Raising the Cost of Doing Business in Lower Income Countries:
Trade Agreements with Stringent Multilateral Environmental Regulations[1]

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ABSTRACT: We explore how multilateral environmental regulations may adversely affect trade flows between countries with different incomes. Using the gravity equation, we examine the effect on bilateral trade flows of increases in environmental regulation stringency ratings, taken from survey data covering a panel of 137 countries. We test for significant differences in the effects of the stringency of environmental regulations on exports across countries' income levels and EU membership. We show that an increase in environmental regulation stringency leads to a dramatic decrease in exports from poorer EU members; conversely, a similar change in environmental regulation does not appear to significantly affect the exports of richer EU members. The results are consistent with our theoretical model of the costs of multilateral environmental regulations, which are disproportionately borne by poorer countries due to both the 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

When markets fail to address some problem perceived by the populace, a government may decide to intervene by imposing regulations within its jurisdiction. The textbook treatment of fiscal federalism prescribes that regulations should be promulgated by the lowest level of government with full jurisdiction over the problem (Hindriks and Myles 2013). Hence, when common problems spill over national borders, groups of countries may agree to impose regulations multilaterally upon themselves. Multilateral regulations range from military policy (e.g., nuclear proliferation) to trade policy (e.g., GATT/WTO limitations on tariffs) to environmental policy (e.g., Paris Climate Agreement). Regional environmental regulation has occurred inside common markets, such as the National Emissions Ceiling (NEC) directive that was designed to address regional air pollution concerns in the European Union (EU), 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).[2] Despite the logic behind multilateral regulations and the reduced barriers to trade that typically accompany them, some prominent multilateral economic integration agreements (e.g., NAFTA and the EU) have recently encountered a strong populist backlash.

A newly formed common market should theoretically result in labor-intensive production relocating to the jurisdictions with the lowest ratio of wages to labor

[2] The EU has passed, beginning in 1980, a series of specific directives with stated limits on, for example, sulfur dioxide concentrations in ambient air. After a couple of decades of evolution, these regulations became the NEC.

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.

productivity, boosting the exports of poorer countries with lower wages and dampening exports of richer countries with higher wages. However, assuming that the richer countries already have higher environmental regulations—which would be consistent with the Environmental Kuznets Curves described in Grossman and Krueger (1995) and Yandle et al. (2004) – those countries can raise production costs in the poorer countries by pushing for common environmental regulations that meet their higher standards. In addition to this consequence of multilateral environmental regulations stemming the tide of production flowing towards poorer countries, common environmental regulations also have the unintended consequences of incentivizing migration of cheap labor from poorer countries to richer countries (because the policy discourages the jobs from coming to them). At the confluence of intensified migration with lost sovereignty to multilateral institutions, we are now observing an uptick in fractious backlashes against globalization, as exemplified in the Brexit decision. Thus, these consequences are worthy of further study.

In this article, we explore how the consequences of increasing environmental regulation stringency differ for richer and poorer EU member states. Likewise, we also explore how changes in EU environmental regulations may also affect EU members' exports differently than non-EU members. We model the possibility that high income members of a trade bloc may benefit from environmental regulations imposed on the entire group as a protectionist measure (i.e., 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).

We demonstrate empirically that the more stringent environmental regulations in the EU may indeed have benefited richer member states at the expense of poorer member states.[3]

Our empirical analysis exploits survey data from the World Economic Forum in which business executives rate the effective stringency of environmental regulations 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 across countries and income categories. We control for whether an increase in environmental regulation stringency occurred within an EU member country as well as for membership in other EIAs, allowing estimation of the effects of environmental regulation inside and outside the EU.

Our empirical analysis approaches this question from two angles. In both cases, the hypothesis tested is that relatively rich members of the European Union will see somewhere between no effect and a mildly positive effect from increases in environmental regulation stringency while the relatively poor members of the European Union will see a negative effect from increases in environmental regulation stringency. In one specification, we treat a country's per-capita GDP as a continuous variable and estimate a level at which the effect of environmental regulation stringency switches from positive to negative. We find that this estimated level is within the lower range of the support of per-capita GDPs of EU member-states. For the other specification, we split the sample of countries between "rich" and "poor" members of the EU based on per-capita GDPs. We find, using this specification, that the effect of increased environmental

[3] Salop and Scheffman (1983) note that such an outcome may even be desirable from the standpoint of richer EU countries. It raises their rivals' costs, allowing them to capture greater market share without lowering price.

regulation stringency for EU member-states is zero to mildly positive for rich member-states and negative for poor member-states. We find strong empirical support for our model.

There are important implications of our results for current policy debates surrounding global environmental policymaking. For example, the Paris Climate Agreement of 2016, in which signatories pledged to take substantial steps to reduce greenhouse-gas emissions, gave those signatories a considerable degree of flexibility in pursuing their targeted reductions.[4] Our analysis supports this general approach. An approach that imposes the same regulations on multiple countries at varying levels of economic development may have uneven effects on those countries – typically benefitting the richer countries at the expense of poorer countries. Thus, the acceptability of Paris Climate Agreement to poorer countries rests on the opportunity presented by Clean Development Mechanism to transfer resources from richer countries to poorer countries to cover their expenses of lowering global emissions at their relatively low marginal abatement cost.

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; Ederington, Levinson, and Minier 2005; Levinson and Taylor 2008). Also,

[4] See https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement for details.

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 1998; Levinson and Taylor 2008). 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 5 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, Kónya, and Mátyás 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 an endogeneity problem (Jug and Mirza 2005). In Appendix A, we explicitly show how environmental outcome variables introduce endogeneity into gravity equation and then generates a bias in the 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 studies 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). Ederington and Minier (2003) report (non-gravity-type) instrumental variables estimations of the effect of stringent environmental regulations on imports into the United States and obtain results indicating that stringent environmental regulations inside a domestic industry lead to statistically and economically significant increases in imports. Cole and Elliot (2003) also find a significant effect of environmental regulation on trade flows by demonstrating that regulations are likely endogenous and controlling for that endogeneity. All three studies' results point to a significantly greater effect of environmental regulation stringency on trade flows when environmental policy is modeled as endogenous.

We add to this growing literature in a few important ways. The first is by using a measure 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 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 (using per-capita GDP as both a continuous and a discrete variable), because the effects may drastically differ for high income countries and low-income countries.

2.1 Unilateral versus Multilateral 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. 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, both in a model and empirically, 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 1972). 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 because 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

[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.

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 countries if all countries must 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. This effect may be even greater if "dirty" industries are already disproportionately concentrated in poorer countries. 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:

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

[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 – 2009 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.

[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.

subject to a budget constraint:

$$M_j \geq \sum_{i=1}^{N} p_{ij} x_{ij} \tag{2}$$

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 first order condition of this constrained optimization's Lagrangian is given by:

$$\left[\sum_{i=1}^{N} \mu_i x_{ij}^{\rho}\right]^{\frac{1}{\rho}-1} \mu_i x_{ij}^{\rho-1} = \lambda p_{ij} \tag{3}$$

Without loss of generality, we can divide the FOC for good i by that of good 1:

$$\left(\frac{x_{ij}}{x_{1j}}\right)^{\rho-1} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right) \tag{4}$$

Solving for x_{ij}:

$$x_{ij} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right)^{\frac{1}{\rho-1}} x_{1j} \tag{5}$$

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

$$x_{ij} = \left(\frac{p_{ij} / \mu_i}{p_{1j} / \mu_1}\right)^{-\sigma} x_{1j} \tag{6}$$

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

$$\sum_{i=1}^{N} p_{ij} x_{ij} = M_j = \left(\frac{p_{1j}}{\mu_1}\right)^{\sigma} x_{1j} \sum_{i=1}^{N} \mu_i^{\sigma} p_{ij}^{1-\sigma} \tag{7}$$

This equation can easily be solved for each x_{ij}, yielding:

$$x_{ij} = \frac{\mu_i^{\sigma} p_{ij}^{-\sigma}}{\sum_{i=1}^{N} \mu_i^{\sigma} p_{ij}^{1-\sigma}} M_j \tag{8}$$

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:

$$p_{ij} x_{ij} = \frac{\mu_i^{\sigma} p_{ij}^{1-\sigma}}{I_j} M_j \tag{9}$$

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:

$$p_{ij} = p_i D_{ij}^{\delta} e^{-\psi 1\{EIA\}} \tag{10}$$

where p_i is the price of the good in its home country, D_{ij} is the distance between country *i* and country *j*, ψ is the effect of an EIA on the logged price of the good produced in country i but sold in country j, and 1{EIA} equals 1 if *i* and *j* are members of an EIA.

We assume that a good's quality is increasing in the GDP of the country where it is produced:

$$\mu_i = \kappa M_i^{\alpha} \tag{11}$$

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

$$p_{ij}x_{ij} = \frac{\kappa^{\sigma}}{I_j}\left[\frac{M_i^{\alpha\sigma} M_j}{D_{ij}^{\delta(\sigma-1)}}\right] e^{(\sigma-1)\psi 1\{EIA\}} \tag{12}$$

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:

$$\pi_i = (p_i - c_i)\sum_{j=1}^{N} x_{ij} = (p_i - c_i)\sum_{j=1}^{N} \frac{\mu_i^{\sigma} p_{ij}^{-\sigma}}{I} M_j \tag{13}$$

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

$$\sum_{j=1}^{N}(1-\sigma)x_{ij} - \sum_{j=1}^{N}(-\sigma)c_i \frac{x_{ij}}{p_i} = 0 \tag{14}$$

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

$$p_i = \left(\frac{\sigma}{\sigma - 1}\right)c_i \tag{15}$$

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

$$M_i = \pi_i = \frac{c_i}{\sigma - 1}\sum_{j=1}^{N} x_{ij} \tag{16}$$

3.3 Effects of Environmental Regulatory Compliance

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[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.

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 (15) into (4), 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):

$$\left(\frac{x_{ij}^{t}}{x_{kj}^{t}}\right)^{\rho-1} = \frac{(c_i + tr_i)/\mu_i}{(c_k + tr_k)/\mu_k} \tag{17}$$

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 because of the environmental regulations:

$$\frac{c_i/\mu_i}{c_k/\mu_k} > \frac{(c_i + r_i)/\mu_i}{(c_k + r_k)/\mu_k} \tag{18}$$

Performing some basic algebra yields:

$$c_i r_k > c_k r_i \tag{19}$$

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 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 during much of the time studied). 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:

$$\left(\frac{x_{kj}^0}{x_{ij}^0}\right)^{1-\rho} > \left(\frac{x_{kj}^1}{x_{ij}^1}\right)^{1-\rho} \tag{20}$$

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 equilibrate 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 some agents.

4. Data

The main independent variable in our analysis is the "Stringency of Environmental Regulation" variable. This variable is collected by the World Economic Forum (WEF) and asks the question, "How stringent is your country's environmental regulation? (1 = lax compared with most countries, 7 = among the world's most stringent". (See World Economic Forum (2009, 400, Table 2.01)) The data come from the WEF's Executive Opinion Survey of thousands of business leaders operating internationally. As argued above and in Appendix B, we believe that this survey measure eliminates some of the endogeneity concerns that we may have with purely policy-based measures. We collected this measure for a broad panel of countries from 2001-2009. The list of countries and number of years for which we have data for each can be found in Table 1.

The main dependent variable in our analysis is the bilateral export flows between countries over the same period. These data come from the International Monetary Fund (IMF) Direction of Trade Statistics Database.

GDP data used in the regressions were extracted from the Penn World Table version 8.1 (Feenstra, Inklaar, and Timmer 2015). Bilateral "gravity-type" variables used in some of the regressions, such as physical distance, common language, common border, and landlocked status, come from the World Bank's "Trade, Production and Protection, 1976-2004" database (Nicita and Olarreaga 2007). Economic integration agreements data come from Jeffrey Bergstrand's webpage (Bergstrand 2017).

Finally, we assembled EU membership data using widely available resources. We classify a country as an EU member throughout the entire time of the sample (2001-2009) even if it joined midway through the sample period – as several East Central European nations did in 2004. We take this step because all prospective members were already charged with harmonizing their regulatory climate to EU standards by the beginning of the sample period as a condition of their membership candidacy.

Summary statistics for the variables above can be found in Table 2.

5. Regression Specifications

5.1 Regression Models Used in Gravity-Type Regressions

All regression specifications found below use the "Gravity Model" first developed by Tinbergen (1962) and further elaborated by Anderson and van Wincoop (2003) as a baseline. This equation found that the bilateral trade volume between two countries can be largely predicted by the product of the two countries' GDPs divided by the distance between them. All three variables have good explanatory power, are plausibly exogenous, and can be nicely transformed into a log-linear specification.

In addition to being a traditional "workhorse" model for trade studies for decades, the gravity model and the econometrics of gravity-type trade equations, such as the one found above, is a topic that has received a lot of attention in recent years from international trade scholars. A good summary of these issues can be found in Head and Mayer (2014). When using annual bilateral country pair trade data, approximately 20%-25% of the observations will be zeros. When log-linearizing a gravity equation for an OLS estimation, these observations will have to be dropped from the sample in a way that is non-random. Head and Mayer (2014) discuss the different ways of solving this problem and conclude that none will necessarily work under all assumptions. Instead, they suggest using several different regression specifications and testing the robustness of the results across specifications.

To this end, we use three different regression specifications. The first is a simple OLS regression with bilateral country pair fixed effects where all the zero observations are dropped from the sample. While this approach is straightforward, the obvious drawback is that observations will be dropped from the sample in a non-random fashion, thereby adding a potential sample selection bias to the estimate.

Santos Silva and Tenreyo (2006) argue that a Poisson pseudo-maximum likelihood (PML) estimator can handle the zero observations issue, and apply it to the gravity equation setting. The Poisson PML estimator (with bilateral country pair fixed effects)[9] thus forms the basis of our second set of regressions.

However, Head and Mayer (2014) noted that the Poisson PML estimator may "overweight" large observations and may not be robust to certain types of heteroscedasticity. As a result, they argue that a Gamma PML estimator, while

[9] More precisely, we used the *xtpoisson, fe* command in Stata, specifying the bilateral country pairs as the cross-sectional variable.

preserving some of the good properties of the Poisson estimator, such as handling the zeroes problem, may perform better under certain assumptions about heteroscedasticity.

Therefore, the third specification that we use in our analysis in the Gamma PML estimator. A practical difficultly that we run in to is that there is not a direct Stata command for handling the Gamma estimator in a panel data setting. Furthermore, using Stata's index function to create several thousand bilateral dummy variables for a PML regression overtaxes our computer system.[10] Therefore, we are unable to include bilateral fixed effects in our Gamma PML regressions.

To address this problem, we use a two-step procedure. First, we run an OLS regression with bilateral fixed effects on the variables used in the two specifications used above. We then take the predicted bilateral fixed effects from the OLS regressions and, in turn, regress them on several bilateral "gravity type" variables: the log of physical distance between the countries, a common border dummy, a common language dummy, and the landlocked status of both countries. We take the residuals from this regression (that is, that part of the predicted bilateral fixed effects from OLS that cannot be explained by the gravity variables) and include them as regressors along with the bilateral variables in our Gamma PML regressions. In doing so, we can simulate the impact of bilateral fixed effects in the Gamma PML regressions as closely as possible given our computational constraints. However, we are not able to do so perfectly.

5.2 GDP Per-Capita Used as Continuous Interaction Term

In addition to the three estimators noted above, we use two regression specifications in our empirical analysis. The first specification treats the log of GDP per-

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[10] The Stata command used here is *glm, family(gamma)*.

capita in the exporting country as a continuous independent variable and looks at the interaction of GDP per-capita with an increase in environmental regulation stringency. The second specification (described in the next subsection) uses GDP per-capita as a means of splitting the sample between rich (per-capita GDP over \$10,000) and poor (below \$10,000) sub-samples in both the exporting and importing countries.

The regressions found in the first subsection are of the following form:

$$\begin{aligned} X_{i,j,t} = \beta_0 + \beta_1 lnRGDP_{i,t} + \beta_2 lnRGDP_{j,t} + \beta_3 EU_{i,j,t} + \beta_4 ENVREGS_{i,t} \\ + \beta_5 ENVREGS_{j,t} + \beta_6 ENVREGS_{i,t} * EU_{i,t} + \beta_7 lnGDPPC_{i,t} \\ + \beta_8 ENVREGS_{i,t} * lnGDPPC_{i,t} + \beta_9 ENVREGS_{i,t} * lnGDPPC_{i,t} \\ * EU_{i,t} + \beta_{10} ALLOTHEREIAS_{i,j,t} + \delta_{i,j} + \theta_t + ln\varepsilon_{i,j,t} \end{aligned} \tag{21}$$

where $X_{i,j,t}$ is the value of exports[11] from country *i* to country *j* in year *t*, $RGDP_{i,t}$ is the real GDP[12] of country *i* in year *t*, $EU_{i,j,t}$ is a dummy variable indicating if both country *i* and *j* were both EU members in year *t*, $GDPPC_{i,t}$ is the per-capita gross domestic product[13] of country *i* in year *t*, $ENVREGS_{i,t}$ is the stringency of environmental regulations variable in country *i* in year *t*, and $ALLOTHEREIAS_{i,j,t}$ is a dummy variable indicating the existence of an economic integration agreement (other than EU membership) between countries *i* and *j* in year *t*. $\delta_{i,j}$ is a bilateral country pair fixed-effect in some of the regression specifications below and a vector of bilateral "gravity"

[11] These values are converted to U.S. dollars using current exchange rates as reported by the IMF Direction of Trade Statistics database.

[12] For this variable, we use GDP converted to dollars using current exchange rates as reported by the World Development Indicators database.

[13] For this variable, we use real GDP per-capita in constant 2011 dollars using a chained price index as reported by the Penn World Tables 9.0.

variables in others,[14] and θ_t is a year fixed-effect.[15] Our theory predicts the following signs on the coefficients: $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$, β_4 ambiguous, β_5 ambiguous, $\beta_6 < 0$, β_7 ambiguous, $\beta_8 > 0$, $\beta_9 > 0$, $\beta_{10} > 0$.

The result that we are most interested in is the interaction effect between environmental regulation stringency and GDP per-capita. That is, we estimate:

$$\frac{\partial^2 X_{i,j,t}}{\partial ENVREGS_{i,t} \partial lnGDPPC_{i,t}} = \beta_8 + \beta_9 * EU_{i,t} \tag{22}$$

Our main prediction is that $\beta_9 > 0$ (that is, an increase in environmental regulation stringency has a lower impact on relatively rich countries that are EU members). Backing up the 2nd derivative in equation (22) by one step, we also derive that:

$$\frac{\partial X_{i,j,t}}{\partial ENVREGS_{i,t}} = \beta_4 + \beta_6 * EU_{i,t} + \beta_8 * lnGDPPC_{i,t} + \beta_9 * EU_{i,t} * lnGDPPC_{i,t} \tag{23}$$

For poorer EU members, our model predicts that the increase in environmental regulation stringency will have a negative effect on exports, while it will have a "less negative" to positive effect for richer EU members. That is, in addition to $\beta_9 > 0$, we also predict that $\beta_4 + \beta_6 < 0$. Furthermore, we can derive a level of GDP per-capita (call it $GDPPC^{EU}$) where the effect of increased environmental regulation stringency switches from negative to positive by setting equation (23) equal to zero and solving for $GDPPC$:

$$GDPPC^{EU} = exp\left(-\frac{\beta_4 + \beta_6}{\beta_8 + \beta_9}\right) \tag{24}$$

[14] It is worth noting here that the use of bilateral fixed effects and not exporter and importer fixed effects differs from the strategy of Head and Mayer (2014). Because our main regressors of interest (particularly $ENVREGS$) are country-year specific, we cannot replicate this strategy precisely.

[15] The inclusion of bilateral fixed effects follows Baier and Bergstrand (2004), Baier and Bergstrand (2007), and Baier et al (2008), among others.

We expect that this estimated value will fall somewhere in the support of the distribution of per-capita GDPs for EU members. That way, poorer EU members will face a negative effect of increase environmental regulation stringency, while richer members will face a positive effect.

Strictly speaking, our model does not make any predictions about what will happen in non-EU member-states when environmental regulation stringency increases. As we note, the decision to adopt more stringent environmental regulations unilaterally is highly endogenous, which may significantly attenuate the mechanism described above. However, we believe that it will be consistent with the spirit of the model if we observe a similar effect of increases in environmental regulation stringency on trade flows in non-EU countries, but that the “threshold” value between positive and negative effects would be lower than for EU countries. More formally, we predict that $\beta_8 > 0$, and that

$$GDPPC^{NONEU} = exp\left(-\frac{\beta_4}{\beta_8}\right) < GDPPC^{EU} = exp\left(-\frac{\beta_4 + \beta_6}{\beta_8 + \beta_9}\right) \tag{25}$$

It is also possible that that $\beta_8 > 0$, (that is, that the exports will be increasing in per-capita GDP interacted with environmental regulation stringency). However, our prediction here is not as strong for non-EU members as for EU members.

The results of these three regressions can be found in Tables 3 and 4. Our first hypothesis, that $\beta_9 > 0$ (i.e., that an increase in environmental regulation stringency for EU members will be less harmful for relatively rich members of the EU) is supported by the data. In all three regression specifications, the coefficient is positive, significant at the 1% level, and has a range in value between 0.0681 and 0.104. Using the Log-Linear OLS result, this estimated coefficient means that for an EU member, the effect on exports a one-point increase in environmental regulation stringency will be 0.086% higher given a 1% increase in the country's per-capita GDP.

Furthermore, we can use the formula found in equation (24) above to derive an estimated threshold level of per-capita GDP where the effect of an increase in environmental regulation stringency switches from negative (for low per-capita GDP countries) to positive (for high per-capita GDP countries). The results of this calculation can be found in Table 4. In the Log-Linear OLS specification, the estimate threshold value for EU members is $13,049. This falls near the bottom of the support of per-capita GDP in our sample but is still higher than 11.57% of the country-year per-capita GDP observations in our EU member sample. For the Poisson specification, the threshold rises significantly, to $20,986, which is greater than 37.50% of the EU country-year observations. On the other hand, the threshold estimate falls to $7,354 in the Gamma GLM specification, which is slightly below the support of our observations (the minimum EU member per-capita GDP being Bulgaria in 2001, which had a per-capita GDP of $7,577). While the Gamma GLM estimate is a little on the low side, the other two estimates are well within the support of EU members' per-capita GDP during this time. Taken together, the data support the idea that the "threshold" value at which increased environmental regulation stringency switches from a positive to negative effect on exports is in the lower half of the distribution of EU members' per-capita GDPs.

As noted above, our theory does not make a straightforward prediction about the effect of environmental regulation stringency unilaterally adopted by non-EU members. However, it would be consistent with the spirit of our hypothesis if the same basic dynamics described above applied to non-EU members. At the same time, we predict that the threshold level at which the effect changes from negative to positive will be lower for non-EU members. That is, non-EU members will have a greater scope to adopt and/or enforce only those environmental measures that were compatible with their economic development. Therefore, it will be easier for lower-to-middle income countries that are not EU members to comply with greater environmental regulation stringency.

The first part of this hypothesis, that $\beta_8 > 0$, is partially borne out by the data. The coefficient is positive and statistically significant using the Log-Linear OLS specification and is positive but insignificant when using the Poisson and Gamma GLM specification. Using equation (25), we can calculate the threshold value of per-capita GDP for when an increase in environmental regulation stringency switches from having a positive to a negative effect on exports for non-EU members. The Log-Linear OLS specification predicts that the threshold value is \$6,221 for non-EU members, while the Poisson specification predicts that it is \$5,423. The Gamma PML specification, on the other hand predicts that the threshold will be close to zero. While the Gamma specification yields a prediction value much lower than the others, all three predicted values are positive and less than the predicted threshold for EU members. Furthermore, the Log-Linear OLS and Poisson specification predictions are a little bit shy of \$8,000 in 2011 PPP-adjusted dollars, which is consistent with the environmental Kuznets Curve estimates of Grossman and Krueger (1995). Taken as a whole, we find these empirical results to be supportive of the theory outlined above.

5.3 GDP Per-Capita Used for Sample Splits

This section, rather than treating per-capita GDP as a continuous variable, divides our data sample into different subsamples using a threshold level of \$10,000 in per-capita

GDP using 2011 PPP-adjusted dollars. The regression specification followed in all the empirical analyses in this subsection is of the form:

$$lnX_{i,j,t} = \beta_0 + \beta_1 lnRGDP_{i,t} + \beta_2 lnRGDP_{j,t} + \beta_3 EU_{i,j,t} + \beta_4 ENVREGS_{i,t} + \beta_5 ENVREGS_{j,t} + \beta_6 ENVREGS_{i,t} * EU_{i,t} + \beta_7 ALLOTHEREIAS_{i,j,t} + \delta_{i,j} + \theta_t + ln\varepsilon_{i,j,t} \quad (21)$$

where $X_{i,j,t}$ is the value of exports from country *i* to country *j* in year *t*, $RGDP_{i,t}$ is the real GDP of country *i* in year *t*, $EU_{i,j,t}$ is a dummy variable indicating if both country *i* and *j* were both EU members in year *t*, $ENVREGS_{i,t}$ is the stringency of environmental regulations variable in country *i* in year *t*, and $ALLOTHEREIAS_{i,j,t}$ is a dummy variable indicating the existence of an economic integration agreement (other than EU membership) between countries *i* and *j* in year *t*. $\delta_{i,j}$ is a bilateral country pair fixed-effect in some of the regression specifications below and a vector of bilateral "gravity" variables in others, and θ_t is a year fixed-effect.[16] Our theory predicts the following signs on the coefficients: $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$, β_4 ambiguous, β_5 ambiguous, $\beta_6 < 0$, $\beta_7 > 0$.

For each specification, we run seven regressions on different sub-samples of the overall sample using the $10,000 GDP per-capita threshold. The results of this sample split are shown in Table 1 above. We then run regressions for seven different combinations of these sub-samples: exports from all countries to all countries, from rich countries to rich countries, from rich countries to poor countries, from rich countries to

[16] The inclusion of bilateral fixed effects follows Baier and Bergstrand (2004), Baier and Bergstrand (2007), and Baier et al (2008), among others.

all countries, from poor countries to rich countries, from poor countries to poor countries, and from poor countries to all countries.

We have two hypotheses that we are testing. The first is $\beta_6 < 0$, implying that environmental regulations associated with EU membership are not as helpful for a country's exports as unilateral environmental regulations. We expect that this effect will be stronger in poorer countries than in richer countries. We also test to see if $\beta_4 + \beta_6 < 0$, which implies that EU environmental regulations are positively harmful for some countries' exports. We do not expect this hypothesis to be generally true, but rather just for the poorer members of the EU.

5.3.1 First Specification – Log-Linear OLS with Zeroes Dropped

Our first regression specification is log-linear OLS with the zero trade-flow observations dropped from the sample and bilateral country pair fixed-effects. As noted above, there may be a strong selection bias in this specification.

The results of our regressions can be found in Table 5. As expected, the GDPs of both the exporting and importing countries are positively and significantly associated with the volume of trade between the two across all sub-samples. The coefficient on the stringency of environmental regulations for exporting countries variable is negative across all sub-samples, but perhaps surprisingly, only significant when the exporting country is rich. However, the coefficient on environmental regulations interacted with EU membership is significant across all specifications. More importantly, it is positive when the exporting countries are rich and negative when the exporting countries are poor.[17] This result provides evidence that multilateral environmental regulations disproportionately hurt poorer countries when they are imposed upon them.

To test this idea more directly, we look at the sum of the coefficients on environmental regulations and environmental regulations interacted with EU membership ($\beta_4 + \beta_6$ in the notation above) in Table 6. For all the sub-samples that have rich exporters, this sum is positive. Furthermore, an F-test on the sum of these coefficients shows that sum is significantly different from zero. However, once we switch to the poor exporting countries sub-sample, the sign of the sum switches to negative. Once again, the F-test shows that these sums are also significantly different from zero.

This last result is particularly important to our hypothesis. An increase in environmental stringency for rich EU members does not harm their exports. On the contrary, our data indicate that it may benefit exports. However, the same increase for a poor EU member harms the country's exports. Not only is the sum statistically significant, but it is also rather large – a one point increase (on the seven-point scale) in environmental stringency results in a more than 51% decrease on average for poor EU members. While it may not be correct to attribute all the changes in environmental stringency for poor EU members to multilateral regulations imposed by the EU, the fact that we do not have nearly the same result for poor non-EU countries gives us good reason to believe that EU membership is responsible for at least part of the effect.

5.3.2 Second Specification – Poisson PML Estimation

[17] Because there are more rich countries than poor countries in the EU according to our classification scheme, we expect that the coefficient for the "All-All" sample will look more like the rich country subsample than the poor country subsample.

As noted above, the log linear OLS with zeroes dropped specification potentially suffers from a selection bias problem. Therefore, Santos Silva and Tenreyo (2006) argue that a Poisson PML estimator might better handle the econometric issues that arise in gravity-type equations – particularly the zeroes problem.

The results of these regressions can be found in Table 7. The coefficients on environmental stringency in the exporting country are generally positive here, but only sporadically significant (though, most notably, for poor-poor country trade). However, the coefficients on environmental stringency interacted with EU membership are close to zero and insignificant for rich exporters, but negative and significant for poor exporters.

Table 8 shows us what occurs when the two coefficients are added together. Here our results look close to what our hypothesis predicted. The net effect on exports of environmental stringency and EU membership is close to zero and statistically insignificant when the exporting countries are rich. However, for poor countries, the coefficients are all negative and are significantly different from zero in 2 out of the 3 subsamples. While the magnitudes of these coefficients are slightly diminished from the log linear OLS specification, they are still economically meaningful. Therefore, we can conclude that our results from the previous specification are robust to using a Poisson PML estimator.

5.2.3 Third Specification – Gamma PML Estimator

The results of these regressions can be found in Table 9. The results in this specification are not as consistent with our hypotheses as the specifications above. While the coefficient on the interaction term between EU membership and environmental regulation stringency is negative and significant for rich exporting countries, both its sign and significance level are more erratic for poor exporting countries.

Table 10 shows the sum of the two coefficients of interest. For all sub-samples, the effect of more stringent environmental regulations for EU members on their exports is positive and often statistically significant. Furthermore, the effect tends to be larger for poorer countries than for rich countries.

The results from this specification are not consistent with the hypotheses above. We are inclined to discount them because, while we attempted to simulate bilateral fixed effects in these regressions, we were not fully able to do so. Therefore, there may be a remaining omitted variables bias problem. Secondly, while Head and Mayer (2014) argued that the Gamma PML estimator might be appropriate for some error structures, it was not appropriate for all. It is because of their analysis and because we cannot directly observe our error terms that we look at a wide variety of specifications in this study.

5.2.4 Summary of Results Across Specifications

The log linear OLS and Poisson specifications provide strong evidence in support of our hypothesis that multilateral environmental regulations imposed by the EU are harmful to the exports of the EU's poorer members. On the other hand, the Gamma PML specification does not support the hypothesis.

As noted above, the econometric issues raised by gravity-type regressions are still being worked out, and no single specification clearly dominates the others in the literature. Thus, while we do not have a clearly preferred specification, we think the fact the results from the two specifications that allow us to include bilateral pair fixed effects support our hypothesis constitutes good evidence that our theory has some empirical grounding.

6. Conclusions

Clearly, changes in the stringency of environmental regulations could have differing effects on bilateral trade flows depending on the respective incomes of the effected countries. Richer countries inside an economic integration agreement, such as the European Union, have an incentive to impose environmental regulations on the entire group of countries in the agreement so that poorer countries must raise their standards (raising production costs in poorer countries). The consequences of an increase in environmental regulation stringency differ dramatically for high income countries in the EU compared to low-income countries.

We have shown the theoretical possibility that high income members of an EIA could increase exports by imposing more stringent environmental regulations on all members – and especially low-income members – of the EIA. Similarly, our model indicates that such an increase in environmental regulation stringency would decrease exports from low-income members of the EIA.

We empirically tested our model by estimating the effects of changes in individual countries' environmental regulation stringency on bilateral trade flows. Our focus was on the European Union because it represents a large EIA with a wide distribution of economic development that also has both a history of environmental activism and a strong multilateral rule-making authority. Furthermore, a growing backlash against the Union's perceived remoteness from the concerns of its citizens has recently led to political earthquakes such as the Brexit vote.

Our empirical analysis indicates that for members of the EU, an increase in environmental regulation stringency has a positive effect on exports for the organization's richer members, but a negative effect for the organization's poorer members. Our regression analyses find that this switching point is somewhere near the lower end of the support of the EU's per-capita income distribution.

Although we found that an increase in environmental regulation stringency in a high-income country generally increases its exports to other high-income countries, we detected little statistical difference between high income, EU members and high income, non-EU members. Conversely, an increase in environmental regulation stringency generally 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 richer countries appears to be less harmful.

Regional trade blocs have grown rapidly in the last two decades. Furthermore, these trade blocs are increasingly 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. Indeed, recent backlashes against globalization, typified by the Brexit vote, have given voice to voters who are concerned about the loss of national sovereignty to multilateral institutions. At the same time, this backlash has largely not translated into an opposition to trade agreements per se. On the contrary, many pro-Brexit politicians in the UK have talked about having the freedom to make trade agreements best suited to the UK economy. Their arguments focus less on trade with the European Union and more on rules and regulations made by distant policymakers.

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.[18]

[18] For example, following Maloney and McCormick (1982), we could model firms in country *i* lobbying for environmental regulations because their profits vary with environmental regulation. If trade bloc 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 idea is left for future research.

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Table 1 -- Rich and Poor Countries in Dataset

Rich Countries				Poor Countries			
Country	Years	Country	Years	Country	Years	Country	Years
ARG	2	NZL	9	AGO	5	MDA	5
AUS	9	OMN	3	ALB	5	MDG	7
AUT	***9***	***POL***	***8***	ARG	7	MEX	5
BGR	***2***	***PRT***	***9***	ARM	5	MKD	7
BHR	6	QAT	5	AZE	5	MLI	7
BRN	2	RUS	5	BDI	5	MNG	5
CAN	9	SAU	3	BEN	5	MOZ	7
CHE	9	SGP	9	BFA	4	MRT	4
CHL	4	***SVK***	***9***	BGD	9	MUS	6
CYP	***6***	***SVN***	***9***	***BGR***	***7***	MWI	6
CZE	***9***	***SWE***	***9***	BIH	5	MYS	3
DEU	***9***	TTO	7	BOL	9	NGA	9
DNK	***9***	TUR	3	BRA	9	NPL	5
ESP	***9***	USA	9	CHL	5	PAK	7
EST	***8***			CHN	9	PAN	9
FIN	***9***			CIV	2	PER	9
FRA	***9***			CMR	5	PHL	9
GBR	***9***			COL	9	***POL***	***1***
GRC	***7***			CRI	9	PRY	9
HKG	9			DOM	9	RUS	4
HRV	8			ECU	8	RWA	1
HUN	***9***			EGY	8	SEN	4
IRL	***9***			***EST***	***1***	SLV	9
IRN	1			ETH	7	SUR	3
ISL	9			GEO	6	SYR	3
ISR	9			GHA	2	TCD	6
ITA	***9***			GMB	7	THA	9
JPN	9			GTM	9	TJK	5
KAZ	3			HND	9	TTO	2
KOR	9			IDN	9	TUN	8
KWT	5			IND	9	TUR	6
LBN	1			JAM	9	TZA	7
LTU	***7***			JOR	9	UGA	7
LUX	***7***			KAZ	2	UKR	9
LVA	***5***			KEN	7	URY	9
MEX	4			KGZ	5	UZB	1
MLT	***7***			KHM	5	VEN	9
MUS	3			LKA	9	VNM	9
MYS	6			***LTU***	***2***	ZAF	9
NLD	***9***			***LVA***	***4***	ZMB	7
NOR	9			MAR	8	ZWE	9

EU Countries in ***Bold Italics***

Table 2 -- Summary Statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
lrxp	Log of Real Exports	78,422	16.25	3.81	-14.15	26.59
lrgdp_exp	Log of Real GDP, Exporting Country	91,781	11.67	1.78	6.45	16.39
lrgdp_imp	Log of Real GDP, Importing Country	91,781	11.66	1.76	7.55	16.40
envregs_exp	Environmental Regulation Index, Exporting Country	91,781	4.11	1.15	1.60	6.80
envregs_imp	Environmental Regulation Index, Importing Country	91,781	4.11	1.15	1.60	6.80
EU_X_envregs_exp	Interaction Term, Exporting Country	91,781	1.24	2.24	0.00	6.80
EU_X_envregs_imp	Interaction Term, Importing Country	91,781	1.20	2.22	0.00	6.80
all_other_EIAs	Dummy Variable for All Other EIAs	91,781	0.28	0.45	0.00	1.00

Table 3 -- Regressions Interacted with Per-Capita GDP			
	(1)	(2)	(3)
Specification	Log-Linear OLS	Poisson	Gamma GLM
Log Real GDP Exporter	0.490***	0.955***	0.996***
	(5.814)	(9.219)	(59.60)
Log Real GDP Importer	0.690***	1.050***	0.725***
	(10.41)	(12.83)	(35.51)
Stringency of Env. Regs. Exporter	-0.576***	-0.259	0.154
	(-4.090)	(-1.431)	(1.222)
Stringency of Env. Regs. Importer	-0.00200	0.0795***	0.185***
	(-0.118)	(3.572)	(5.828)
EU Member X Env. Regs. Exporter	-0.864***	-1.076***	-0.803***
	(-3.048)	(-3.486)	(-5.579)
EU Member X Env. Regs. Importer	0.0387	-0.120***	0.0423**
	(1.191)	(-4.146)	(2.475)
Per-Capita GDP X EU X Env. Regs Exporter	0.0860***	0.104***	0.0681***
	(3.026)	(3.365)	(4.803)
Per-Capita GDP X Env. Regs Exporter	0.0659***	0.0301	0.00485
	(4.226)	(1.542)	(0.462)
Bilateral EIA	0.100**	-0.0493	0.120
	(2.500)	(-1.052)	(1.535)
Constant	1.589		-2.798***
	(1.277)		(-6.518)
Bilateral Controls	Fixed Effects	Fixed Effects	Bilateral Variables
Year Controls	X	X	X
Observations	78,422	84,365	91,781
Number of Country Pairs	13,314	12,522	

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 -- Cutpoints for Switch in Env. Regs. Effect			
Implied Threshold for:	Log-Linear OLS	Poisson	Gamma GLM
EU Members	$13,049	$20,986	$7,354
Non-EU Members	$6,221	$5,423	$0

Table 5 -- OLS With Zeros Dropped

	(1) All-All	(2) Rich-Rich	(3) Rich-Poor	(4) Rich-All	(5) Poor-Rich	(6) Poor-Poor	(7) Poor-All
lrgdp_exp	0.632***	0.850***	0.349*	0.583***	0.502***	0.613***	0.557***
	(8.288)	(5.421)	(1.941)	(4.963)	(3.928)	(3.797)	(5.385)
lrgdp_imp	0.692***	0.879***	0.619***	0.724***	0.570***	0.477***	0.645***
	(10.41)	(8.191)	(6.750)	(10.62)	(2.877)	(2.847)	(5.364)
envregs_exp	-0.0141	0.0189	-0.105**	-0.0573*	-0.00242	-0.0256	-0.0147
	(-0.712)	(0.568)	(-1.992)	(-1.795)	(-0.0734)	(-0.725)	(-0.611)
envregs_imp	-0.00110	0.0485	-0.0119	-0.00843	0.00226	-0.0127	0.0116
	(-0.0647)	(1.545)	(-0.534)	(-0.449)	(0.0390)	(-0.366)	(0.397)
EU_X_envregs_exp	0.119***	0.0471	0.203***	0.153***	-0.304**	-0.660***	-0.501***
	(4.044)	(1.177)	(3.432)	(4.172)	(-2.406)	(-2.661)	(-3.381)
EU_X_envregs_imp	0.0400	0.00718	-0.197**	0.0698**	0.0313	-0.390	0.00760
	(1.229)	(0.187)	(-2.410)	(2.214)	(0.429)	(-1.228)	(0.134)
all_other_EIAs	0.102**	-0.127*	0.183***	0.0515	0.0627	0.283***	0.166**
	(2.537)	(-1.744)	(3.286)	(1.204)	(0.616)	(2.906)	(2.219)
Constant	-0.0539	-3.378	4.744*	1.176	2.293	1.884	0.603
	(-0.0461)	(-1.426)	(1.960)	(0.715)	(0.824)	(0.726)	(0.338)
Observations	78,422	16,517	21,390	37,907	19,807	20,708	40,515
Number of Bilateral Pairs	13,314	2,989	4,153	6,560	3,960	4,675	8,001
R-squared	0.130	0.226	0.141	0.172	0.080	0.102	0.097

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 -- Net Effect of EU Environmental Regulations; OLS Regressions

	All-All	Rich-Rich	Rich-Poor	Rich-All	Poor-Rich	Poor-Poor	Poor-All
Net Effect	0.1048	0.0660	0.0982	0.0958	-0.3068	-0.6854	-0.5157
P-Value of F-Test of Joint Significance	0.0000***	0.0224**	0.0053***	0.0000***	0.0103**	0.0051***	0.0004***

Table 7 -- Poisson Regressions

	(1) All-All	(2) Rich-Rich	(3) Rich-Poor	(4) Rich-All	(5) Poor-Rich	(6) Poor-Poor	(7) Poor-All
lrgdp_exp	1.019***	0.650***	0.676***	0.609***	1.207***	0.455**	1.026***
	(10.48)	(5.057)	(5.703)	(4.659)	(5.337)	(2.462)	(5.942)
lrgdp_imp	1.049***	0.835***	1.125***	1.103***	0.872***	0.758***	1.111***
	(12.80)	(7.179)	(5.752)	(12.60)	(3.594)	(3.270)	(6.956)
envregs_exp	0.0367*	0.0385	0.0132	0.0465	0.00452	0.0848***	0.0207
	(1.793)	(1.096)	(0.338)	(1.460)	(0.200)	(3.398)	(0.973)
envregs_imp	0.0852***	0.154***	-0.0294	0.0730***	0.0988	0.0132	0.0856*
	(3.604)	(4.379)	(-1.481)	(3.056)	(1.455)	(0.384)	(1.913)
EU_X_envregs_exp	-0.0171	-0.0212	-0.00551	-0.0289	-0.114*	-0.228**	-0.158**
	(-0.657)	(-0.642)	(-0.0973)	(-0.887)	(-1.804)	(-2.244)	(-2.548)
EU_X_envregs_imp	-0.141***	-0.187***	-0.0737	-0.127***	-0.223***	-0.0557	-0.192***
	(-4.641)	(-4.891)	(-1.266)	(-3.971)	(-2.934)	(-0.334)	(-2.897)
all_other_EIAs	-0.0579	-0.161**	-0.120*	-0.108**	-0.0371	0.0999	0.00313
	(-1.256)	(-2.456)	(-1.761)	(-2.333)	(-0.898)	(1.368)	(0.0705)
Observations	84,365	16,455	21,770	38,354	21,171	24,092	45,641
Number of Bilateral Pairs	12,522	2,778	3,787	6,086	3,662	4,299	7,463

Robust z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8 -- Net Effect of EU Environmental Regulations; Poisson Regressions

	All-All	Rich-Rich	Rich-Poor	Rich-All	Poor-Rich	Poor-Poor	Poor-All
Net Effect	0.0196	0.0173	0.0077	0.0176	-0.1095	-0.1433	-0.1378
P-Value of Chi-Squre Test of Joint Significance	0.3179	0.4377	0.8139	0.4150	0.0480**	0.1394	0.0090***

Table 9 -- Gamma Distribution Maximum Likelihood Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All-All	Rich-Rich	Rich-Poor	Rich-All	Poor-Rich	Poor-Poor	Poor-All
lrgdp_exp	0.999***	1.093***	0.957***	1.025***	1.062***	0.914***	0.986***
	(53.11)	(67.59)	(49.37)	(61.74)	(33.58)	(26.94)	(38.30)
lrgdp_imp	0.738***	0.729***	0.747***	0.740***	0.740***	0.678***	0.709***
	(35.65)	(38.90)	(45.78)	(43.85)	(19.18)	(18.53)	(26.42)
envregs_exp	0.221***	0.130***	0.104**	0.118***	0.234***	0.228***	0.243***
	(9.232)	(2.819)	(2.509)	(3.010)	(3.442)	(3.492)	(4.513)
envregs_imp	0.201***	0.118***	0.135***	0.154***	0.154**	0.138	0.186***
	(6.397)	(3.519)	(3.185)	(6.115)	(2.414)	(1.503)	(4.265)
EU_X_envregs_exp	-0.0651***	-0.0286***	-0.0969***	-0.0696***	0.0849*	-0.157***	-0.0321
	(-6.833)	(-2.628)	(-7.838)	(-6.900)	(1.954)	(-4.025)	(-1.032)
EU_X_envregs_imp	0.112***	0.169***	0.245***	0.209***	0.0539***	-0.0464	0.0431***
	(7.200)	(12.54)	(5.554)	(7.828)	(3.590)	(-1.134)	(2.588)
all_other_EIAs	-0.179**	-0.159	0.308***	0.0541	-0.111	0.391***	0.0523
	(-2.459)	(-1.604)	(3.965)	(0.406)	(-0.955)	(4.692)	(0.776)
lkm	-1.462***	-1.492***	-1.511***	-1.544***	-1.192***	-1.172***	-1.243***
	(-42.46)	(-23.77)	(-24.93)	(-25.23)	(-18.69)	(-16.97)	(-26.46)
border	1.001***	0.694***	0.842***	0.789***	1.255***	1.121***	1.169***
	(13.56)	(9.831)	(4.844)	(8.666)	(7.842)	(10.46)	(12.09)
com_lang	1.242***	1.486***	1.285***	1.346***	1.083***	1.205***	1.231***
	(26.45)	(18.99)	(22.83)	(27.85)	(13.26)	(14.99)	(20.19)
ldlock1	-0.893***	-0.621**	-1.445***	-1.029***	-0.743***	-1.039***	-0.892***
	(-6.922)	(-2.499)	(-14.65)	(-6.079)	(-3.636)	(-5.921)	(-5.837)
ldlock2	-1.640***	-1.436***	-1.537***	-1.565***	-1.389***	-1.910***	-1.695***
	(-23.88)	(-10.63)	(-15.33)	(-17.38)	(-8.708)	(-15.99)	(-18.22)
feresids	0.479***	0.504***	0.551***	0.521***	0.466***	0.503***	0.482***
	(50.07)	(16.47)	(36.72)	(31.75)	(28.77)	(36.62)	(42.78)
Constant	-1.617***	-2.312***	-1.353**	-1.504***	-4.498***	-2.527***	-3.110***
	(-4.158)	(-4.444)	(-2.445)	(-3.440)	(-5.193)	(-3.030)	(-4.970)
Observations	91,781	16,889	22,935	39,824	23,095	28,862	51,957

Robust z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10 -- Net Effect of EU Environmental Regulations; Gamma PML Regressions

	All-All	Rich-Rich	Rich-Poor	Rich-All	Poor-Rich	Poor-Poor	Poor-All
Net Effect	0.1559	0.1016	0.0074	0.0489	0.3194	0.0717	0.2107
P-Value of Chi-Squre Test of Joint Significance	0.0000***	0.0149**	0.8370	0.1596	0.0001***	0.3381	0.0010***

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

$$\ln \varepsilon_{ijt} = \gamma_1 S_{it} + \gamma_2 S_{jt} + \gamma_3 S_{it} E_{ijt} + u_{ijt} \tag{A1}$$

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; $E(u_{ijt})=0$.

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[19]. 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

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

where the error term in equation (A6) is: $\upsilon_{ijt} = u_{ijt} + O_{it}$

(A7)

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[19] 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.

Because O_{it} determines Q_{it}, the correlation between O_{it} and Q_{it} is likely to be 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

$$\ln y_k = -\ln \mu_k + \ln \varepsilon \tag{B1}$$

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

$$y_k = \frac{\varepsilon_i}{\mu_k} \tag{B2}$$.

Executives are asked to rate between 1 and 7 each country's environmental regulation stringency relative to other countries; we assume a commonly known threshold, τ_i, to exist between each two levels, as is illustrated below in Figure B1. An executive gives country k a rating of i $\in \{2,\ldots,6\}$ if the signaled regulatory laxness is between τ_{i-1} and τ_i; likewise, a rating of 7 is given when the signal exceeds τ_6 and a rating of 1 is given when the signal is beneath τ_1.

Figure B1: Theoretical thresholds between rating levels

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 each 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

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

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

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

. .

. .

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

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

Setting up GMM, the expected value of x_i is

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

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

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

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.