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Abstract

The argument that stringent environmental regulations are generally thought to harm export flows is crucial when determining policy recommendations related to environmental preservation and international competitiveness. By using bilateral trade data, we examine the relationships between trade flows and various environmental stringency indices. Previous studies have used energy intensity, abatement cost intensity, and survey indices for regulations as proxies for the strictness of environmental policy. However, they have overlooked the indirect effect of environmental regulations on trade flows. If the strong version of the Porter hypothesis is confirmed, we need to consider the effect of environmental regulation on GDP, because GDP induced by environmental regulation affects trade flows. The present study clarifies the effects of regulation on trade flows by distinguishing between the indirect and direct effects. Our results indicate an observed non-negligible indirect effect of regulation, implying that the overall effect of appropriate regulation benefits trade flows.

Keywords: Environmental regulations, Porter hypothesis, Trade and environment, Gravity model

JEL: Q56; Q59; F18

1 Introduction

Strengthening environmental regulations may affect both the international competitiveness of firms and the leakage of pollutants through changes in trade flows. Thus, the effect of regulations on trade flows is crucial in policy debates. This topic has been explored extensively in the past decade (e.g., Copeland and Taylor 2003), with policymakers and academic researchers tending to agree that more stringent environmental regulations require abatement costs, which thereby increases production costs and may result in weaker industry competitiveness (Pethig 1976; McGuire 1982; Jenkins 1998). On the other hand, Porter and van der Linde (1995) suggest that environmental regulations encourage the development of new production processes and can thus confer comparative advantage. Moreover, while some empirical studies have found that stricter regulations reduce trade flows (e.g., Van Beers and Van den Bergh 1997), other studies have indicated the opposite result (Costantini and Crespi 2008).

The inconclusiveness of the findings of previous studies may be because they overlook both the direct and the indirect effects of regulation. Regulation may increase GDP and thus raise export flows. In addition, the strong version of the Porter hypothesis claims that environmental regulation enhances economic performance—at least in the medium run—for compliant firms, the sector to which they belong, and, eventually, the economy as a whole. In particular, Costantini and Mazzanti (2012) find evidence in support of the strong Porter hypothesis.

The contradictory nature of the results of previous research might also be driven by authors using various proxies of environmental variables. Energy intensity, abatement cost intensity, and survey indices have been generally used as proxies for the stringency of regulations. However, each of these proxies is distinct. Energy intensity, defined as energy use relative to the gross domestic product (GDP), is likely to reflect regulations that are strongly related to energy, whereas abatement cost intensity, defined as abatement cost relative to GDP, tends to reflect regulations that relate to a relatively wide range of industries. Moreover, previous works have typically used three survey indices: the survey conducted at the United Nations Conference on Trade and Development (UNCTAD) in 1976, the one conducted at the United Nations Conference on Environment and Development (UNCED) in 1992, and those conducted by the Center for International Earth Science Information Network (CIESIN) in 2002 and 2005.

These indices indicate not only the stringency of the environmental legislation but also the length of its existence, the industries the policy applies to, and the degree of environmental awareness displayed by the citizens of that particular country (Xu 2000).

This study clarifies how various environmental regulation proxies affect export flows, by estimating both the indirect and the direct effects. No previous study has thus far investigated these individual effects. Which version of the Porter hypothesis should be better investigated at the empirical level has been widely debated. The distinction between the strong and weak versions of the hypothesis gives rise to a different choice in the dependent variable adopted in the empirical model. The former version refers to an increase in economic scale, while the latter refers to an improvement in environmental technology. Indeed, the basic distinction often explains the divergent results (see Ambec et al. 2010 for recent reviews). Hence, our study aims to show (i) whether the strong version of the Porter hypothesis is confirmed and (ii) the overall effect of regulation on export flows.

The remainder of the paper is organized as follows. The next section presents the background. Section 3 explains our model and Section 4 discusses the empirical results. The last section concludes and contextualizes our findings.

2 Background

In this section, we summarize the research findings on this topic (see Table 1 for a summary). Van Beers and Van den Bergh (1997) employ the gravity model, using two indices, namely their own stringency index[1] and an index based on energy intensity. By using data from OECD countries in 1992, they conclude that environmental stringency has a statistically significant negative effect on international competitiveness. Harris et al. (2002) use a three-way fixed-effects model that allows for the importing country, the exporting country, and time-specific effects. By using an index based on the energy intensity of 24 OECD countries from 1990 to 1996, they find a relationship between stringency and trade flows without these specific fixed effects. However, its significance fades when the importing or exporting country effects are taken into

[1] This index was constructed from seven variables: protected areas as a percentage of the national territory in 1990, the market share of unleaded petrol in 1990, the recycling rate for paper in 1990, the recycling rate for glass in 1990, the percentage of the population connected to sewage treatment plants in 1991, the level of energy intensity in 1980, and changes in energy intensity from 1980 to 1991.

consideration. Jug and Mirza (2005) use 12 European Union (EU) countries' abatement costs, measured as the total current expenditure provided by Eurostat, to examine the relationship between relative stringency and export flows. They modify the empirical gravity equations used by Van Beers and Van den Bergh (1997) and by Harris et al. (2002) as well as consider the issue of endogeneity, finding statistically significant negative effects on international competitiveness using OLS, fixed-effects estimates, and the generalized method of moments (GMM) procedure with instrumental variables (IVs).

Xu (2000) uses 1992 UNCED data[2,3] for 20 countries and finds a positive relationship between environmental stringency and aggregate export flows using OLS. In addition, Costantini and Crespi (2008) find a positive relationship between abatement cost intensity and export flows, although they focus on energy technology. Furthermore, Costantini and Mazzanti (2012) test the strong and narrowly strong versions of the Porter hypothesis[4] and find evidence in support of both for the EU in 1996–2007 using abatement cost intensity, energy tax, environmental tax, and the Eco-Management and Audit Scheme initiatives. These results indicate that environmental regulations may have a positive effect on international competitiveness.

(Insert Table 1)

As described in the Introduction, previous studies have tended to use three proxies of environmental regulations: energy intensity, abatement cost intensity, and

[2] The survey here used 25 questions to categorize (1) environmental awareness levels; (2) the scope of the policies adopted; (3) the scope of the legislation enacted; (4) control mechanisms put in place; and (5) the degree of success in implementing the legislation. For each report, 25 questions were answered for 20 elements; therefore, 500 assessment scores were obtained for each country. The possible assessment scores were 0, 1, and 2. Each country's score ranged from 0 to 1000. The more stringent the assessment, the higher the score was.

[3] This survey included both developed and developing countries, and is comparable among countries because the United Nations imposed a standard reporting format (see Dasgupta et al. 2001 for more details). The indices developed by Dasgupta et al. (2001) and Eliste and Fredriksson (2002) are hereafter referred to as the DMRW index and EF index, respectively. Dasgupta et al. (2001) randomly select 31 UNCED reports from a total of 145. Eliste and Fredriksson (2002) extend this dataset to 62 countries using the same methodology as Dasgupta et al. (2001). While their measure of the stringency of environmental regulations is an index for the agricultural sector, it sufficiently reflects the stringency of all sectors. In fact, the correlations for each sector's score in Eliste and Fredriksson (2002) range from 0.855 to 0.968.

[4] The narrowly strong version of the Porter hypothesis meets the definition that a more stringent regulatory framework might positively impact only the green side of the economy.

survey indices[5]. Studies using energy intensity have not obtained robust results. When the endogeneity of stringency or fixed effects are taken into consideration, the estimation results become statistically insignificant (e.g., Harris et al. 2002). By contrast, studies using abatement cost intensity obtain statistically significant results. Their findings indicate that environmental regulations may have a negative effect on aggregate trade flows (e.g., Jug and Mirza 2005), except in the energy industry (e.g., Costantini and Crespi 2008). Finally, the results obtained using the UNCTAD index present statistically significant positive effects (Xu 2000).

3 Empirical Strategy

3.1 Model

3.1.1 GDP per worker model

We consider both the direct and indirect effects of environmental policy on export flows. In terms of the indirect effect, the degree to which environmental policy may affect GDP and thus export flows depends on whether the strong version of the Porter hypothesis is confirmed. To examine this indirect effect, we use the following model of GDP per worker:

$$\ln(y_{zt}) = \gamma_t + \gamma_z + \gamma_1 \ln(k_{zt}) + \gamma_2 \ln(s_{zt}) + \gamma_3 \ln(Str_{zt}) + \varepsilon_{zt} \quad (1)$$

This model, based on Barro and Lee (2010), uses the Cobb–Douglas production function. Here, z denotes country z; t denotes the year; y_{tz} denotes real GDP per worker[6]; γ_t denotes the time-fixed effects; γ_z denotes the country-fixed effects; k_{tz} denotes capital stock per worker; s_{tz} denotes average years of schooling (for the population aged 15 and over); Str_{tz} denotes the stringency of the environmental policy; and ε_{tz} denotes the error term. Barro and Lee (2010) consider output to be determined by the product of total factor productivity, the stock of physical

[5] Although Costantini and Mazzanti (2012) use abatement cost, energy tax, environmental tax, and the Eco-Management and Audit Scheme initiatives as proxies of environmental regulation, our study focuses on abatement cost to ensure comparability with previous research.

[6] We use GDP per worker instead of GDP per capita following Barro and Lee (2010).

capital, and human capital stock. These three factors correspond to γ_t, k_{tz}, and s_{tz}, respectively. They further assume that human capital per worker is related to the number of years of schooling that a person receives. In our model, we also consider the relationship between human capital per worker and the stringency of environmental regulations.

Following Barro and Lee (2010), in our model, we use 10-year lagged *k* as an IV for *k* and the 10-year lags in *s* for individuals aged 40–74 years old as an IV for *s*. We also use adjusted savings from CO_2 damage and from particulate emissions (PE) damage (during the previous five years on average) as the IVs for stringency. Previous studies have addressed the simultaneity problem of the stringency variables. Since the environment might be considered a superior good, its demand (and therefore environmental stringency) increases with GDP levels. In addition, higher levels of net imports (i.e., a trade deficit) may help relax environmental regulations, thereby affecting trade flows (Trefler 1993; Ederington and Minier 2003). Rose and Spiegel (2009) use adjusted savings from CO_2 damage and from PE damage as IVs. These values are considered to be measures of actual and potential environmental damage. They therefore tend to correlate with the stringency variables, whereas they do not directly affect trade flows and are weakly correlated with trade flows[7,8]. We use these IVs to estimate equation (1).

To analyze abatement cost intensity and energy intensity, we use fixed-effects and random-effects estimations with IVs, whereas to consider the survey indices, we use two-stage least squares regressions. Then, we calculate the fitted value of GDP to include in equation (2), as described in the next subsection.

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[7] We also consider two factors that influence stringency: environmental quality as a normal good and the cost of compliance. A country that strengthens its environmental regulations can be seen as a member of a group of nations that voluntarily provides a public good, because additional demand for environmental quality comes with higher levels of wealth. We follow Cole and Elliott (2003) by suggesting that the key determinant of stringency is per capita income and considering a country's average GNP per capita and the lagged five years as IVs. Following Ederington and Minier (2003), we also consider the political-economy variable to be an IV. GNP per capita is taken from the World Development Indicators (WDI). As political-economy variables, we obtain the "polity" score from the Polity IV dataset. This index ranges from −10 (a high autocracy) to 10 (a high democracy). Although we do not show the results because of space limitations, when we use these IVs in place of the adjusted savings from CO_2 damage and from PE damage, we obtain results almost identical to our main results.

[8] Jug and Mirza (2005) also consider the endogeneity of environmental regulations. Because of data limitations, we are not able to incorporate their IVs into this paper. These data are available only for EU countries.

3.1.2 Trade model

As discussed in Section 2, the strong version of the Porter hypothesis refers to an increase in economic scale. We address this issue by using the following gravity model in line with Costantini and Mazzanti (2012)[9,10]:

$$\begin{aligned} Exp_{ijt} &= \alpha + \alpha_t + \beta_1 Mass_{ijt} + \beta_2 Sim_{ijt} + \beta_3 Endw_{ijt} \\ &+ \beta_4 \ln(Dist_{ij}) + \beta_5 RTA_{ijt} + \beta_6 \ln(Str_{it}) + \beta_7 \ln(Str_{jt}) + \varepsilon_{ijt} \end{aligned}, \quad (2)$$

where *i* and *j* denote exporters and importers, respectively, and *t* denotes the year. Exp, α, and α_t represent the bilateral export flows from country *i* to country *j*, a constant term, and the time-fixed effects, respectively. $Dist$, RTA, Str, and ε_{ijt} represent the distance between country *i* and country *j*, a dummy variable that takes a value of 1 if *i* and *j* belong to the same regional trade agreement and 0 otherwise, the stringency of environmental regulations, and the error term, respectively.

Following Costantine and Mazzanti (2012), we consider a synthetic measure of the impact of country-pair size as a proxy of the "mass" in gravity models ($Mass_{ijt}$):

$$Mass_{ijt} = \ln\left(GDP_{it} + GDP_{jt}\right), \quad (3)$$

We then use the fitted values of *GDP* obtained in equation (1) to consider the indirect effect of *Str*. We also consider a measure of relative country size by computing the similarity index of the GDPs of two trading partners (Sim_{ijt}) calculated as in Egger

[9] In gravity models, it is better to either consider some of the effects associated with heterogeneity as asserted by Helpman et al. (2008) or treat country effects in a panel context as discussed by Baldwin and Taglioni (2006). As a robustness check, we include country-fixed effects (i.e., exporter and importer fixed effects or trade pair fixed effects) in our model. The results are almost identical to the results in equation (1) (see also footnote 17).

[10] Recently, the literature on gravity models has developed the use of multilateral resistance variables (Anderson and van Wincoop 2003). However, GDP and other time-varying variables cannot be used because of the application of the exporter-time or importer-time dummies. Therefore, we do not include these terms.

(2000):

$$Sim_{ijt} = \ln\left[1 - \left|\left(\frac{GDP_{it}}{GDP_{it} + GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}}\right)^2\right|\right], (4)$$

where GDP represents the fitted values of *GDP* obtained in equation (1). The larger this measure, the more similar the two countries are in terms of their GDPs and the greater is the expected share of intra-industry trade.

We also consider a measure of the distance between the relative endowment of domestic assets ($Endw_{ijt}$), which is approximated by equation (5), where GDP per capita is a proxy of the capital/labor ratio of each country:

$$Endw_{ijt} = \left|\ln\left(\frac{GDP_{it}}{POP_{it}}\right) - \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right)\right|, (5)$$

where GDP represents the fitted values of *GDP* obtained in equation (1) and *POP* corresponds to the population. The larger this difference, the higher the volume of inter-industry trade and the lower the share of intra-industry trade should be[11].

We use the Poisson pseudo maximum likelihood model following Tenreyro (2007), which identifies some of the issues associated with log-linearizing in the gravity model. The log-normal model is based on the questionable assumption that the error terms have the same variance for all pairs of origins and destinations (homoskedasticity). In the presence of heteroskedasticity, both the efficiency and the consistency of the

[11] Costantini and Mazzanti (2012) consider the role of innovative capacity by using "general R&D expenditure by public institutions for environmental protection purposes," which is obtained from Eurostat. It is important to consider the role of technological capabilities also in our analysis. Because the data obtained from Eurostat covers smaller number of countries than "Research and development expenditures (% of GDP)" obtained from the World Development Indicators (WDI), we tried to use the data from the WDI to consider the role of technological capabilities. However, the data period of the data from WDI is from 1996, so that we cannot include it for the model including the DMRW index or EF index. Therefore, we decided to use the data from WDI as a robustness check. We include it into equation (1) as an additional explanatory variable, predict the fitted values of GDP, and use the fitted values in equation (2) as predicted GDPs, obtaining results almost identical to our main results. We show these results in Appendix C.

estimators are at stake (Silva and Tenreyro 2006; Burger et al. 2009). Silva and Tenreyro (2006) also mention that pairs of countries with zero-valued bilateral trade flows are omitted from the sample as a result of the logarithmic transformation. Zero-valued observations contain important information for understanding the patterns of bilateral trade, and should not be discarded a priori (Burger et al. 2009). This necessity can create additional bias. In our estimation, the number of observations is about 20% higher when we use the Poisson model than when we use OLS.

3.2 Data

3.2.1 Stringency variables

In this study, several types of policy variables are used based on previous studies, including energy intensity, abatement cost intensity, the UNCED index, and the CIESIN index. Energy intensity is calculated as energy use (kg of oil equivalent) divided by real GDP (constant $). Data on energy use and real GDP are obtained from the World Development Indicators (WDI). We extend the seven-year time span from 1990–1996 used by Harris et al. (2002) to include 1990–2003. We also extend our country sample from 24 OECD countries, as in Harris et al. (2002), to 89 countries, including both developing and developed nations[12].

Abatement cost intensity is calculated as abatement cost divided by GDP following Jug and Mirza (2005) and Costantini and Crespi (2008). Abatement cost intensity corresponds to Current environmental protection expenditure (public+industry) as % of GDP, which is obtained from Eurostat. The time span in our study is extended from 1996–1999, as in Jug and Mirza (2005), to 1996–2003.

Two types of UNCED indices are constructed following Dasgupta et al. (2001) and Eliste and Fredriksson (2002). With regard to the CIESIN index, we use "WEFSTR for 2000" from the 2001 Environmental Sustainability Index (ESI), "WEFGOV for 2001" from the 2002 ESI, and "WEFGOV for 2003" from the 2005 ESI. Table 2 presents the details of these indices. These survey indices reflect not only the strictness of the regulations but also their quality. The UNCED index includes answers to various

[12] We exclude Middle Eastern countries from our estimation sample (Qatar, the United Arab Emirates, Bahrain, Kuwait) because they use extremely large quantities of energy and including them would cause heterogeneity (see Figure 1).

questions, such as “For how long has a significant environmental policy existed?”, “How did the policy evolve?”, and “What is the coverage of the policy?” (see Dasgupta et al. 2001 for more details). The CIESIN index measures quality by inquiring about the “clarity and stability of regulations,” the “flexibility of regulations,” “environmental policy leadership,” and the “consistency of regulation enforcement.” We list the countries in Appendix A.

(Insert Table 2)

Real GDP per capita tends to be correlated with the stringency of regulations, as discussed in Managi et al. (2009), because higher incomes encourage stricter regulation as a result of greater demand for a better environment. To confirm this relationship, Figure 1 shows the simple scatter plots for the relationship between the environmental stringency variables and GDP per capita. Although we find positive correlations between them, there is a large degree of variance in our sample.

(Insert Figure 1 and Figure 2)

Figure 2 shows the scatter plots for the stringency indices for 2000. Concerning the relationship between energy intensity and WEFSTR, we note a correlation of –0.66, which confirms the presence of variance. For countries with low WEFSTR, we find a wide range of energy intensities, while countries with high WEFSTR have relatively low energy intensities. This finding implies that countries with high WEFSTR tend to be energy efficient. On the other hand, there is a large degree of variance between abatement cost intensity and WEFSTR (correlation: –0.33). Like the relationship between WEFSTR and energy intensity, countries with high WEFSTR tend to have relatively low abatement cost intensities. Because a strong positive correlation exists between WEFSTR and GDP per capita, economic growth tends to lead to more stringent environmental regulation in terms of WEFSTR. In addition, we find a large degree of variance between abatement cost intensity and energy intensity (correlation: 0.23). Abatement costs may be mainly spent by firms in the manufacturing sector, while energy is mainly spent by energy-intensive companies such as those in the iron and steel sectors. The large variance among the stringency indices in Figure 2 suggests that each proxy of environmental regulations is distinct.

3.2.2 Other variables

We obtain bilateral export flow data from the Direction of Trade Statistics provided by the International Monetary Fund. Data on GDP and population are taken from the WDI. Data for distance and the regional trade agreement dummy are obtained from the Rose dataset (see Rose 2005; Rose and Spiegel 2009). The adjusted savings from CO_2 damage and from PE damage are obtained from the WDI[13]. Following Rose and Spiegel (2009), we use the average values for the past five years as the IV. Finally, real GDP per worker is obtained from the Penn World Tables 6.3 and capital stock per worker from the Extended Penn World Tables[14]. Data on average years of schooling come from Barro and Lee (2010).

4 Results

4.1 GDP per worker model

The estimated results of equation (1) are shown in Table 3. We assume human capital per worker to be related to average years of schooling and the stringency of the environmental regulations in question. We expect the coefficient of capital stock per worker to be positive based on the Cobb–Douglas production function and that of average years of schooling to be positive based on the endogenous economic growth literature. On the other hand, the expected signs of the stringency variables are unclear. As discussed in Section 1, it is generally believed that more stringent environmental regulations require abatement costs and therefore increase production costs. In such a case, strict regulations may lower production. However, if the new production method improves environmental technology and leads to higher productivity, stringency might lead to more production (i.e., according to the strong version of the Porter hypothesis).

As shown in Table 3, the results of the Hausman tests indicate that for both abatement cost intensity and energy intensity, the preferred model is to use random

[13] CO_2 damage is estimated to be $20 per ton of carbon (in 1995 $) multiplied by the number of tons of carbon emitted. PE damage is calculated as willingness to pay to avoid mortality attributable to PE.
[14] See http://homepage.newschool.edu/~foleyd/epwt/.

effects. Our main point of interest, the sign of the coefficients of the stringency variables, differs for different proxies.

First, by examining abatement cost intensity, we obtain statistically significant negative results, which indicate that stricter environmental policy lowers GDP. On the other hand, concerning energy intensity, because more stringent environmental policy is correlated with less energy intensity, the negative coefficients for energy intensity indicate that GDP increases with strict environmental policies. This latter result suggests that the strong version of the Porter hypothesis is likely to hold. Here, abatement cost is thought to mainly reflect the costs incurred in the manufacturing sector and not necessarily be related to an increase in revenue. For instance, Shadbegian and Gray (2005) find that abatement expenditure contributes little or nothing to production[15]. On the other hand, energy-related technology improvement or adoption (i.e., energy efficiency) tends to be considered to have productivity benefits (Porter and Van der Linde 1995; Boyd and Pang 2000; Worrell et al. 2003; Zhang and Wang 2008; Kounetas et al. 2012). Porter and Van der Linde (1995) suggest that energy efficiency leads to productivity improvement. Our result on energy intensity is thus consistent with the strong version of the Porter hypothesis.

With regard to the survey indices, we obtain statistically significant positive signs only for the WEFSTR and WEFGOV for 2001 indices. These positive signs indicate that stricter regulations increase GDP, suggesting that the strong version of the Porter hypothesis is likely to hold. The survey indices reflect not only the strictness of environmental regulations but also their consistency and stability. Hence, there is a possibility that the strong version of the Porter hypothesis is supported because the survey indices tend to capture regulation quality.

In addition, for the other variables, we generally obtain the expected signs[16].

4.2 Trade model

In this subsection, we show the estimation results for equation (2). For the robustness check of the estimation results for abatement cost intensity and energy

[15] These authors also examine within-industry heterogeneity, estimating separate impacts for subgroups of plants. However, they find little evidence of significant differences across these groups.

[16] We obtain statistically insignificant coefficients for average years of schooling because of the correlation between this variable and the stringency variables.

intensity, we use three types of specifications, as shown in (a)–(f). Current environmental stringency variables are used in (a) and (d), whereas (b) and (e) use one-year-lagged environmental stringency variables and (c) and (f) use two-year-lagged environmental stringency variables. We consider the time-fixed effects by including a time dummy[17]. To consider the lag in the effect of regulations on trade flows using the survey indices, we use three types of cross-sectional data depending on the sample year, as shown in the tables[18].

The estimated results of equation (2) are shown in Tables 4 and 5. Most of the coefficients of *Mass*, *Sim, and Endw* are consistent with those in Costantini and Mazzanti (2012). The estimates for distance are negative and statistically significant for all specifications. On the other hand, we obtain the unexpected or insignificant results for regional trade agreements except in two cases, perhaps because our sample is relatively small or some regional trade agreements are appropriate only for certain products.

The coefficients of the stringency variables vary. First, with regard to the coefficients of abatement cost intensity, we obtain statistically significant negative signs, consistent with the findings of Jug and Mirza (2005). This result implies that stricter regulations in exporting countries have a negative effect on their export flows, on average. This effect is the direct effect of the stringency variables on aggregate trade flows. We discuss the effect of GDP induced by the stringency variables (i.e., the "indirect" effect) in the next subsection.

Second, concerning the coefficients of exporter energy intensity, we obtain statistically significant negative signs in contrast to those of Harris et al. (2002). There is a possibility that this is because they do not consider the endogeneity issue (if we exclude IVs, we obtain statistically insignificant results).

Finally, for the coefficients of the exporter survey indices (specifications (g) to (s)), some coefficients are positive and statistically significant[19]. This result generally implies the positive direct effects of environmental regulation in line with the findings

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[17] As a robustness check, we also include exporter and importer fixed effects and obtain almost the same results for the stringent variables as those presented in Tables 4 and 5.

[18] We could not implement a panel analysis because each survey index captures the status of the regulations during just one year.

[19] We obtain statistically insignificant coefficients for the DMRW index and WEFGOV for 2001. This may be because their observations are relatively small.

of Xu (2000)[20].

In summary, on average, the abatement cost intensity has a negative effect on aggregate export flow, whereas the results regarding energy intensity and the survey indices suggest positive effects on aggregate export flows[21]. As we have already mentioned, we should consider overall effects of the stringency variables by considering not only direct effects but also indirect effects. We calculate these effects in the next subsection.

4.3 Direct and indirect effects

While the stringency of environmental policy affects GDP (see Section 4.1), an increase in GDP induced by the environmental policy increase aggregate export flows (see Section 4.2), which is considered to be an indirect effect of environmental policy on aggregate export flows. In this subsection, we consider the overall effect of environmental policy. Table 6 shows the indirect, direct, and overall effects of each stringency variable. To calculate these elasticities, we use the estimated coefficients and sample means. We find that the direct effect of the stringency variables is statistically significant except for the DMRW index and WEFGOV for 2001. On the other hand, our results show that the indirect effect of the stringency variables is statistically significant with regard to abatement cost intensity, energy intensity, WEFSTR for 2000, and WEFGOV for 2001. We thus obtain statistically significant overall elasticities for abatement cost intensity, energy intensity, and WEFSTR for 2000. Further, the magnitude of the indirect effect is not relatively small compared with the direct effect. This finding confirms that it is necessary to consider not only the direct effect of the stringency variables on export flows but also the effect of GDP (i.e., the indirect effect).

The results for abatement cost intensity show that both the direct and the indirect elasticities are negative and statistically significant, meaning that a 1% increase in abatement cost intensity results in a 0.078% decrease in aggregate export flows, on

[20] As a robustness check, we estimate equation (1) by using the decomposed indices for WEFSTR, WEFGOV for 2001, and WEFGOV for 2003. The decomposed indices are shown in Appendix B. Most of these results are consistent with those of our aggregate-level estimation. The results are available upon request.

[21] As a robustness check, we obtain sector-level export flow data from the Global Trade Atlas. We refer to sectors using two-digit HS codes. Most of these results using these data are consistent with those of our aggregate-level estimation. The results are available upon request.

average. This finding implies that more stringent environmental policy in terms of abatement cost intensity tends to lower aggregate export flows, on average. On the other hand, on average, a 1% decrease in energy intensity leads to a 0.013% increase in aggregate export flows as a result of the direct effect and a 0.005% increase as a result of the indirect effect. In other words, a 1% decrease in energy intensity results in a 0.018% increase in aggregate export flows, on average. This finding implies, on average, more stringent environmental policy in terms of energy intensity tends to increase aggregate export flows.

With regard to the survey indices, we obtain a statistically significant overall elasticity only for WEFSTR for 2000. In other words, the estimation results for the survey indices are not robust, perhaps because of the relatively small sample size used. The result of WEFSTR for 2000 shows that both the direct and the indirect elasticities are positive and statistically significant, meaning that a 1% increase in WEFSTR for 2000 results in a 0.053% increase in aggregate export flows, on average. This finding implies that more stringent environmental policy in terms of the survey index (WEFSTR for 2000) tends to increase export flows.

To summarize, the strong version of the Porter hypothesis is confirmed for energy intensity and WEFSTR for 2000, resulting in an increase in export flows, while it is not confirmed for abatement cost intensity.

5 Conclusion and discussion

Our results indicate that, on average, while an increase in abatement cost intensity negatively affects aggregate export flows, a decrease in energy intensity and an increase in the survey indices positively affect aggregate export flows. Our results also show that an increase in abatement cost intensity decreases both aggregate export flows and GDP, on average. Since the abatement cost is mainly related to manufacturing sectors, our result implies its average effect in this sector is negative, while energy intensity tends to reflect energy-intensive sectors such as cement and steel. However, as mentioned in footnote 18, our subsample (sector-level) estimations imply the negative effects of abatement costs for these energy-intensive sectors. Therefore, rather than the *amount* of abatement costs, how abatement costs *are applied* may positively affect aggregate export flows and GDP. In other words, the positive effect of energy intensity may imply that the policy outcome is crucial to the increase in export flows or GDP. Moreover, while abatement costs do not necessarily improve energy efficiency (i.e., energy intensity), energy intensity does tend to reflect the outcome of applying such costs. The survey indices capture both the strictness of the regulations and their quality. The positive effect of the survey index thus implies the importance of quality when formulating environmental regulations. Overall, our results confirm the importance of considering either the quality of environmental regulations or the efficiency of the abatement cost.

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Appendix A

(Insert Table A.1 and Table A.2)

Appendix B: Decomposed indices

The decomposed indices are available for WEFSTR for 2000, WEFGOV for 2001, and WEFGOV for 2003; we obtained these decomposed indices from the World Economic Forum 2000, 2002, and 2004. The survey questions are shown in Table B.1.

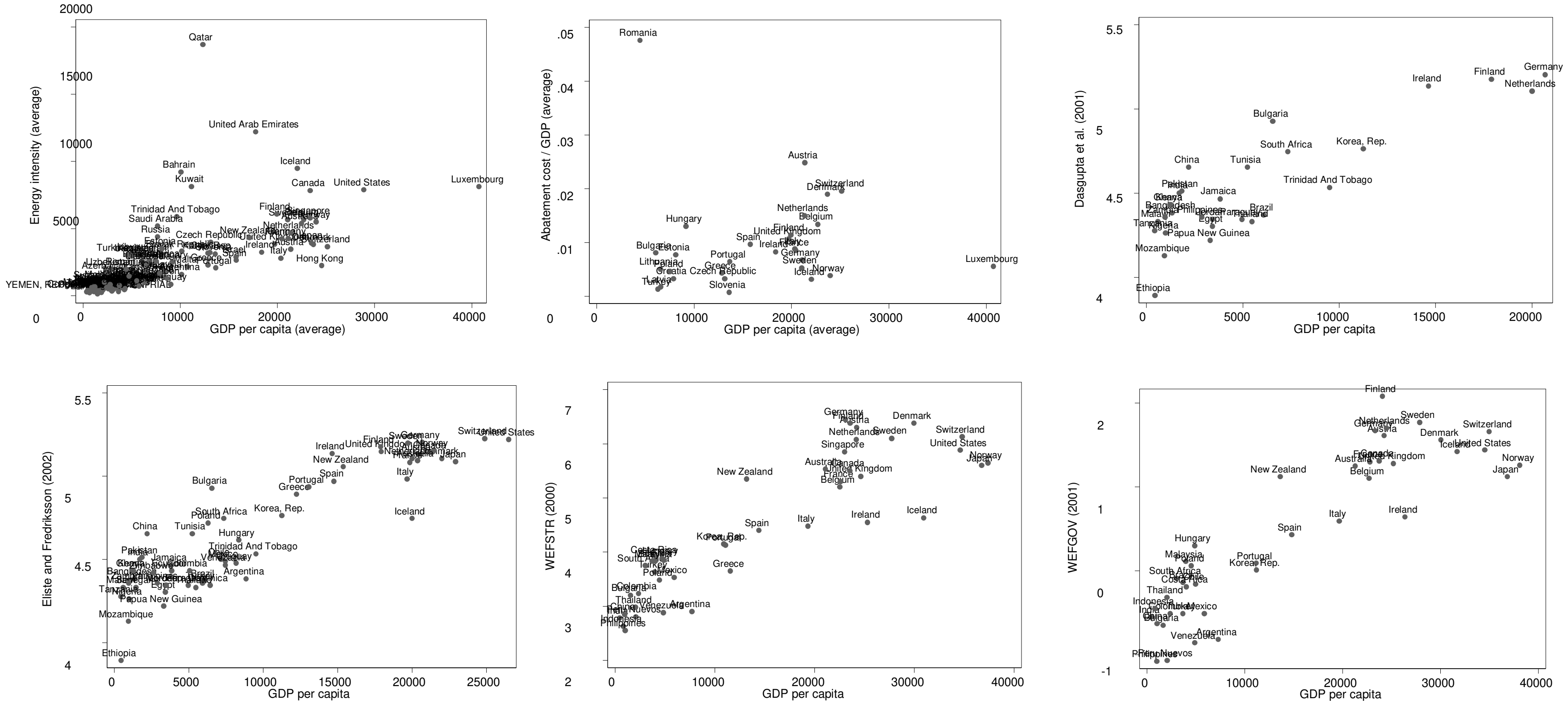
(Insert Table B.1)

Appendix C: Robustness check

We include "R&D expenditure" obtained from the World Development Indicators into our GDP per worker models. Table C-1 presents the estimation results, showing that we obtained statistically significant coefficients for the stringency variables except for WEFGOV2001. This finding is almost in line with the estimated results of the models excluding R&D expenditure. Moreover, by using the estimated coefficients in Table C.1, we predict the fitted value of GDP to estimate the trade model. The estimation results of the trade model are shown in Tables C.2 and C.3. These results are also almost in line with our main results.

(Insert Table C.1, Table C.2, and Table C.3)

Figure 1. Simple scatter plots between stringency indices and GDP per capita



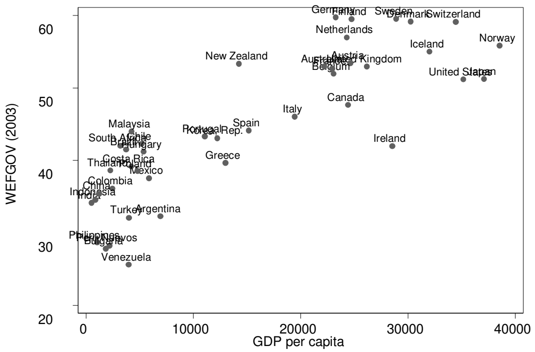

WEFGOV (2003)
GDP per capita
Germany
Finland
Sweden
Denmark
Switzerland
Netherlands
Norway
Iceland
New Zealand
Austria
United Kingdom
Belgium
United States
Japan
Canada
Italy
Ireland
Malaysia
Spain
Portugal
Korea, Rep.
South Africa
Chile
Hungary
Greece
Thailand
Poland
Costa Rica
Mexico
Colombia
China
Indonesia
India
Turkey
Argentina
Philippines
Peru
Brazil
Bulgaria
Venezuela

Figure 2. Relationship among stringency indices (year=2000)

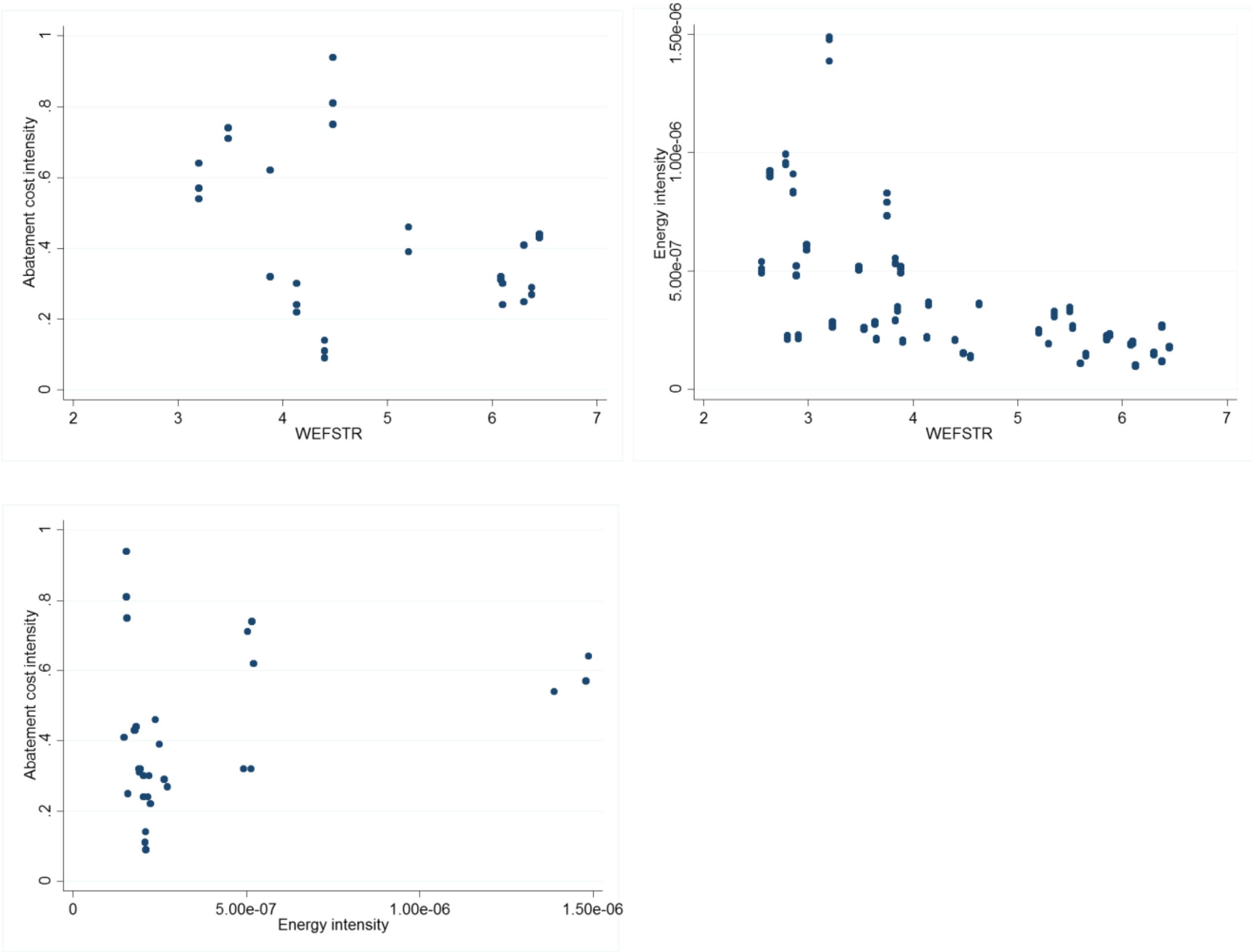


Table 1. Previous studies applying gravity modeling

Authors	Stringency variable	Data	Method	Instruments	Sector	Result (+: positive effect on international competitiveness, -: negative effect on international competitiveness)
Van Beers and Van den Bergh (1997)	Their original index and an index based on energy intensity	21 OECD countries, 1992	OLS	No	Aggregate, footloose, and dirty	[Exporter stringency] Aggregate and footloose: Significant (–) Dirty: Insignificant
Xu (2000)	UNCED survey	20 countries, 1992	OLS	No	Aggregate, environmentally sensitive goods (ESGs) and non-resource-based ESGs	[Exporter stringency] Significant (+)
Harris et al. (2002)	Index based on energy intensity	24 OECD countries, 1990–1996	Fixed effects	No	Aggregate, footloose, and dirty	[Exporter stringency] Fixed effects: Insignificant
Jug and Mirza (2005)	Total current expenditure	Exporters: 19 EU countries Importers: 12 EU countries, 1996–1999	OLS, Fixed effects, and GMM with IV	Yes	Nine sectors	[Relative stringency] Significant (–)
Costantini and Crespi (2008)	Total current expenditure	20 OECD countries, 1996–2005	OLS, Fixed effects, FEGLS estimator, and IV estimator	Yes	Energy technology	[Exporter's relative stringency] Significant (+)
Costantini and Mazzanti (2012)	Energy tax, Environment tax, Pace*, and Emas** (Eurostat)	14 EU countries, 1996-–2007	Dynamic panel data analysis	Yes	Manufacturing sectors (19 sectors)	[Exporter's stringency]] Significant (+)

* Pace corresponds to pollution abatement and control expenditures as a percentage of GDP.

** Emas corresponds to the Number of Eco-Management and Audit Scheme initiatives by private firms as a percentage of GDP.

Table 2. Details of WEFSTR for 2000, WEFGOV for 2001, and WEFGOV for 2003

Index	The definition of the index (source: ESI)
WEFSTR for 2000	Average responses to the following survey questions: “Air pollution regulations are among the world’s most stringent”; “Water pollution regulations are among the world’s most stringent”; “Environmental regulations are enforced consistently and fairly”; and “Environmental regulations are typically enacted ahead of most other countries.”
WEFGOV for 2001	This represents the principal component of responses to several World Economic Forum survey questions touching on aspects of environmental governance: air pollution regulations, chemical waste regulations, clarity and stability of regulations, flexibility of regulations, environmental regulatory innovation, environmental policy leadership, stringency of environmental regulations, consistency of regulation enforcement, stringency of environmental regulations, toxic waste disposal regulations, and water pollution regulations.
WEFGOV for 2003	This represents the principal components of survey questions addressing several aspects of environmental governance: air pollution regulations, chemical waste regulations, clarity and stability of regulations, flexibility of regulations, environmental regulatory innovation, environmental policy leadership, consistency of regulation enforcement, stringency of environmental regulations, toxic waste disposal regulations, and water pollution regulations.

Table 3. GDP per worker model

	Abatement cost intensity		*Energy intensity*		*DMRW index*	*EF index*	*WEFSTR*	*WEFGOV 2001*	*WEFGOV 2003*
Specification	*Random*	*Fixed*	*Random*	*Fixed*					
Sample period	1996–2003	1996–2003	1990–2003	1990–2003	1992	1992	2000	2001	2003
ln Capital stock per worker$_i$	0.671***	1.568	0.675***	0.595***	0.613***	0.647***	0.288	0.386***	0.423**
	(0.044)	(4.042)	(0.074)	(0.145)	(0.125)	(0.047)	(0.178)	(0.138)	(0.171)
ln Average years of schooling$_j$	0.043	–0.021	–0.032	–0.013	–0.104	–0.038	–0.006	0.022	0.037
	(0.033)	(0.494)	(0.041)	(0.108)	(0.200)	(0.069)	(0.042)	(0.035)	(0.042)
ln Stringency$_i$	**–0.647****	–1.472	**–0.648*****	–0.688***	**1.024**	**0.393**	**1.717****	**0.778****	**1.300**
	(0.301)	(2.691)	**(0.130)**	(0.129)	**(1.522)**	**(0.594)**	**(0.763)**	**(0.377)**	**(0.938)**
Constant	3.153***	–4.103	–6.501***	–6.522***	–0.236	1.969	4.928***	5.496**	0.697
	(0.489)	(39.612)	(1.728)	(1.574)	(6.063)	(2.371)	(1.036)	(1.232)	(1.850)
Hausman test	Prob>chi2=0.926		Prob>chi2=0.768						
R squared	0.898	0.772	0.826	0.810					
Test of endogeneity					chi2=1.59 (p=0.66)	chi2=2.18 (p=0.54)	chi2=4.74 (p=0.19)	chi2=4.96 (p=0.17)	chi2=3.89 (p=0.27)
Test of overidentifying restrictions					chi2=0.59 (p=0.44)	chi2=0.15 (p=0.70)	chi2=4.51 (p=0.10)	chi2=7.98 (p=0.05)	chi2=0.41 (p=0.52)
Number of countries	17	17	92	92	23	51	38	37	41
Observations	84	84	889	889	23	51	38	37	41

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Capital stock per worker, average years of schooling, and stringency variable are instrumented by using 10-year lagged capital stock per worker, 10-year lags for average years of schooling for people 40 to 74 years of age, and adjusted savings from CO_2 damage and from PE damage.

Table 4. Gravity model estimation by using energy intensity, abatement cost intensity, and the DMRW and EF indices

Stringency data	*Abatement cost intensity*			*Energy intensity*			*DMRW index Reference year=1992*			*EF index Reference year=1992*		
Specification	*(a)*	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	*(h)*	*(i)*	*(j)*	*(k)*	*(l)*
Year used to measure stringency	current-year	one-year-lagged	two-year-lagged	current-year	one-year-lagged	two-year-lagged	1992	1992	1992	1992	1992	1992
Sample period (except for stringency)	1996–2003	1997–2003	1998–2003	1990–2003	1991–2003	1992–2003	1992	1993	1994	1992	1993	1994
$Mass_{ijt}$	1.905***	1.915***	1.926***	1.569***	1.555***	1.552***	1.317	1.290	1.251**	1.534***	1.516***	1.484***
	(0.047)	(0.063)	(0.068)	(0.012)	(0.012)	(0.013)	(1.058)	(1.006)	(0.490)	(0.049)	(0.058)	(0.064)
$Endw_{ijt}$	–0.146	0.080	–0.061	–0.272***	–0.282***	–0.287***	0.150	–0.018	0.012	–0.111	–0.128*	–0.085
	(0.106)	(0.154)	(0.147)	(0.013)	(0.014)	(0.014)	(0.381)	(0.546)	(0.148)	(0.087)	(0.072)	(0.083)
Sim_{ijt}	0.678***	0.672***	0.667***	0.604***	0.600***	0.601***	0.699	0.605	0.583	0.624***	0.588***	0.589***
	(0.043)	(0.056)	(0.058)	(0.009)	(0.009)	(0.010)	(1.079)	(1.352)	(0.562)	(0.037)	(0.047)	(0.048)
$\ln Distance_{ij}$	–1.434***	–1.488***	–1.494***	–1.159***	–1.149***	–1.153***	–0.885	–0.757	–0.721	–0.971***	–0.943***	–0.958***
	(0.065)	(0.086)	(0.090)	(0.016)	(0.016)	(0.017)	(1.984)	(1.738)	(0.701)	(0.042)	(0.045)	(0.052)
Regional trade agreement	0.121	0.296	0.171	0.438***	0.429***	0.429***	0.339	0.222	0.151	0.081	0.022	0.007
	(0.281)	(0.433)	(0.416)	(0.025)	(0.025)	(0.027)	(0.998)	(0.640)	(0.737)	(0.116)	(0.144)	(0.136)
$\ln Stringency_i$	**–1.419*****	**–1.892*****	**–1.961*****	**–0.395*****	**–0.401*****	**–0.403*****	**3.558**	**3.093**	**3.329**	**1.917*****	**2.091*****	**2.505*****
	(0.176)	**(0.272)**	**(0.274)**	**(0.051)**	**(0.054)**	**(0.057)**	**(30.130)**	**(23.171)**	**(10.654)**	**(0.264)**	**(0.365)**	**(0.447)**
Constant	–38.644***	–38.443***	–38.920***	–32.880***	–32.497***	–32.458***	–41.931	–40.047	–40.272	–39.647***	–40.257***	–41.109***
	(1.380)	(1.884)	(2.006)	(0.051)	(0.473)	(0.497)	(122.732)	(92.050)	(40.272)	(1.804)	(1.999)	(2.146)
Number of countries	17	17	17	89	89	89	26	26	26	56	56	56
Observations	1568	1372	1176	76422	70566	64874	650	650	650	2506	2506	2506

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Stringency variables are instrumented by using adjusted savings from CO_2 damage and from PE damage.

Table 5. Gravity model estimation by using the ESI policy indices for aggregate export flows

Stringency data	*WEFSTR Reference year=2000*			*WEFGOV Reference year=2001*			*WEFGOV Reference year=2003*
Specification	*(m)*	*(n)*	*(o)*	*(p)*	*(q)*	*(r)*	*(s)*
Year used for stringency	2000	2000	2000	2001	2001	2001	2003
Sample period (Except for stringency)	2000	2001	2002	2001	2002	2003	2003
$Mass_{ijt}$	1.573***	1.572***	1.617***	1.648***	1.668***	1.664***	1.668***
	(0.045)	(0.042)	(0.039)	(0.051)	(0.049)	(0.046)	(0.039)
$Endw_{ijt}$	–0.244***	–0.291***	–0.305***	–0.835***	–0.935***	–0.959***	–0.194***
	(0.071)	(0.069)	(0.068)	(0.174)	(0.182)	(0.168)	(0.065)
Sim_{ijt}	0.692***	0.688***	0.708***	0.685***	0.721***	0.722***	0.718***
	(0.039)	(0.039)	(0.037)	(0.050)	(0.049)	(0.049)	(0.039)
$Distance_{ij}$	–1.149***	–1.153***	–1.206***	–0.854***	–0.862***	–0.872***	–1.169***
	(0.054)	(0.049)	(0.051)	(0.052)	(0.054)	(0.051)	(0.041)
Regional trade agreement	0.470***	0.453***	0.501***	0.039	0.097	0.110	0.322***
	(0.097)	(0.092)	(0.090)	(0.156)	(0.148)	(0.140)	(0.086)
ln Stringency$_i$	**0.428****	**0.343***	**0.277**	**0.484**	**0.442**	**0.457**	**1.015*****
	(0.209)	**(0.201)**	**(0.185)**	**(0.383)**	**(0.394)**	**(0.396)**	**(0.237)**
Constant	–29.690***	–29.571***	–30.203***	–32.918***	–33.403***	–33.074***	–35.608***
	(1.417)	(1.330)	(1.219)	(1.585)	(1.614)	(1.500)	(1.363)
Number of countries	38	38	38	24	24	24	38
Observations	1232	1232	1232	484	484	484	1232

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Stringency variables are instrumented by using adjusted savings from CO_2 damage and from PE damage.

Table 6. Elasticities

Stringency data	*Abatement cost intensity*	*Energy intensity*	*DMRW index Reference year=1992*	*EF index Reference year=1992*	*WEFSTR Reference year=2000*	*WEFGOV Reference year=2001*	*WEFGOV Reference year=2003*
Sample period	1996–2003	1990–2003	1992	1992	2000	2001	2003
Elasticity (Direct)	–0.047***	–0.013***	0.118	0.064***	0.014**	0.016	0.034***
Elasticity (Indirect)	–0.031**	–0.005***	0.014	0.008	0.039**	0.052**	0.029
Elasticity (Overall)	–0.078**	–0.018***	0.132	0.072	0.053**	0.041	0.063

Notes: *, **, and *** denote significance at 90%, 95%, and 99%, respectively.

Table A.1 Country list for energy intensity and abatement cost intensity

Energy intensity 89 countries					Abatement cost intensity 17 countries
Argentina	Ecuador	Italy	Panama	Tunisia	Belgium
Australia	Egypt	Jamaica	Paraguay	Turkey	Denmark
Austria	El Salvador	Japan	Peru	Ukraine	Finland
Bangladesh	Ethiopia	Jordan	Philippines	United Kingdom	France
Belgium	Finland	Kazakhstan	Poland	United States	Germany
Bolivia	France	Kenya	Portugal	Uruguay	Hungary
Brazil	Georgia	Korea, Rep.	Romania	Venezuela	Iceland
Bulgaria	Germany	Luxembourg	Russia	Zambia	Italy
Cameroon	Ghana	Macedonia	Senegal	Zimbabwe	Netherlands
Canada	Greece	Malaysia	Slovak Republic		Norway
Chile	Guatemala	Mexico	South Africa		Poland
China	Honduras	Morocco	Spain		Portugal
Colombia	Hong Kong	Mozambique	Sri Lanka		Spain
Republic of Congo	Hungary	Nepal	Sweden		Sweden
Costa Rica	Iceland	Netherlands	Switzerland		Turkey
Cote d'Ivoire	India	New Zealand	Syrian Arab Republic		United Kingdom
Croatia	Indonesia	Nicaragua	Tanzania		United States
Czech Republic	Iran	Nigeria	Thailand		
Denmark	Ireland	Norway	Togo		
Dominican Republic	Israel	Pakistan	Trinidad and Tobago		

Table A.2 Country list for policy indices

Dasgupta et al. (2001) 26 countries		Eliste and Fredriksson (2002) 56 countries				WEFSTR for 2000, WEFGOV for 2001, and WEFGOV for 2003 38 countries		
Bangladesh	Malawi	Argentina	Finland	Malawi	Sweden	Argentina*	Hungary*	Portugal
Brazil	Mozambique	Australia	France	Mexico	Switzerland	Australia	Iceland	South
Bulgaria	Netherlands	Austria	Germany	Morocco	Tanzania	Austria	India*	Africa*
China	Pakistan	Bangladesh	Ghana	Mozambique	Thailand	Belgium	Indonesia*	Spain
Egypt	Papua New	Brazil	Greece	Netherlands	Trinidad	Brazil*	Ireland	Sweden
Finland	Paraguay	Bulgaria	Hungary	New	and Tobago	Bulgaria*	Italy	Switzerland
Germany	Philippines	Canada	Iceland	Zealand	Tunisia	Canada	Japan	Thailand*
Ghana	Switzerland	Chile	India	Norway	Turkey	Chile*	Korea, Rep.	United
India	Tanzania	China	Ireland	Pakistan	United	China*	Malaysia	Kingdom
Ireland	Thailand	Colombia	Italy	Papua New	Kingdom	Colombia*	Mexico*	United
Jamaica	Trinidad and	Czechoslovakia	Jamaica	Guinea	United	Costa	Netherlands	States
Jordan	Tobago	Denmark	Japan	Paraguay	States	Rica*	New	
Kenya	Tunisia	Ecuador	Jordan	Philippines	Uruguay	Denmark	Zealand	
Korea, Rep.	Zambia	Egypt	Kenya	Poland	Venezuela	Finland	Norway	
			Korea,	Portugal	Zambia	France	Philippines*	
			Rep.	Senegal		Germany	Poland*	
				Spain				

Note: * not included in our gravity model using WEFGOV for 2001 due to data limitation.

Table B.1. Definition of decomposed indices

Index		Definition
overall	Stringency of environmental regulations	The stringency of overall environmental regulations in your country is: (1=lax compared with most other countries, 7=among the world's most stringent)
leader	Environmental policy leadership	Compared with other countries, your country normally enacts environmental regulations: (1 = much later, 7 = ahead of most others)
cla_sta	Clarity and stability of regulations	Environmental regulations in your country are: (1 = confusing and frequently changing, 7 = transparent and stable)
flex	Flexibility of regulations	Environmental regulations in your country: (1 = offer no options for achieving compliance, 7 = are flexible and offer many options for achieving compliance)
enforce	Consistency of regulation enforcement	Environmental regulation in your country is: (1 = not enforced or enacted erratically, 7 = enforced consistently and fairly)

Table C.1. GDP per worker model

	Abatement cost intensity		Energy intensity		WEFSTR	WEFGOV 2001	WEFGOV 2003
Specification	*Random*	*Fixed*	*Random*	*Fixed*			
Sample period	1997–2003	1997–2003	1997–2003	1997-2003	2000	2001	2003
ln Capital stock per worker$_i$	0.584***	0.906	0.942*	0.959***	0.225	0.568***	0.496***
	(0.101)	(2.568)	(0.560)	(0.131)	(0.181)	(0.090)	(0.172)
ln Average years of schooling$_j$	0.077	–0.054	–0.110	–0.057	0.036	0.033	0.065*
	(0.054)	(0.271)	(0.222)	(0.053)	(0.043)	(0.025)	(0.037)
ln Stringency$_i$	**–1.010*** **	**–1.009**	**–0.635*** **	**–0.539*** **	**2.052*** **	**0.465**	**1.097***
	(0.353)	**(1.533)**	**(0.212)**	**(0.168)**	**(0.700)**	**(0.313)**	**(0.655)**
ln R & D expenditures	1.015	–6.344	0.602	–1.428***	–1.246***	–0.314	–0.608
	(0.862)	(20.773)	(1.669)	(0.502)	(0.474)	(0.580)	(0.541)
Constant	0.820	21.156	–10.300**	–3.248	8.612***	4.685**	**2**.297
	(2.193)	(37.874)	(4.324)	(2.592)	(1.911)	(2.269)	(1.422)
Hausman test	Prob>chi2=1.000		Prob>chi2=0.844				
R squared	0.797	0.333	*0.796*	0.842			
Test of endogeneity					chi2=10.14 (p=0.04)	chi2=5.80 (p=0.21)	chi2=3.81 (p=0.43)
Test of overidentifying restrictions					chi2=1.41 (p=0.49)	chi2=4.26 (p=0.23)	chi2=0.40 (p=0.53)
Number of countries	14	14	53	53	26	24	29
Observations	68	68	227	277	26	24	29

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Capital stock per worker, average years of schooling, and stringency variable are instrumented by using 10-year lagged capital stock per worker, 10-year lags for average years of schooling for people 40 to 74 years of age, adjusted savings from CO_2 damage and from PE damage, and. one year lags for R&D expenditures. Because the data period of R&D expenditures is from 1996, we cannot use DMRW index and EF index.

Table C.2. Gravity model estimation by using energy intensity, and abatement cost intensity

Stringency data	Abatement cost intensity			Energy intensity		
Specification	(a)	(b)	(c)	(d)	(e)	(f)
Year used to measure stringency	current-y ear	one-year-lagged	two-year-lagged	current-year	one-year-lagged	two-year-lagged
Sample period (except for stringency)	1997–20 03	1998–2003	1999–2003	1997–2003	1998–2003	1999–2003
Mass$_{ijt}$	1.906***	1.895***	1.903***	1.703***	1.698***	1.697***
	(0.077)	(0.110)	(0.099)	(0.026)	(0.026)	(0.027)
Endw$_{ijt}$	–0.147	0.186	–0.103	–0.219***	–0.223***	–0.224***
	(0.182)	(0.238)	(0.163)	(0.027)	(0.027)	(0.028)
Sim$_{ijt}$	0.683***	0.686***	0.695***	0.661***	0.659***	0.659***
	(0.075)	(0.091)	(0.080)	(0.021)	(0.021)	(0.020)
Distance$_{ij}$	–1.578***	–1.597***	–1.559***	–1.067***	–1.060***	–1.057***
	(0.115)	(0.149)	(0.121)	(0.030)	(0.030)	(0.030)
Regional trade agreement	0.030	–0.365	–0.161	–0.371***	–0.371***	–0.374***
	(0.332)	(0.463)	(0.408)	(0.056)	(0.056)	(0.056)
ln Stringency$_i$	**–2.092*** **	**–2.435*** **	**–2.102*** **	**–0.510*** **	**–0.512*** **	**–0.493*** **
	(0.380)	**(0.661)**	**(0.358)**	**(0.136)**	**(0.137)**	**(0.138)**
Constant	–38.255***	–37.706***	–38.052***	–37.933***	–37.644***	–37.454***
	(1.981)	(2.826)	(2.609)	(1.296)	(1.295)	(1.305)
Number of countries	14	14	14	53	53	53
Observations	887	708	638	17611	17341	17140

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Stringency variables are instrumented by using adjusted savings from CO_2 damage and from PE damage.

Table C.3. Gravity model estimation by using the ESI policy indices for aggregate export flows

Stringency data	*WEFSTR Reference year=2000*			*WEFGOV Reference year=2001*			*WEFGOV Reference year=2003*
Specification	*(m)*	*(n)*	*(o)*	*(p)*	*(q)*	*(r)*	*(s)*
Year used for stringency	2000	2000	2000	2001	2001	2001	2003
Sample period (Except for stringency)	2000	2001	2002	2001	2002	2003	2003
$Mass_{ijt}$	1.634***	1.622***	1.632***	1.705***	1.736***	1.689***	1.739***
	(0.068)	(0.053)	(0.055)	(0.043)	(0.050)	(0.038)	(0.038)
$Endw_{ijt}$	–0.398***	–0.426***	–0.350***	–0.271***	–0.280***	–0.110	–0.107
	(0.084)	(0.073)	(0.084)	(0.067)	(0.088)	(0.074)	(0.071)
Sim_{ijt}	0.777***	0.680***	0.706***	0.739***	0.800***	0.749***	0.753***
	(0.051)	(0.047)	(0.053)	(0.045)	(0.049)	(0.041)	(0.042)
$Distance_{ij}$	–1.154***	–1.063***	–1.255***	–1.037***	–1.244***	–1.180***	–1.216***
	(0.079)	(0.050)	(0.072)	(0.048)	(0.057)	(0.048)	(0.048)
Regional trade agreement	–0.530***	–0.283**	–0.682***	0.090	–0.611***	–0.259***	–0.252**
	(0.129)	(0.113)	(0.122)	(0.102)	(0.125)	(0.104)	(0.102)
ln $Stringency_i$	**0.192**	**0.335**	**0.024**	**0.729*** **	**0.378*** **	**0.540*** **	**1.144*** **
	(0.345)	**(0.220)**	**(0.288)**	**(0.127)**	**(0.144)**	**(0.129)**	**(0.254)**
Constant	–30.695***	–31.731***	–29.609***	–34.871***	–33.188***	–32.812***	–37.850***
	(2.020)	(1.640)	(1.602)	(1.261)	(1.394)	(1.108)	(1.484)
Number of countries	38	38	38	24	24	24	38
Observations	1232	1232	1232	484	484	484	1232

Notes: Robust standard errors in parentheses. *i* and *j* denote exporters and importers, respectively. *, **, and *** denote significance at 90%, 95%, and 99%, respectively. Stringency variables are instrumented by using adjusted savings from CO_2 damage and from PE damage.