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TRADE FLOW CONSEQUENCES OF THE EUROPEAN UNION'S REGIONALIZATION OF ENVIRONMENTAL REGULATIONS

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“Trade Flow Consequences of the European Union’s Regionalization of Environmental Regulations”

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ABSTRACT: Groups of countries in a region sometimes impose environmental regulations on themselves, particularly inside the European Union. Regional environmental regulations might affect trade flows to and from the regulated countries differently than unilaterally generated regulations for two reasons. The first we term the uneven competitiveness effect: A given increase in production costs across all countries is a higher percentage increase in production costs for countries that produce low-cost goods than for those that produce high-cost goods. The second reason we term the uneven burden of compliance: Because high-income countries are more likely than low income countries to have relatively stringent environmental regulations in place prior to the creation of regional environmental regulations, the cost of compliance with a given regional environmental regulation might be lower for high income countries than for low-income countries.

Using the gravity equation, we test the effect on bilateral trade flows of increases in environmental regulation stringency ratings, taken from survey data, with a panel of 56 countries, controlling for European Union membership and income levels. We find significant differences in the effects on EU members’ exports and non-EU members’ exports’ as well as across income levels of countries. An increase in environmental regulation stringency leads to a dramatic decrease in exports from low-income EU members; conversely, a similar change in environmental regulation stringency leads to an increase in exports from high income, EU-member countries. The results are consistent with the hypothesized uneven competitiveness effect and the uneven burden of compliance.

Keywords: International trade; gravity equation; regional regulations; environmental regulations; European Union regulations; environment and trade

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1. Introduction

Groups of countries sometimes impose regulations on themselves. The nature of these regulations ranges from military policy, such as nuclear proliferation restrictions, to trade policy, such as limitations on tariffs due to World Trade Organization membership. One specific form of group regulation is regional environmental regulation: A group of countries in a region imposes environmental regulations on all members of the group. Regional environmental regulation has occurred inside common markets, such as the European Union, and other economic integration agreements (EIAs), such as the North American Agreement on Environmental Cooperation treaty that was designed to accompany the North American Free Trade Agreement (NAFTA).[3,4] In this paper, we show that the consequences of increasing environmental regulation stringency differs across low-income and high-income member countries of the European Union. We model and demonstrate empirically the possibility for high-income members of a region to benefit from environmental regulations imposed on the entire group as a protectionist measure—that is, as a means of deterring industry from relocating to the lower-income countries to take advantage of the lower production costs offered there and of simultaneously increasing sales of exports of domestic producers.

This paper exploits survey data from the World Economic Forum in which business executives rate environmental regulation stringency in various countries. Using these data in a gravity equation context, we test the effect of an increase in environmental regulation stringency on bilateral trade flows from all countries (in the dataset) to all

[3] The EU has passed, beginning in 1980, a series of specific directives with stated limits on, for example, sulfur dioxide concentrations in ambient air.
[4] The North American Agreement on Environmental Cooperation does not create new environmental standards or limits on pollutions. Rather, it is designed to encourage enforcement of existing environmental standards within NAFTA member countries.

countries, from high-income countries to high-income countries, from high-income countries to low-income countries, from low-income countries to high-income countries, from low-income countries to low-income countries, and from low-income countries to all countries. We control for whether an increase in environmental regulation stringency occurred within a European Union member country, allowing estimation of the effects of environmental regulation inside and outside a region.

2. Background

Many economists have investigated the relation between international trade flows and environmental regulations. Some research on this subject has tested whether a country can increase its ability to export by reducing the stringency of environmental regulations and therefore lowering the costs of production for exporters (Ederington and Minier, 2003; Levinson and Taylor, 2004; Ederington et al., 2005). Also, the pollution haven hypothesis (PHH) states that “dirty” industries will relocate to those countries that lower their environmental standards, further increasing those countries’ exports (Mani and Wheeler, 1999; Levinson and Taylor, 2004). The combination of lowered costs for domestic exporters and the relocation of dirty industries from countries with stringent environmental regulations to pollution havens theoretically leads to predictions of increased exports when a country lowers its environmental regulation stringency. Empirically, however, the effects of changes in environmental regulation stringency have not been clear. Those studies that have found support for the PHH have generally been limited to studies of the United States and some of its trade partners or studies of only European countries.

For over forty years, international-trade economists have empirically tested the effects of changes in determinants of trade patterns by using the gravity equation, explained further in section 4 of this paper. Until recently, most gravity equation estimates had not found empirical evidence to support that a decrease in environmental regulation stringency leads to an increase in exports (Harris et al., 2002). Furthermore, early gravity equation estimates of the effect of environmental regulations on trade flows rely on proxies for environmental regulation stringency that likely introduced endogeneity to the estimates (Jug and Mirza, 2005). In appendix A, we explicitly show how environmental outcome variables introduce endogeneity into gravity equation estimates of the effects of environmental regulation stringency on trade flows. In addition, we introduce a new proxy for environmental regulation stringency—survey data—and show that it might not introduce endogeneity in appendix B.

More recent gravity equation estimates that appropriately accounted for unobservable country characteristics that could affect both the choice of environmental regulation stringency and the level of economic activity has found statistically significant, positive effect of lowering environmental regulation stringency on exports (Jug and Mirza, 2005). Jug and Mirza run instrumental variables estimations of gravity equation estimates of the effect of environmental regulation compliance expenditure and obtain results that are similar to a non-gravity equation study (Ederington and Minier, 2003) that had been conducted using U.S. data. Both studies' results obtain a significant positive effect on exports when environmental regulation stringency is relaxed. We improve on these studies in multiple ways. The first is by using a proxy for environmental regulation stringency—survey data from the World Economic Forum—that is less likely to introduce endogeneity. Using this proxy also allows us to include many more non-European and low-income countries in our dataset than most previous studies. The second is by using gravity equation estimation techniques developed by Baier and Bergstrand that allow the inclusion of an economic integration agreement variable in the gravity equation without biasing estimates (Baier and Bergstrand, 2004). The third is by controlling for the possible interaction between European Union membership and environmental regulations. Regulations imposed by the EU on the entire group might have different effects than unilaterally generated regulations. Finally, we estimate the effects of changes in environmental regulation stringency on trade flows for countries of different income levels, because the effects may drastically differ for high-income countries and low-income countries.

2.1 Unilateral versus Regional Environmental Regulations

When an increase in environmental regulation stringency occurs unilaterally due to changes within the country (e.g. pressure from constituents for a cleaner environment), the effect on exports from that country to other countries could be positive or negative. Technology spillovers, other countries' taste for "green" goods, establishment and protection of property rights, and signaling of governmental stability could all contribute to a positive effect on exports from a country due to a unilateral increase in environmental regulations in the low-income country. Porter and Van der Linde (1995) argue that stringent environmental regulations can benefit a country not only through improved environmental quality but also through the development of comparative advantages in highly regulated industries.

Conversely, the increased cost of production due to the increase in regulations could contribute to a negative effect on exports because of the resultant higher price of domestically produced goods relative to foreign goods. This could be exacerbated if some "dirty" industries choose to relocate because of the increased cost of production. The net effect of a unilateral increase in environmental regulation stringency therefore seems to be an empirical question.

When an increase in environmental regulation stringency occurs due to changes beyond an individual country's control (e.g. the European Union imposes environmental standards on all members), it is possible that any possible positive effect on exports from that country due to the change would be diminished while the negative effect would be simultaneously magnified. Any positive effect resulting from establishment and protection of property rights and signaling of governmental stability might disappear because the regulations are not self-imposed; externally generated regulations do not necessarily signal stability or protection of property rights: People do not believe that a power-hungry dictator has truly eschewed the development of nuclear weapons when threats of UN sanctions and even war have forced the dictator to stop nuclear weapon development in his country. The cost of production might increase even more than in the case of self-imposed regulations if generalized environmental standards applied across a group of countries ignore differences in individual country characteristics, such as variance in the sulfur content of coal and oil across countries; these characteristics are less likely to be ignored by policymakers in each individual country, and the lowest-cost type of regulation (that achieves the same outcome standard) could be chosen on a tailored basis in the case of a unilateral environmental regulation increase (Oates and Schwab, 1996).

One largely unexplored area in the empirical international trade literature is the interaction of economic integration agreements (EIAs), such as the European Union and NAFTA, and environmental regulations. We show, in a model in section 3 and empirically in section 5, that the (possibly unintended) consequences of regional environmental regulations that could differ across income levels of countries. Low-income countries in an EIA could be more adversely affected by an increase in production costs caused by environmental regulations than high-income countries for two possible reasons. The first we term the uneven competitiveness effect, and it is a reframing of the Alchian-Allen hypothesis (Alchian and Allen, 1964). The second reason we term the uneven burden of compliance: Because high-income countries are more likely than low-income countries to have relatively stringent environmental regulations in place prior to the creation of regional environmental regulations, the cost of compliance with a given regional environmental regulation might be lower for high-income countries than for low-income countries. The remainder of section 2 briefly explains these two effects.

2.2 Uneven Competitiveness Effect

The Alchian-Allen hypothesis is that the presence of a per-unit transport cost lowers the relative price of high-quality goods compared to low-quality goods. For example, transportation costs cause firms to export high-quality apples while keeping low-quality apples for domestic consumption, a phenomenon that Alchian and Allen refer to as “shipping the good apples out.” We reframe the Alchian-Allen hypothesis to examine an increase in production cost due to an increase in environmental regulation stringency. This is explained briefly here and shown more explicitly in a model in section 3.

If production costs in all countries in a region increase by some constant *k* as a result of regional environmental regulations, the percent increase in price will be higher for countries that produce low-priced goods than countries that produce high-priced goods. If there are other producers outside the region whose costs are not increased by *k*, then the impact on each country's competitiveness (relative to the rest of the world) caused by the increase in price falls more heavily on the low-income countries inside the group than the high-income countries.[5] In other words, there is an uneven effect on country competitiveness across income groups.

2.3 Uneven Burden of Compliance

The second reason that low-income countries could be more adversely affected than high-income countries due to an increase in regional environmental regulation stringency is that the costs of compliance with the regulation may not be equally distributed among all countries. High-income countries typically have more stringent environmental regulations in place than low income countries prior to the passage of any regional environmental regulations.[6] Compliance with regional environmental regulations would be less costly in those high-income countries than in low-income

[5] We employ the term, "competitiveness," to mean a country's ability to export goods – an increase in price of a country's goods, due to an increase in production costs, means that the country cannot export as many goods because of substitution and income effects on the parts of foreign consumers.

[6] As evidence that high income countries typically have more stringent environmental regulations than low income countries, note that the mean rating of the environmental regulation stringency of the high income countries in the World Economic Forum's Global Competitiveness Report for years 2000 – 2005 is 5.77 on a scale of 1 to 7 where 7 is "very stringent" and 1 is "very lax", while that of low income countries over the same period is 3.46.

countries, if all countries have to meet some constant standard of compliance. Thus, the increase in production costs would be higher in low-income countries than in high-income countries: the uneven burden of compliance. The uneven burden of compliance is modeled in section 3.

3. Model

3.1 Consumption

Each of N different countries produces a single product, whose exogenous quality is differentiated from the products of other countries.[7] The representative consumer in country j maximizes his CES (Constant Elasticity of Substitution) utility function:

$$U_j(x) = \left[\sum_{i=1}^{N} \mu_i x_{ij}^{\rho}\right]^{\frac{1}{\rho}}$$

Subject to a budget constraint:

$$M_j \geq \sum_{i=1}^{N} p_{ij} x_{ij}$$

Where M_j is country j's income (real GDP), p_{ij} is the price of country i's good when it is sold in country j, x_{ij} is the quantity of good produced in country i that gets consumed in country j, μ_i is the quality of country i's good, and ρ ($0 < \rho < 1$) is a preference parameter capturing the substitutability between goods: As ρ approaches 1, the goods are nearly perfect substitutes, and as ρ approaches 0, the goods are more complimentary. The FOC of this constrained optimization's LaGrangian is given by:

$$\frac{1}{\rho}\left[\sum_{i=1}^{N} \mu_i x_{ij}^{\rho}\right]^{\frac{1}{\rho}-1} \rho \mu_i x_{ij}^{\rho} = \lambda p_{ij}$$

[7] Instead of a single product, it could be that each country produces a variety of products. This variety could even be endogenized, following Dixit-Stiglitz, but that complication seems unnecessary here.

Dividing the FOC for good i by that of good 1 yields:

$$\left(\frac{x_{ij}}{x_{1j}}\right)^{\rho-1} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right) \tag{3.1}$$

Solving for x_{ij}:

$$x_{ij} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right)^{\frac{1}{\rho-1}} x_{1j}$$

Let σ denote the elasticity of substitution, i.e. $\sigma = 1 / (1 - \rho)$ and $1 < \sigma < \infty$:

$$x_{ij} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right)^{-\sigma} x_{1j}$$

Multiplying both sides by p_{ij} and summing over i to produce country j's income on the LHS, we find:

$$\sum_{i=1}^{N} p_{ij} x_{ij} = M_j = \left(\frac{p_{1j}}{\mu_1}\right)^{\sigma} x_{1j} \sum_{i=1}^{N} \mu_i^{\sigma} p_{ij}^{1-\sigma}$$

Solving this expression for x_{ij} yields:

$$x_{ij} = \frac{\mu_i^{\sigma} p_{ij}^{-\sigma}}{\sum_{i=1}^{N} \mu_i^{\sigma} p_{ij}^{1-\sigma}} M_j \tag{3.2}$$

The denominator of this demand is a quality-adjusted price index for country j, which we will refer to as I_j. This Marshallian Demand immediately implies the total expenditure of those in country j on the goods from country i is given by:

$$p_{ij} x_{ij} = \frac{\mu_i^{\sigma} p_{ij}^{1-\sigma}}{I_j} M_j$$

Because of transport costs and tariffs, the price of an imported good is more expensive than the same good in its home country. We model this accordingly:

$$p_{ij} = p_i D_{ij}^{\delta} e^{-\psi 1\{EIA\}}$$

Where p_i is the price of the good in its home country, D_{ij} is the distance between country i and country j, and 1{EIA} equals 1 iff i and j are members of an EIA (Economic Integration Agreement). We assume that a good's quality is increasing in the GDP of the country where it is produced:

$$\mu_i = \kappa M_i^{\alpha}$$

Substituting these two expressions into the expenditure shares produces the gravity equation, where κ and α are simply parameters:[8]

$$p_{ij} x_{ij} = \frac{\kappa^{\sigma}}{I_j} \left[\frac{M_i^{\alpha\sigma} M_j}{D_{ij}^{\delta(\sigma-1)}} \right] e^{(\sigma-1)\psi 1\{FTA\}} \tag{3.3}$$

3.2 Production

The representative producer in each country is a monopolistically competitive firm with a constant marginal cost that varies across countries, c_i. We assume c_i is increasing in μ. The producer's objective is to maximize profits:

$$\pi_i = (p_i - c_i) \sum_{j=1}^{N} x_{ij}(p) = (p_i - c_i) \sum_{j=1}^{N} \frac{\mu_i^{\sigma} p_{ij}^{-\sigma}}{I} M_j$$

We assume that the country is a price index taker. The FOC governs the country's optimal pricing policy:

[8] By allowing these parameters to vary depending on whether we are considering trade between rich and poor countries or rich to rich, this model becomes more flexible and implicitly makes these parameters a function of what determines rich and poor.

$$\sum_{j=1}^{N}(1-\sigma)x_{ij}-\sum_{j=1}^{N}(-\sigma)c_i\frac{x_{ij}}{p_i}=0$$

Making the optimal price a simple mark-up over marginal cost:

$$p_i=\left(\frac{\sigma}{\sigma-1}\right)c_i \tag{3.4}$$

This yields a simple expression for the country's income:

$$M_i=\pi_i=\frac{c_i}{\sigma-1}\sum_{j=1}^{N}x_{ij} \tag{3.5}$$

3.3 Effects of Environmental Regulatory Compliance

We investigate the possible effects of changes in environmental regulation stringency by examining comparative statics in a partial equilibrium—one without income effects—and then discuss the potential role of those income effects.

We model environmental regulation as an exogenous change that benefits the representative consumer's utility at the expense of higher marginal cost in production. The benefits are assumed to be accrued in a linearly separable portion of the utility function, which implies that only the costs (and not the benefits) alter the behavior of agents in our existing model.

Substituting (3.4) into (3.1), we reach a reduced form Marginal Rate of Substitution (MRS) for consumers in country *j* considering imports from country *i* and country *k*. To examine the substitution effect of environmental regulations, consider the reduced MRS both before and after an increase in environmental regulation stringency (t=0 and t=1, respectively):

$$\left(\frac{x_{ij}^t}{x_{kj}^t}\right)^{\rho-1}=\frac{(c_i+tr_i)\sigma/\mu_i(1-\sigma)}{(c_k+tr_k)\sigma/\mu_k(1-\sigma)}$$

Where r is the increase in marginal cost due to regulation, t is both a superscript and dummy variable indicating pre- and post-regulation periods, and two different countries selling goods in country j are indexed by i and k. We compare the pre- and post-regulation MRS to find the condition under which the MRS has decreased as a result of the environmental regulations:

$$\frac{c_i\sigma / \mu_i(1-\sigma)}{c_k\sigma / \mu_k(1-\sigma)} > \frac{(c_i + r_i)\sigma / \mu_i(1-\sigma)}{(c_k + r_k)\sigma / \mu_k(1-\sigma)}$$

Performing some basic algebra yields

$$c_i r_k > c_k r_i \tag{3.6}$$

which holds when $c_i > c_k$ and $r_k \geq r_i$. When the marginal cost of production is higher in country i than in country k, or when the cost of compliance is greater in country k than in country i, the effect of an increase in regional environmental regulation stringency is to decrease the MRS. The aforementioned Alchian-Allen hypothesis is a special case of this condition, where the costs of compliance are equal for both countries: $r_k = r_i$.

There is good reason to suspect that this condition holds for the EU. High-income member nations typically produce more expensive (and higher quality) products than low-income member nations and most nations seeking to join (e.g., financial services produced in London versus textiles in Turkey, a candidate state). Likewise, the high-income member nations on average have stricter environmental regulations than low-income member nations and most nations seeking to join. Consequentially, we would expect that regulatory cost of low-income members or candidate members would be greater than high-income member nations. If this condition does indeed hold, then:

$$\left(\frac{x_{kj}^{0}}{x_{ij}^{0}}\right)^{1-\rho} > \left(\frac{x_{kj}^{1}}{x_{ij}^{1}}\right)^{1-\rho} \tag{3.7}$$

Hence, *ex post* exports from country *k* to country *j* are smaller than *ex ante*, relative to the exports of country *i*. The partial equilibrium effect of the regulation is to cause consumers to substitute away from less-costly goods to more-expensive goods because the costs of the regulation somewhat equilibrates the marginal costs of those goods.

The partial equilibrium results indicate that richer countries grab a larger market share when environmental regulations are increased. However, this can be (somewhat) counteracted by a general equilibrium effect: The size of the overall market is decreased by the income effect of the environmental regulation. In contrast, expanding an EIA lowers tariffs, producing a wealth effect in the opposite direction. Hence, if an increase in environmental regulations is accompanied by a sufficient expansion in EIAs, then the market can grow and rich countries can increase their market share. Thus, the presumed exogeneity of environmental regulations is drawn into question because the unintended consequences of that regulation may disproportionally benefit particular agents.

Following Maloney and McCormick (1982), we could model firms in country *i* lobbying for environmental regulations because their profits vary with environmental regulation. If regulations were determined by a vote of industry representatives, then the median-cost country could effectively choose its first-best alternative. The situation is more interesting when environmental regulations, once passed, are irreversible (i.e. environmental regulations can only be tightened, not slackened). In this case, existing EU members could extract (nearly) all of the gains from integration simply by increasing environmental regulations up to a participation constraint for countries seeking membership. This particular idea is left for future research.

4. Econometric Issues with the Gravity Equation

The literature on the effects of environmental regulations on trade flows has suffered from the lack of a standard measure of environmental regulation stringency. Previous gravity equation estimates of the effect of environmental regulation stringency on trade flows have relied on outcome measures, such as energy intensity, carbon emissions, and sulfur emissions; as these studies admit, endogeneity is an issue when using these outcome variables as proxies for environmental regulation stringency. We explicitly show the potential endogeneity of such an outcome variable in appendix A.

Instead of an outcome variable, we use the results of the World Economic Forum's Global Competitiveness Report survey, which asks thousands of executives from around the world to rate each country's environmental regulation stringency (Porter et al., 2000–2005). This survey asks executives to rate overall environmental regulation stringency in each country, compared to all other countries. The rating scale is from 1 to 7, where 1 is "lax compared with most other countries" and 7 is "among the world's most stringent." We show in appendix B that endogeneity is possibly avoided by using survey data as a proxy for environmental regulation stringency.

As the topic of regional environmental regulation necessarily requires a regional agreement that imposes the regulation on a group of countries, we first discuss the pitfalls of including an economic integration agreement (EIA) variable in the gravity equation. Specifically, we address the endogeneity inherent in the selection into EIAs and how other authors have dealt with that problem.

4.1 Endogeneity in the gravity equation

A typical gravity equation that includes a variable for economic integration agreements is

$$PX_{ijt} = \beta_0 Y_{it}^{\beta_1} Y_{jt}^{\beta_2} D_{ij}^{\beta_3} e^{\beta_4 L_{ij}} e^{\beta_5 A_{ij}} e^{\beta_6 E_{ijt}} \varepsilon_{ijt} \tag{4.1}$$

where PX_{ij} is the value of the merchandise trade flow from exporter *i* to importer *j*, Y_i is the level of gross domestic product in country *i*, D_{ij} is the great circle distance between the economic centers of countries *i* and *j,* L_{ij} is a dummy variable equal to 1 if countries *i* and *j* share a common language, equal to 0 otherwise, A_{ij} is a dummy variable for adjacency that is equal to 1 if countries *i* and *j* share a common land border, equal to 0 otherwise, E_{ijt} is a dummy variable equal to 1 if countries *i* and *j* are both in economic integration agreement (EIA), and ε_{ijt} is assumed to be a log-normally distributed error term. In log form, equation (4.1) becomes

$$\ln PX_{ijt} = \ln\beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln D_{ij} + \beta_4 L_{ij} + \beta_5 A_{ij} + \beta_6 E_{ijt} + \ln\varepsilon_{ijt} \tag{4.2}$$

Early versions of the gravity equation applied to international trade flows did not have formal theoretical foundations (for examples, see Tinbergen (1962), Linnemann (1966), Aitken (1973) and Sapir (1981)); instead, these earlier studies relied either on informal economic foundations or to a physical science analogy. Since 1979, however, formal theoretical economic foundations for a gravity equation similar to equation 1 have surfaced, such as Anderson (1979), Bergstrand (1985), Deardorff (1998), Baier and Bergstrand (2001), Eaton and Kortum (2002), and Anderson and van Wincoop (2003). All of these models include an explicit role for prices across countries in order to generate unbiased estimates. Anderson and van Wincoop specifically include multilateral (price) resistance terms for each country in their system of equations, and solve their system using a custom nonlinear least squares program. Anderson and Van Wincoop (2003) and Feenstra (2004, Ch. 5) both suggest using country-specific fixed effects as an alternative method for accounting for multilateral price terms that will also generate unbiased coefficient estimates.

Extending this literature are Baier and Bergstrand (2004) and Baier and Bergstrand (2007). Baier and Bergstrand (2004) shows that gravity equation estimates of the trade-flow effects of free-trade agreements that include bilateral-pair fixed effects are both plausible and consistent across various econometric specifications. Baier and Bergstrand (2007) contains a formal demonstration that bilateral-pair fixed effects and time dummies specifications of the gravity equation yield the same results as the method of generating custom nonlinear least squares programs employed by Anderson and van Wincoop.

4.2. Endogeneity in the Economic Integration Agreement variable

An endogeniety bias arises when RHS variables are correlated with the error term. In equation (4.2), the economic integration agreement (EIA) variable, E_{ijt}, could potentially be correlated with the error term, rendering estimates of the effect of EIAs therefore biased; empirically and theoretically, the determinants of whether a bilateral pair chooses to join an EIA tend to be the same factors that explain large trade flows: size and similarities of countries' GDPs, distance between the two countries and distance to the rest of the world, whether they share a common language, and differences in relative factor endowments with respect to each other and the rest of the world (Baier and Bergstrand, 2004). The error term could capture unobservable policy-related barriers, such as intra-country shipping regulations, in one or both countries that affect trade between the two and are not accounted for in a typical gravity model. Joining an EIA might entail not just the liberalization of tariffs barriers and other border costs but also that of internal, unobservable non-tariff barriers. Furthermore, it seems likely that country pairs that have already harmonized many non-tariff barriers could easily choose to adopt an EIA because the costs of implementing it are relatively low. Failure to econometrically account for this would introduce an underestimation of the effect of joining an EIA due to a selection bias (Baier and Bergstrand, 2006). In the case of the European Union, a specific EIA where economic integration of monetary policies, antitrust policies, environmental regulations, and securities regulations is a stated goal, the liberalization of non-tariff barriers clearly poses an important potential welfare gain for EU members.

This paper appears to be the first to include bilateral-pair fixed effects in gravity equation estimates of the effects of environmental regulation stringency on trade flows. Baier and Bergstrand (2007) showed that OLS with bilateral-pair fixed effect terms can correct the omitted variable bias on the EIA variable. Yet, to date, no authors of gravity equation-type estimates of the effects of environmental regulation stringency on trade flows have dealt with the potential endogeneity arising from the inclusion of an EIA variable in the gravity equation. Further, following Egger (2000), time dummies are included as well. Thus, equation 2 with bilateral pair fixed effects (δ_{ij}) and time dummies (λ_t) included becomes

$$\ln X_{ijt} = \ln \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 E_{ijt} + \delta_{ij} + \lambda_t + \ln \varepsilon_{ijt} \tag{4.3}$$

Distance, language, and adjacency have all been dropped from equation (4.3) because they are time invariant and therefore completely captured by the bilateral-pair fixed effect term.

The inclusion of bilateral fixed effects in the analysis of the effect of the European Union (and its predecessors, the European Economic Community and European Community) yields striking results when compared to the typical gravity equation estimates that do not include bilateral-pair fixed effects. While most estimates of the effect of the European Union on trade flows found little evidence that membership in the EU by two countries increased bilateral trade flow between them (for example, see Frankel [1997] or Sapir [1981]), more recent studies that have included bilateral-pair fixed effects have found dramatic increases in bilateral trade flows due to European Union membership of both trading partners (Baier, Bergstrand, Egger, and McLaughlin, 2007).

4.3. Avoiding endogeneity with survey data

To avoid endogeneity, we use survey data rating environmental regulation stringency. In this survey, thousands of business executives are asked to rate countries' environmental-regulation stringency levels, relative to all other countries, on a scale of 1 to 7, where 1 indicates that a country has lax standards compared to others and 7 indicates that a country has very strict standards compared to others. We use the mean response of the executives' ratings of each country each year as a proxy for environmental regulation stringency. The model of an ordinal signal on a latent variable presented in appendix B shows that utilization of this survey variable might avoid the endogeneity issue that outcome variables introduce.

4.4. Interaction of European Union membership and regulations

In addition to using a new proxy to test the effects of environmental regulation stringency on trade flows, we also test whether there is any interaction between membership in the European Union and environmental regulations affecting trade flows. Previous studies have sometimes controlled for economic-integration agreements (EIAs) (see Harris, Konya, and Matyas (2002)), while others ignore EIAs altogether when analyzing environmental regulation stringency effects on trade flows; no gravity-type estimate has investigated whether EIAs interact with country-level environmental regulations. The European Union (EU) has had specific environmental regulations that apply to all members in force since at least 1980 (for an example, see Council Directive 80/779/EEC of July 15, 1980, on air-quality limit values and guide values for sulfur dioxide and suspended particulates). These EU-level regulations are interpreted and acted upon by country-level environmental regulation agencies; hence, an interaction effect should not be ignored.

5. Data

We examine a panel of 56 countries from 2000 to 2005, listed in table 1. The 56 countries included in the dataset were the only 56 countries for which survey data exists in all years. Data on membership in the EU were taken from the EU's website and are detailed in table 2. For the purposes of this paper, we have grouped all countries into either "High Income" or "Low Income." Countries grouped into "High Income" had real per capita GDPs of $10,000 or more in the year 2000 according to IMF data.[9] These groupings are shown in table 3.

Nominal exports data come from the IMF's Direction of Trade Statistics CD-ROM. These were converted to real exports using country specific CPIs, base year 2000, taken from the IMF. Observations of no recorded trade between two countries for a given year or recorded trade of zero were replaced with trade of $1 to avoid losing observations in the regressions when taking their natural logs. Current GDP, denominated in U.S. dollars, was converted to real GDP using those same CPIs. GDP data also came from the IMF.

Ratings of environmental regulation stringency come from the World Economic Forum's annual Global Competitiveness Report. Only those countries that were rated in all years 2000–2005 in the survey were included in this dataset; hence, the dataset is a balanced panel. Summary statistics of all variables as well as definitions are provided in table 4.

6. Results

The export flows are analyzed in six different patterns: all countries to all countries, high-income countries to high-income countries, high-income countries to low -income countries, low-income countries to high-income countries, low-income countries to low-income countries, and low-income to all countries. The econometric specification of equation 4.3 is

[9] The choice of $10,000 as the threshold is justified by examining a scatterplot and a kernel density plot of real per capita GDP. If income is bimodal, Figure 1 shows the threshold between the two is at or near $10,000.

$$\ln rxp_{ijt} = \ln\beta_0 + \beta_1 \ln RGDP_{it} + \beta_2 \ln RGDP_{jt} + \beta_3 EU_{ijt} + \beta_4 ENVREGS_{it} + \beta_5 ENVREGS_{jt} + \beta_6 ENVREGS_{it} * EU_{ijt} + \delta_{ij} + \lambda_t + \ln\varepsilon_{ijt} \quad (6.1)$$

where

rxp_{ijt}= value of real exports from country *i* to country *j* in year *t*

$RGDP_{it}$= real GDP in country *i* in year *t*

EU_{ijt}=dummy indicating whether countries *i* and *j* were EU members in year *t*

$ENVREGS_{it}$=environmental regulation stringency in country *i* in year *t*

$ENVREGS_{it}*EU_{ijt}$=interaction term

δ_{ij}=bilateral pair fixed effect term

λ_t=time dummy for year *t*

The primary hypothesis tested is that exports from a low-income country will be more negatively affected by an increase in environmental regulation stringency if that country is a member of the EU than if that country were not an EU member. This hypothesis will be supported if coefficient on the *ENVREG* EU* interaction term is negative and significant in the low income to all countries regression. A secondary hypothesis being tested is that a high-income country experiences a greater increase in its exports due to an increase in environmental-regulation stringency if it is in the EU; this is consistent with the idea that EU-wide regulations affect low income EU members' competitiveness more, relative to high income EU members' competitiveness.

$ENVREGS_{it}$ ranges from a possible minimum of 1 to a possible maximum of 7, where 7 indicates that country *i* has very stringent environmental regulations, compared to other countries, and 1 indicates that country *i* has very lax environmental regulations, compared to other countries. Thus, a positive coefficient on $ENVREGS_{it}$ would indicate that a unilateral increase in environmental regulation stringency in country *i* results in an overall increase in exports from that country its trading partners, ceteris paribus. This could result from technology spillovers, consumer demand for "green" goods in trading partner countries, or signaling of regime stability and property right development. It could also indicate that $ENVREGS_{it}$ proxies for some other factor that affects trade. A negative coefficient on $ENVREGS_{it}$ would indicate that exports from country i decrease as a result of an increase in environmental regulation stringency in country i, indicating that the increased production costs made firms in country i less competitive.

The interaction term, $ENVREGS_{it}*EU_{ijt}$, estimates the effect of an increase in environmental regulation stringency of the exporter, i, given that country i is in the EU. Its coefficient, β_6, when added to the coefficient on $ENVREGS_{it}$, β_4, estimates the net effect on exports of an increase in environmental regulation stringency in European Union member countries.

Table 5 presents the results of gravity equation estimates of equation (6.1). Each column corresponds to one of the groupings of bilateral pairs: column 1 shows estimates for all bilateral pairs (all-all), column 2 shows estimates for high-income countries exporting to high-income countries (high-high), column 3 shows high-income to low-income country pairs (high-low), column 4 shows low-income to high-income country pairs (low-high), column 5 shows low income to low-income country pairs (low-low), and column 6 shows pairs of low-income countries exporting to both high- and low-income countries (low-all).

In table 5, there are significant differences across groupings in the estimates of the effects of an increase in environmental regulation stringency. Overall, it appears that an increase in environmental regulation stringency leads to an increase in exports, as the generally positive and significant estimates of *exp_envregs* in table 5 indicate. This might indicate that the effects on exports of technology spillovers, high-income countries' consumer taste for "green" goods, signaling of the establishment and protection of property rights, signaling of governmental stability, or developing comparative advantages in regulated industries more than offset the negative effect resulting from an increase in production costs due to more stringent regulations. It is also possible that these positive coefficient estimates result from some omitted variable, such as an interaction effect with other, unspecified EIAs. It is particularly odd that an increase in environmental regulation stringency leads to a statistically significant increase in exports from high-income countries to high-income countries (column 2). One explanation could be that increases in overall environmental regulation stringency sometimes are attached to subsidies or governmental aid to exporting industries, particularly those that would be most harmed by the change.

The coefficient estimates for the interaction term, *exp_EU_envregs*, should be added to the estimates on *exp_envregs* in table 5 for estimates of the effect on exports of an increase in environmental regulation stringency for EU members. The joint effects of the two estimates are tested for significance with Wald tests. These joint effects and the results of the tests are reported in table 6.

The results reported in table 6 elucidate that EU membership changes the effect of an increase in environmental regulation stringency. The results are consistent with the hypothesis that increases in environmental regulation stringency have different consequences for low-income EU members' competitiveness than for low-income non-EU members. The effect of an increase in environmental regulation stringency on exports from low-income EU members to every other grouping is negative and significant in table 6. Specifically, a one-point increase in environmental regulation stringency rating causes exports from low-income EU members to all high-income countries to decrease by 30 percent, exports from low-income EU members to all low-income countries to decrease by 54.6 percent, and exports from low income, EU members to all countries to decrease by 43.8 percent. Conversely, from table 5, a one point increase in environmental regulation stringency ratings in a low-income non-EU member country causes exports to all the other groups (high income, low income, and all) to increase by nearly 10 percent.

The results are also consistent with the hypothesis that high-income EU member countries are made relatively more competitive vis-à-vis low-income countries due to an increase in environmental regulation stringency. In table 6, columns 2 and 3 give the joint effect of an increase in environmental regulation stringency on exports from high-income countries to other country groupings. From column 2, the effect of a one-point increase in environmental regulation stringency on exports from high-income countries in the EU to all high-income countries is an increase of about 8.7 percent, statistically significant at the 10 percent level (p-value of 0.0645). Column 3 shows that when environmental regulation stringency increases by one point, exports from high-income countries in the EU to all low income countries increase by about 10.18 percent, although this estimate is not statistically significant (p-value of 0.1083). Exports from high-income non-EU countries to other high income countries also increase, although the increase is slightly larger at about 13 percent, when environmental regulation stringency increases by one point and exports from high-income non-EU countries to low-income countries are not statistically affected. High-income countries in general seem to increase their competitiveness compared to low-income countries by increasing regulatory stringency.

The joint effect estimates presented in table 6 suggest that an EU-level regulation that increases environmental regulation stringency for all EU members could have an enormous impact on exports flowing from those countries. In particular, low-income EU countries' exports might decrease as a result while high-income EU countries actually might experience an increase in exports.

7. Conclusion

Changes in environmental regulation stringency in a country theoretically and empirically have different effects on bilateral trade flows depending on whether the country is part of the European Union and on whether the country is a high income or low income country. High-income countries inside an economic integration agreement, such as the European Union, might have incentive to impose environmental regulations on the entire group of countries in the agreement. Regardless of whether the profit incentive actually exists or whether regulations are imposed on the entire EU, the consequences of an increase in environmental regulation stringency differ dramatically for high-income countries in the EU compared to low-income countries.

An increase in environmental regulation stringency in the exporting country generally increases exports from high-income EU member countries to all high-income countries, although the difference between the estimate for high-income EU members and high income non-EU members is negligible. Exports from high-income EU members to all low-income countries increases significantly when environmental regulation stringency is increased in the exporting country, while exports from high-income non-EU members does not change significantly due to a similar change.

Conversely, an increase in environmental regulation stringency unequivocally decreases exports from low-income countries in the EU. A similar change in stringency has either no significant effect on low-income non-EU countries or possibly even a positive effect. We conclude that a European Union decree of increased environmental regulation stringency for all countries could have a negative impact on exporting industries in low-income EU countries while the impact on high-income countries is possibly positive.

Regional trade blocs have grown rapidly in the last two decades; furthermore, these trade blocs are no longer simple "free-trade agreements" but now also include other economic integration objectives like harmonization of competition law policy and monetary policy. This research shows that the interaction effects of regional trade blocs and regulations should not be ignored. Additionally, this paper indicates a possible political economy story behind the proliferation of the regionalization of regulations in general and of environmental regulations specifically. The possible political economy of the regionalization of regulations offers many topics for future research, as does the investigation of its empirical effects on different groups in the region.

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Table 1: Countries in dataset

All Countries	
ARGENTINA	JAPAN
AUSTRALIA	JORDAN
AUSTRIA	KOREA
BELGIUM	MALAYSIA
BOLIVIA	MAURITIUS
BRAZIL	MEXICO
BULGARIA	NETHERLANDS
CANADA	NEW ZEALAND
CHILE	NORWAY
CHINA,P.R.: MAINLAND	PERU
CHINA,P.R.:HONG KONG	PHILIPPINES
COLOMBIA	POLAND
COSTA RICA	PORTUGAL
CZECH REPUBLIC	RUSSIA
DENMARK	SINGAPORE
ECUADOR	SLOVAK REPUBLIC
EL SALVADOR	SOUTH AFRICA
FINLAND	SPAIN
FRANCE	SWEDEN
GERMANY	SWITZERLAND
GREECE	THAILAND
HUNGARY	TURKEY
ICELAND	UKRAINE
INDIA	UNITED KINGDOM
INDONESIA	UNITED STATES
IRELAND	VENEZUELA, REP. BOL.
ISRAEL	VIETNAM
ITALY	ZIMBABWE

Table 2: European Union countries

European Union Countries
AUSTRIA
BELGIUM
CZECH REPUBLIC
DENMARK
FINLAND
FRANCE
GERMANY
GREECE
HUNGARY
IRELAND
ITALY
NETHERLANDS
POLAND
PORTUGAL
SLOVAK REPUBLIC
SPAIN
SWEDEN
UNITED KINGDOM

Note: The other European Union members during this time period (Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia) are not included in the dataset because those countries' environmental regulation stringencies were not rated in every year from 2000 to 2005.

Table 3: High income countries and low income countries

High Income	Low Income	
AUSTRALIA	ARGENTINA	***SLOVAK REPUBLIC***
AUSTRIA	BOLIVIA	SOUTH AFRICA
BELGIUM	BRAZIL	THAILAND
CANADA	BULGARIA	TURKEY
CHINA,P.R.:HONG KONG	CHILE	UKRAINE
CZECH REPUBLIC	CHINA,P.R.: MAINLAND	VENEZUELA, REP. BOL.
DENMARK	COLOMBIA	VIETNAM
FINLAND	COSTA RICA	ZIMBABWE
FRANCE	ECUADOR	
GERMANY	EL SALVADOR	
ICELAND	***GREECE***	
IRELAND	***HUNGARY***	
ISRAEL	INDIA	
ITALY	INDONESIA	
JAPAN	JORDAN	
NETHERLANDS	KOREA	
NEW ZEALAND	MALAYSIA	
NORWAY	MAURITIUS	
SINGAPORE	MEXICO	
SPAIN	PERU	
SWEDEN	PHILIPPINES	
SWITZERLAND	***POLAND***	
UNITED KINGDOM	***PORTUGAL***	
UNITED STATES	RUSSIA	

Note: Countries in ***bold italics*** are EU members.

Table 4: Summary Statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
lrxp	log of real exports	18480	4.2832	3.6955	-9.2103	12.5052
lrgdp_exporter	log of real GDP of exporter	18480	5.0259	1.6475	1.4179	9.3042
lrgdp_importer	log of real GDP of importer	18480	5.0259	1.6475	1.4179	9.3042
envregs_exp	environmental regulation stringency rating, exporter	18480	4.5244	1.2706	2.3	6.8
envregs_imp	environmental regulation stringency rating, importer	18480	4.5244	1.2706	2.3	6.8
EU	dummy = 1 if both exporter and importer are in EU in year *t*, = 0 otherwise	18480	0.0725	0.2594	0	1
EU*envregs_exp	interaction term = env. reg. stringency rating, exporter if exporter in EU in year *t*, = 0 otherwise	18480	1.7411	2.5878	0	6.8

Table 5: Gravity estimate with bilateral pair fixed-effects and time dummies

	(1)All-All	(2)High-High	(3)High-Low	(4)Low-High	(5)Low-Low	(6)Low-All
lrgdp_exporter	0.7766	0.6778	0.1702	0.8753	0.7742	0.8179
	(41.82)**	(6.98)**	(1.31)	(26.86)**	(23.13)**	(34.54)**
lrgdp_importer	0.1930	0.7576	0.1777	1.0010	0.2328	0.2091
	(10.39)**	(7.80)**	(9.29)**	(4.52)**	(6.96)**	(6.91)**
envregs_exp	0.1595	0.1353	-0.0406	-0.0242	0.1920	0.0993
	(5.18)**	(2.72)**	(0.61)	(0.40)	(3.11)**	(2.27)*
envregs_imp	-0.0412	0.0752	-0.0847	-0.0819	-0.1424	-0.0543
	(1.50)	(2.12)*	(2.49)*	(1.01)	(2.39)*	(1.22)
EU	-0.0672	0.1009	-0.0259	-0.0614	-0.1107	-0.0709
	(0.89)	(1.41)	(0.30)	(0.41)	(0.43)	(0.53)
EU*envregs_exp	-0.2093	-0.0481	0.1424	-0.2755	-0.7383	-0.5373
	(3.40)**	(0.73)	(1.61)	(1.79)	(4.70)**	(4.82)**
Constant	-0.8273	-2.4295	2.9455	-4.6702	-1.9325	-1.3236
	(3.85)**	(2.80)**	(3.61)**	(3.36)**	(5.79)**	(4.49)**
Observations	18480	3312	4608	4608	5952	10560
Bilateral Pairs	3080	552	768	768	992	1760
R^2	0.14	0.21	0.11	0.19	0.14	0.15

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Note: Regressions of the natural log of real exports in years 2000 – 2005 from exporting country, *i*, to importing country, *j*, on the natural log of real GDPs of both countries, the level of each countries' environmental stringency rating, an EU dummy (EU) equal to one if both the exporter and importer were in the EU in year *t*, and the exporter's environmental stringency rating interacted with a dummy indicating whether the exporter was in the EU in year *t* (EU*envregs_exp). Dummy variables for years 2001, 2002, 2003, 2004, and 2005 are included in each regression (estimates not reported here; available upon request). Fixed-effects for each bilateral pair are included in each regression.

Column 1 includes all country pairs in the dataset; column 2 includes only pairs where both exporter and importer are considered "high income;" column 3 includes only pairs where the exporter is "high income" and the importer is "low income;" column 4 includes only pairs where the exporter is "low income" and the importer is "high income;" column 5 includes only pairs where the exporter is "low income" and the importer is "low income;" and column 6 includes only pairs where the exporter is "low income" paired with all countries in the dataset.

Table 5a: Gravity estimate with bilateral pair fixed-effects and time dummies, GDP coefficients restricted to unity

	(1)All-All	(2)High-High	(3)High-Low	(4)Low-High	(5)Low-Low	(6)Low-All
envregs_exp	0.1382	0.1409	-0.0307	-0.0547	0.1355	0.0550
	(4.22)**	(2.83)**	(0.37)	(0.92)	(2.10)*	(1.22)
envregs_imp	-0.0959	0.0773	-0.2990	-0.0831	-0.3401	-0.1057
	(3.30)**	(2.17)*	(7.28)**	(1.02)	(5.47)**	(2.29)*
EU	-0.3152	0.0460	-0.3770	-0.1058	-0.4507	-0.3084
	(3.96)**	(0.65)	(3.61)**	(0.71)	(1.68)	(2.21)*
EU*envregs_exp	-0.1934	-0.0516	0.1385	-0.2938	-0.7542	-0.5425
	(2.95)**	(0.78)	(1.28)	(1.90)	(4.55)**	(4.68)**
Constant	-5.6670	-5.6831	-4.7999	-5.1007	-5.5115	-5.7250
	(30.48)**	(19.23)**	(13.41)**	(10.19)**	(18.30)**	(22.75)**
Observations	18480	3312	4608	4608	5952	10560
Bilateral Pairs	3080	552	768	768	992	1760
R^2	0.01	0.13	0.02	0.01	0.04	0.02

Note: Regressions of the natural log of real exports minus log of real GDP of exporter and importer (restricting their coefficients to unity) in years 2000 – 2005 from exporting country, *i*, to importing country, *j*, on the natural log of real GDPs of both countries, the level of each countries' environmental stringency rating, an EU dummy (EU) equal to one if both the exporter and importer were in the EU in year *t*, and the exporter's environmental stringency rating interacted with a dummy indicating whether the exporter was in the EU in year *t* (EU*envregs_exp). Dummy variables for years 2001, 2002, 2003, 2004, and 2005 are included in each regression (estimates not reported here; available upon request). Fixed-effects for each bilateral pair are included in each regression.

Column 1 includes all country pairs in the dataset; column 2 includes only pairs where both exporter and importer are considered "high income;" column 3 includes only pairs where the exporter is "high income" and the importer is "low income;" column 4 includes only pairs where the exporter is "low income" and the importer is "high income;" column 5 includes only pairs where the exporter is "low income" and the importer is "low income;" and column 6 includes only pairs where the exporter is "low income" paired with all countries in the dataset.

Table 6: Net Effects of an Increase in Environmental Regulation Stringency for EU Members from Table 5 Estimates

	All-All	High-High	High-Low	Low-High	Low-Low	Low-All
Net effect	-0.0498	0.0872	0.1018	-0.2997*	-0.5463**	-0.4380**
P-Value of Wald test of joint significance	0.3640	0.0645	0.1083	0.0449	0.0004	0.0001

* significant at 5%; ** significant at 1%

Note: The net effect for EU members arises from summing the coefficient on exp_envregs and the coefficient on exp_EU_regs shown in Table 5.

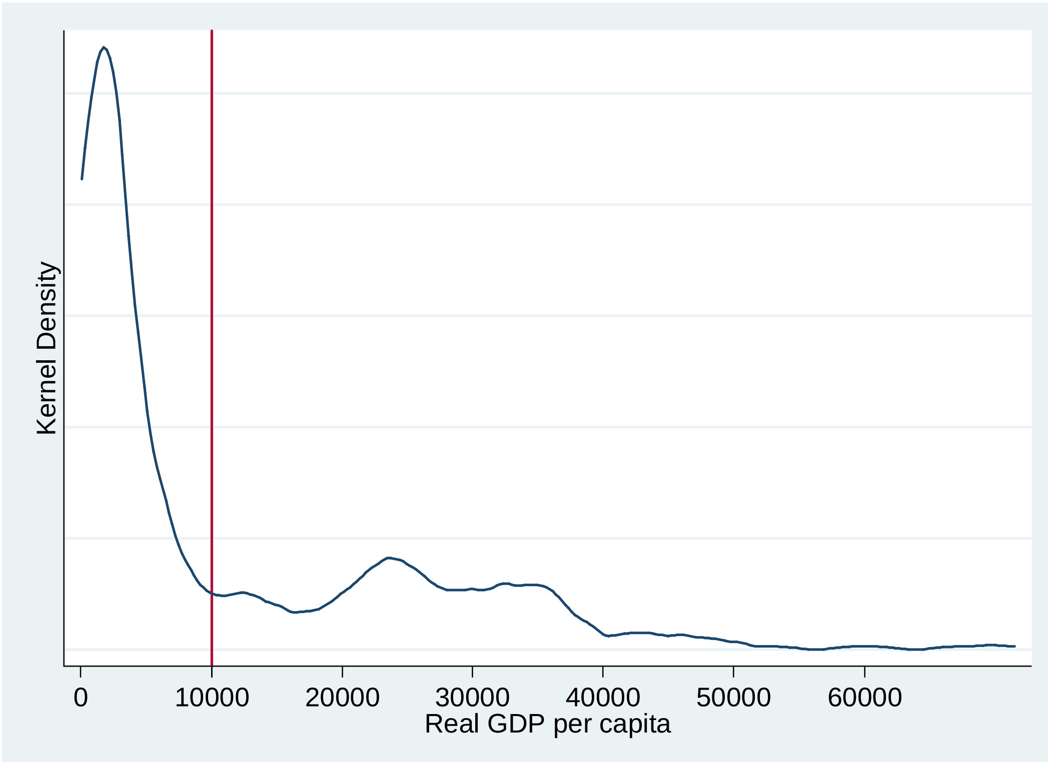
Table 6a: Net Effects of an Increase in Environmental Regulation Stringency for EU Members from Table 5a Estimates

	All-All	High-High	High-Low	Low-High	Low-Low	Low-All
Net effect	-0.0552	0.0893	0.1078	-0.3485**	-1.0943**	-0.4875**
P-Value of Wald test of joint significance	0.3436	0.0589	0.1630	0.0194	0.0001	0.0000

* significant at 5%; ** significant at 1%

Note: The net effect for EU members arises from summing the coefficient on exp_envregs and the coefficient on exp_EU_regs shown in Table 5a.

Figure 1: Kernel Density of Real GDP per Capita with $10,000 cutoff line added



Appendix A: Endogeneity from environmental regulation stringency variables

Estimates of the effects of changes in environmental regulation stringency might also suffer from endogeneity in a gravity context when the measure of environmental regulation stringency is an outcome measure, such as energy use per capita, carbon dioxide emissions, or sulfur emissions. Countries' initial endowments of such sulfur- and carbon dioxide- emitting resources as coal and oil, as well as differences in the sulfur content of such resources, are not controlled for in typical gravity specifications but certainly would affect both choice of regulation levels as well as measured outcomes of a given level of regulation.

To formally demonstrate this, let S_{it} represent environmental regulation stringency in country *i* at time *t*. Equation (4.3) implicitly includes this variable of interest in the error term. Thus, the error term from equation (4.3), $ln\ \varepsilon_{ijt}$, can be written

$$\ln \varepsilon_{ijt} = \gamma_1 S_{it} + \gamma_2 S_{jt} + \gamma_3 S_{it} E_{ijt} + u_{ijt} \qquad \text{(A1)}$$

where S_{it} is environmental regulation stringency and E_{ijt} still indicates whether both countries are in an economic integration agreement in year *t*. The interaction term accounts for the possibility of EIA-level imposition of environmental regulations differing from unilateral changes in environmental regulations. u_{ijt} is white noise; $E(u_{\text{ijt}})=0$.

Most estimates of the effects of environmental regulations on bilateral trade flows rely on proxies for environmental regulation stringency; for example, Van Beers and Van den Bergh (1997) use societal indicators of environmental regulations' effects, such as recycling rates and market share of unleaded gasoline for part of their analysis; Harris et al. (2002), following another method used by Van Beers and Van den Bergh, use energy intensity measures, such as energy consumed per capita in a country in year *t* compared to that consumed per capita in a baseline year, 1980. Usage of such an environmental policy outcome variable as proxy for environmental regulation stringency can easily introduce endogeneity into estimates of the effects of changes in that outcome variable on trade flows. Let Q denote the proxy used for environmental regulation stringency:

$$Q = f(S, O) \qquad \text{(A2)},$$

where *S* is the actual stringency level and *O* represents other relevant factors that could affect the outcome variable such as country endowment of petroleum reserves or the sulfur content of coal and petroleum[10]. We assume a simple functional form for *Q*:

$$Q = \frac{1}{\psi}S - \frac{1}{\psi}O \qquad \text{(A3)}.$$

Solving for S yields

$$S = \psi Q + O \qquad \text{(A4)}.$$

Substituting equation (A4) into equation (A1),

$$\ln \varepsilon_{ijt} = \gamma_1 \psi_1 Q_{it} + \gamma_2 \psi_2 Q_{jt} + \gamma_3 \psi_3 Q_{it} E_{ijt} + u_{ijt} + O_{it} \qquad \text{(A5)}$$

Specification of the gravity equation shown in equation (4.3) to include *Q*, the proxy for environmental stringency, gives

$$\begin{aligned} \ln X_{ijt} &= \ln \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln N_{it} + \beta_4 \ln N_{jt} \\ &+ \beta_8 E_{ijt} + \beta_9 Q_{it} + \beta_{10} Q_{jt} + \beta_{11} Q_{it} E_{ijt} + \delta_{ij} + \lambda_t + \ln \varepsilon_{ijt} \end{aligned} \qquad \text{(A6)}$$

where the error term in equation (A6) differs from that given in equation (4.3) because the first three terms of the RHS in equation (A5) are now explicitly in the RHS of equation A6. The error term in equation (A6) is therefore

[10] If energy intensity is used as the proxy, then endowment of energy-rich resources is important. If sulfur emissions are used, then the differences in sulfur content of coal, petroleum, and other resources affects the outcome Q.

$$\ln \varepsilon_{ijt} = u_{ijt} + O_{it} \tag{A7}$$

Because O_{it} determines Q_{it}, the correlation between O_{it} and Q_{it} is non-zero, implying that

$$E(u_{ijt} + O_{it} \mid Q_{it}) \neq 0 \qquad \text{(A8).}$$

Thus, any outcome measure that depends on both environmental regulation stringency and country-specific endowment characteristics introduces bias into gravity equation estimates of the effect of environmental regulation stringency on trade flows.

Appendix B: Modeling an ordinal signal on a latent variable

Let the data generating process be given by

$$\ln y_k = -\ln \mu_k + \ln \varepsilon \qquad \text{(B1)}$$

where *y* is the regulatory stringency level chosen by the country *k*, μ is the regulatory laxness signaled by the country, ε is noise in executive *i*'s observation of the signal, and ε~U[0,1]. Rewriting equation (B1) yields

$$y_k = \frac{\varepsilon_i}{\mu_k} \qquad \text{(B2).}$$

Executives are asked to rate between 1 and 7 each country's environmental regulation stringency relative to other countries; we assume some threshold, τ_i, to exist between each two levels, as is illustrated below in Figure B1. If the signaling process for country *k* yields a result in excess of a given threshold, the executive rates country *k*'s stringency at the next higher level.

Figure B1: Thresholds in rating range

Rating: 1 2 3 4 5 6 7

τ_1 τ_2 τ_3 τ_4 τ_5 τ_6

Note that, despite the appearance of τ_i in Figure B1, the levels of τ_i are not restricted to any range. Rather, these thresholds are simply the information that is signaled to executives. For a simple example, assume the entirety of the signaling process is done by the amount of money spent on enforcement of environmental regulations. Executives rate each country according to the millions of dollars spent on regulations in a given year, while controlling for their expectations of corruption and governmental inefficiency in each country. If the range of expenditure on regulation is from $1,000,000 to $71,000,000, then the thresholds could be any transformation of six points on the expenditure line that maintains their collinearity and the ratios of the distances between them.

Let $x_{i,k}$ denote the rating given by executive i to country k. Given the six thresholds, the probability that country k will receive any given rating can be written as

$$prob(x_{ik} = 1) = prob(\ln y_k < \ln \tau_1) \tag{B3.1}$$

$$prob(x_{ik} = 2) = prob(\ln y_k < \ln \tau_2) - prob(\ln y_k < \ln \tau_1) \tag{B3.2}$$

$$prob(x_{ik} = 3) = prob(\ln y_k < \ln \tau_3) - prob(\ln y_k < \ln \tau_2) \tag{B3.3}$$

. .

. .

$$prob(x_{ik} = 6) = prob(\ln y_k < \ln \tau_6) - prob(\ln y_k < \ln \tau_5) \tag{B3.6}$$

$$prob(x_{ik} = 7) = 1 - prob(\ln y_k < \ln \tau_6) \tag{B3.7}$$

Using equation (B2), equations (B3.1 – B3.7) can be restated as

$$prob(x_{ik} = 1) = prob(\ln y_k < \ln \tau_1) = prob(\frac{\varepsilon_i}{\mu_k} < \tau_1) = prob(\varepsilon_k < \mu_k \tau_1) = F(\mu_k \tau_1) \tag{B4.1}$$

$$prob(x_{ik} = 2) = prob(\ln y_k < \ln \tau_2) - prob(\ln y_k < \ln \tau_1) = F(\mu_k \tau_2) - F(\mu_k \tau_1) \tag{B4.2}$$

$$prob(x_{ik} = 3) = prob(\ln y_k < \ln \tau_3) - prob(\ln y_k < \ln \tau_2) = F(\mu_k \tau_3) - F(\mu_k \tau_2) \tag{B4.3}$$

. .

. .

$$prob(x_{ik} = 6) = prob(\ln y_k < \ln \tau_6) - prob(\ln y_k < \ln \tau_5) = F(\mu_k \tau_6) - F(\mu_k \tau_5) \tag{B4.6}$$

$$prob(x_{ik} = 7) = 1 - prob(\ln y_k < \ln \tau_6) = 1 - F(\mu_k \tau_1) \tag{B4.7}$$

Setting up GMM, the expected value of x_i is

$$E(x_{ik}) = 1prob(x_{ik} = 1) + 2prob(x_{ik} = 2) + \cdots + 7prob(x_{ik} = 7) \tag{B5}$$

$$E(x_{ik}) = F(\mu_k\tau_1) + 2[F(\mu_k\tau_2) - F(\mu_k\tau_1)] + \cdots + 7[1 - F(\mu_k\tau_6)] \quad \text{(B6)}$$

$$E(x_{ik}) = 7 - F(\mu_k\tau_1) - F(\mu_k\tau_2) - \cdots - F(\mu_k\tau_6) \quad \text{(B7)}$$

Along with the assumption that ε~U[0,1], we scale τ_i such that $\sum_{l=1}^{6}\tau_l = 1$. The expected value of x_i is thus

$$E(x_{ik}) = 7 - \mu_k\tau_1 - \mu_k\tau_2 - \cdots - \mu_k\tau_6 = 7 - \mu_k\sum_{l=1}^{6}\tau_l \quad \text{(B8)}$$

$$E(x_{ik}) = 7 - \mu_k \quad \text{(B9)}$$

Therefore, by GMM estimation of the parameter μ, equation (B9) is rewritten as

$$\hat{\mu} = 7 - \bar{x} \quad \text{(B10)}$$

where $\mu = \hat{\mu} + v$ and $v \sim N(0,\bullet)$. Thus, our best guess of μ, the regulatory laxness signaled by a country, is an affine transformation of $\bar{x}$, albeit measured with error, v. However, because

$$\beta\mu = \beta(7 - \bar{x} + v) \quad \text{(B11)}$$

$$= 7\beta + \tilde{\beta}\bar{x} + \beta v \quad \text{(B12),}$$

any bias from first and third terms in the RHS of equation B4.2 is lumped into the intercept and error term, respectively, yielding $\tilde{\beta}$ as an unbiased estimate on the sample mean.