0897)	(0.0932)
Governance controls	N	Y	Y	N	Y	Y
Macroeconomic controls	N	Y	Y	N	Y	Y
Country fixed effects	N	Y	N	N	Y	N
Industry fixed effects	Y	N	N	Y	N	N
Year fixed effects	N	N	Y	N	N	Y
Country-Year fixed effects	Y	N	N	Y	N	N
Industry -Year fixed effects	N	Y	N	N	Y	N
Country-Industry fixed effects	N	N	Y	N	N	Y
R-squared	0.825	0.824	0.980	0.825	0.824	0.980
Observations	6763	6763	6763	6763	6763	6763

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 2001 and 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions.

Table 10: Estimated effects of MEC with two-way fixed effects

Model	(25)	(26)	(27)	(28)
Dependent variable: ln(value added)				
ln(MEC^1)	1.364**	1.302**	1.110	5.647**
	(0.538)	(0.554)	(0.739)	(2.577)
ln(Environmental Index)	-0.649*	-0.874***	-0.630**	
	(0.331)	(0.227)	(0.252)	
R-squared	0.986	0.987	0.987	0.988
Observations	1833	1833	1833	1833
Model	(29)	(30)	(31)	(32)
Dependent variable: ln(value added)				
ln(MEC^2)	1.375**	1.309**	1.119	5.834**
	(0.537)	(0.552)	(0.741)	(2.608)
ln(Environmental Index)	-0.647*	-0.872***	-0.628**	
	(0.331)	(0.227)	(0.252)	
R-squared	0.986	0.987	0.987	0.988
Observations	1833	1833	1833	1833
Governance controls	N	Y	Y	N
Macroeconomic controls	N	N	Y	N
Country fixed effects	N	N	N	N
Industry fixed effects	N	N	N	N
Year fixed effects	Y	Y	Y	Y
Country-Year fixed effects	N	N	N	Y
Country-Industry fixed effects	Y	Y	Y	Y

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 2001 and 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions

Table 11: Country-Industry fixed effects with observations for years with lowest and highest environmental index

Model	(33)	(34)	(35)	(36)
Dependent variable: ln(value added)				
ln(MEC[1])	0.215**	0.218**	0.213**	0.227**
	(0.0960)	(0.0965)	(0.0966)	(0.102)
ln(Environmental Index)	-0.379***	-0.304***	-0.278***	
	(0.120)	(0.114)	(0.0885)	
ln(Environmental Index)*ln(Pollution Intensity)	-0.413***	-0.413***	-0.413***	-0.411***
	(0.0297)	(0.0297)	(0.0297)	(0.0302)
Governance controls	N	Y	Y	N
Macroeconomic controls	N	N	Y	N
Country fixed effects	Y	Y	Y	N
Industry fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	N
Country-Year fixed effects	N	N	N	Y
R-squared	0.826	0.826	0.828	0.830
Observations	6763	6763	6763	6763

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 1999 - 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions

Table 12: Accounting for industry pollution intensity

Full sample			
Dependent variable: ln(value added)			
ln(Environmental Index) - No MEC control	-0.188**	-0.191**	-0.134
ln(Environmental Index) - MEC^1 control	-0.193**	-0.195**	-0.134
Relative to estimate without MEC control	97.4%	97.9%	100.0%
ln(Environmental Index) - MEC^2 control	-0.192**	-0.196**	-0.134
Relative to estimate without MEC control	97.9%	97.4%	100.0%
Observations	6763	6763	6763
Years 2001 and 2005			
Dependent variable: ln(value added)			
ln(Environmental Index) - No MEC control	-0.781***	-0.795***	-0.761***
ln(Environmental Index) - MEC^1 control	-0.733***	-0.746***	-0.630**
Relative to estimate without MEC control	106.5%	106.6%	120.8%
ln(Environmental Index) - MEC^2 control	-0.731***	-0.743***	-0.628**
Relative to estimate without MEC control	106.8%	107.0%	121.2%
Observations	1833	1833	1833
Governance controls	Y	Y	Y
Macroeconomic controls	Y	Y	Y
Country fixed effects	Y	Y	N
Industry fixed effects	Y	N	N
Year fixed effects	Y	N	Y
Industry-Year fixed effects	N	Y	N
Country-Industry fixed effects	N	N	Y

Notes: Year-country clustered standard errors of mean in parentheses. Dependent variable is log of industry value added in current USD for the 26 ISIC revision two three-digit manufacturing industries and for 49 countries from 1999 - 2005. *10% level, **5% level, ***1% level. See Appendix C for more detailed variable descriptions.

Table 13: Estimating bias with omitted MEC

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