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Unravelling the Worldwide Pollution Haven Effect[1]

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Abstract

This paper tackles the "pollution haven" argument by estimating the pollution content of imports (PCI). The PCI is then decomposed into three components: (i) a "deep" component (i.e. traditional variables unrelated to the environmental debate); (ii) a factor endowment component and (iii) a "pollution haven" component reflecting the impact of differences in environmental policies. The estimation is carried out for 1987 for an extensive data set covering 10 pollutants, 48 countries and 79 ISIC 4-digit sectors. … /…

JEL Classification numbers: F18, Q56
Key Words: Trade and the environment, pollution haven effect, factor endowment effect

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Unravelling the Worldwide Pollution Haven Effect[1]

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Abstract

This paper tackles the 'pollution haven' argument by estimating the pollution content of imports (PCI). The PCI is then decomposed into three components: (i) a 'deep' component (i.e. traditional variables unrelated to the environmental debate); (ii) a factor endowment component and (iii) a 'pollution haven' component reflecting the impact of differences in environmental policies. The estimation is carried out for 1987 for an extensive data set covering 10 pollutants, 48 countries and 79 ISIC 4-digit sectors. Decompositions based on cross-section econometric estimates suggest a significant pollution haven effect which increases the PCI of the North because of stricter environmental regulations in the North. At the same time, the factor endowment effect lowers the PCI of the North, as the North is relatively well-endowed in capital and pollution-intensive activities are capital intensive. On a global scale, because the bulk of trade is intra-regional with a high North-North share, these effects are small relative to the 'deep' determinants of the worldwide PCI. In sum, differences in factor endowments and environmental policies have only marginally affected the PCI of world trade at the end of the eighties.

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1. Introduction

For the environmentally minded, globalization reflected in rising trade shares in world GDP is worrisome, directly because the activity of trading itself generates pollution, and indirectly because lower environmental standards generate a comparative advantage in "dirty" industries for developing countries. In this context, globalization, which reduces transport costs and/or trade barriers, would shift investment and production of "dirty"goods to the South. As a result, globalization would lead to an increase in the pollution content of imports (PCI) by the North in conformity with what has been called the "pollution haven (PH) hypothesis" (henceforth PHH), and to a worldwide increase in the production of dirty products. Likewise, the literature has emphasized that a tightening of environmental standards in the North would lead industries to relocate to the South according to what is referred to as the "pollution haven (PH) effect". Overall, it is fair to say that empirical support for the PHH is weak, while the PH effect, which is often taken for granted has, apart from recent empirical support for the US, also been elusive.[3]

In his review of the state of knowledge on the PHH, Taylor (2005) points out that the literature lacks a compelling multi-country test of the PHH noting that the challenge for empiricists is to develop "clever methods that eliminate the need for some of the data". This paper is a first step in this direction. We argue (with some supporting evidence) that one can assume constancy in emissions per unit of labor. This allows us then to carry out a systematic global estimation of the pollution content of trade across all industrial sectors in which we disentangle the role of factor endowments and environmental policies from the more fundamental (or "deep") determinants of bilateral trade. However, because this assumption is strong, we also check that results still hold in the case of SO_2, the only pollutant for which emission data are available across countries and sectors.

To our knowledge, this global exercise is novel. As an example of what transpires from our estimates, consider the usual version of the PH effect identified in the literature. Because of a

[3] Although the PH effect is obviously a worldwide issue involving rich and poor countries, faced with lack of data, researchers have conducted their investigations by carrying out "partial" studies. Effects contributing to the location of economic activity (see the illustrative example in section 2) have often been analyzed in the context of firm case studies (e.g. Eskeland and Harrison (2002)) or case studies of a particular pollutant (e.g. Antweiler et al. (2001) for SO_2 emissions). Several studies on the US controlling for unobserved heterogeneity and the endogeneity of environmental policy have detected a significant PH effect (Cole et al (2005), Ederington et al (2004, 2005) and Levinson and Taylor (2008) using a panel data set of US industries). When covering more countries, the analysis is often limited to specific sectors (e.g. Cole and Elliott (2003)) with less clear-cut results.

shift in comparative advantage, a tightening of Northern environmental standards will increase the pollution content of imports by the North. But what about the South? In reality, developing countries are also importing dirty products, and they may even be larger importers of those goods if one takes into account the fact that highly polluting activities are often capital-intensive (referred to as the factor-endowment (FE) effect in the literature). So a tightening of Northern environmental standards will also decrease the pollution content of imports by the South, leading to an ambiguous change of the global pollution content of North-South trade. But composition effects do not stop here since trade includes intra-regional (i.e. North-North and South-South) trade. The framework proposed in this paper weighs the importance of the PH and FE effects taking into account composition effects that have been ignored so far in the literature.

Although we carry out robustness checks, data limitations force us to make assumptions about emission intensities so that it should be seen as first-time estimates of orders of magnitude of the PHH for a large set of countries in the late 80s, taking into account the following issues discussed in the debate. First, both PH and FE effects are quantified in a setting with a large set of developed (North) and developing (South) countries. Second, 79 4-digit manufacturing sectors are covered (not only the five dirtiest usually aggregated into one sector) and the analysis is carried out for 10 categories of pollutants. Third, to identify the PH effect, we use the lead content of gasoline (and other indicators) as a proxy for environmental stringency used in lieu of income per capita. Finally, a flexible gravity-type framework provides a good control for non-environment-related determinants of the pollution content of trade.

Section 2 discusses briefly the PH and FE effects, arguing that they can be usefully captured by the pollution content of trade (in our case, the pollution content of imports (PCI)). Section 3 constructs estimates of the PCI for 10 pollutants for a large cross-section of countries and industries accounting for roughly 60% of world trade. Section 4 estimates a model of bilateral trade in emissions (one for each pollutant) in which factor endowments, environmental policies, and `deep' determinants (i.e. all remaining determinants) are separately identified. These estimates then serve to decompose the relative importance of the PH and FE effects in the debate on the PHH. In addition to standard robustness checks on the main dataset, section 5 drops the assumption of constancy of emissions per worker and introduces alternative proxies for environmental regulation. Section 6 concludes.

2. The Pollution Content of Trade: A Framework

A simple example serves to introduce the notion of the pollution content of trade, measured here by the pollution content of imports (PCI). The example illustrates how the PCI serves to analyse the trade and the environment relationship by identifying a *PH effect* and a *FE effect*. We then present a framework of bilateral commodity trade that is useful to link the PCI to underlying determinants.

2.1 The Pollution Haven Effect: An Illustrative Identification

To fix the terms of the debate about the PH effect, and to motivate the choice of the pollution content of imports (PCI), consider the following simple hypothetical example in a Heckscher-Ohlin framework.[4] Two countries, North (N) and South (S), produce two goods, a `dirty' and a (completely) `clean' good, with pollution per unit of output of the dirty good being initially identical in N and S so that both countries are the same in all respects except that N has a higher income per capita than S. Assume then that environmental quality is a normal good. Stricter environmental standards in N will lower emissions per unit of output and abatement costs will raise the unit price of the dirty good. N will then import the dirty good and hence its trade will be "embodied" with emissions (i.e. $PCI_{NS} > 0$). Conversely, S will import the clean good from its partner and so the PCI of S will be zero as there is no intra-industry trade in a Heckscher-Ohlin setting (i.e. $PCI_{SN} = 0$). Therefore, in this two-commodity world, the PCI of N from S is positive ($PCI_{NS} > 0$) and the PCI of S from N is zero ($PCI_{SN} = 0$) since S imports the clean good. Differences in environmental standards alone lead to trade and to an increase in world pollution since the opportunity to trade has led to a shift in the production of the dirty good to S.

Next, consider two experiments involving the gains from trade specialisation. First, consider globalization via a reduction in transport costs, or a reduction in trade barriers. This will lead S to specialize in the production of dirty products. Globalization thus increases PCI_{NS} in conformity with what has been called the PH hypothesis (some of the previously dirty production in N is now carried out in S under less-stringent environmental standards). As a

[4] We could have carried out the analysis by measuring the pollution content of exports. Since the econometric analysis is carried out on bilateral trade, both approaches are in effect equivalent. Because export data are less reliable, we use imports to minimize measurement errors.

second experiment, consider a tightening of environmental regulations in N. This is also expected to lead to a relocation of dirty industries from N to S, increasing PCI_{NS} further through what is referred to as the PH effect in the literature.

Bring in now factor endowment differences, supposing that dirty industries are capital intensive (as assumed in Copeland and Taylor (2003)) and that N is relatively well-endowed in capital. If the PH effect was small (as suggested by recent US-based evidence mentioned above), then the FE effect on comparative advantage could well dominate. Assume this to be the case. Then, S will be importing the dirty good although it has lower environmental standards, a configuration referred to as reflecting the FE hypothesis according to Copeland and Taylor (2004).

Starting from this new configuration, consider again the two experiments above. A reduction in transport costs and/or trade liberalization, might then lead dirty activities to move to N, resulting in an increase in dirty imports of S from N. Conversely, a tightening of environmental policy in N will have the reverse effect, with dirty activities moving to S and increasing PCI_{NS}.

Clearly in a multi-commodity world, PCI_{NS}, $PCI_{SN} \neq 0$, and if the relative strength of the PH effect dominates, one would expect to observe $PCI_{NS} > PCI_{SN}$. Thus, the relative strength of the PH versus the FE effect is a determinant shaping the worldwide allocation of the PCI between groups of countries. It also plays a crucial role regarding the impact of globalization or environmental policy changes on the pollution content of trade.

To get a full picture of the factors underlying the evolution of the worldwide pollution content of trade, scale (N and S have different economic weight and both may grow) and technique (abatement activities are different in N and S and vary across time) effects should also be factored in, as well as differences in emission intensities across commodities. And since the debate on trade and the environment is usually couched in terms of the contribution of rich and poor countries, compositional effects across regions should also be taken into account. The framework below shows how this can be done.

2.2 Framework

Any suitable framework for a positive analysis of the PHH needs to make a distinction between clean and dirty sectors in terms of their damage to the environment and to link environmental damage directly to production activities. This is best done by embedding emission intensities per unit of activity in a multi-sector bilateral trade framework at the industry level. This allows the exploitation of the variance in the data on commodity trade and on emission intensities.

A recasting of Romalis (2004) provides this framework. He considers a two-region (North and South) setting in which countries are identical in each country grouping and in which preferences are represented by a single consumer sharing identical homothetic preferences across all countries. In each country, a continuum of industries are ranked by factor intensity (in his case, skilled and unskilled labor and in ours capital and labor) with production taking place under monopolistic competition with increasing returns to scale. Firms can costlessly differentiate their products. Transport costs lead to a departure from factor price equalization which pins down the trade structure, while monopolistic competition gives rise to N-S intra-industry trade. Romalis (2004) produces evidence in support of his model showing that a typical Northern's country market share of skilled intensive products rises with the skill-intensity of the industry. Translating his results to our setting, a typical Northern country's market share of capital-intensive pollution-intensive products rises with the capital intensity of the industry.

For our purposes, the combination of transport costs and monopolistic competition in Romalis' model results in predictions about the location of production and bilateral trade in each industry. Trade shares depend on the interaction of factor intensities and relative factor costs which in turn depend on relative factor abundance and policies. To translate these predictions into our bilateral setting, let M_{ijs} denote imports of sector s by country *i* from country *j*, Δkl_{ijs} the differences in capital-labor intensities for industry s, and $\Delta\theta_{ij}$ the difference in the stringency of the environmental policies between i and j (assumed to have the same impact on emissions across sectors). Let Ω_{ij} capture other exogenous (or "fundamental") determinants of bilateral trade at the national level, which in our gravity-type approach include distance and other country-specific determinants of bilateral trade. Then the model can be expressed as:

$$M_{ijs} = f\left(\Omega_{ij}, \Delta kl_{ijs}, \Delta\theta_{ij}\right) \quad (1)$$

To establish the desired link between trade volumes and the pollution content of trade measured by the PCI, we disaggregate across pollutants and sectors, the disaggregation across sectors to recognize that the usual two-sector "dirty/clean" distinction is insufficient.[5] As usual, there is a trade-off between the variance in the data by proceeding at a disaggregate level and introducing measurement errors that lead to less precise and less robust results.

Let then emissions per US dollar of production in country *j*, sector *s* and pollutant *k* be given by g^{k}_{js} and define two PCI measures: (i) total import-embodied emissions across sectors, Z^{k}_{ij}, (expressed in terms of physical units of pollution) and average emission intensities, G^{k}_{ij}, (expressed as physical units of pollution per one US dollar of imports). The two PCI measures of country *i* from country *j* for pollutant *k*, are then given by:[6]

$$Z^{k}_{ij} = \sum_{s} g^{k}_{js} M_{ijs}; \quad G^{k}_{ij} \equiv \frac{Z^{k}_{ij}}{M_{ij}} = \sum_{s} g^{k}_{js} \mu_{ijs} \quad (2)$$

where $M_{ij} = \sum_{s} M_{ijs}$ and μ_{ijs} is the share of sector *s* in country *i* imports from country *j*. For each pollutant, the total PCI indicator (similar indicators has been previously used by Antweiler (1995) and Ederington et al. (2004)) and the average PCI are used in the econometric estimates. In our view, changes in the volume of pollution embodied in worldwide trade (i.e. in PCI) is the simplest, most direct step to do in the analysis of the PH effect.

[5] The traditional approach relies on the less accurate comparison between "clean" and "dirty" sectors. It is true that, at the 3-digit ISIC level, the group of "dirty" sectors (reported in table A2 in Appendix 2) does not seem to change much across pollution criteria (e.g. actual emissions vs. abatement costs, see Mani and Wheeler (1997)). However, the definition of "clean" sectors is more ambiguous, and the intermediate sectors that are dropped from the usual analysis of clean vs. dirty industries often represent a substantial part of the PCI (up to 50% for some pollutants according to our estimates, see table A3 in Appendix 2). Moreover, at the 4-digit ISIC level, the classification of dirty sectors is not robust across pollutants. Two examples taken from the IPPS coefficients of the World Bank, establish the superiority of our approach. Take first the manufacture of leather products (ISIC 3233) which is one of the cleanest activities in terms of SO_2 released in the air, but also one of the most polluting ones in terms of metal toxic pollution. Take next sugar factories and refineries (ISIC 3118): it has the opposite pattern, releasing much SO_2 in the air, but negligible toxic pollution. Overall, more than a quarter of ISIC 4-digit categories exhibit a similar pattern, ranking in the top ten most polluting sectors according to one pollution criteria and among the ten cleanest according to another.

[6] The *average* pollution content can also be called average pollution *intensity*.

3. Measuring the PCI

The PCI measures in section 2 are now constructed for a sample of 48 countries (29 developing and 19 developed countries) using sectoral data on emissions for the US for 1987 which is the only source of comprehensive data on emissions for a large number of pollutants.[7] These emissions coefficients are available from the US IPPS for 14 pollutants (here aggregated into 10 pollutants - see Table A3 in the Appendix). They are computed for 79 4-digit ISIC industries (see Hettige et al. 1995).[8]

It is clear that having emissions coefficients for only one year is a major drawback and that applying US coefficients to a large sample of countries that includes developed and developing countries is problematic. How we deal with this problem will be explained shortly. While estimations and decompositions are carried out for 10 pollutants, to save space we discuss results for three pollutants widely used in other studies: sulfuric acid in the air (SO_2), total toxic pollution (TPTT) and biological oxygen demand in water (BOWT) and report the decompositions for all pollutants in figure 2. All three pollutants generate relatively small trans-border externalities beyond those embodied in trade.[9]

Emission intensities in the IPPS database are only reported for the US, but we have to apply them to all countries in the sample. For the reasons discussed below, we assume constancy of emission intensities per worker across countries. Consider first the following supporting evidence on SO_2. Olivier and Berdowski (2001) have constructed country-specific SO_2 emission coefficients for a large sample of countries on the basis of data collected by for a small number of manufacturing sectors. Using several methods, Grether, Mathys and de Melo (2009) disaggregate this data into 7 sectors and 62 countries and show that, for SO_2 at least, emissions per unit of *labor* are similar across Northern and Southern countries while there is a large difference in emissions per unit of *output* between North and South (see Figure 1).

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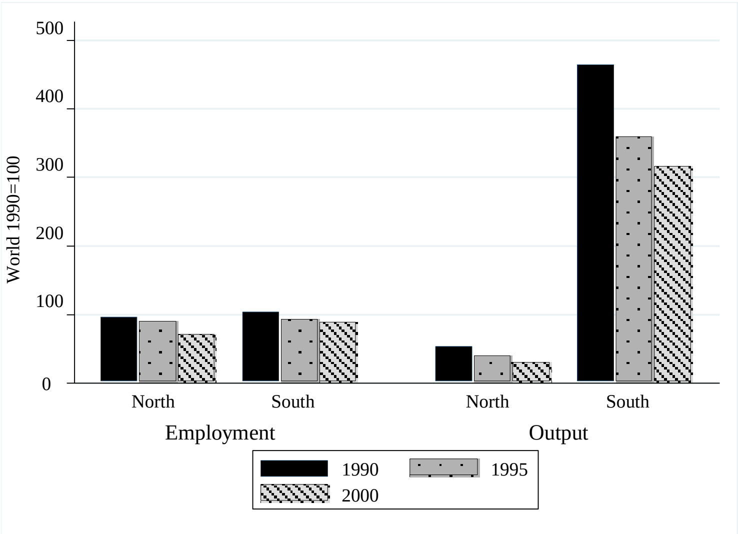
[7] See Appendix table A1 for a list of the countries.

[8] Variables are described in Appendix 1 and Appendix table A6.

[9] SO_2 is mainly emitted by fossil fuel combustion. It may cause respiratory diseases and damage trees and crops. It is also a prime source of acid rain, which damages forests and buildings and contributes to the acidification of lakes and streams. Toxic pollution is measured as toxic chemicals in air, land and water (the rank correlation between the total measure and the media-specific measure is 0.93 for air, 0.87 for land and 0.46 for water). It causes damage to internal organs, neurological functions and can result in decreased hutching success, reproductive problems and cancers. Biological oxygen demand in water measures how much oxygen is being used by aerobic microorganisms to decompose organic matter (e.g. dead plants, leaves, manure, sewage, food waste). If these bacteria use too much of the dissolved oxygen, then not enough will be left for other organisms.

Figure 1: SO_2 Emission Intensities for North and South



Note: North: United States, Canada, High income Asia and Europe.

South: Latin America, Africa and Low income Asia.

Second, using this same SO_2 data, we searched for a systematic relation between emissions per capita and development characteristics. Sector-specific White-robust regressions using PPP GDP per capita[10] as the explanatory variable confirm the pattern in table 1, i.e. that intensities per USD are significantly lower in richer countries. However, when intensities per worker are used instead of emissions per dollar of output as the explained variable, the coefficient is non-significant. Results (reported in Appendix table A4) suggest that emissions per worker are roughly constant across countries (indicating that higher emissions per capita in the South are compensated for by lower labor productivity in the South since $e_X \equiv E/X$, $a_L \equiv L/X$, $e_L \equiv E/L$, then $e_X \equiv e_L a_L$).[11]

Third, and again on the basis of the same SO_2 data, section 5.2. shows that the orders of magnitude suggested by the present paper do not depend on whether emissions per worker are kept fixed or allowed to vary across countries.

[10] GDP per capita square terms turn out not to be significant.

[11] In the absence of factor price equalisation through trade, if within-sector differences in technology are Hicks neutral, a labor-abundant poor country will use a more labor intensive technique of production. Thus constant emissions per unit of labor would be consistent with higher emission intensities per unit of output in low-income countries

Fourth, the constancy of emissions intensities by worker is in accordance with the evidence in Hettige et al (2000) who found that emissions per employee are roughly constant across countries for one of our pollutants, biochemical oxygen demand in water (BOWT).

On the basis of this evidence, we adjust the US per employee IPPS coefficients, $e^{k}_{L,US,s}$, by each country's industry labor-output ratio $a^{S}_{L,J} \equiv L_{js} / X_{js}$, i.e. $g^{k}_{js} = e^{k}_{L,US,s}\left(a^{S}_{LJ}\right)$ which amounts to assuming a constancy of emissions per unit of labor (section 5 uses the country-specific SO2 emission intensities to check the robustness of our results to this assumption. Table 1 summarizes for the two country groupings (North and South), the main factors at stake: the constructed indices of PCI on the assumption of the constancy of e_L, the proxy for the stringency of environmental policy, and factor endowments (specific variables that are used are explained and justified in section 4).

Three patterns stand out in the data. First, as expected, the proxy indicator for environmental policy - the lead content of gasoline - indicates a much more stringent environmental policy in the North, and even if this is an imperfect proxy, the difference in average values is large suggesting room for strong PH effect in the data. Second, as would be suggested if FE effects were important, there is a great difference in the average capital-labor endowment ratios between the two groups of countries. Third, again not surprisingly, the volume of trade is much larger for the North, suggesting that composition effects might be important depending on the pattern of trade of the North. This is further confirmed by the share of intra-regional trade figures in parenthesis in total imports for both the North and the South. For both group of countries, inter-regional trade is only about 10% of total trade.

Finally, the bottom of the table reports the `pollution haven ratio' for each one of the three pollutants defined for pollutant k as the ratio of the average PCI for high-income (denoted by subscript `N') to low-income (denoted by subscript `S') countries (for the PH-ratios of the remaining pollutants, see Appendix table A3):

Table 1:Environmental Stringency Index, Factor Endowments, Imports and Pollution-Haven Ratios by Country Grouping

Variable (units)	Statistics	North** (19 countries)	South** (29 countries)
Lead Content			
(Grams / Gallon)	Mean	0.24	0.58
	(C.V.)	(0.76)	(0.43)
Capital/Labor			
(1987 Thousand US Dollars	Mean	88.94	9.67
per employee)	(C.V.)	(0.38)	(0.89)
Imports*			
(Million Current US Dollars)	Mean	930 (815)[a]	99 (92)[b]
	(C.V.)	(1.34)	(1.30)
PCI-BOWT*			
(Million Pounds)	Mean	1.19	0.17
	(C.V.)	(1.29)	(1.00)
	PH-Ratio[c]	**0.89**	
PCI-SO_2*			
(Million Pounds)	Mean	7.24	1.27
	(C.V.)	(1.31)	(1.32)
	PH-Ratio[c]	**0.67**	
PCI-TPTT*			
(Million Pounds)	Mean	5.39	0.86
	(C.V.)	(1.18)	(1.11)
	PH-Ratio[c]	**0.63**	

Notes: Data are averages over 1986-1988. PH-Ratios for the remaining pollutants are reported in appendix table A3.

* Bilateral data averaged by importer.

** The split by income group used 11,000$ as break point which corresponds to the trough in the bimodal distribution. See table A1 for the list of countries.

[a] N-N; [b] S-S trade in parenthesis;[c] See equation 3 for the definition.

C.V.: Coefficient of variation, PCI: Pollution content of imports, BOWT: Biological oxygen demand in water, SO_2: Sulfur dioxide in the air, TPTT: Total Toxic Pollution

$$PH^k = \frac{G_N^k}{G_S^k} \tag{3}$$

According to the reasoning in section 2.1, should the PHH find support in the raw (but constructed) data, and should most trade be inter rather than intra-regional, one would expect to find $PH^k > 1, \forall k$. The presumption here is that the PH effect dominates the FE effect. In fact, as shown in the bottom of the table, the opposite is the case for all three pollutants reported in the table (but also for the other pollutants). To go further and elucidate why the average PCI is systematically lower in the North (i.e. $PH^k < 1, \forall k$), one needs to disentangle and take out the impact of the fundamental determinants of trade that are embodied in the constructed PCI. It could well be that the PCI is mainly determined by these more fundamental determinants of trade patterns than those identified in the PHH debate.

4. Unraveling the Pollution Haven Effect

To disentangle the correlates of the PCI, we estimate the relation suggested by equation (1). Assuming that determinants enter multiplicatively and omitting pollutant superscript *k*, the PCI of country *i*'s imports from country *j*, Z_{ij}, can be decomposed into a "deep" determinant component, Ω_{ij} (i.e. the import-embodied pollution that would occur for reasons unrelated to environmental policy and endowments), an FE effect, κ_{ij}, and a PH effect, ℓ_{ij}:

$$Z_{ij} = \Omega_{ij} \kappa_{ij} \ell_{ij} \tag{4}$$

This multiplicative form between the three components is easy to handle, particularly in a gravity-like framework and it is also convenient to carry out the decomposition that is proposed in the next section. We proceed in two steps. First, we regress for each pollutant k, the bilateral PCI, Z_{ij}, on a set of explanatory variables capturing the effects identified in equation (4). In a second step, we use the estimated coefficients to decompose the total predicted PCI for each pollutant into the three components, namely "deep", "FE", and "PH" effects.

Estimation uses 1987 data and is based on a gravity-type equation (5) which is convenient to include the "fundamental" determinants of bilateral trade. The PH effect is captured by differences in the lead content of gasoline presented in table 1.[12]

The capital-labor ratio serves as proxy for endowment differences, i.e. captures the FE effect. To avoid erroneously attributing variations in bilateral PCIs to the two effects of interest, it is important to have as complete as possible a set of control variables in the vector of "deep" determinants. Thus the sets of α and β coefficients control for these "deep" determinants of bilateral trade, the former set relating to gravity-type controls, and the latter including other controls. The gravity-type controls include log distance *($DIST_{ij}$)*, the extent of the potential market *($MKT_{ij}=ln(GDP_i * GDP_j)$)*, proxied by the product of GDPs (since these cannot be entered individually in the presence of fixed effects), common religion *(CR_{ij})*, common language *(CL_{ij})* and landlockedness *(LL_{ij})*. Importer *(DM_j)* and exporter *(DE_i)* dummy variables control for country-specific omitted determinants.

$$\begin{aligned} ln Z_{ij}^{k} &= \alpha_o + \alpha_1 DIST_{ij} + \alpha_2 MKT_{ij} + \alpha_3 CR_{ij} + \alpha_4 CL_{ij} + \alpha_5 LL_{ij} \\ &+ \beta_{1i} DE_i + \beta_j DM_j + \beta_3 \Delta SK_{ij} + \beta_4 \Delta HK_{ij} + \beta_5 \Delta COAL_{ij} \\ &+ \beta_6 \Delta OIL_{ij} + \gamma_1 \Delta LEAD_{ij} + \gamma_2 \Delta KL_{ij} + \varepsilon_{ij} \end{aligned} \tag{5}$$

As further control variables, we include proxies for differences in natural resource endowments across countries, oil production ($\Delta OIL_{ij} = ln\left(\frac{OIL_i}{OIL_j}\right)$) and coal production ($\Delta COAL_{ij} = ln\left(\frac{COAL_i}{COAL_j}\right)$) since it is known that many pollution-generating activities are linked to the weight-reducing activities associated with the processing of primary products which are natural-resource based and hence less sensitive to differences in environmental policies. We also include two measures of skills since it has sometimes been claimed that pollution intensive activities are also skill-intensive (see Cole and Elliott (2005)). The two variables are differences in the skill ratio (i.e. (skilled+ base skills)/unskilled labor)

[12] This index is a market-share weighted sum of the maximum lead content of different gasolines (see Grether and Mathys (2002) and appendix 1 for further details). It has been used by Hilton and Levinson (1998), Damania et al. (2003), Fredriksson et al (2005) and Cole et al. (2006) as a proxy for environmental policy.

$\Delta SK_{ij} = ln\left(\frac{SK_i}{SK_j}\right)$), and differences in the ratio of high skilled labor (skilled/base skills), ($\Delta HK_{ij} = ln\left(\frac{HK_i}{HK_j}\right)$). To sum up, one may expect these control variables to be related to the bilateral PCI, although their influence is ultimately an empirical matter.[13]
To these variables we add the PH and FE variables mentioned above, namely the difference in the maximum lead content of gasoline ($\Delta LEAD_{ij} = ln\left(\frac{LEAD_i}{LEAD_j}\right)$), and the difference in capital-labor ratios ($\Delta KL_{ij} = ln\left(\frac{KL_i}{KL_j}\right)$).

Equation (5) is estimated for each one of the ten pollutants for average values over the 1986-88 period and observations with aggregate bilateral trade below a threshold of 10,000$ are dropped (leading to a loss of 3% of observations). Results for the three selected pollutants are discussed below (results for the remaining seven pollutants are summarized in figure 2, see section 4.2).

Three objections come to mind when estimating (5) by OLS. [14] First, the results could be entirely driven by the volume of trade rather than the composition of trade. To address this potential shortcoming, we regress the average (G_{ij}^k) instead of the total PCI (Z_{ij}^k), thereby focusing only on the composition effect. As the trade volume dimension is absent, the traditional gravity-type control variables should in principle all disappear. However, we maintain distance as a regressor to control for the fact that dirty industries are predominantly weight-reducing activities (see supporting evidence in e.g. Grether and de Melo (2004)) and

[13] For reference, Antweiler, Copeland and Taylor (2001) estimate the correlates of per capita concentration intensities in 103 cities as:
$(z/N)_{kt} = \alpha_0(K/L)_{kt}+\alpha_1 Y_{kt} +\alpha_2((X+M)/Y)_{kt} +...$
where Y is GDP *k* is an index for 43 countries and *t = 1,16* years and +... indicates the inclusion of country fixed effects, interaction terms for the three RHS variables plus squared values of the three RHS variables. In this specification, α_0 and interaction terms capture composition effects, while α_1 captures the combined scale and technique effects and α_2 captures the trade-induced effect. Cole and Elliott (2003) estimate a fairly similar relationship, but with emission intensities per capita as the LHS variable.
[14] We checked for heteroskedacity by using the Poisson estimator suggested in Santos Silva and Tenreyro (2006) obtaining similar results.

hence might be particularly sensitive to transport costs. The alternative specification then becomes:

$$
\begin{aligned}
lnG_{ij}^{k} = &\tilde{\alpha}_o + \tilde{\alpha}_1 DIST_{ij} + \tilde{\beta}_1 DE_i + \tilde{\beta}_2 DM_j \\
&+ \tilde{\beta}_3 \Delta SK_{ij} + \tilde{\beta}_4 \Delta HK_{ij} + \tilde{\beta}_5 \Delta COAL_{ij} \qquad (6) \\
&+ \tilde{\beta}_6 \Delta OIL_{ij} + \tilde{\gamma}_1 \Delta LEAD_{ij} + \tilde{\gamma}_2 \Delta KL_{ij} + \tilde{\varepsilon}_{ij}
\end{aligned}
$$

Second, one could object to the inclusion of intra-regional trade in the context of an estimation of the PH effect which is supposed to operate between, rather than within, regions so that all intra-regional bilateral trade (i.e. N-N and S-S) should be deleted. Thus, as a robustness check, we also report estimates of (5) over a sample that excludes intra-regional trade. However, as intra-regional trade should also respond to the same determinants as N-S and S-N trade and since we are interested in capturing the PH and FE effects at the worldwide level, we consider that the relevant coefficient estimates for the decomposition exercise are those derived from the whole sample.

Finally, one could object that *LEAD* may be endogenous (as suggested by Ederington and Minier (2003) who found evidence that environmental policy has partly served as a substitute for protection using aggregate data). To deal with this potential problem, we also instrument *LEAD* by the UN's measure of Human development (the *HDI*). To be an appropriate instrument, the HDI has to be correlated with environmental regulation and orthogonal to the error term of the PCI regression. We expect that the HDI, takes into account different development dimensions of countries, will be directly correlated with environmental regulation (which it is) .Our maintained hypothesis is that the PCI is not directly affected by the HDI since environmental policies would be the main channels through which institutional and policy choices are likely to influence the PCI. So, in the absence of a better instrument, we stick to the HDI as an instrument for the potential endogeneity of the environmental policy proxy, checking robustness to the choice of environmental proxy in section 5.1, and arguing that environmental policy may not be a substitute for protection at the aggregate bilateral level.

4.1 Correlates of the PCI

Table 2 reports results for the two specifications (5 and 6), the two samples (world or NS only), and for the three selected pollutants: SO_2, BOWT, and TPTT. Overall, results are encouraging. Start with estimates of equation (5). First, the signs of the variables of interest are as expected in all specifications, and significant most of the time. The same comment applies to the gravity-related controls. For example, the coefficient on distance is negative and slightly higher than the "average" estimate of -1.0 from meta studies, which is what one might expect since weight-reducing dirty industries are more sensitive to transport costs than clean industries (see e.g. the estimates in Grether and de Melo (2004)). Likewise, common language and common religion enhances trade. Finally, landlockdness (0 if neither country in the dyad is landlocked, 1 if one is and 2 if both are) has a negative correlation with trade volume presumably via higher transport costs. As to the other controls for which we have no a priori expectations, they are only significant in some specifications.

Second, as to the comparison between OLS and 2SLS estimates for equation (5), coefficients do not change sign and, except for BOWT, are very similar in terms of significativity for all variables apart from LEAD, which becomes significant through the instrumentation.

In the first stage regression the coefficient of LEAD is -1.45 and significant at the 1% level. The F-statistics takes a value of 56.4 signifying the absence of a weak instrument problem. In the absence of other suitable instruments, we cannot test for the exogeneity of LEAD and we rely on the 2SLS estimates for the simulations reported below.

Table 2: Pollution Content of Imports Regressions, 1987

	Biochemical Oxygen Demand Water (BOWT)				SO_2 in the Air (SO_2)				Total Toxic Pollution Intensity (TPTT)			
	Total PCI		Av. PCI	NS PCI	Total PCI		Av. PCI	NS PCI	Total PCI		Av. PCI	NS PCI
	OLS	2SLS	2SLS	2SLS	OLS	2SLS	2SLS	2SLS	OLS	2SLS	2SLS	2SLS
Δlead	-0.16***	-0.32***	-0.39***	-0.39***	-0.02	-0.21***	-0.19***	-0.20***	-0.01	-0.21***	-0.20***	-0.21***
	[5.31]	[5.22]	[10.28]	[5.37]	[0.60]	[3.86]	[6.53]	[3.05]	[0.52]	[4.26]	[7.71]	[3.36]
Δ Capital/Labor	-0.11	-0.29***	-0.42***	-0.2	-0.18**	-0.16**	-0.36***	-0.44***	-0.19**	-0.12*	-0.41***	-0.32***
	[1.22]	[3.29]	[6.22]	[1.54]	[2.44]	[2.05]	[7.01]	[3.76]	[2.18]	[1.77]	[9.04]	[2.95]
Δ Skill Ratio[a)]	0.09	0.33**	-0.23*	-0.05	0.50***	0.47***	-0.14	0.18	0.38***	0.30**	-0.50***	-0.04
	[0.81]	[1.97]	[1.93]	[0.33]	[5.24]	[3.14]	[1.48]	[1.29]	[4.22]	[2.20]	[6.18]	[0.33]
Δ High Skill Ratio[b)]	-0.18	-1.89***	0.17	-1.20***	-0.62***	-2.08***	0.21	-0.97***	-0.43*	-1.78***	0.92***	-0.55**
	[0.75]	[7.64]	[0.91]	[4.59]	[3.17]	[9.44]	[1.46]	[4.08]	[1.91]	[9.01]	[7.30]	[2.45]
Δcoal	-0.02	0.01	-0.10***	0.14***	0.03**	0.04**	-0.09***	0.18***	0	0.01	-0.16***	0.14***
	[0.79]	[0.43]	[5.88]	[3.80]	[2.03]	[2.19]	[6.52]	[5.38]	[0.02]	[0.36]	[13.50]	[4.51]
Δoil	0.03	0	0.01	0.28***	0.05***	0.02	0.02	0.27***	0.04*	0	-0.01	0.22***
	[1.04]	[0.07]	[0.74]	[5.82]	[2.93]	[0.66]	[1.21]	[6.09]	[1.98	[0.18]	[0.51]	[5.12]
Distance	-1.34***	-1.34***	-0.24***	-1.55***	-1.32***	-1.32***	-0.20***	-1.51***	-1.25***	-1.25***	-0.11***	-1.39***
	[15.35]	[21.23]	[5.91]	[13.12]	[15.96]	[23.58]	[6.39]	[14.05]	[15.87]	[24.95]	[3.92]	[13.59]
GDP_i*GDP_j	0.94***	0.55***		0.61***	0.96***	0.59***		0.63***	0.93***	0.57***		0.61***
	[22.00]	[43.30]		[28.91]	[24.74]	[51.77]		[32.56]	[22.33]	[56.43]		[33.73]
Common Language	1.14***	1.14***		0.50***	1.00***	1.00***		0.70***	0.92***	0.92***		0.49***
	[7.52]	[8.24]		[2.93]	[6.74]	[8.15]		[4.53]	[6.79]	[8.34]		[3.37]
Common Religion	0.72***	0.72***		0.34	0.74***	0.74***		0.37*	0.67***	0.67***		0.35*
	[5.18]	[4.52]		[1.63]	[5.34]	[5.25]		[1.94]	[6.42]	[5.29]		[1.92]
Landlocked	-0.67**	-2.08***		-0.44	-0.46*	-1.57***		0.11	-0.54**	-1.54***		-0.43
	[2.49]	[7.67]		[1.33]	[1.99]	[6.52]		[0.35]	[2.11]	[7.13]		[1.50]
Observations	2107	2107	2107	1109	2107	2107	2107	1109	2107	2107	2107	1109
R-squared	0.73	0.73	0.34	0.78	0.74	0.74	0.47	0.8	0.78	0.78	0.49	0.81

Notes: Dependent variable (in log): Total PCI: Total bilateral PCI, Av. PCI: Average bilateral PCI, NS PCI: Total bilateral PCI between North and South.

Absolute value of t statistics in brackets, in 2SLS regressions lead is instrumented with the human development index, first stage F statistics are 48.50 for the average PCI regressions and 56.43 for the others, fixed effects are not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%, [a)] (skilled+base skills) / unskilled, [b)] skilled / base skills

When we abstract from volume effects, and hence focus on detecting PH and FE effects in the composition of bilateral trade (equation (6)), we still find the same signs for both variables of interest. Finally, estimates are sufficiently close when the sample is restricted to North-South bilateral trade flows indicating that the results of decompositions reported below would not be overly sensitive to the choice of sample. However in two out of three cases the contribution of the FE effect would be larger if we were to carry out decompositions based on this restricted sample.

In sum, we retain from the estimates in table 2 that the data support the presence of PH and FE effects, although the OLS estimates for LEAD are not significant in two cases. The average values of endowments and policies reported in table 1 allow one to deduce the sign of these effects on PCI_{NS} and PCI_{SN}. Thus, starting from the "deep" determinants of bilateral trade, the PCI_{NS} will be reduced through the `FE' effect because the North has a comparative advantage in dirty products. Likewise, because of more stringent environmental standards, the $PCI_{NS}$ will be increased through the `PH' effect. The opposite patterns will hold for PCI_{SN}. However, to go further, we need to take into account the fact that there is horizontal trade which will be reflected in PCI_{NN} and PCI_{SS} values with the worldwide effect being a weighted average of vertical and horizontal trade flows. We now carry out a decomposition of the PCI into its constituents parts.

4.2 Decomposing the PCI into the PH and the FE effects

For each region normalize the deep determinants of the PCI to unity. Then for each pollutant k, the total percentage increase in the PCI due to the FE and the PH effects will be given by:

$$1 + TOT = (1 + FE)\,(1 + PH) \quad (7)$$

where FE and PH are the respective percentage increases in the PCI due to each effect.

Decomposition results are reported in Table 3 for the three pollutants with overall decomposition results for the ten pollutants reported in figure 2 below. Take for example biochemical oxygen demand in water (BOWT). Starting from the base (or `fundamental') PCI, adding differences in factor endowments reduces the PCI by 4% while adding differences in environmental regulations increases the PCI by 11% so that taken together, the two effects increase the world PCI by 7%, which is also shown in figure 2. Next focus on the PH effect. The worldwide result (11% increase) is in fact a weighted average of the PH effect on intra-regional flows (13%) and the PH effect on inter-regional flows (1%), with corresponding weights of 88% and 12%. Similarly, the aggregate PH effect on inter-regional flows is decomposed into a Northern (173%) and a Southern (-70%) component, with import shares being respectively 29% and 71%.

Several patterns stand out in table 3. Start with row 1. As emphasized by participants in the PH debate, whatever the pollutant, Northern imports from the South display a significant PH effect resulting in a strong increase in the PCI. Likewise the FE effect is also estimated to have a significant impact on the PCI in the opposite direction. Move to row 2 which gives the corresponding decomposition for Southern imports from the North. A reverse pattern of similar magnitude is evident. As shown along row 3, these countervailing forces naturally tend to cancel out, so that FE and PH effects on overall trade are several orders of magnitude smaller than on isolated (either Northern or Southern) inter-regional trade. As could be expected, the net impact is driven by the Northern pattern, but the mitigating impact of the Southern PCI (at least more than a quarter of vertical PCI) should not be underestimated. Composition effects are also evident when comparing relative magnitudes in rows 4 and 5. First, intra-regional FE and PH effects are much smaller than corresponding inter-regional effects. Second, since 75% of the world PCI is accounted for by intra-regional trade, the overall effects are much smaller than those that one would obtain if considering only North-South trade as is done in typical case studies carried out for industrialized countries. These two results corroborate results by Ederington et al. (2006) who find stronger PH effects for inter-regional than intra-regional trade and conclude that because of the dominance of N-N trade in global trade, PH effects are likely to be small.

Finally, note that the relative strength of PH and FE effects is not invariant across pollutants, a result which is confirmed by the differences in estimates across pollutants in figure 2. For two out of the three pollutants of table 3, the PH effect dominates the FE effect whatever the type of imports considered, while for the third pollutant (biochemical oxygen demand), the PH effect is only dominated in the case of Northern imports from the South.

Figure 2 compares side by side the results of the decomposition for the 10 pollutants. Recall that the PHH is said to hold if the PH effect is positive and dominates the FE effect. No clear-cut verdict emerges as to the strength of the PHH since it holds for 4 (Biological oxygen demand, SO2, total suspended particulates and NO2) out of the 10 pollutants. For one pollutant, toxic metal pollution, both the FE and the PH effect go in the opposite direction of what would be expected. “Iron and steel” and “non-ferrous metals” are the two main polluting industries in this case and hence a possible explanation for this counter-intuitive result could be the fact that these are weight-reducing and hardly mobile industries (as also suggested in de Melo and Grether, 2004). For the remaining pollutants, effects are either small or support either the PH or the FE effect but not both.

These decompositions also provide an estimate of the possible reduction in the worldwide PCI if there were a complete harmonization of environmental policies, meaning that the world wide PH effect on the PCI could be suppressed, by equalising environmental regulation between countries. The harmonization effect can be approximately read off the relevant PH columns in table 3 by changing the sign (the exact estimate would be given by (-x/(1+x/100)) where x is the percentage change reported in table 3). For the three pollutants in table 3, harmonization of environmental policies would reduce the PCI by roughly 10% for biochemical oxygen demand and SO_2 and increase it by 3% in the case of total toxic pollution.

Table 3: Decomposition of the PCI into the FE and the PH-Effect (%)

			Biochemical Oxygen Demand Water (BOWT)			SO_2 in the Air (SO_2)			Total Toxic Pollution Intensity (TPTT)		
Row	**Import Flows [a)]**	**Number of observations**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**
1	**NS**	**544**	-68	173	-14	-44	114	20	-38	106	27
2	**SN**	**565**	127	-70	-33	61	-65	-44	42	-64	-49
3	**NS+SN**	**1109**	-19	1	-19	-13	15	1	-8	8	-1
4	**NN**	**342**	-1	13	12	-1	9	9	0	-3	-3
5	**SS**	**656**	-22	-16	-34	-1	-6	-7	-5	-9	-13
6	**NN+SS**	**998**	-2	13	11	-1	9	8	0	-3	-4
7	**World**	**2107**	-4	11	7	-3	10	6	-2	-1	-3
			Ω	**Ω κ**	**Ω κ ℓ**	**Ω**	**Ω κ**	**Ω κ ℓ**	**Ω**	**Ω κ**	**Ω κ ℓ**
8	**Share of NS in NS+SN**		75	29	79	70	45	83	63	42	81
9	**Share of NN in NN+SS**		97	98	98	95	96	96	95	95	95
10	**Share of NS+SN in World**		14	12	11	22	20	21	24	22	24

Notes:

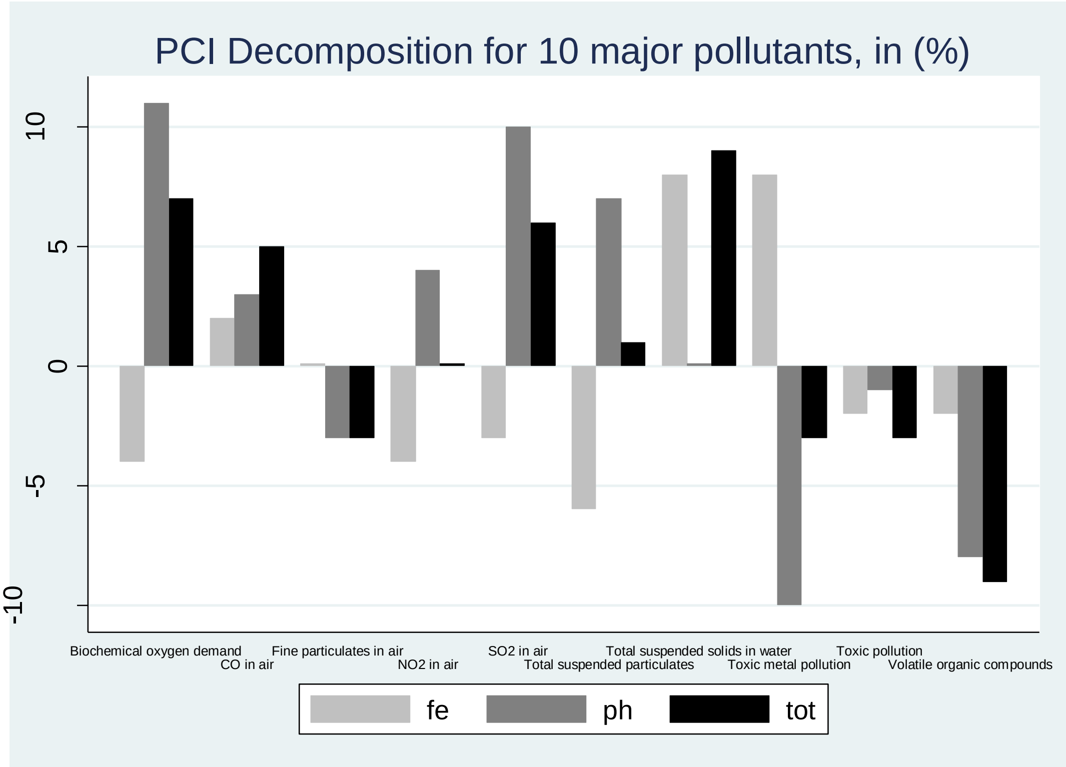
[a)] NS: North imports from the South, SN: South imports from the North, NN: North imports from the North, SS: South imports from the South.

Along rows: TOT = (1+FE)*(1+PH) -1. For example for row 7: (1-0.04)*(1+0.11)-1 ≈ 0.07. Due to rounding, the decomposition only holds approximatel.

Along columns: $AGG_v = \theta * CMP_1 + (1-\theta) * CMP_2$ where AGG_v is the aggregate effect (v = NS+SN, NN+SS, World) CMP_1 and CMP_2 are the two corresponding components and θ is the share of CMP_1 in the relevant PCI (**Ω** for the FE and the TOT effects, **Ω κ** for the PH effect , **Ω κ ℓ** is only reported for the sake of completeness).

For CO, NO2 and total suspended particulates a harmonization would also lead to decreased pollution of the world PCI while for fine particulates, toxic metal pollution and volatile organic compounds, an equalisation of environmental regulations would lead to increased PCI (for total suspended solids in water and toxic pollution, effects would be small). Note that in this exercise the relative level of regulations does not matter, because only differences between countries would influence trade flows while in a real-world policy scenario regulation levels would be of major importance.

Figure 2: The Pollution-Haven Hypothesis for 10 major pollutants, 1987



Notes:(TOT) is the sum of the factor-endowment (FE) and the pollution-haven (PH) effects according to the decomposition given by equation 7.

5. Robustness Checks

Two exercises are carried out. Section 5.1 computes confidence intervals and checks sensitivity to the selection of the GDP threshold used for the construction of income groups. Section 5.2 tackles the sensitivity of results for SO_2 emissions to dropping the assumption of the constancy of e_L and to the selection of two alternative proxies for environmental regulation.

5.1 Robustness check on the main dataset

As to the estimates in tables 2 and 3, three sensitivity tests suggest overall robustness. First, we computed confidence intervals for the predicted values of the different PCI levels. Results are reported in Appendix table A5. The sign of the individual effects does not change most of the time, but there are several changes in the total effects. Aggregate worldwide effects remain small, and one can conclude that we obtain the same orders of magnitude. Second, we checked for changes in the selection of per capita GDP threshold. Two alternative thresholds were considered to add or take away five countries to the original group of 19 Northern countries vs. 29 Southern countries. Results reported in Appendix table A6, show that the overall patterns are quite insensitive to this change of definition. Third, arguing that environmental stringency is endogenous to bilateral trade flows at the sector level is questionable. Indeed, one might argue that environmental stringency is less likely to be endogenous when bilateral trade data are used along with national environmental regulation. In fact, endogeneity would apply if environmental regulation were a substitute for protection. This would be most likely if either environmental regulation was sector specific and/or trade flows were only country and not country-pair specific. We therefore also report results based on the simple OLS regression (see table A7 in Appendix). Results are very similar.

5.2 Robustness to data availability: Results for SO_2 emissions[15]

Tables 4 and 5 report results of two explorations with SO_2 emission data for 2000 (again based on the data prepared in Grether et al 2009a). First, we introduce two alternative proxies for environmental stringency, namely, the environmental regulatory regime index (Esty and Porter, 2005) and the air pollution regulation index from the WEF's Global competitiveness report. These proxies are only available for recent years, and are not available for all countries and hence our sample is reduced to 39 (38 for the regulatory regime index) countries.[16] Second, we relax the assumption of the constancy of emission per worker (on the same set fo reduced countries).

[15] We thank two anonymous referees for having suggested this additional robustness check.
[16] For the detailed country list, see table A1 in the Appendix.

Table 4: Pollution Content of Imports Regressions for SO_2, 2000

	US emission coefficients				Country-specific emission coefficients			
	Air Pollution Regulation		Regulatory Regime Index		Air Pollution Regulation		Regulatory Regime Index	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Δ Environmental Stringency	1.96***	1.60***	1.44***	2.57***	2.68***	3.23***	1.13***	2.39***
	[5.04]	[4.11]	[5.89]	[10.06]	[6.94]	[7.56]	[4.78]	[8.56]
Δ Capital/Labor	-1.35***	-1.24***	-0.78***	-0.97***	-0.65***	-0.96***	-0.17	-0.39***
	[8.62]	[8.22]	[6.13]	[7.71]	[3.93]	[5.79]	[1.30]	[2.82]
Δ Skill Ratio	-0.28***	-0.33***	0.07	0.31***	-0.15*	-0.08	-0.33***	-0.07
	[3.54]	[4.02]	[1.01]	[3.44]	[1.77]	[0.90]	[4.55]	[0.66]
Δ High Skill Ratio	0.19***	-0.11	0.22	0.78***	0.02	0.18**	-0.04	0.60***
	[2.87]	[1.52]	[1.58]	[9.25]	[0.22]	[2.31]	[0.30]	[6.40]
Δ Coal	-0.08***	-0.27***	-0.08**	-0.13***	-0.13***	-0.27***	-0.21***	-0.26***
	[2.96]	[9.94]	[2.10]	[4.13]	[4.42]	[8.92]	[6.35]	[7.63]
Δ Oil	0.09***	-0.01	0.22***	0.27***	0.12***	-0.04	0.19***	0.25***
	[3.33]	[0.26]	[4.79]	[7.36]	[3.61]	[1.00]	[4.34]	[6.25]
Distance	-1.44***	-1.44***	-1.40***	-1.40***	-1.41***	-1.41***	-1.39***	-1.37***
	[20.84]	[22.76]	[18.91]	[20.31]	[18.85]	[20.37]	[17.40]	[18.39]
GDPi*GDPj	1.25***	0.45***	1.03***	0.48***	1.10***	0.48***	1.10***	0.49***
	[26.08]	[40.75]	[8.11]	[42.53]	[22.84]	[39.73]	[8.54]	[38.98]
Common Language	0.84***	0.84***	0.86***	0.86***	0.87***	0.87***	0.90***	0.90***
	[6.19]	[5.43]	[6.29]	[5.39]	[5.77]	[5.16]	[5.94]	[5.18]
Common Religion	-0.01	-0.12	0.09	0.10	-0.02	-0.02	-0.01	-0.01
	[0.20]	[0.19]	[0.74]	[0.78]	[0.39]	[0.34]	[0.09]	[0.09]
Landlocked	0.07	-0.36*	-0.45**	-1.47***	-1.10***	-1.90***	-1.10***	-2.24***
	[0.40]	[1.94]	[2.07]	[8.96]	[6.29]	[9.53]	[4.80]	[9.66]
Observations	650	650	600	600	650	650	600	600
R-squared	0.86	0.86	0.86	0.86	0.85	0.85	0.85	0.85

Notes:

See text for sample size. Dependent variable (in log): Total bilateral PCI.

Absolute value of t statistics in brackets, in 2SLS regressions the environmental index is instrumented with the human development index, first stage F statistic is 115 with the air pollution regulation index and 72 with the regulatory regime index. A higher value of the index implies a more stringent policy. Fixed effects are not reported.
* significant at 10%; ** significant at 5%; *** significant at 1%, [a] (skilled+base skills) / unskilled, [b] skilled / base skills

Table 5: Decomposition of the PCI into the FE and the PH-Effect (%): Results for SO_2 with two alternative measures of environmental regulation

				US emission coefficients						Country-specific emission coefficients					
				Air Pollution Regulation			Regulatory Regime Index			Air Pollution Regulation			Regulatory Regime Index		
Row	**Import Flows [a]**	**Obs. Air Reg.**	**Reg. Index**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**
1	**NS**	**165**	**154**	-86	118	-70	-77	321	-1	-80	472	12	-49	285	97
2	**SN**	**165**	**154**	163	-56	15	145	-81	-53	237	-84	-45	68	-81	-68
3	**NS+SN**	**330**	**308**	-41	-23	-54	63	-60	-34	-33	53	3	-8	53	40
4	**NN**	**110**	**110**	-3	4	1	-3	-6	-9	-2	12	10	-1	-5	-6
5	**SS**	**210**	**182**	-76	-11	-79	-62	-18	-67	-56	-3	-58	-28	-23	-45
6	**NN+SS**	**320**	**292**	-19	3	-16	-12	-7	-18	-28	7	-23	-11	-11	-21
7	**World**	**650**	**600**	-24	-1	-25	2	-22	-21	-29	17	-17	-11	1	-10

Notes: Decompositions using coefficient estimates reported in table 4. See table 3 for definitions and evaluation of the decomposition.

Regression results are reported in table 4. Columns 2-5 report results when US emission coefficients are applied to all countries, while columns 6-9 report corresponding results, when country specific emission coefficients are used. For each case, OLS and 2SLS results are reported. The variables of interest have always the expected sign (note that a sign reversal is expected for the first line in table 2, as a higher lead content means a lower environmental stringency) and are most of the time highly significant. Results are also very similar across the different specifications. Table 5 shows the corresponding decomposition results and confirms previous findings. Although composition effects lead to a variety of patterns at the aggregate level, results for the first two rows, which relate to North-South trade, are perfectly in line with those of table 3.

6. Conclusions

This paper contributes to the debate on trade and the environment by extending the usual case studies (one country or a few products) to a systematic analysis of the content of individual pollutants in global trade at the most disaggregated level for which one can hope to get available emission data. While the results share the limitations of other studies due to the absence of more systematic emission data, the paper goes beyond previous contributions that focus on a handful of "dirty" industries or a case study of a specific pollutant or a specific country. In our unraveling of the PH effect, we have controlled for the transport cost component of the PCI as well as other "deep" determinants of the bilateral pollution content of trade. This has allowed us to better isolate the role of differences in factor endowments and environmental policies. We do find evidence of traditional PH and FE effects that have often been elusive in the literature, although these effects cannot be said to be systematic nor quantitatively important or as robust as one would wish across all pollutants.

This said, the results suggest diversity in magnitudes across pollutants and a rather small contribution of the PHH factors in the overall PCI of world trade, notably because of composition factors usually not considered in the debate. Thus, for several pollutants, the PCI of the North is lower because on average its endowments are favorable to activities with high emissions and likewise its PCI is higher for other pollutants because of the probable delocalization of dirty industries to the South associated with stricter environment policies in the North. Yet, for each one of the 10 pollutants we find that these effects contribute to less than 10% of the overall determinants of emissions. Taken together, at least for 1986-88, it would appear that differences in factor endowments and environmental policies have only marginally affected the pollution content of world trade although the impact has been stronger on vertical (North-South) trade flows. These results carry over for one pollutant, SO_2, for which country-specific emissions and alternative environmental proxies are available for the year 2000. Much like in an earlier debate around the Leontief paradox regarding the factor content of US trade, better data will be required to get a firmer grasp of the quantitative importance of the effects involved.

References

Antweiler W. (1996), "The Pollution Terms of Trade", *Economic Systems Research*, Vol. 8 (4), pp. 361-365.

Antweiler, W., B. Copeland and S. Taylor (2001),"Is Free Trade Good for the Environment? " *American Economic Review*, Vol. 91(4), pp.877-908.

Cagatay, S., and H. Mihci (2006), "Degree of Environmental Stringency and the Impact on Trade Patterns", *Journal of Economic Studies*, Vol. 33(1), pp. 30-51.

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

Cole, M.A (2004), "US Environmental Load Displacement: Examining Consumption, Regulations and the Role of NAFTA", *Ecological Economics,* Vol. 48(4), pp. 439-50.

Cole, M.A., R.J.R. Elliott and P. Fredriksson (2006), "Endogenous Pollution Havens: Does FDI Influence Environmental Regulations?", *Scandinavian Journal of Economics*, Vol. 108 (1), pp. 157-178.

Cole, M.A. and R.J.R. Elliott (2005), "FDI and the Capital Intensity of "Dirty" Sectors: A Missing Piece of the Pollution Haven Puzzle", *Review of Development Economics*, Vol. 9(4), pp. 530-548.

Cole, M.A, R.J.R. Elliott and K. Shimamoto (2005), "Why the Grass is not Always Greener: The Competing Effects of Environmental Regulations and Factor Intensities on US Specialization", *Ecological Economics*, Vol. 54 (1), pp. 95-109.

Cole, M.A. and R.J.R. Elliott (2003), "Do Environmental Regulations Influence Trade Patterns? Testing Old and New Trade Theories", *The World Economy*, Vol. 26 (8), pp. 1163-86.

Cole, M.A. and R.J.R. Elliott (2003), "Determining the Trade-Environment Composition Effect: The Role of Capital, Labor and Environmental Regulations", *Journal of Environmental Economics and Management*, Vol. 46 (3), pp. 363-383.

Copeland, B.R. and M.S. Taylor (2004), "Trade, Growth and the Environment", *Journal of Economic Literature*, Vol. 42, pp. 7-71.

Copeland, B.R. and M.S. Taylor (2003), Trade and the Environment: Theory and Evidence, Princeton University Press.

Damania, R., P.G. Fredriksson and J.A. List (2003)," Trade Liberalization, Corruption and Environmental Policy Formation: Theory and Evidence", *Journal of Environmental Economics and Management*, Vol. 46(3), pp. 490-512.

Ederington, J. and J. Minier, (2003), "Is Environmental Policy a Secondary Trade Barrier? An Empirical Analysis", *Canadian Journal of Economics*, Vol. 36(1), pp. 137-54.

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

Ederington, J., A. Levinson and J. Minier, (2005), "Footloose and Pollution-Free", *The Review of Economics and Statistics*, Vol. 87(1), pp. 92-99.

Eskeland, G. and A. Harrison, (2002), "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis", *Journal of Development Economics*, Vol. 63(1), pp. 1-23.

Esty D. C. and M.E. Porter (2005), "National Environmental Performance: An Empirical Analysis of Policy Results and Determinants", *Environment and Development Economics*, Vol. 10(4), pp.391-434.

Frankel, J. and A. Rose, (2005), "Is Trade Good for the Environment? Sorting out the Causality", *The Review of Economics and Statistics*, Vol. 87(1), pp.85-91.

Fredriksson, P.G., E. Neumayer, R. Damania and S. Gates (2005), "Environmentalism, Democracy and Pollution Control", *Journal of Environmental Economics and Management*, Vol.45, pp. 343-365.

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

Grether, J.-M. and J. de Melo, (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.

Grether, J.-M. , N. Mathys and J. de Melo, (2006), "Unravelling the Worldwide Pollution Haven Effect", CEPR Discussion paper #5815

Grether, J.-M. , N. Mathys and J. de Melo, (2009), "Trade, Technique and Composition Effects in SO_2 Manufacturing Emissions, 1990-2000", *Environmental and Resource Economics*, Vol. 43 (2), pp. 257-274.

Harris, M., L. Konya and M. Matyas, (2001), "Modelling the Impact of Environmental Regulations on Bilateral Trade Flows: OECD 1990-96", mimeo, University of Melbourne.

Hettige, H.P., M. Mani and Wheeler, D. (2000), "Industrial Pollution in Economic Development: The Environmental Kuznets Curve Revisited", *Journal of Development Economics*, Vol. 62(2), pp. 445-76.

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

Hilton, F. G. H., and A. Levinson (1998). "Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions," *Journal of Environmental Economics and Management*, Vol. 35(2), pp. 126-141.

Isham, I., L. Pritchett, M. Woolcock and G. Busby, (2005), "The Varieties of Resource Experience: Natural Resource Export Structures and the Political Economy of Economic Growth", *World Bank Economic Review*, Vol. 19(2), pp. 141-74.

Jug, J. and D. Mirza, (2005), "Environmental Regulation in Gravity Equations: Evidence from Europe", *The World Economy*, Vol. 28(11), pp. 1591-615.

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.

Levinson, A. and S. Taylor, (2008),"Unmasking the Pollution Haven Effect", *International Economic Review*, Vol. 49 (1), pp. 223-254.

Mani, M. and Wheeler, D., (1997), "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, pp. 115-128.

Mantovani, A. and M. Vancauteren (2004), "Environmental Policy and Trade in the Single Market", mimeo, Louvain.

Nicita, A. and M. Olarreaga,(2007), "Trade, Production and Protection, 1976-04", *World Bank Economic Review*, 21(1), pp. 265-71.

Olivier, J.G.J and J.M. Berdowski, (2001), "Global emissions sources and sinks", in: Berdowski, J., Guicherit, R. and B.J. Heij (Eds.), The Climate System. A.A. Balkema Publishers/Swets & Zeitlinger Publishers, Lisse, The Netherlands, pp. 33-78.

Romalis, J.(2004), "Factor Proportions and the Structure of Commodity Trade ", *American Economic Review*, Vol. 94(1), pp. 67-97.

Santos Silva, J.M.C. and- S. Tenreyro (2006), "The Log of Gravity", *The Review of Economics and Statistics*, Vol. 88(4), pp.641-58.

Taylor, M.S. (2005), "Unbundling the Pollution Haven Hypothesis", *B.E. Journals in Economic Analysis & Policy*, Vol. 4(2), article 8.

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

Van Beers, C. and J. van den Bergh, (1997), "An Empirical Multi-Country Analysis of the Impact of Environmental Regulation on Foreign Trade Flows", *Kyklos*, Vol. 50 (1), pp. 29-46.

World Economic Forum, Global Competitiveness Report 2001-2002.

Appendices to

Unravelling the Worldwide Pollution Haven Effect

Bilateral trade flows are taken from the "Trade and Production Database" by Olarreaga and Nicita (2001). Imports (imports are known to be more reliable than exports) for 48 developing and developed countries are available at the 4-digit ISIC level (see appendix A1 for a country-list). To transform real bilateral trade flows into the pollution content of imports we used the World Bank's "Industrial Pollution Pojection System" (IPPS). See Hettige et al. (1995) for a detailed description. These IPPS coefficients allow us to estimate the amount of pollution (in pounds or kilograms) emitted per employee by 4-digit ISIC. In total 10 different pollutants (see table A3 in Appendix 2 for a detailed list of these pollutants) are proposed. Concerning the exact measure, we use the lower bound estimation of pollution per employee. Note that these IPP coefficients are strictly speaking only available for 1987 for the US industries. Hettige, Mani and Wheeler (2000) show that pollution/labor ratios seem to be roughly constant across countries. Hence using employment/output ratios by 3-digit industry (4-digit data are not available) and country from the "Trade and Production Database" allows us to compute a pollution per dollar of import coefficient specific to each country.

The distance and the common language variables are taken from the CEPII database. The common religion variable has been constructed on the basis of the CIA's World fact-book and GDP values are extracted from the World Bank's WDI Indicators (2004). Capital and labor endowment data are from Sandeep Mahajan (PRMEP), World Bank 2001. Skill ratios and coal and oil production have been taken from Gourdon, Maystre and de Melo (2008)[17]. The human development index for 1987 has been extracted from the UN website.

The data source 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 obtain an index of environmental stringency for the 80s for a large set of countries, the average maximum lead content represents at least one of the most important environmental indicator. Note also that Damania et al (2003) showed that this indicator is closely correlated with other proxies for environmental stringency.

[17] Gourdon J., Maystre N. and J. de Melo (2008), "Openness, inequality and poverty: Endowments matter", Journal of International Trade and Economic Development, Vol. 17 (3), pp. 343-378.

Appendix 2: Tables

Table A1: Countries in the sample

Argentina	Jordan
Australia*	Japan*
Austria*	Kenya
Bolivia	Korea, Rep.
Canada*	Sri Lanka
Chile	Mexico
China	Malawi
Cameroon	Malaysia
Colombia	Netherlands*
Costa Rica	Norway*
Denmark*	New Zealand*
Ecuador	Pakistan
Egypt, Arab Rep.	Panama
Spain*	Peru
Finland*	Philippines
France*	Portugal*
United Kingdom*	Singapore*
Greece*	Sweden*
Guatemala	Thailand
Honduras	Trinidad and Tobago
Indonesia	Turkey
India	Uruguay
Ireland*	United States*
Italy*	Venezuela, RB

Note:
* stands for developed economies, i.e-. economies where the average GDP per capita over the sample period in 1995 PPP dollars is higher than $11'000.
The following countries are not covered in the robustness section on SO2 emissions: Cameroon, Guatemala, Sri Lanka, Malawi, New Zealand, Pakistan, Portugal, Thailand, Trinidad and Tobago. When using the regulatory regime index: Turkey is also absent from the sample.

Table A2: Dirty and Clean Sectors

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 (2003).

Table A3: Pollutants

IPPS-Pollutants - per employee, lower bound		Pollution share of dirty sectors (in %)*	PH-Ratio
TPTT	Toxic pollution intensity – TOTAL	73	0.63
MPTT	Toxic metal pollution intensity – TOTAL	85	0.70
S2AI	SO2 – AIR	65	0.67
N2AI	NO2 – AIR	61	0.69
COAI	CO – AIR	59	0.79
VOAI	Volatile organic compounds – AIR	59	0.52
FPAI	Fine particulates – AIR	64	0.75
TSAI	Total suspended particulates – AIR	48	0.56
BOWT	Biochemical oxygen demand – WATER	79	0.89
TSWT	Total suspended solids – WATER	91	0.53

Note: * Dirty sectors account for 18% of total imports.

Table A4: Regressions of SO2 emission per worker (per dollar) on constant and GDP per capita PPP in constant 2000 international dollars

Sectors	Emission per worker			Emission per dollar		
	GDP per capita		F-stat	GDP per capita		F-stat
Refineries, coke and gas	1.59		1.49	-5.91	***	9.05
	(1.31)			(1.96)		
Iron and Steel	0.134		0.01	-6.03	***	13.57
	(1.28)			(1.64)		
Non-ferrous Metals	4.03	*	3.00	-4.83	**	4.78
	(2.33)			(2.21)		
Chemicals	1.65		0.97	-5.85	***	12.19
	(1.67)			(1.67)		
Building materials (cement)	-0.55		0.18	-9.31	***	61.94
	(1.32)			(1.18)		
Pulp and Paper	1.69		1.39	-6.57	***	20.14
	(1.44)			(1.46)		

Note:
F-stat: F-statistic of the whole regression (including the constant).
$S0_2$ Emission data are from Grether et al (2009).
* significant at 10%, ** significant at 5%, *** significant at 1%.

Table A5: Confidence Intervals for the decomposition estimates (%)

		Biochemical Oxygen Demand Water (BOWT)			SO_2 in the Air (SO_2)			Total Toxic Pollution Intensity (TPTT)		
Import Flows [a)]	**Number of Observations**	**FE-Effect**	**PH-Effect**	**TOT Effect**	**FE-Effect**	**PH-Effect**	**TOT Effect**	**FE-Effect**	**PH-Effect**	**TOT Effect**
NS	**544**	-75 ; -60	167 ; 180	-34 ; 12	-53 ; -34	107 ; 122	-3 ; 47	-48 ; -27	101 ; 111	4 ; 55
SN	**565**	118 ; 138	-77 ; -63	-50 ; -11	56 ; 66	-73 ; -55	-58 ; -26	38 ; 47	-72 ; -56	-61 ; -35
NS+SN	**1109**	-26 ; -11	-17 ; 20	-38 ; 6	-18 ; -5	-3 ; 33	-20 ; 26	-15 ; -1	-8 ; 23	-21 ; 23
NN	**342**	-1 ; -1	9 ; 17	8 ; 16	-1 ; 0	5 ; 13	4 ; 13	0 ; 0	-7 ; 0	-7 ; 1
SS	**656**	-26 ; -18	-16 ; -15	-38 ; -31	-4 ; 1	-6 ; -5	-10 ; -4	-7 ; -3	-9 ; -8	-16 ; -11
NN+SS	**998**	-2 ; -1	9 ; 16	7 ; 15	-1 ; 0	5 ; 12	4 ; 12	0 ; 0	-7 ; 0	-7 ; 0
World	**2107**	-6 ; -2	5 ; 17	-1 ; 14	-5 ; -1	3 ; 16	-2 ; 15	-4 ; 0	-7 ; 5	-11 ; 5

Notes:
95% Confidence intervals on the predicted values are reported.
[a)] See notes table 3.

Table A6: Decomposition of the PCI into the FE and the PH-Effect (in %) with Changing Income Group Definition

Import Flows [a]	Income Group Definition [b]	Number of Observations	Biochemical Oxygen Demand Water (BOWT)			SO_2 in the Air (SO_2)			Total Toxic Pollution Intensity (TPTT)		
			FE-Effect	PH-Effect	TOT Effect	FE-Effect	PH-Effect	TOT Effect	FE-Effect	PH-Effect	TOT Effect
NS	**Initial**	**544**	**-86**	**173**	**-14**	**-44**	**114**	**20**	**-38**	**106**	**27**
	Higher	473	-54	111	-3	-40	112	27	-33	97	31
	Lower	549	-69	166	-20	-46	16	11	-40	99	19
SN	**Initial**	**565**	**127**	**-70**	**-33**	**61**	**-65**	**-44**	**42**	**-64**	**-49**
	Higher	489	78	-60	-28	46	-58	-38	32	-56	-42
	Lower	575	164	-63	-3	76	-52	-16	52	-53	-29
NS+SN	**Initial**	**1109**	**-19**	**1**	**-19**	**-13**	**15**	**1**	**-8**	**8**	**-1**
	Higher	962	-8	-3	-12	-8	12	3	-5	4	-1
	Lower	1124	-31	20	-17	-19	30	5	-15	25	6
NN	**Initial**	**342**	**-1**	**13**	**12**	**-1**	**9**	**9**	**0**	**-3**	**-3**
	Higher	182	-1	16	14	-1	11	10	0	-3	-3
	Lower	550	0	11	11	1	7	8	1	-6	-4
SS	**Initial**	**656**	**-22**	**-16**	**-34**	**-1**	**-6**	**-7**	**-5**	**-9**	**-13**
	Higher	963	-33	-12	-41	-12	-3	-15	-11	-7	-17
	Lower	433	-29	-21	-45	-10	-11	-19	-11	-14	-23
NN+SS	**Initial**	**998**	**-2**	**13**	**11**	**-1**	**9**	**8**	**0**	**-3**	**-4**
	Higher	1145	-3	15	11	-2	9	8	-1	-3	-4
	Lower	983	0	11	10	-0	6	7	1	-6	-5

Notes:

[a] See notes table3.

[b] Higher: Treshold at US $ 15'000; Greece, Ireland, Portugal, Singapore and Spain become Southern countries.

[c] Lower: Treshold at US $ 6'500; Argentina, Korea, Mexico, Trinidad Tobago and Uruguay become Northern countries.

Table A7: Decomposition of the PCI into the FE and the PH-Effect (%)
Results from OLS regression, previous 2SLS results in parenthesis

			Biochemical Oxygen Demand Water (BOWT)			SO_2 in the Air (SO_2)			Total Toxic Pollution Intensity (TPTT)		
Row	**Import Flows** [a)]	**Number of observations**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**	**FE-Effect**	**PH-Effect**	**TOT-Effect**
1	**NS**	**544**	-36	90	21	-50	8	-46	-52	7	-49
			(-86)	(173)	(-14)	(-44)	(114)	(20)	(-38)	(106)	(27)
2	**SN**	**565**	39	-40	-17	67	-7	55	66	-6	57
			(127)	(-70)	(-33)	(61)	(-65)	(-44)	(42)	(-64)	(-49)
3	**NS+SN**	**1109**	-16	31	11	-42	5	-39	-45	4	-42
			(-19)	(1)	(-19)	(-13)	(15)	(1)	(-8)	(8)	(-1)
4	**NN**	**342**	-1	11	10	-2	1	0	-1	0	0
			(-1)	(13)	(12)	(-1)	(9)	(9)	(0)	(-3)	(-3)
5	**SS**	**656**	-6	-8	-14	0	0	0	-7	-1	-8
			(-22)	(-16)	(-34)	(-1)	(-6)	(-7)	(-5)	(-9)	(-13)
6	**NN+SS**	**998**	-2	11	10	-2	1	0	-1	0	-1
			(-2)	(13)	(11)	(-1)	(9)	(8)	(0)	(-3)	(-4)
7	**World**	**2107**	-2	13	10	-14	2	-12	-17	1	-16
			(-4)	(11)	(7)	(-3)	(10)	(6)	(-2)	(-1)	(-3)

Notes:
[a)] NS: North imports from the South, SN: South imports from the North, NN: North imports from the North, SS: South imports from the South.
Along rows: TOT = (1+FE)*(1+PH) -1,
Along columns: $AGG_v = \theta * CMP_1 + (1-\theta) * CMP_2$ where AGG_v is the aggregate effect (v = NS+SN, NN+SS, World) CMP_1 and CMP_2 are the two corresponding components and θ is the share of CMP_1 in the relevant PCI (**Ω** for the FE and the TOT effects, **Ω κ** for the PH effect , **Ω κ ℓ** is only reported for the sake of completeness).

Table A8: Variable Description

Variabe	Description	Source
E/L	Pollution per employee	IPPS, World Bank (for SO2: Grether et al 2009)
L/X	Inverse labour productivity	Trade and Production Database, 1976-2000
M	Bilateral import flows	Trade and Production Database, 1976-2000
DIST	Geodesic Distance between the most important cities	http://www.cepii.fr
MKT	Product of GDPs	World Bank Development Indicator 2004
CR	Common Religion	Correlation Coefficient, based on CIA's World Factsbook
CL	Dummy for common language	http://www.cepii.fr
LL	Dummy for landlockedness	http://www.cepii.fr
SK	Proportion of population over 15 years with completed primary education with respect to population with less than 4 years of schooling in 1987.	Barro and Lee (2000)
HK	Proportion of population over 15 years with completed high education with respect to population with less than 4 years of schooling in 1987.	Barro and Lee (2000)
COAL	Production of coal	World Energy Council (2004)
OIL	Production of oil	World Energy Council (2004)
LEAD	Average maximum lead content in gasoline	Octels world wide gasoline survey, prepaired base available on http://www2.unine.ch/Jahia/site/irene/op/edit/pid/12149?matrix=101
	Alternative measures of environmental regulation:	
	Air pollution regulation	WEF's Global competitiveness report
	Regulatory Regime Index	Esty and Porter (2005)
K/L	Capital to labour ratio	Sandeep Mahajan (PRMEP), World Bank 2001
HDI	Human development indicator for 1987	United Nations Database

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