A Gravity Analysis of The Pollution Content of Trade*

Jean-Marie Grether†, Nicole Mathys‡, Jaime de Melo§

September 2005
WORK IN PROGRESS

Abstract

The paper analyses the pollution content of imports for 16 different pollutants and more than 50 countries over the 1986-1996 period in a gravity framework. Average emission intensities are correlated with standard gravity variables, with dirty products more highly correlated with trade barriers (i.e transport costs) than clean products. Factor endowments and environmental policy motives for specialization in dirty products prove difficult to disentangle. Using CO2 emissions per dollar of GDP as our preferred proxy for environmental stringency reveals both a factor endowment and a pollution haven effect, the latter with a larger elasticity. Results provide the basis for a new decomposition of the pollution content of trade into the technique, composition and scale effects identified in the literature.

JEL Classification numbers: F12, F18.

Key Words: Trade and the environment, gravity model.

*We thank Céline Carrère for very helpful suggestions and econometric advices.
†University of Neuchâtel, e-mail: jean-marie.grether@unine.ch
‡University of Lausanne, e-mail: nicole.mathys@unil.ch
§University of Geneva and CEPR, e-mail: demelo@ecopo.unige.ch

1 Introduction

Trade liberalization, and more generally globalization in the form of reduction in transaction costs have been accompanied by a sharp increase in the growth in world trade. For a sample of OECD countries over the post World War II period, Baier and Bergstrand (2001) estimate that income growth explains 67%, tariff reductions 25% and transport-cost declines 8% of the average world trade growth. For the environmentally minded, this trend of increasing world trade in world GDP is worrisome and one often hears that globalization has increased trade in dirty products and has been detrimental to the environment. It is fair to say that the debate on globalization and the environment is far from being settled, as convincing evidence of the often-mentioned "race-to-the bottom" and "pollution-haven" effects have proved to be rather elusive. This is not surprising because much of the evidence on the pollution effect is either too detailed (firm-specific or emission-specific) or too fragmentary (case studies) to give a broad appreciation of the extent of globalization over the past twenty years. The same criticism largely applies to the evidence of growth on the environment and indirectly on the impact of trade policy on the environment.

This paper takes another look at the debate on trade and the environment by taking seriously the claim that international trade in polluting products is increasing, even though trade in global waste is small. The debate centers on three factors occupying center-stage in the debate on the relation between trade and the environment.[1] First, by creating pollution havens, trade, but also reduction in trade barriers accompanying globalization, may encourage polluting processes to move to countries with weak environmental policies. Second, the pattern of growth could be biased towards dirty rather than clean industries. Third, differences in endowments and in accompanying growth patterns may have implications for trade in dirty products as polluting industries may remain in high-income countries despite much tighter regulation if these cost disadvantages are offset by differences in factor endowments. Isolating the relative importance of each effect has been a matter of intense research activity in recent years.[2]

We wish to detect whether while the world economy was going global with the increasing volume of world trade, i.e. from the early 80s to the late 90s, trade has been skewed towards dirty industries, and if possible what have been the most important factors leading to any shifts in trade patterns. We use disaggregated data across 79 sectors (this allows us to capture realistically the most polluting generating activities and also to compute an overall index of the pollution content of trade), disaggregated data across 16 emission pollutants (this allows us to see if trade encourages certain type of pollutant activities), and a sufficiently large sample of countries (67) to capture at least two-thirds of world trade.

Since we are interested in the determinants of the patterns of trade in dirty products across countries, the gravity model is a natural framework, although

[1] See Copeland and Taylor (2003) for a review of the trade and the environment debate.
[2] See Cole and Elliott (2001).

as shown from our brief review in section 2, it is only recently that it has started to be used in the trade and the environment debate. At our level of sectoral disaggregation, 5 activities emerge as emissions-intensive (using a classification based either emissions or expenditures on abatement in the US). As a prelude, section 3, contrasts the characteristics and patterns of bilateral trade in these activities with bilateral trade in clean activities. Broadly speaking, results are much in line with previous research.

But in fact all activities emit pollutants and if one really wants to know how much emissions are embodied in overall trade, one must estimate a model of the pollution content of trade, taking all activitities into account. Section 4 lays down a simple framework to analyze the pollution content of trade at the aggregate level. Our empirical strategy is guided by the availabilty of emission pollutants. These are available for one year only, 1987, and for one country, the US. Results with this aggregate model are reported in section 5. They pave the way to a new decomposition of the aggregate pollution of imports at the world wide level, which is presented, along with some robustness checks, in section 6.

2 Gravity and The Environment: Selected Review

Several papers have already investigated the environment and trade topic in the gravity framework (we will not mention trade and the environment papers that do not use the gravity framework in order to keep this section short - see Anriquez (2002), Brunnermeier and Levinson (2004) or Copeland and Taylor (2004) for nice surveys of the general trade and environment literature) but they all rely basically on a distinction between dirty and non-dirty industries. In an early paper van Beers and van den Bergh (1997) regress bilateral trade flows for 21 OECD countries in 1992 on standard variables like gross domestic product, population, integration dummies, distance and on a proxy for environmental strictness. They define bilateral trade flows in several ways: total bilateral trade flows, bilateral trade flows in pollution-intensive sectors (14 sectors) and bilateral trade flows in pollution-intensive sectors that are non-resource based. To proxy environmental strictness they use a measure closely related to the Polluter Pays Principle (a combination of output oriented indicators: like recycling rates and energy intensity). Imports (for all three definitions of trade flows) are always negatively influenced by the environmental stringency. This suggests that strict environmental policies go together with import barriers. In a later paper the same authors (van Beers and van den Bergh, 2003) apply a similar methodology to sector data. They find that exports in chemicals and steel are not affected by the relative stringency of environmental policy (this is in line with Tobey, 1990). For mining and non-ferrous metals the effect is significantly negative and for paper significantly positive. The latter may be explained by cost reducing innovations.

Harris et al. (2002) have panel data at hand (24 OECD countries 1990-1996) which allows them adding importer, exporter and time dummies to control for unobserved heterogeneity. Apart from the additional time dimension, the estimation equation is similar to the one run by van Beers and van den Bergh (1997). For total imports the environmental regulation of the importing country has a strongly significant negative effect and the regulation of the exporting country has no significant effect. For dirty imports, the stringency of the importing country has again a significant negative effect while now the regulation of the exporting effect has a significant positive effect. The same result holds for the regression with footloose dirty imports. For each type of imports, there is a contradiction with the results of van Beers and van den Bergh (1997). Also based on van Beers and van den Bergh (1997), Cagatay and Mihci (2003) restrict their analysis on exports in five dirty sectors. They use a new proxy for environmental stringency- the index of environmental sensibility index, which is based on the following 4 subindices: climate change, acidification, use of water resources and waste management. They run the gravity regression first on the whole sample of 31 countries (8 developing, 23 developed). Then they split the sample keeping only developed countries as reporters and only developing countries as partners. As intuition suggests, the negative effect of environmental stringency on exports is more important for the subsample. Xu (2000) finds that in a sample of 20 countries more stringent environmental regulations do not reduce total exports, exports in dirty sectors nor exports in non-resource based dirty sectors. Moreover he does not find any evidence that new trade barriers are introduced in parallel with more stringent environmental regulation.

Grether and de Melo (2003) use panel data for 52 developing and developed countries over the 1981-1998 period. To proxy the difference in environmental stringency they use the difference in GDP per capita. Using Hausman-Taylor regressions they find that there is a significant negative effect of environmental regulation on trade flows only for footloose dirty industries. There is no significant effect for the total of dirty industries and the sectoral analysis is rather mixed. Kahn and Yoshino (2004) apply the gravity framework to analyse the relationship between regional trading blocks and the pollution haven hypothesis (PHH). They find general support for the PHH outside of RTA blocs. Furthermore they compute that the income elasticity of dirty exports is smaller than the income elasticity of clean exports for low and high income countries. The inverse is true for middle income countries. To explain this, they bring the endowment dimension back into the picture: middle income countries have greater access to capital than poor countries and laxist environmental regulations compared to high income countries. Low income countries on the other hand have not the necessary capital to specialize in dirty goods.

In a recent study Jug and Mirza (2005) investigate the role of product differentiation in the trade and environment debate. Using European panel data (1996 - 1999 for 12 importing and 19 exporting countries) they show that trade in sectors with relatively homogenous goods is relatively more sensitive to changes in environmental regulations. Mantovani and Vancauteren (2005) examine also European data. They follow Ederington et al. (2003) and find that domestic environmental regulation has a larger negative effect when treated as an endogenous variable. Also, they show that EU countries relax their domestic regulations in manufacturing industries that face increased trade liberalisation due to harmonisations, while CEEC countries set more stringent regulations.

3 Trade in Dirty Products: A First Glance

As mentioned in the introduction, so far the analysis of trade in dirty products has mainly proceeded on the basis of data for the US using either pollution abatement cost per unit of output, or alternatively actual emissions per unit of output, which is preferable because it gives a more direct measure of trade in dirty products.[3] At the three-digit ISIC level, the top five most pollutant sectors are (in decreasing order of pollution intensity and skipping petroleum products): iron and steel, non-ferrous metals, industrial chemicals, other non-metallic mineral products and paper and products. When compared to the five cleanest industries[4], dirty sectors stand apart along three characteristics. First, they are about three times as energy intensive, which is to be expected since these industries use raw materials as inputs and carry out weight-reducing activities using mechanical force or high temperatures. Second, dirty sectors are about threee times more land-intensive as they need space for extracting activities, but also to store raw materials and the waste residuals they produce. Third, dirty sectors are about twice as capital intensive and less labor intensive (40%).

We look first for differences in the patterns of sectoral trade between dirty and clean industries using a standard gravity trade model. Let then subscripts i and j refer to importing and exporting countries respectively, and superscript l refers to a sector. We opt for a specification of the gravity model with two sets of country fixed effects, depending on the country being an exporter (EXP_j) or an importer (IMP_i) (leading to $2*(n-1)=132$ dummies). This specification corresponds to the current accepted specification of the gravity model (see e.g. Anderson and Van Wincoop (2003) and Feenstra (2003, chp. 5). With this formulation, the country dummies control for all determinants of bilateral trade that are country-specific (e.g. income, population, remoteness, infrastructure or any other omitted country-specific effects that influence the volume of trade). This formulation is very convenient for our purposes, as it allows us to focus attention on the bilateral variables relevant for the analysis of trade in dirty products, namely transport costs, endowment differences, and environmental policy differences between trading partners. As usual, the standard transport cost function, θ_{ij}, depends on distance and a vector of bilateral variables that influence transaction costs. These latter include common border (BOR_{ij}), common language (LNG_{ij}), colonial ties (COL_{ij}), common religion (REL_{ij}), and either of the two countries being an island (IS_{ij}) or landlocked (LL_{ij}).[5] Assum-

[3] Mani and Wheeler (1997) show that results are very similar whichever method is used.
[4] See table A2 in the Appendix for the exact list of dirty and clean industries.
[5] See the Appendix for a description of data sources and how variables were calculated.

ing the standard multiplicative form yields the following expression for transport costs:

$$\theta_{ij} = (DIST_{ij})^{\gamma}\, e^{\delta_1 REL_{ij} + \delta_2 LL_{ij} + \delta_3 IS_{ij} + \delta_4 BOR_{ij} + \delta_5 LNG_{ij} + \delta_6 COL_{ij}} \qquad (1)$$

Substituting (1) into the standard gravity model and assuming a multiplicative error term[6], yields the following expression to estimate the correlates of the pattern of bilateral imports in polluting products for sector s.

$$\begin{aligned} \ln M_{ijs} = {} & \eta + \beta_i IMP_i + \beta_j EXP_j + \alpha_1 \ln DIST_{ij} + \alpha_2 REL_{ij} \\ & + \alpha_3 LL_{ij} + \alpha_4 IS_{ij} + \alpha_5 BOR_{ij} + \alpha_6 LNG_{ij} + \alpha_7 COL_{ij} \\ & + [\alpha_8 ENVIRON_{ij}] + [\alpha_9 ENDOW_{ij}] + \varepsilon_{i,j} \end{aligned} \qquad (2)$$

The determinants of interest here are the variables in brackets to be discussed in greater detail when results are presented. The first is a proxy for the regulatory gap between importing and exporting country $[ENVIRON_{ij}]$, the second is a proxy for differences in relative factor endowments $[ENDOW_{ij}]$. Unfortunately, no reliable aggregate comprehensive measure exists that can be expected to capture the effect of differences in environmental policy for a large number of countries (over time). Hence, the best one can do is to take various partial measures of environmental policy. This forces us to experiment with the following alternative proxies. Starting with the measure that seems to be the most reliable, one would expects that the difference in the average lead content of gasoline, $\Delta LEAD_{ij} = (LEAD_i) - (LEAD_j)$ would be a good proxy of the regulatory gap.[7] Likewise, an alternative proxy is the difference in carbon dioxide emissions per capita, $\Delta CO2_{ij} = (CO2_i/N_i) - (CO2_j/N_j)$.

Differences in comparative advantages also depend (in addition to differences in environmental policies) on factor endowments. Hence we include a proxy for differences in factor endowments between importing and exporting countries. Ideally, the measure should contain at least three factors: capital (physical and human), land and/or a mesaure of natural resources, and labor. For our sample of countries, we could only obtain data on aggregate capital and labor, so we include $\Delta(K/L)_{ij} = K_i/L_i - K_j/L_j$. As mentionned in the introduction, taken together, differences in environmental policies and differences in comparative advantage may go in opposite directions, perhaps canceling each other out.

Before estimating (2), several comments appear in order. First, (2) states that estimation should be at the sector level, here ten sectors (5 dirty and 5

[6] The appropriateness of the assumption of a multiplicative error term has been questioned though, so far, the evidence seems to support this specification. See Brun et al. (2005, appendix 4).

[7] Among the proxy variables not included is the difference in GDP per capita across partners, $(\Delta Y/N)_{ij} = (Y_i/N_i) - (Y_j/N_j)$. Grether and de Melo (2004) used this variable. Here it has two important drawbacks. First, differences in income per capita obviously do not depend only on differences in the regulatory environment. Second, we use ΔY_{ij} as an instrumental variable to correct for the obvious endogeneity of environmental policies.

clean) at the 3-digit ISIC level will be considered. However, because there is considerable noise in the data at this level of disaggregation, we report first results for the aggregate of polluting industries (or of clean sectors). Second, it is likely that the indicators of environmental policy will be endogenous. To this effect, we use as instrument the difference in income per capita between i and j and report only IV results.[8] Finally, to eliminate yearly noise in the data and to be able to compare two different periods, we report results based on a three year average. Period one covers 1986-1988 and period two covers 1994-1996.

Tables 1a and 1b here: Trade in Dirty and Clean Products: Gravity model results for the two periods

We start with the difference in lead content as proxy for the regulatory gap. Compared with other proxies, lead which reflects more directly policy than the other proxies, should perform better. In fact, this is not the case. This is evident from column 1 which gives the results for dirty industries aggregated into one activity, accounting for 16% percent of trade. The results suggest that, after controlling for other factors, bilateral imports are greater for countries that have a relatively high maximum lead content and therefore a relatively laxist environmental regulation. This finding does not support the pollution haven hypothesis. Could this result be due to a dominating effect of relative factor endowments in the determination of trade patterns? Column 2 shows however that if we use both differences in factor endowments and in lead content neither set of variables is significant.

Turning to the alternative proxy for environmental stringency, namely $CO2$ emissions per dollar of GDP changes the picture. In the preferred specification (column 4) the coefficients on $\Delta CO2_{ij}$ and on $\Delta(K/L)_{ij}$ are significant and have the expected signs. It is hard to come up with a plausible explanation for these contrasting results. However, given the variety of factors that influence trade in dirty products, one should not be too surprised that any single overall proxy for environmental policies will fail to give consistently significant and stable patterns.

We also report results for clean sectors in the second half of tables 1a and 1b. This allows us to check if there are any significant differences between clean and dirty sectors when it comes to the standard regulatory and factor endowments effects identified in the literature. In our classification of clean sectors, it turns out that several 'overall' clean industries share common attributes with the dirty sectors such as being rather capital intensive and pollution intensive for some pollutants (i.e. machinery except electrical and machinery electrical). Therefore, one should not be surprised that the coefficient estimates on the variables of interest turn out to be rather similar to those for dirty industries.

[8] In his US study of the influence of tax policy on interstate waste shipments, with OLS Levinson (1999) found that higher taxes were associated with higher imports of waste, a counterintuitive result that was reversed when he controlled for the endogeneity of trade taxes.

More generally the gravity model, known to give more satisfactory results at the aggregate than at the sector level, performs rather well here. Indeed all the control variables enter with the right sign and almost always significantly. Two other remarks should be made. First, we confrm the results in Grether and de Melo (2004) who found that the coefficient for the distance variable, a proxy for transport costs, is consistently higher for dirty than for clean industries. This is a plausible, and conforting result, hinting perhaps at over-pessimism on the part of those concerned that trade and globalization are inimical to the environment. Second, the coefficient on colonial ties and the dummy for a common language are always higher and more significant for clean compared to dirty sectors, perhaps reinforcing the result that transport costs would be what matters most in explaining the pattern of trade of dirty industries.

Results for the second period reported in table 1b are qualitatively similar to those for the first period. The transport cost dummies coefficients are stable and usually retain their significance. Importantly, the coefficient on distance is again consistently higher for the dirty industries, suggesting a robust result. When using CO2 as the environmental proxy, the introduction of endowment differences reduces now the significance of the environmental proxy. Though we would not want to make much of this contrast, it is consistent with a view that the regulatory gap is losing in significance in explaining the pattern of trade in dirty products as environmentally laxist countries are 'catching up'.

Table 2 here: Results for two Dirty Sectors for both Periods.

Table 2 reports coefficient estimates for two dirty industries: other non-metallic mineral products (ISIC 369) and non-ferrous metals (ISIC 372). Except for distance, the traditional gravity variables coefficients are unstable. While the expected sign holds for both periods, the coefficients of interest, ΔEN and $\Delta CO2$ also exhibit instability. Clearly, noisy data have a strong impact on results at this level of disaggregation.

To sum up, this first inquiry into the patterns of trade in dirty products produces mixed results which are furthermore unstable when one works with disaggregated data. However, overall, the model performs satisfactorily enough to be used in our subsequent inquiry into the pollution content of trade. Moreover, one result is robust: dirty industries consistently have higher transport costs that clean industries. This result alone suggests that transport costs have a potentially strong mitigating impact on the pollution haven and factor endowment effects. We also find that when using $CO2$ emissions as proxy for environmental stringency, a regulatory gap between importing and exporting countries reduces the volume of bilateral trade in dirty products and differences in factor endowments matter with imports of dirty products mitigated by relative capital-labor intensity in the importing country. However, this result is not robust to other proxies for the regulatory gap.

4 The Pollution Content of Trade: A Framework

We now turn to the alternative and more complete approach in which we seek to estimate the pollution content of trade at the aggregate level. The small open economy (SOE) model developed in Copeland and Taylor (2003) allows one to distinguish three main channels through which growth and policy changes will affect the pollution content of trade. First is the scale effect resulting from growth which will be captured by the growth of world imports over the sample period. The second is a composition effect which depends on national attributes (environmental and trade policies included) giving rise to comparative advantage. This effect is captured by changes in the composition of imports across sectors and countries. The third is a technique effect which accounts for changes in emissions intensities per dollar. This is the hardest to capture since it depends both on domestic environmental policies and on trade policies at the sectoral level and we have only emission data for one country, the US, and for one year, 1987. We will use several approaches to try and deal with this issue.

More concretely, our estimation is guided by the availability of data on pollution emissions for a large number of sectors ($s = 1, ..., 79$) pollutants ($k = 1, ..., 16$) and countries ($i, j = 1, ...67$). This level of disaggregation across pollutants, sectors and countries allows us to be more exhaustive than previous attemps in measuring the pollution content of trade, here captured by the pollution content of imports. Let Z_{ij} represent the pollution content of imports of country i coming from j. Let then:

$$Z_{ij}^k = G_{ij} M_{ij} \tag{3}$$

where G_{ij}^k is per dollar average emission of pollutant k and M_{ij} is the value of imports of i from j. Since we are working with sectoral data, $G_{ij}^k = \sum_s g_{is}^k \mu_{ijs}$ where g is per dollar emissions at the sector level and μ is the share of sector s in country i imports.[9]

With this notation, determining the pollution content of imports consists in specifying functional forms for bilateral e imports, M_{ij},and average emission intensity, G_{ij}^k. While we present reduced forms, these are obtainable from the SOE model and the different models giving rise to the gravity equation. Starting with bilateral imports, as in section 3, the aggregate volume of bilateral volume of import of i from j is :[10]

$$M_{ij} = M_{ij}(\theta_{ij}, Y_i, Y_j, N_i, N_j, P_i, P_j) \tag{4}$$

[9] To estimate G_{ij}, it may seem more sensible to use the emission intensities of the exporter (g_{js}), where pollution is effectively generated. However, the factor content approach of the SOE model is one in which countries import the services of the factors (here emissions) that they choose not to use domestically. Thus, in terms of opportunity cost, it makes more sense to use the emission intensities of the importer (g_{is}).

[10] See Deardoff (1998) and Anderson and van Wincoop (2003) for a derivation of (4).

where θ_{ij} represents bilateral transport costs, Y_i, Y_j are GDPs, N_i, N_j, are population and P_i, P_j are price indices capturing bilateral trade resistance (sometimes referred to as 'remoteness'). As to the determinants of average pollution intensity, these are given by:

$$g_{is} = f(T_i, V_i);\ \mu_{ijs} = f(\theta_{ij}, \Delta T_{ij}, \Delta V_{ij}) \tag{5}$$

where T_i represents a vector of sectoral pollution emission control policies in country i and V_i, factor endowments, both variables contributing to a country's pattern of comparative advantage across industries. Trade costs are included as a determinant of μ because, as we have seen in section 3, clean and dirty sectors are differentially affected by transport/transaction cost barriers. Together, (3) to (5) imply that, for a given pollutant k:

$$G_{ij}^k = G_{ij}^k(\theta_{ij}, T_i, V_i, \Delta T_{ij}, \Delta V_{ij}) \tag{6}$$

$$Z_{ij}^k = Z_{ij}^k(\theta_{ij}, Y_i, Y_j, N_i, N_j, P_i, P_j, T_i, V_i, \Delta T_{ij}, \Delta V_{ij}) \tag{7}$$

which are general expressions for the average emission intensity (G) and the aggregate pollution content (Z) of bilateral trade between two countries in pollutant k.

Given that the gravity model performs satisfactorily at the sectoral level, the success in implementing this framework revolves on obtaining information on pollution emission components at the sector level, g_{ij}^k (trade shares, μ_{ijs}, are readily available). As mentioned above, regarding emission intensities at the sector level (g), we only have reliable data for one country, the US, and one year, 1987 (i.e $g_{i,j,t}^k = g_{US,j,1987}^k$). Faced with this difficulty, we cannot capture directly the contribution of differences in emissions across countries or a change in emission technique (perhaps induced by policy implementation or rising income). Thus, we proceed in two steps. In section 5, we assume away these differencies and impose US intensities to all countries and all years. This allows us to analyze approximately the pollution content of world trade, because our sample covers the major world traders, although we need to keep in mind that we miss to include the technical and part of the composition effect. Section 6 presents and alternative methodology in order to reintroduce these dimensions into the analysis.

5 The Pollution Content of Trade: Results

As explained above, the combination of US intensities with trade flows allows to calculate the pollution content of all country pairs ($Z_{ij} = G_{ij}M_{ij} = \sum_s g_{USj}M_{ijs}$) for each one of the 16 pollutants.[11] As in section 3, the estimation of (7) relies on the introduction of importer and exporter dummies which

[11] See table A3 for the list of pollutants, along with an estimate of the share of dirty sectors in the aggregate pollution content of imports.

capture all variables that are country-specific (namely Y_i,Y_j,N_i, N_j, P_i, P_j, T_i and V_i). This leads to the following specification:

$$\begin{aligned} \ln Z^k_{ij} \quad = \quad & \eta + \beta_i IMP_i + \beta_j EXP_j + \alpha_1 \ln DIST_{ij} + \alpha_2 REL_{ij} \\ & + \alpha_3 LL_{ij} + \alpha_4 IS_{ij} + \alpha_5 BOR_{ij} + \alpha_6 LNG_{ij} + \alpha_7 COL_{ij} \\ & + \alpha_6 LNG_{ij} + \alpha_7 COL_{ij} + \alpha_8 \Delta CO2_{ij} + \alpha_9 \Delta (K/L)_{ij} + \varepsilon_{i,j} \end{aligned} \tag{8}$$

which is almost identical to (2) except that the LHS is different (and pollutant-specific) and we restrict here the analysis to the proxy for environmental policy that gave us more reasonable results ($CO2$).

Results appear in table 3. As suggested by the theoretical framework, trade-embodied emissions are larger if the importer has a more stringent environmental policy ($\alpha_8 < 0$) and is less capital-intensive ($\alpha_9 < 0$) than the exporter. The corresponding estimated elasticities are highly significant for period 1, and remain within a narrow range ($-2.82 < \alpha_8 <$ d -2.15) and ($-0.95 < \alpha_9 < -0.54$). These parameters lose significance in period 2. One obvious (and plausible) explanation is that first period emission intensities used in the calculations are less relevant at the end of the sample period. However, broadly speaking, results are consistent with expectations and exhibit a very similar pattern across pollutants. This robustness across 16 pollutants stands in sharp contrast with the results in section 3. This consistency across pollutants would appear to suggest that our approach working with the aggregate pollution content of trade may be worth pursuing in the quest to disentangle environmental policy and factor endowment motives in the pattern of trade in polluting products.

Table 3: Determinants of the Pollution Content of Imports

Turn now to the bilateral proxies for trade barriers. As in section 3, most results are significant over the two periods and consistent with those obtained earlier. Note that the framework identifies two channels through which an increase in trade barriers (θ) affects the pollution content of imports (Z). First is a *scale* (or gravity-type) effects which works through a reduction in trade volume (M). The second is a *composition* effect that affects the average emission intensity (G) through trade shares (μ). For most indicators that enter the θ_{ij} function, those effects are reinforcing, because, as previously noted in section 3, trade in dirty industries appears to be more affected by trade barriers than trade in clean products. As a result, an increase in trade barriers shifts the composition of imports towards cleaner industries, further reducing the pollution content of trade. This explains why the pollution content of imports is so strongly negatively correlated with distance and positively correlated with common religion vis-à-vis the trading partner. There are only two ambiguous cases: common language and colonial ties, which act as trade facilitators on the trade volume side, but favor cleaner imports on the composition side. It turns out that the first effect is dominant for the former, while both effects cancel out each other for the later.

The second exercise isolates the *composition* effect. Calculated average emission intensities are regressed on the set of explanatory variables of equation (6). As it relies again on dummy variables to control for unobservable country-specific effects, the empirical specification is identical to (8), except that $\ln(G^k_{ij})$ is now the LHS variable. Results are reported in table 4 and are generally consistent with previous estimates.

Table 4: Determinants of the Average Emission Intensity of Imports

Environmental policy and relative endowment differentials exhibit the expected signs and are significant only for the first period. Trade barriers proxies are now easier to interpret as they capture only the composition effect. As previously noted, higher trade barriers in the sense of larger distance or religious differences makes imports cleaner on average, as do stronger colonial ties. The only inconsistency comes from the impact of a common language: for a number of pollutants, it appears to increase the average intensity of imports, while the analysis at the sector level suggested that it promoted clean imports more vigourously. This may be due to the improper classification of clean sectors for certain pollutants.

6 Extensions and Robustness

We know that due to lack of data our estimates of average emissions are measured with error. Thus, a simple extension of the analysis is to estimate the determinants of the average emission intensity of US imports for 1987 (the year in which emission intensities were estimated at the sector level). This makes use of the same specification as (8), but with $\ln(G^k_{US,j,87})$ on the LHS and dropping the importer and exporter dummies as we are now limited to 55 observations.

Table 5: Determinants of the Average Emission Intensity of US Imports in 1987

Results (see table 5) are fairly satisfactory given the limited degrees of freedom. The parameters of the traditional trade barrier indicators are less significant than in the previous tables, with a pattern that differs across pollutants. However, environmental policy and relative endowment proxies have the expected signs and are significant for a large majority of pollutants.

Although interesting for their own's sake, these results also provide the basis to "fill in the data gap", and estimate emission intensities that vary both across countries and through time, not only at the national level (G) but also at the sector level (g). To achieve this, we make three assumptions: (i) the estimated parameters of table 5 are also applicable to other countries and other years (ii) differences of sectoral intensities across countries are homogeneous, (iii) all sectoral intensities grow at a constant rate over time. We will show that these assumptions, together with the results of table 5, allow us to give estimates for a complete and new decomposition of the world pollution content of trade into the technique, the composition and the scale effect over the 1986-1996 period.

7 Conclusions

[TO BE COMPLETED]

References

[1] ANDERSON, J.E. and VAN WINCOOP, E., 2003, "Gravity with Gravitas: A Solution to the Border Puzzle", *American Economic Review*, 93(1), pp. 170-192.

[2] ANRIQUEZ, G. (2002), Trade and the Environment: An Economic Literature Survey, mimeo, University of Maryland

[3] BAIER, S.L and BERGSTRAND, J.H., 2001, "The Growth of World Trade: Tariffs, Transport Costs, and Income Similarity", *Journal of International Economics*, 53: 1-27.

[4] BRUN, J.F., GUILLAUMONT, P. and MELO, J. DE, 2005, "Has Distance Died? Evidence from a Panel Gravity Model", *World Bank Economic Review*: 19(1), 99-120.

[5] BRUNNERMEIER S. B., AND A. LEVINSON (2004), "Examining the Evidence on Environmental Regulations and Industry Location", *Journal of Environment & Development*, 13 (1), 6-41.

[6] CIA's World Factbook: http://www.cia.gov/cia/publications/ factbook/docs/profileguide.html.

[7] COLE, M.A. and ELLIOT, R.J.R. (2001), "Factor Endowments or Environmental Regulations? Determining the Trade-Environmental Composition Effect", University of Birmingham, Discussion Paper 01-06.

[8] COPELAND, B.R. and, TAYLOR, M.S. (2003), Trade and the Environment: Theory and Evidence, Princeton University Press.

[9] Copeland, B.R. and, Taylor, M.S. (2004), “Trade, Growth and the Environment”, Journal of Economic Literature, 42/1, 7-71.

[10] Damania, R., P.G. Fredriksson and J.A. List (2000), Trade Liberalization, Corruption and Environmental Policy Formation: theory and Evidence, Centre for International Economic Studies, Discussion Paper No. 0047, Adelaide University, Australia.

[11] Ederington, J., A. Levinson and J. Minier, 2004, "Trade Liberalization and Pollution Havens", Advances in Economic Analysis & Policy, Vol. 4 (2), Article 6.

[12] Evenett, S.J. and Keller, W., 2002, “On Theories Explaining the Success of the Gravity Equation”, *Journal of Political Economy*, 110: 281-316.

[13] Estevadeordal, A., Frantz, B. and Taylor, A., 2002, “The Rise and Fall of World Trade, 1987-1939”, nber Working Paper Series # 9318.

[14] Feenstra, R., 2003, *Advanced International Trade*, Princeton University Press, chap.5.

[15] Grether, J.-M. and N. Mathys (2002), Lead content of gasoline 1983-1995, University of Neuchâtel, Switzerland.

[16] Grether, J.-M. and de Melo, J., (2004), “Globalization and dirty industries: Do pollution havens matter?” in R.E. Baldwin and A. Winters eds., *Challenges to Globalization: Analyzing the Economics*, University of Chicago Press, pp. 167-208.

[17] Harris, M. N., L. Konya and L. Matyas (2002), "Modelling the Impact of Environmental Regulations on Bilateral Trade Flows: OECD, 1990-1996", *The World Economy*, 25(3), 387-405.

[18] Helpman, E., M. Melitz and Y. Rubinstein (2004), “Trading Partners and Trading Volumes,” Harvard University.

[19] Hettige, H.P., Martin, P., Singh, M. and Wheeler, D. (1995), “The Industrial Pollution Projection System”, WPS# 1431, The World Bank, Washington, D.C.

[20] Jug, J. and D. Mirza (2004), "Environmental Regulation and Trade in Europe: The Role of Differentiation", mimeo University of Nottingham.

[21] Kahn, M. and Y. Yoshino (2004), "Testing the Pollution Havens Inside and Outside of Regional Trading Blocs", Advances in Economic Analysis & Policy, Vol. 4 (2), Article 4.

[22] Laursen, K. (2000), *Trade Specialisation, Technology and Economic Growth: Theory and Evidence from Advanced Countries*, Edward Elgar.

[23] Levinson, A (1999), "State Taxes and Interstate Hazardous Waste Shipments", American Economic Review, 89(3), pp. 666-77.

[24] Mani, M. and Wheeler, D., (1999), "In Search of Pollution Havens? Dirty Industry in the World Economy, 1960-95", in P. Fredriksson (ed), Trade, Global Policy, and the Environment, WBDP #402, World Bank, 115-128.

[25] Mantovani, A. and M. Vancauteren (2005), "Environmental Policy and Trade in the Single Market", Working paper .

[26] Olarreaga, M. and A. Nicita (2001), "Trade and Production, 1976-99", World Bank.

[27] Tobey, J. (1990), "The Effects of Domestic Environmental Policies on Patterns of World Trade : En Empirical Test", Kyklos, Vol. 43 (2), pp. 191-209.

[28] Van Beers, C. and J. van den Bergh (1997), An empirical Multi-Country Analysis of the Impact of Environmental Regulations on Foreign Trade Flows", *Kyklos* 50(1), 29-46.

[29] Van Beers, C. and J.C.J.M. van den Bergh (2000), The Impact of Environmental Policy on Foreign Trade: Tobey revisited with a Bilateral Flow Model, Tinbergen Institute Discussion Paper.

[30] Xu, X. (2000), "International Trade and Environmental Regulations: Time Series Evidence and Cross Section Tests", Environmental and Resource Economics, Vol. 17(3), 233-257.

Tables:

Table 1a: Trade in Dirty and Clean Products: Gravity Model Results for Period 1

	Dirty Sectors				Clean Sectors			
DIST	-1.59***	-1.58***	-1.64***	-1.64***	-1.24***	-1.28***	-1.22***	-1.27***
	[31.41]	[28.18]	[31.05]	[29.43]	[26.29]	[24.70]	[25.13]	[24.31]
BOR	0.09	0.09	0.22	0.22	0.22	0.25	0.65***	0.64***
	[0.44]	[0.42]	[1.03]	[1.01]	[1.15]	[1.21]	[3.19]	[3.05]
LL	-0.04	0.07	0.65	0.62	0.83	0.83	0.43	0.39
	[0.05]	[0.09]	[1.00]	[0.97]	[1.17]	[1.17]	[0.70]	[0.64]
IS	-0.73***	-0.73***	-0.73***	-0.72***	-0.64***	-0.59***	-0.61***	-0.57***
	[3.15]	[3.07]	[3.06]	[3.04]	[2.97]	[2.68]	[2.79]	[2.58]
LNG	0.50***	0.53***	0.44***	0.47***	0.95***	0.95***	0.92***	0.95***
	[4.66]	[4.53]	[4.02]	[4.11]	[9.78]	[9.14]	[9.32]	[9.03]
REL	0.23*	0.30**	0.24*	0.30**	0.06	0.11	0.15	0.15
	[1.95]	[2.29]	[1.94]	[2.27]	[0.54]	[0.94]	[1.32]	[1.28]
COL	0.45**	0.31	0.54**	0.41*	0.73***	0.66***	0.76***	0.71***
	[2.05]	[1.31]	[2.38]	[1.73]	[3.52]	[2.99]	[3.56]	[3.14]
ΔLEAD	0.26***	8.16			0.48***	3.39		
	[4.69]	[1.50]			[9.05]	[0.67]		
ΔCO2			-4.86***	-2.47***			-3.95***	-2.01***
			[13.98]	[10.23]			[12.68]	[10.36]
ΔEN		8.96		-0.69***		3.03		-0.48***
		[1.22]		[7.95]		[0.44]		[6.01]
Constant	24.52***	-8.11	23.47***	21.14***	21.87***	9.71	20.73***	19.01***
	[45.50]	[0.40]	[42.96]	[29.64]	[43.20]	[0.51]	[40.93]	[39.61]
Observations	2723	2276	2586	2229	2919	2435	2780	2395

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 1b: Trade in Dirty and Clean Products: Gravity Model Results for Period 2

	Dirty Sectors				Clean Sectors			
DIST	-1.57***	-1.63***	-1.61***	-1.68***	-1.23***	-1.28***	-1.27***	-1.28***
	[32.78]	[31.80]	[34.91]	[34.23]	[28.96]	[27.05]	[31.06]	[28.40]
BOR	0.08	-0.12	0.12	-0.11	0.31*	0.17	0.38**	0.29
	[0.42]	[0.58]	[0.63]	[0.54]	[1.78]	[0.87]	[2.26]	[1.58]
LL	-0.94	-0.98	-0.96*	-1.04*	-0.14	-0.21	-0.44	-0.53
	[1.45]	[1.56]	[1.66]	[1.88]	[0.24]	[0.35]	[0.88]	[1.10]
IS	0.25	0.24	-0.01	0.03	-0.55**	-0.55**	-0.57***	-0.53***
	[1.04]	[1.00]	[0.03]	[0.14]	[2.53]	[2.51]	[2.89]	[2.70]
LNG	0.62***	0.55***	0.62***	0.58***	0.91***	0.92***	0.87***	0.91***
	[6.17]	[5.30]	[6.30]	[5.73]	[10.33]	[9.68]	[10.03]	[9.89]
REL	0.42***	0.44***	0.39***	0.37***	0.16*	0.20*	0.20**	0.25**
	[3.88]	[3.68]	[3.65]	[3.21]	[1.70]	[1.81]	[2.11]	[2.35]
COL	0.48**	0.36*	0.41**	0.28	0.57***	0.46**	0.57***	0.40**
	[2.33]	[1.66]	[1.97]	[1.31]	[3.07]	[2.29]	[3.05]	[2.04]
ΔLEAD	2.60***	6.69*			4.57***	7.02*		
	[6.65]	[1.69]			[13.01]	[1.91]		
ΔCO2			-5.00***	-8.94*			-4.72***	-9.87**
			[11.89]	[1.76]			[13.31]	[2.11]
ΔEN		1.23		1.38		1.07		1.84
		[0.69]		[0.77]		[0.65]		[1.12]
Constant	22.47***	22.98***	24.02***	26.06***	20.43***	21.30***	22.75***	24.58***
	[43.33]	[35.54]	[49.48]	[14.37]	[44.08]	[37.10]	[52.67]	[14.63]
Observations	2796	2277	3181	2523	2955	2388	3387	2657

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 2: Results for two Dirty Sectors for both Periods

(other non-metallic minerals, ISIC 369 and non-ferrous metals, ISIC 372)

	Period 1		**Period 2**	
	ISIC-369	**ISIC-372**	**ISIC-369**	**ISIC-372**
DIST	-1.76***	-1.63***	-1.75***	-1.81***
	[25.11]	[22.43]	[28.16]	[26.95]
BOR	0.52**	0.12	0.71***	0.1
	[2.01]	[0.45]	[3.13]	[0.40]
LL	-0.73	-0.99	-0.32	-1.04
	[0.59]	[1.18]	[0.37]	[1.23]
IS	-0.28	-0.12	-0.32	-0.78***
	[0.98]	[0.40]	[1.19]	[2.70]
LNG	0.29*	0.03	0.46***	0.38***
	[1.91]	[0.21]	[3.47]	[2.64]
REL	0.18	0.05	0.22	0.22
	[1.04]	[0.32]	[1.48]	[1.38]
COL	0.59**	0.78***	0.54**	0.44*
	[2.17]	[2.77]	[2.17]	[1.66]
ΔEN	-0.95***	0.09	2.41	2.82
	[6.05]	[1.05]	[1.08]	[1.23]
ΔCO2	-1.33***	-1.67***	-12.11*	-12.83*
	[2.84]	[4.62]	[1.91]	[1.95]
Constant	20.59***	17.16***	24.49***	26.80***
	[17.58]	[21.97]	[11.70]	[11.51]
Observations	1508	1608	1935	1865

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 3a: Determinants of the Pollution Content of Imports (first set of 5 polluants)

	Period 1					Period 2				
	TPA	TPL	TPW	TPT	N2A	TPA	TPL	TPW	TPT	N2A
DIST	-1.46***	-1.54***	-1.63***	-1.50***	-1.63***	-1.51***	-1.58***	-1.62***	-1.54***	-1.65***
	[26.38]	[25.31]	[23.39]	[25.92]	[25.50]	[32.39]	[30.92]	[28.87]	[31.86]	[31.38]
BOR	0.26	0.11	0.12	0.17	0.28	-0.1	-0.25	-0.28	-0.19	-0.12
	[1.17]	[0.45]	[0.41]	[0.73]	[1.08]	[0.55]	[1.21]	[1.21]	[0.96]	[0.56]
LL	0.05	-0.2	0.08	-0.1	0.71	-0.25	-0.54	-0.39	-0.41	-0.28
	[0.07]	[0.29]	[0.10]	[0.16]	[1.01]	[0.53]	[1.02]	[0.68]	[0.82]	[0.52]
IS	-0.52**	-0.43*	-0.53*	-0.47*	-0.42	-0.06	0.04	-0.11	-0.03	-0.03
	[2.20]	[1.65]	[1.80]	[1.94]	[1.57]	[0.30]	[0.18]	[0.47]	[0.13]	[0.15]
LNG	0.90***	1.00***	1.17***	0.94***	0.97***	0.80***	0.79***	0.94***	0.79***	0.85***
	[8.16]	[8.19]	[8.43]	[8.19]	[7.63]	[8.47]	[7.64]	[8.28]	[8.04]	[8.03]
REL	0.61***	0.69***	0.89***	0.66***	0.75***	0.45***	0.53***	0.64***	0.49***	0.66***
	[4.72]	[4.91]	[5.52]	[4.93]	[5.10]	[4.05]	[4.39]	[4.80]	[4.30]	[5.30]
COL	0.31	0.26	0.07	0.26	0.26	0.31	0.3	0.17	0.29	0.21
	[1.29]	[0.99]	[0.23]	[1.04]	[0.95]	[1.50]	[1.33]	[0.69]	[1.37]	[0.91]
ΔEN	-0.57***	-0.57***	-0.58***	-0.57***	-0.67***	0.22	0.31	-0.18	0.28	-0.86
	[6.62]	[6.05]	[5.34]	[6.30]	[6.83]	[0.13]	[0.16]	[0.09]	[0.16]	[0.44]
ΔCO2	-2.15***	-2.19***	-2.53***	-2.16***	-2.79***	-5.65	-6.07	-4.95	-5.91	-3.25
	[9.51]	[8.82]	[8.94]	[9.20]	[10.78]	[1.16]	[1.13]	[0.84]	[1.16]	[0.59]
Constant	28.58***	29.87***	27.96***	30.03***	29.95***	32.10***	33.33***	30.96***	33.53***	32.58***
	[40.81]	[38.82]	[31.83]	[41.12]	[37.22]	[18.05]	[17.06]	[14.47]	[18.16]	[16.27]
Observations	2515	2515	2512	2515	2513	2735	2735	2733	2735	2733

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 3b: Determinants of the Pollution Content of Imports (second set of 5 pollutants)

	Period 1					Period 2				
	MPA	**MPL**	**MPW**	**MPT**	**S2A**	**MPA**	**MPL**	**MPW**	**MPT**	**S2A**
DIST	-1.76***	-1.74***	-1.72***	-1.72***	-1.67***	-1.70***	-1.73***	-1.67***	-1.72***	-1.68***
	[25.45]	[25.27]	[26.19]	[25.51]	[25.31]	[30.36]	[31.31]	[31.34]	[31.35]	[31.25]
BOR	0.01	0.01	0.12	0.02	0.11	-0.19	-0.25	-0.23	-0.23	-0.22
	[0.03]	[0.05]	[0.47]	[0.08]	[0.40]	[0.83]	[1.11]	[1.06]	[1.04]	[1.03]
LL	0.03	0.37	0.44	0.34	0	0.05	-0.15	0.25	-0.14	-0.57
	[0.04]	[0.49]	[0.60]	[0.46]	[0.01]	[0.08]	[0.27]	[0.46]	[0.25]	[1.03]
IS	-0.66**	-0.69**	-0.44	-0.68**	-0.46	-0.03	-0.12	-0.11	-0.12	-0.01
	[2.26]	[2.39]	[1.59]	[2.40]	[1.64]	[0.12]	[0.51]	[0.49]	[0.50]	[0.04]
LNG	0.96***	0.99***	1.00***	0.98***	1.04***	0.89***	0.84***	0.89***	0.83***	0.86***
	[6.96]	[7.22]	[7.69]	[7.26]	[7.94]	[7.77]	[7.50]	[8.25]	[7.50]	[7.85]
REL	0.60***	0.67***	0.61***	0.66***	0.78***	0.50***	0.51***	0.52***	0.49***	0.64***
	[3.74]	[4.21]	[4.06]	[4.24]	[5.10]	[3.78]	[3.90]	[4.11]	[3.81]	[5.06]
COL	0.53*	0.44	0.32	0.45	0.31	0.47*	0.36	0.27	0.37	0.25
	[1.76]	[1.46]	[1.11]	[1.53]	[1.08]	[1.88]	[1.50]	[1.16]	[1.52]	[1.06]
ΔEN	-0.95***	-0.71***	-0.90***	-0.71***	-0.73***	0.58	0.63	-0.89	0.69	-1.07
	[9.33]	[6.70]	[9.26]	[6.81]	[7.11]	[0.28]	[0.31]	[0.46]	[0.34]	[0.54]
ΔCO2	-2.55***	-2.58***	-2.68***	-2.56***	-2.55***	-7.61	-7.67	-3.56	-7.83	-2.47
	[10.33]	[9.25]	[11.47]	[9.34]	[9.53]	[1.29]	[1.32]	[0.64]	[1.36]	[0.44]
Constant	26.92***	29.22***	24.90***	29.21***	31.18***	29.33***	33.02***	26.32***	33.03***	33.17***
	[42.37]	[33.79]	[41.42]	[34.30]	[37.51]	[13.72]	[15.66]	[13.03]	[15.79]	[16.15]
Observations	2499	2502	2499	2504	2513	2718	2723	2710	2723	2733

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 3c: Determinants of the Pollution Content of Imports (final 6 pollutants)

	Period 1						Period 2					
	COA	VOA	FPA	TSA	BOW	TSW	COA	VOA	FPA	TSA	BOW	TSW
DIST	-1.78***	-1.51***	-1.74***	-1.62***	-1.68***	-2.03***	-1.79***	-1.54***	-1.78***	-1.65***	-1.70***	-1.96***
	[26.09]	[26.51]	[23.42]	[24.08]	[22.13]	[24.54]	[31.97]	[32.87]	[28.99]	[30.01]	[28.10]	[29.30]
BOR	0.02	0.32	0.36	0.26	0.23	-0.33	-0.35	-0.04	0.04	-0.09	-0.22	-0.68**
	[0.07]	[1.38]	[1.21]	[0.94]	[0.76]	[0.97]	[1.53]	[0.22]	[0.16]	[0.42]	[0.89]	[2.51]
LL	0.41	0.54	0.43	0.46	0.04	-0.36	-0.56	0	-0.78	-0.69	-0.39	-0.59
	[0.54]	[0.85]	[0.52]	[0.62]	[0.05]	[0.39]	[0.97]	[0.00]	[1.23]	[1.22]	[0.62]	[0.86]
IS	-0.51*	-0.54**	-0.58*	-0.37	-0.75**	-0.54	0.01	-0.21	-0.03	0.01	-0.33	-0.1
	[1.78]	[2.23]	[1.84]	[1.31]	[2.34]	[1.54]	[0.05]	[1.02]	[0.10]	[0.04]	[1.26]	[0.36]
LNG	1.13***	0.93***	1.15***	1.00***	1.20***	1.29***	0.92***	0.80***	0.93***	0.83***	0.92***	1.01***
	[8.27]	[8.20]	[7.81]	[7.46]	[7.96]	[7.87]	[8.14]	[8.41]	[7.44]	[7.40]	[7.49]	[7.45]
REL	0.73***	0.70***	0.86***	0.82***	0.74***	0.83***	0.64***	0.55***	0.69***	0.65***	0.59***	0.78***
	[4.62]	[5.33]	[5.02]	[5.31]	[4.22]	[4.33]	[4.83]	[4.96]	[4.74]	[5.00]	[4.15]	[4.90]
COL	0.31	0.26	0.32	0.4	0.25	0.59	0.26	0.21	0.16	0.32	0.37	0.31
	[1.03]	[1.04]	[0.99]	[1.37]	[0.77]	[1.63]	[1.04]	[1.00]	[0.60]	[1.32]	[1.40]	[1.03]
ΔEN	-0.78***	-0.54***	-0.74***	-0.70***	-0.76***	-0.95***	-0.21	-0.73	-0.11	-0.15	-0.04	0.28
	[7.41]	[6.11]	[6.42]	[6.67]	[6.51]	[7.46]	[0.10]	[0.42]	[0.05]	[0.08]	[0.02]	[0.12]
ΔCO2	-2.82***	-2.48***	-2.69***	-2.63***	-2.61***	-2.42***	-5.27	-3.52	-5.2	-4.77	-5.97	-7
	[10.16]	[10.73]	[8.96]	[9.63]	[8.50]	[7.21]	[0.90]	[0.72]	[0.81]	[0.82]	[0.94]	[1.00]
Constant	31.63***	28.83***	29.11***	29.16***	29.35***	35.11***	34.98***	32.04***	32.68***	32.32***	32.92***	37.67***
	[36.69]	[40.10]	[31.16]	[34.37]	[30.73]	[33.71]	[16.42]	[17.92]	[13.96]	[15.36]	[14.30]	[14.79]
Observations	2511	2513	2501	2513	2510	2515	2731	2733	2720	2733	2729	2729

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 4a: Determinants of the Average Emission Intensity of Imports (first set of 5 pollutants)

	Period 1					Period 2				
	TPA	TPL	TPW	TPT	N2A	TPA	TPL	TPW	TPT	N2A
DIST	-0.15***	-0.23***	-0.31***	-0.19***	-0.31***	-0.17***	-0.24***	-0.28***	-0.20***	-0.31***
	[6.07]	[7.51]	[7.57]	[6.96]	[10.32]	[7.80]	[9.09]	[8.31]	[8.66]	[11.69]
BOR	-0.08	-0.23*	-0.22	-0.17	-0.06	-0.1	-0.25**	-0.28**	-0.19**	-0.12
	[0.75]	[1.83]	[1.30]	[1.54]	[0.50]	[1.18]	[2.33]	[2.01]	[2.00]	[1.15]
LL	-0.14	-0.38	-0.1	-0.29	0.52	0.2	-0.09	0.06	0.04	0.16
	[0.52]	[1.13]	[0.23]	[0.98]	[1.55]	[0.88]	[0.31]	[0.16]	[0.17]	[0.59]
IS	-0.11	-0.02	-0.12	-0.07	-0.03	0.13	0.23**	0.08	0.16	0.16
	[1.07]	[0.17]	[0.69]	[0.63]	[0.20]	[1.37]	[1.99]	[0.52]	[1.62]	[1.40]
LNG	0.04	0.14**	0.32***	0.08	0.11*	-0.02	-0.02	0.12*	-0.03	0.04
	[0.86]	[2.23]	[3.86]	[1.60]	[1.80]	[0.36]	[0.43]	[1.80]	[0.59]	[0.77]
REL	0.15***	0.24***	0.43***	0.21***	0.31***	0.06	0.14**	0.25***	0.10*	0.27***
	[2.71]	[3.41]	[4.55]	[3.38]	[4.36]	[1.13]	[2.27]	[3.14]	[1.90]	[4.36]
COL	-0.22**	-0.26**	-0.46**	-0.27**	-0.27**	-0.11	-0.12	-0.24	-0.13	-0.21*
	[2.01]	[1.99]	[2.56]	[2.28]	[2.02]	[1.14]	[0.99]	[1.64]	[1.23]	[1.79]
ΔEN	-0.12***	-0.13***	-0.13**	-0.12***	-0.23***	-0.54	-0.45	-0.93	-0.48	-1.61*
	[3.22]	[2.67]	[2.03]	[2.88]	[4.87]	[0.67]	[0.45]	[0.75]	[0.55]	[1.65]
ΔCO2	-0.19*	-0.23*	-0.57***	-0.21*	-0.83***	0.83	0.42	1.53	0.58	3.2
	[1.86]	[1.84]	[3.40]	[1.90]	[6.77]	[0.37]	[0.15]	[0.43]	[0.24]	[1.16]
Constant	8.22***	9.51***	7.58***	9.67***	9.61***	7.72***	8.95***	6.57***	9.15***	8.21***
	[26.43]	[24.74]	[14.55]	[28.78]	[25.10]	[9.35]	[8.81]	[5.11]	[10.31]	[8.17]
Observations	2515	2515	2512	2515	2513	2735	2735	2733	2735	2733

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 4b: Determinants of the Average Emission Intensity of Imports (second set of 5 pollutants)

	Period 1					Period 2				
	MPA	MPL	MPW	MPT	S2A	MPA	MPL	MPW	MPT	S2A
DIST	-0.45***	-0.42***	-0.40***	-0.41***	-0.35***	-0.36***	-0.39***	-0.34***	-0.38***	-0.34***
	[10.03]	[9.50]	[9.77]	[9.58]	[10.73]	[9.65]	[10.76]	[9.58]	[10.62]	[12.38]
BOR	-0.33*	-0.32*	-0.21	-0.31*	-0.24*	-0.19	-0.26*	-0.24*	-0.24	-0.23**
	[1.80]	[1.79]	[1.26]	[1.81]	[1.75]	[1.25]	[1.73]	[1.69]	[1.64]	[2.04]
LL	-0.17	0.17	0.23	0.14	-0.2	0.48	0.3	0.68*	0.31	-0.13
	[0.35]	[0.34]	[0.51]	[0.29]	[0.54]	[1.24]	[0.79]	[1.89]	[0.84]	[0.45]
IS	-0.29	-0.3	-0.06	-0.30*	-0.06	0.22	0.11	0.14	0.12	0.18
	[1.51]	[1.62]	[0.32]	[1.65]	[0.41]	[1.33]	[0.72]	[0.94]	[0.76]	[1.53]
LNG	0.1	0.12	0.14*	0.12	0.18***	0.04	0	0.05	0	0.04
	[1.08]	[1.39]	[1.72]	[1.36]	[2.76]	[0.56]	[0.04]	[0.75]	[0.05]	[0.77]
REL	0.16	0.22**	0.16*	0.22**	0.33***	0.13	0.14	0.15*	0.13	0.26***
	[1.53]	[2.18]	[1.73]	[2.20]	[4.32]	[1.42]	[1.63]	[1.80]	[1.49]	[3.93]
COL	0	-0.09	-0.21	-0.08	-0.22	0.07	-0.04	-0.12	-0.03	-0.17
	[0.00]	[0.46]	[1.19]	[0.41]	[1.53]	[0.41]	[0.22]	[0.79]	[0.21]	[1.38]
ΔEN	-0.43***	-0.27***	-0.37***	-0.27***	-0.28***	-0.26	-0.26	-1.75	-0.2	-1.82*
	[6.49]	[3.90]	[6.20]	[4.06]	[5.49]	[0.19]	[0.19]	[1.36]	[0.15]	[1.78]
ΔCO2	-0.61***	-0.61***	-0.75***	-0.60***	-0.59***	-0.9	-0.81	3.2	-0.97	3.98
	[3.83]	[3.43]	[5.15]	[3.47]	[4.40]	[0.23]	[0.21]	[0.87]	[0.26]	[1.37]
Constant	6.31***	8.86***	4.26***	8.84***	10.83***	4.80***	8.47***	1.79	8.48***	8.81***
	[15.41]	[15.90]	[11.41]	[16.45]	[26.03]	[3.33]	[6.08]	[1.35]	[6.20]	[8.32]
Observations	2499	2502	2499	2504	2513	2718	2723	2710	2723	2733

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 4c: Determinants of the Average Emission Intensity of Imports (final 6 pollutants)

	Period 1						Period 2					
	COA	VOA	FPA	TSA	BOW	TSW	COA	VOA	FPA	TSA	BOW	TSW
DIST	-0.47***	-0.20***	-0.43***	-0.31***	-0.36***	-0.71***	-0.45***	-0.20***	-0.45***	-0.32***	-0.37***	-0.63***
	[12.05]	[7.38]	[9.44]	[8.89]	[7.83]	[13.36]	[13.49]	[9.20]	[11.38]	[10.72]	[9.40]	[13.96]
BOR	-0.33**	-0.02	0	-0.08	-0.11	-0.67***	-0.35***	-0.05	0.03	-0.1	-0.23	-0.70***
	[2.03]	[0.20]	[0.00]	[0.60]	[0.58]	[3.08]	[2.59]	[0.51]	[0.20]	[0.82]	[1.44]	[3.79]
LL	0.18	0.34	0.21	0.27	-0.17	-0.55	-0.11	0.44**	-0.34	-0.25	0.06	-0.14
	[0.43]	[1.16]	[0.41]	[0.71]	[0.34]	[0.93]	[0.32]	[1.98]	[0.85]	[0.82]	[0.15]	[0.30]
IS	-0.11	-0.14	-0.17	0.03	-0.34*	-0.13	0.21	-0.01	0.16	0.2	-0.13	0.1
	[0.66]	[1.22]	[0.90]	[0.18]	[1.74]	[0.59]	[1.45]	[0.15]	[0.94]	[1.59]	[0.79]	[0.50]
LNG	0.27***	0.07	0.31***	0.14**	0.34***	0.43***	0.11*	-0.01	0.11	0.01	0.11	0.20**
	[3.42]	[1.32]	[3.39]	[2.04]	[3.70]	[4.09]	[1.69]	[0.32]	[1.39]	[0.24]	[1.39]	[2.13]
REL	0.29***	0.25***	0.43***	0.38***	0.30***	0.37***	0.25***	0.16***	0.32***	0.27***	0.21**	0.40***
	[3.17]	[4.13]	[4.05]	[4.74]	[2.76]	[3.04]	[3.22]	[3.18]	[3.40]	[3.82]	[2.24]	[3.71]
COL	-0.22	-0.27**	-0.21	-0.13	-0.28	0.06	-0.16	-0.21**	-0.26	-0.1	-0.04	-0.11
	[1.31]	[2.34]	[1.08]	[0.85]	[1.36]	[0.25]	[1.12]	[2.22]	[1.48]	[0.76]	[0.25]	[0.54]
ΔEN	-0.34***	-0.09**	-0.29***	-0.25***	-0.32***	-0.51***	-1	-1.47*	-0.83	-0.9	-0.78	-0.46
	[5.62]	[2.26]	[4.13]	[4.68]	[4.45]	[6.15]	[0.82]	[1.83]	[0.58]	[0.83]	[0.55]	[0.28]
ΔCO2	-0.85***	-0.52***	-0.73***	-0.67***	-0.65***	-0.46**	1.3	2.93	1.17	1.68	0.49	-0.52
	[5.35]	[4.81]	[3.92]	[4.80]	[3.43]	[2.13]	[0.38]	[1.28]	[0.29]	[0.54]	[0.12]	[0.11]
Constant	11.33***	8.49***	8.85***	8.82***	9.03***	14.75***	10.56***	7.67***	8.34***	7.96***	8.57***	13.34***
	[22.89]	[25.14]	[15.32]	[20.29]	[15.42]	[21.95]	[8.37]	[9.21]	[5.59]	[7.07]	[5.81]	[7.77]
Observations	2511	2513	2501	2513	2510	2515	2731	2733	2720	2733	2729	2729

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Exporter and importer dummies are not reported. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Table 5: Determinants of the Average Emission Intensity of US Imports in 1987

	TPA	TPL	TPW	TPT	MPL	MPA	MPW	MPT	N2A	COA	VOA	FPA	BOW	TSW	S2A	TSA
DIST	0.04	-0.05	-0.09	-0.02	0.4	0.31	-0.04	0.4	-0.67**	-0.2	-0.58**	-0.39	-0.65**	0.13	-0.41	-0.46
	[0.23]	[0.18]	[0.26]	[0.09]	[1.17]	[0.91]	[0.12]	[1.17]	[2.68]	[0.67]	[2.42]	[0.75]	[2.31]	[0.34]	[1.31]	[1.51]
BOR	0.1	-0.34	-0.17	-0.21	0.84*	0.65	-0.23	0.83*	-1.09**	-0.42	-0.98**	0.2	-0.82*	0.12	-0.67	-0.41
	[0.35]	[0.73]	[0.32]	[0.53]	[1.70]	[1.34]	[0.45]	[1.69]	[2.59]	[0.79]	[2.25]	[0.23]	[1.81]	[0.21]	[1.33]	[0.90]
LL	0.02	0.2	-0.01	0.08	0.74	0.88	-0.1	0.74	-0.69	-0.43	-0.49	-1.29*	-0.2	0.59	-0.32	-0.69
	[0.04]	[0.43]	[0.02]	[0.20]	[0.98]	[1.37]	[0.19]	[0.99]	[1.26]	[0.63]	[1.34]	[1.91]	[0.27]	[1.26]	[0.45]	[0.97]
IS	-0.29	-0.12	-0.08	-0.19	-0.24	-0.18	-0.03	-0.23	-0.28	-0.43	-0.26	-0.38	-0.25	-0.14	-0.51	-0.29
	[1.54]	[0.46]	[0.30]	[0.85]	[0.61]	[0.46]	[0.11]	[0.60]	[0.97]	[1.26]	[0.90]	[1.10]	[0.73]	[0.34]	[1.48]	[0.87]
LNG	-0.07	-0.07	-0.09	-0.07	-0.69*	-0.59	-0.25	-0.69*	-0.07	-0.53	0.15	-0.81**	-0.4	-0.53	-0.37	-0.59*
	[0.38]	[0.21]	[0.26]	[0.25]	[1.73]	[1.42]	[0.66]	[1.73]	[0.19]	[1.19]	[0.41]	[2.31]	[1.17]	[1.15]	[0.84]	[1.83]
REL	0.78**	0.41	1.17**	0.66	0.9	0.8	0.82	0.9	0.58	1.23*	0.05	0.43	1.84***	0.63	1.25**	0.58
	[2.65]	[0.67]	[2.12]	[1.53]	[1.10]	[1.02]	[1.34]	[1.12]	[1.26]	[1.79]	[0.13]	[0.72]	[2.75]	[0.88]	[2.02]	[1.02]
COL	0.05	-0.01	-0.08	-0.05	0.05	-0.21	-0.25	0.04	-0.39	-0.39	0.18	0.79	0.06	-0.71	-0.2	0.49
	[0.32]	[0.04]	[0.34]	[0.22]	[0.16]	[0.57]	[0.86]	[0.11]	[1.29]	[1.11]	[0.63]	[0.86]	[0.10]	[1.49]	[0.47]	[0.63]
ΔEN	-0.16***	-0.26***	-0.22**	-0.21***	-0.34**	-0.32**	-0.28**	-0.33**	-0.1	-0.12	-0.16*	-0.24*	-0.31***	-0.40***	-0.1	-0.14
	[3.02]	[2.79]	[2.51]	[2.98]	[2.65]	[2.57]	[2.40]	[2.64]	[1.07]	[0.85]	[1.97]	[1.75]	[3.31]	[2.93]	[0.94]	[1.35]
ΔCO2	-0.32**	-0.51**	-0.49***	-0.44**	-0.88***	-0.81***	-0.63**	-0.87***	-0.29	-0.64**	-0.35	-0.45	-0.56***	-0.85***	-0.63*	-0.32
	[2.64]	[2.32]	[3.22]	[2.52]	[3.29]	[2.93]	[2.67]	[3.27]	[1.21]	[2.18]	[1.46]	[1.66]	[3.01]	[3.51]	[1.99]	[1.36]
Const.	6.34***	8.15***	5.42*	8.17***	2.81	0.27	1.3	2.87	13.48***	9.94***	12.66***	9.94**	11.70***	8.48**	11.96***	11.09***
	[4.27]	[3.26]	[1.97]	[3.98]	[0.97]	[0.09]	[0.46]	[1.00]	[6.62]	[3.80]	[6.24]	[2.27]	[4.89]	[2.67]	[4.54]	[4.36]
Obs.	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
R-sq	0.5	0.45	0.49	0.48	0.46	0.45	0.46	0.45	0.36	0.35	0.43	0.37	0.62	0.49	0.35	0.33

Note: *** denotes significant at the 1% level, ** denotes significant at the 5% level, * denotes significant at the 10% level. Figures in parentheses are t-ratios. Variables descriptions are in the appendix. Results are based on instrumental variable regressions (environmental regulation gap is instrumented by the gdp/capita gap.).

Appendix:

Data description:

Bilateral trade flows are taken from the "Trade and Production Database " by Olarreaga and Nicita (2001). Imports for 67 developing and developed countries are available at the 4-digit ISIC level (see appendix A1 for a country-list). In order to transform these simple bilateral trade flows into the pollution content of imports we need some measure of pollution intensity by sector. For this purpose we use the World Bank's "Industrial Pollution Projection System" (IPPS). These IPPS coefficients allow us to estimate the amount of pollution (in pounds or kilograms) emitted per dollar of production or in our case of imports. In total 16 different pollutants (some are overlapping, see appendix A4 for a detailed list of these pollutants) are proposed. Concerning the exact measure of pollution we use the lower bound estimation of pollution by value of output. The IPPS coefficients are strictly speaking only available for 1987 for US industries. Assuming away the technique effect (we know this is a very strong assumption) we apply them to other countries and periods.

Bilateral dummy variables, distance and GDP per capita are taken from Andrew Rose's webpage and completed by the authors with the CIA's World Factbook. The common religion variable is basically a correlation coefficient between the religion matrices of the two trading partners (this variable-construction is inspired by Helpman et al, 2004). Endowment data are extracted from Sandeep Mahajan (PRMEP), World Bank 2001. Data on CO2 emissions in kg per 1995 PPP $ of GDP is taken from the World Bank WDI-CD-ROM (2004).

The database for the maximum lead content in gasoline has been elaborated by Grether and Mathys (2002) on the basis of Octel's Worldwide Gasoline Survey. More precisely the average has been worked out by using different types of gasoline and weighting them by their market share. Therefore, the proxy constructed takes into account the importance of the different types of gasoline in the overall market. If one admits that it is generally more costly to produce gasoline with low lead contents, the selected variable represents not only the maximum lead content observed, but also, and this is the important feature, in some sense the enforced legal limit of lead content in gasoline. Since it is impossible for the moment to get a good global index of environmental stringency for a large set of countries, the average maximum lead content represents at least one of the most important environmental policies. Damania et al (2000) qualified the lead content in gasoline as the "most viable dynamic consumption proxy" for environmental stringency at the country level.

In order to get an idea about the change over time in the analysed relationship, results are only reported for two periods. Each period is defined as the average over three years (1986-88 and 1994-96). The period choice is guided by data availability in general and maps the "IPP coefficient year" for the first period.

Table A1

Countries in the sample

Argentina	Japan
Armenia	Kenya
Australia	Korea, Rep.
Austria	Kuwait
Bangladesh	Sri Lanka
Bulgaria	Latvia
Bolivia	Macao, China
Canada	Morocco
Chile	Moldova
China	Mexico
Cameroon	Malawi
Colombia	Malaysia
Costa Rica	Netherlands
Cyprus	Norway
Denmark	Nepal
Ecuador	New Zealand
Egypt, Arab Rep.	Pakistan
Spain	Panama
Ethiopia	Peru
Finland	Philippines
France	Poland
United Kingdom	Portugal
Germany	Romania
Greece	Singapore
Guatemala	Sweden
Hong Kong, China	Thailand
Honduras	Trinidad and Tobago
Hungary	Turkey
Indonesia	Taiwan
India	Uruguay
Ireland	United States
Iran, Islamic Rep.	Venezuela, RB
Italy	South Africa
Jordan	

Table A2

Variable	Description	Dimension*
BOR	Dummy variable whether the two countries share a common border	i,j
ΔCO2	Difference in CO2 emissions in kg per 1995 PPP $ of GDP (importer-exporter)	i,j,t
COL	Dummy variable whether the two countries have common colonial ties	i,j
DIST	Distance between main cities	i,j
ΔEN	Difference in the capital to labour ratio (importer - exporter)	i,j,t
g	Pollution intensities	s
IS	Dummy variable whether at least one country is an island	i,j
ΔLEAD	Difference in average maximum lead content in gasoline (importer - exporter)	i,j,t
LL	Dummy variable whether at least one country is landlocked	i,j
LNG	Dummy variable whether the country contries share a common language	i,j
M	Imports (country i imports from country j)	i,j,s,t
REL	Correlation coefficient beteen the religion matrices	i,j

Note: * i: importer country, j: exporter country, s: pollutant, t: time

Table A3

Dirty		Clean	
ISIC 3-digit	Description	ISIC 3-digit	Description
341	Paper and products	321	Textiles
351	Industrial chemicals	382*	Machinery except electrical
369	Other non-metallic mineral products	383*	Machinery electrical
371	Iron and steel	384	Transport equipment
372	Non-ferrous metals	385	Professional and scientific equipment

Note: * These sectors have been classified as overall clean. When only looking at pollution intensity in heavy metals however they are on ranks 8 and 9 respectively.
Source: Copeland and Taylor (2002).

Table A4

IPPS-Pollutants - by value of output, lower bound		Pollution share of dirty sectors (in %)*	Pollution content growth rate (in %)**
TPAI	Toxic pollution intensity - AIR	58	116
TPL	Toxic pollution intensity - LAND	78	102
TPWT	Toxic pollution intensity - WATER	93	94
TPTT	Toxic pollution intensity - TOTAL	72	107
MPAI	Toxic metal pollution intensity - AIR	11	94
MPL	Toxic metal pollution intensity - LAND	86	95
MPWT	Toxic metal pollution intensity - WATER	89	96
MPTT	Toxic metal pollution intensity - TOTAL	86	95
S2AI	SO2 - AIR	76	90
N2AI	NO2 - AIR	71	96
COAI	CO - AIR	62	67
VOAI	Volatile organic compounds - AIR	50	106
FPAI	Fine particulates - AIR	80	98
TSAI	Total suspended particulates - AIR	66	96
BOWT	Biochemical oxygen demand - WATER	82	78
TSWT	Total suspended solids - WATER	93	89

Note: * Dirty sectors account for 16% of total imports.
** Growth rate between period 1(1986-1988) and period 2 (1994-1996).
Growth over the same period in imports: 129%.