

Globalization and dirty industries: any pollution havens?*

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Abstract

This paper reviews arguments and evidence on the impact of globalization on the environment, then presents evidence on production and international trade flows in five heavily polluting industries for 52 countries over the period 1981-98. A new decomposition of revealed comparative advantage (RCA) according to geographical origin reveals a delocalization to the South for all heavily polluting industries except non-ferrous metals that exhibits South-North delocalization in accordance with factor-abundance driven response to a reduction in trade barriers. Panel estimation of a gravity model of bilateral trade on the same data set reveals that, on average, polluting industries have higher barriers-to-trade costs (except non-ferrous metals with significantly lower barriers to trade) and little evidence of delocalization in response to a North-South regulatory gap.

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1 Introduction

In the debate on globalization and the environment, at least four links have been identified in which trade liberalization might be harmful for the environment. First, in a second-best situation, trade liberalization may be harmful for the environment. Second, specialization according to comparative may be harmful. In a two-region world, if the environment is a normal good, the reduction in pollution in the North could well be more than compensated by the increased pollution in the South. Third, trade liberalization will increase transportation, thereby indirectly being harmful for the environment. Fourth, any negative effects of trade liberalization on the environment could be exacerbated if pollution is transboundary (e.g. green house gases) as incentives to internalize are low or if property rights in the South are ill-defined.

In addition, as in other aspects of the globalization debate, there is concern that the erasing of national borders through reduced barriers to trade will lead to competition for investment and jobs, resulting in a degradation of environmental standards. In an increasingly integrated world, nations find it more difficult to internalize environmental and social costs into prices. For anti-globalizers, economic integration under free market conditions promotes standard-lowering competition, or what is commonly referred to as a 'race to the bottom'.

Moreover, environmentalists and ecologically-oriented academics point out that the political economy of decision-making is stacked up against the environment. In the North, OECD interest groups that support protectionist measures for other reasons

continue to invoke the race-to-the-bottom model, relying on the perception that the regulatory gap automatically implies a race to the bottom, even though some have argued that countries may circumvent international agreements on tariffs by choosing strategic levels of domestic regulation. Because avoidance of a race to the bottom would call for the enforcement of uniform environmental standards in all countries, which cannot be created, they argue for trade restrictions until the regulatory gap is closed. In the South, corruption is likely to result in poor enforcement of the regulatory framework. Finally, at the international level, environmental activists fear that the dispute settlement mechanism of the WTO favors trade interests over environmental protection.

To sum up, the arguments raised above, as well as empirical evidence reviewed below, suggest that trade liberalization and globalization (in the form of reduced transaction costs) could lead to a global increase in environmental pollution as well as to an increase in resource depletion as natural resource exploiting industries, from forest logging companies to case mining, would have relocated to places with less strict standards or have successfully used the threat of relocation to prevent the imposition of stricter standards. These effects are likely to be more important the further is environmental policy from the optimum and the less well-defined are property rights as is the case for the so-called global commons. It is therefore not surprising that, even if trade liberalization and globalization more generally can lead to both an overall increase in welfare -- especially if environmental policy is not too far from the optimum -- and a deterioration in environmental quality, a fundamental clash will persist between free trade proponents and environmentalists.

This paper addresses the relation between globalization and the environment by re-examining evidence of a North-South delocalization of heavily polluting industries, the causes of any detected relocation not being identified because we are dealing with fairly aggregate data. Section 2 reviews the evidence on "pollution havens"¹, arguing that it is either too detailed (firm-specific or emission-specific evidence) or too fragmentary (case studies) to give a broad appreciation of the extent of delocalization over the past twenty years. The following sections turn to new evidence based on 3-digit ISIC production and trade data for 52 countries over the period 1981-98.² In section 3, we report on the worldwide evolution of heavy polluters (the so-called 'dirty' industries) and on the evolution of North-South revealed comparative indexes. Section 4 then estimates a panel gravity trade model to examine patterns of trade in polluting products. Estimates reveal that transport costs may have acted as a brake on North-South relocation.

2. Pollution Havens or pollution Halos?

We review first the evidence on trade liberalization and patterns of trade in polluting industries based on multi-country studies that try to detect evidence of North-South delocalization. We then summarize results from single-country, often firm-level studies that use more reliable environmental variables and are also often better able to control for

¹ In the public debate, the 'pollution havens' effect refers either to an output reduction of polluting industries (and an increase in imports) or to the relocation of industries abroad in response to a reduction in protections. We survey evidence on both aspects, but only provide evidence on the first effect (sometimes called the direct effect, to distinguish it from the indirect effect when imports of polluting products increase because of tariff reduction).

² An appendix describes data sources and manipulation and the representativity of the sample in terms of global trade and production in polluting activities.

unobservable heterogeneity bias. We conclude with lessons from case studies and political-economy considerations.

2.1 Evidence on production and trade in dirty products

Evidence from aggregate production and trade data is based on a comparison between 'clean' and 'dirty' industries, the classification relying invariably on U.S. data, either on expenditure abatement costs, or on emissions of pollutants.³ Table 1 summarizes the results from these studies. Overall, the studies, which for the most part use the same definition of dirty industries as we do⁴, usually find mild support for the pollution havens hypothesis.

Insert table 1 here:

Multi-country papers on trade and environmental costs

The large number of countries and the industrial-level approach gives breadth of scope in the studies described in table 1, but at a cost. First changing patterns of production and trade could be due to omitted variables and unobserved heterogeneity that cannot be easily controlled for in large samples where aggregated data say very little about industry choices which

³ Most work on the US is based on pollution abatement capital expenditures or on pollution abatement costs (See e.g. Levinson and Taylor (2002, table 1). It turns out that the alternative classification based on emissions (see Hettige et al. 1995) produces a similar ranking for the cleanest and dirtiest industries (5 of the top 6 pollution industries are the same in both classifications).

⁴ As in this paper, polluting industries were classified on the basis of the comprehensive index of emissions per unit of output described in Hettige et al. (1995). That index includes conventional air, water and heavy metals pollutants. As to the applicability of that index based on US data to developing countries, Hettige et al. conclude (p. 2) that, even though pollution intensity is likely to be higher, "the pattern of sectoral rankings may be similar".

would shed light on firms or production stages (Zarsky (1999,p 66)). For example, as pointed out by Mani and Wheeler in their case study of Japan, changes in local factor costs (price of energy, price of land) and changes in policies other than the stringency of environmental regulations could account for observed changes in trade patterns. Second, these studies give no evidence on investment patterns, and how these might react to changes in environmental regulation, which is at the heart of the 'pollution havens' debate.⁵ It is therefore no surprise that, by and large, the papers surveyed in Dean (1992) and Zarsky (1999) fail to detect a significant correlation between the location decision of multinationals and the environmental standards of host countries, suggesting that, after all, when one goes beyond aggregate industry data, the "pollution haven" hypothesis, is a popular myth.

Recent studies respond to the criticism that the evidence so far does not address the research needs because of excessive aggregation. However, this recent evidence, summarized below, is still very partial, and heavily focussed on the US.

2.2 Evidence on the location of dirty industries

Levinson and Taylor (2002) revisit the single-equation model of Grossman-Kruger (1993) using panel data for US imports in a two-equation model in which abatement costs are a function of exogenous industry characteristics while imports are a function of abatement costs. Contrary to previous estimates, they find support for the pollution havens hypothesis: industries whose abatement costs increased the most, saw the largest relative

⁵ Smarzyńska and Wei (2001) cite the following extract from "A Fair Trade Bill of Rights" proposed by the Sierra Club: "in our global economy, corporations move operations freely around the world, escaping tough

increase in imports from Mexico, Canada, Latin American and the rest-of-the-world.⁶

Keller and Levinson (2001) analyze inward FDI into the US over the period 1977-94 drawing on environmental costs across the US that are more comparable than the rough indices that have to be used in cross-country work. They find robust evidence that relative (across States) abatement costs had moderate deterrent effects on foreign investment.

Others have analyzed outward FDI to developing countries. Eskeland and Harrison (2002), examine inward FDI in Mexico, Morocco, Venezuela and Côte d'Ivoire at the four-digit level using US abatement cost data controlling for country-specific factors and find weak evidence of some FDI being attracted to sectors with high levels of air pollution, but no evidence of FDI to avoid abatement costs. They also find that foreign firms are more fuel-efficient in that they use less 'dirty fuels' which support the 'pollution halo' hypothesis: superior technology and management coupled with demands by "green" consumers in the OECD lifts industry standards overall.⁷

Smarzynska and Wei (2001), estimate a probit of FDI of 534 multinationals in 24 transition economies during the period 1989-94 as a function of host country characteristics other than environment-related, a transformed (to avoid outlier dominance) US-based index of dirtiness of the firm at the 4-digit level, an index of the laxity of host country's environmental standards captured by a corruption index, and

control laws, labor standards, and even the taxes that pay for social and environmental needs".

⁶ Ederington and Minier (2001) also revisit The Grossman-Kruger study, assuming that pollution regulation is also endogenous, but determined by political-economy motives. They also find support for the pollution-havens hypothesis, this time because inefficient industries seek protection via environmental legislation.

several measures of environmental standards (participation in international treaties, quality of air and water standards, observed reductions in various pollutants). In spite of this careful attempt at unveiling a 'pollution haven' effect, they conclude that host country environmental standards (after controlling for other country characteristics including corruption) had very little impact on FDI inflows.

2.3 Case studies and political-economy considerations

Reviewing recently available data, Wheeler (2000) shows that suspended particulate matter release (the most dangerous form of air pollution) has been declining rapidly in Brazil, China, Mexico, fast growing countries in the era of globalization and big recipients of FDI. Organic water pollution is also found to fall drastically as income per capita rises (poorest countries have approximately tenfold differential pollution intensity).⁸ In addition to the standard explanations (pollution control is not a critical cost factor for firms, large multinationals adhere to OECD standards), he also points out that case studies show that low-income communities often penalize dangerous polluters even when formal regulation is absent or weak. Wheeler concludes that the "bottom" rises with economic growth.

This result is reinforced by recent evidence based on a political-economy approach that endogenizes corruption in the decision-making process. Assuming that governments' accept bribes in formulation of their regulatory policies, Damia et al (2000) find support in panel data for 30 countries over the

⁷ The mixed evidence on the pollution halo hypothesis is reviewed in Zarsky (1999).

⁸ These results accord with independent estimates of environmental performance constructed by Dasgupta et al. (1996) from a responses to a detailed questionnaire administered to 145 countries (they find a

period 1982-92 that the level of environmental stringency is negatively correlated with an index of corruption and positively with an index of trade openness. Given that corruption is typically higher in low-income countries, this corroborates the earlier finding mentioned above, that environmental stringency increases rapidly with income.

3. Shifting patterns of production and comparative advantage in polluting industries

Direct approaches to the measurement of pollution emission (e.g. Grossman and Krueger (1995), Dean (2000), Antweiler, Copeland and Taylor (2001) and several of the studies mentioned above) use emission estimates at geographical sites of pollutant particles (sulfur dioxide is a favorite) or the release of pollutants in several media (air, water, etc...). That approach has several advantages: emissions are directly measured at each site, and it is not assumed that pollutant intensity is the same across countries. On the other hand activity (e.g. production levels) is not measured directly. Arguably, this is a shortcoming if one is interested in the pollution haven hypothesis. Indeed, emissions could be high for other reasons than the relocation of firms to countries with low standards (China's use of coal as an energy source is largely independent of the existence of pollution havens).

The alternative chosen here is to use an indirect approach in which emission intensity is not measured. We adopt the approach in the studies summarized in table 1 where dirty industries are classified according to an index of emission intensity in the air, water and heavy metals in the US described earlier. We

correlation of about 0.8 between their measure of environment performance or environment policy and income per capita).

selected the same five most polluting industries in the US in (1987) selected by Mani and Wheeler (1999) (three-digit ISIC code in parenthesis): Iron and Steel (371); Non-ferrous metals (372); Industrial chemicals (351); Non-metallic mineral products (369); pulp and paper (341).⁹

Compared to the five cleanest U.S. manufacturing activities (textiles (ISIC 321), Non-electric machinery (382), Electric machinery (383), transport equipment (384), instruments (385), the dirtiest have the following characteristics: 40% less labor-intensive; capital-output ratio twice as high; and an energy-intensity ratio three times as high.

3.1 Shifting patterns of production

We start with examination of the broad data for our sample of 52 countries over the period 1981-98. The sample (years and countries) is the largest for which we could obtain production data matching trade data at the 3-digit ISIC level. Compared to the earlier studies mentioned in table 1, this sample has production data for a larger group of countries, though at a cost because comprehensive data--only available since 1981--implies that we are missing some of the early years of environmental regulation in OECD countries in the seventies.

Because there is a close correlation between the stringency of environmental regulation and income per capita, we start with histograms ranked by income per capita quintile (the data are three-year averages at the beginning and end of period). Given our sample size, each quintile has 10 or 11 observations.

⁹ Mani and Wheeler (1999, table 1) describes the intensity of pollutants emission in water, air and heavy metals.

Insert Figure 1 here:
Production and consumption histograms

Figure 1 reveals a slight change in the middle of the distribution of production and consumption of dirty industries as the second richest quintile sees a reduction in production and consumption shares in favor of the top and lowest quintiles. Turning to export and import shares, one notices a reduction in both trade shares of the highest quintile in favor of the remaining quintiles.

These aggregate figures mask compositional shifts apparent from inspection of the histograms at the industry level (see figure A3.1 in the Appendix). For the second richest quintile, the output share is always decreasing, but the changes in the export share varies a lot across sectors. For the richest quintile, the output share is decreasing except for paper and products (ISIC 341) and other non-metallic mineral products (369), while the export share is always decreasing, except for non-ferrous metals (372).

Insert Figure 2 here:
Exports and imports histograms

3.2 Shifting patterns of revealed comparative advantage

We look next for further evidence of changes in trade patterns in dirty industries. We report on revealed comparative advantage (RCA) indices computed at the beginning or at the end

of the sample period. RCA indices are not measures of comparative advantage since they also incorporate the effects of changes in the policy environment (trade policy, regulatory environment, etc).¹⁰

The RCA index for country i and product p is given by:

$$RCA_i^p = \frac{S_{wp}^{ip}}{S_{wa}^{ia}} = \frac{S_{ia}^{ip}}{S_{wa}^{wp}} \quad (1)$$

where S_{wp}^{ip} (S_{wa}^{ia}) is country i 's share in world exports of polluting products (of all products) and S_{ia}^{ip} (S_{wa}^{wp}) is the share of polluting products in total exports of country i (of the world).

Countries are split into two income groups (see table A1 in the Appendix) that replicate the distinction between the three poorest and two richest quintiles of the previous section: 22 high income countries (1991 GNP per capita larger than 7910 USD according to the World Bank) and 30 low and middle-income countries. A first glimpse at the aggregate figures (see table 2) confirms that the share of less developed countries (LDCs) in world trade of polluting products is on the rise. However, the average annual rate of growth is lower for polluting products than for exports in general. As a result, LDCs as a whole exhibit a decreasing RCA (and an increasing revealed comparative disadvantage) in polluting products (see last columns of table 2).

¹⁰ All calculations based on trade data are based on 'mirror' exports (i.e. trade data in the destination country).

Insert table 2 here:

Share of developing countries in world trade

However, inspection at the industry level (see table A2.1, reveals that this reverse-delocalization outcome is due to the dominating effect of non-ferrous metals (ISIC 372). All other four industries present some ingredient of delocalization, with a particularly strong increase in RCA for industrial chemicals (351). Interestingly, non-ferrous metals represented more than 40% of LDCs exports at the beginning and less than 25% at the end of the period, while the pattern is exactly opposite for industrial chemicals.

To unveil cross-country variations, figure 3 ranks countries by decreasing order of RCAs for both income groups. In each case, the dashed line represents the end-of-period pattern with countries ranked by decreasing order of comparative advantage so that all observations above (below) unity correspond to countries with a revealed comparative advantage (disadvantage). A shift to the right (left) implies increasing (decreasing) revealed comparative advantage, and a flattening of the curve, a less pronounced pattern of specialization.

Figure 3:

Beginning and end-of-period RCAs by income group

Overall, the LDCs pattern of RCAs is characterized by higher upper values of RCAs and a steeper curve than high-income countries. Over time, both curves appear to shift right and become somewhat flatter. The increase in RCAs seems larger in LDCs, where it is concentrated in the middle of the distribution, while it basically affects the end of the

distribution in the other income group. At the industry level (see figure A3.2) results for LDCs are quite similar, except for non-ferrous metals, where the RCA curve shifts in.

Turning back to the aggregate level, and upon closer look, the rightward shift of the RCA curves seems puzzling on two counts. First, how can it be, in a world divided in two groups, that a global trend towards higher values of RCAs may be observed in both groups, rather than more intuitively an increase in one group and a decrease in the other? This contradiction is only apparent: the weighted sum of RCAs is indeed equal to 1.0, but the weights can vary. In fact from (1), if the world is made up of two countries, n and s, then:

$$S_{wa}^{sa} RCA_s^p + S_{wa}^{na} RCA_n^p = 1 \quad (2)$$

Thus, a simultaneous increase in both RCA indices may well happen, provided a larger weight is put on the smaller value.

All well. Does it fit with our case? From table 2, we know that DCs exhibit a smaller RCA and that their share in world exports has increased. So it seems to work nicely... except that both RCAs are decreasing instead of increasing! (see last columns of table 2 for DCs and straightforward calculations for developed countries)

So we are left with a second apparent contradiction: how is it that in a group (the LDCs), most RCAs are increasing (figure 2) while the aggregate RCA of the group is decreasing (table 2)? There again, the answer is in the shares: there has been a "composition effect", with the share of the lowest-RCA countries increasing at the expense of the highest-RCA countries. From (1), it is straightforward to verify that:

$$RCA_s^p = \sum_{i=1}^{n_s} S_{sa}^{ia} RCA_i^p \quad (3)$$

where income-group s (for South) is assumed to be composed of n_s countries and S_{sa}^{ia} is the share of country i in total exports of group s .

Using (3), the change in the aggregate RCA index can be decomposed in the following terms:

$$\Delta RCA_s^p = \sum_{i=1}^{n_s} \Delta S_{sa}^{ia} RCA_i^p + \sum_{i=1}^{n_s} S_{sa}^{ia} \Delta RCA_i^p + \sum_{i=1}^{n_s} \Delta S_{sa}^{ia} \Delta RCA_i^p \quad (4)$$

The first term in (4) represents the above-mentioned "composition effect": it is the part of the aggregate RCA change that is only attributable to changes in countries' shares (e.g. the share of Macau is rising while that of Peru is diminishing but both maintain the same level of RCA). The second term reflects just the opposite: the impact of changes in RCAs at constant countries' shares, and as such may be referred to as a pure "structural effect". Finally, the third term is the "mixed effect", capturing the impact of both changes simultaneously.¹¹

Still, the above pattern does not say anything about the changing pattern of RCAs between the North and the South, which is what the delocalization hypothesis is about. To this effect,

¹¹ Figure 3 only reflects the structural effect, and that is why it suggests an overall increase in RCA which is in apparent contradiction with the aggregate decrease identified in table 2. Applying equation (4) to the LDCs case shows indeed that in the absence of any composition effect, the aggregate RCA of DCs would have increased to 1.17, reversing the pattern of revealed comparative advantage. However, the joint combination of the composition effect and the mixed effect (-0.27) was stronger than the structural effect (0.21), leading to the reported net decrease of the aggregate RCA (for results at the industry level, see table A2.2).

we introduce a new decomposition that isolates the impact of geography on the RCA index. From (1), note that the RCA of country i in product p (RCA_i^p), which is defined as the ratio between the share of product p in total exports of country i (S_{ia}^{ip}) and the share of product p in total world exports (S_{wa}^{wp}), can be decomposed into:

$$RCA_i^p = \sum_{j=1}^N RCA_{ij}^p S_{iwa}^{ija} \quad (5)$$

where the **bilateral RCA** (RCA_{ij}^p) is defined as the ratio between the share of product p in all exports of country i to country j . This share is weighted by the share of country j in total exports country i to the world (S_{iwa}^{ija}).

Now let the world be divided in two groups of countries: n_s in the South, n_N in the North ($n_s+n_N=N$). Then (5) can be rewritten:

$$RCA_i^p = S_i^p + N_i^p \equiv \sum_{j=1}^{n_s} RCA_{ij}^p S_{iwa}^{ija} + \sum_{j=1}^{n_N} RCA_{ij}^p S_{iwa}^{ija} \quad (6)$$

where S_i^p is the South's contribution and N_i^p the North's contribution to RCA_i^p . Thus, in terms of variation between the end (96-98) and the beginning (81-83) of the sample period, one obtains:

$$\Delta RCA_i^p = \Delta S_i^p + \Delta N_i^p \quad (7)$$

Results from applying this decomposition to the two groups of countries are reported in table 3. For each polluting sector,

we report the (unweighted) average of both sides of equation (7) over the LDCs group. It appears that in all cases but one, the North's contribution to the change in the RCA of Southern countries is positive, which is consistent with the pollution haven effect. Again, the only exception is non-ferrous metal, where North-South trade has negatively contributed to the RCA of the South.

Insert table 3 here:

Table 3: North-South bilateral RCAs for polluting products

In sum, the empirical evidence on delocalization of polluting activities towards the South is rather mixed. As a group, developing countries exhibit a surprising reverse-delocalization pattern of increasing revealed comparative disadvantage in polluting products. However, as shown above, this reflects both the pattern of one particular industry (non-ferrous metals) and a composition effect: within the group of developing countries, those less prone to export polluting products have gained ground. In fact, most developing countries have in fact experienced an increase in their RCA in polluting products. Moreover, after controlling for geography, it turns out that for all but for one case (non-ferrous metals), North-South trade has had a positive impact on the South's comparative advantage in these products.

4. Bilateral trade patterns in polluting products

Dirty industries are typically weight-reducing industries. They are also intermediate-goods producing industries. As a result if they move to the South, then transport costs must be incurred if the final (consumer goods) products are still

produced in the North, as would be the case, for example in the newspaper printing industry. Hence the reduction in transport costs and protection that has occurred with globalization may not have had much effect on the location of these industries.

Our third piece of evidence consists of checking if, indeed, polluting industries are not likely to relocate so easily because of relatively high transport costs. To check whether this may be the case, we estimate a standard bilateral trade gravity model for polluting products, and compare the coefficients with those obtained for non-polluting manufactures.

Take the simplest justification for the gravity model: trade is balanced, and each country consumes its output, and that of other countries according to its share, s_i , in world GNP, Y^W . Then (see Rauch, 1999), bilateral trade between i and j will be given by: $M_{ij} = (2Y_i Y_j) / Y^W = f(W_{ij})$. The standard "generalized" gravity equation which can be obtained from a variety of theories can be written as: $M_{ij} = f(W_{ij})(\theta_{ij})^{-\sigma}$ where θ_{ij} is an index of barriers-to-trade between i and j , W_{ij} is a vector of other intervening variables that includes the bilateral exchange rate, e_{ij} , and prices σ is an estimate of the ease of substitution across suppliers.

In the standard estimation of the gravity model, θ_{ij} is captured either by distance between partners, or if one is careful, by relative distance to an average distance among partners in the sample, \overline{DIST} , i.e. by, $DT_{ij} = DIST_{ij} / \overline{DIST}$ and dummy variables that control for characteristics that are specific to bilateral trade between i and j (e.g. a common border, BOR_{ij} , landlockedness in either country, LL_i (LL_j)).¹²

¹² Brun et al. (2002), argue that the standard barriers-to-trade function is misspecified and propose a more general formulation that captures both

Here, we also include an index of the quality of infrastructure in each country in period t , INF_{it} (INF_{jt}) higher values of the index corresponding to better quality of infrastructure.¹³

Finally, because we estimate the model in panel, we include the bilateral exchange rate, RER_{ijt} , defined so that an increase in its value implies a real depreciation of i 's currency.

We estimate in panel the following model (expected signs in parenthesis):

$$M_{ijt} = \alpha_0 (Y_{it})^{\alpha_1} (Y_{jt})^{\alpha_2} INF_{it}^{\alpha_3} INF_{jt}^{\alpha_4} (RER_{ijt})^{\alpha_5} (DT_{ij})^{\beta_1} \left(e^{\alpha_6 BOR_{ij}} \right) \left(e^{\alpha_7 LL_i} \right) \left(e^{\alpha_8 LL_j} \right) (u_{ijt}) \quad (8)$$

$$(\alpha_1 > 0, \alpha_2 > 0, \alpha_3 > 0, \alpha_4 > 0, \alpha_5 < 0, \alpha_6 > 0, \alpha_7 < 0, \alpha_8 < 0, \beta_1 < 0)$$

In a second specification we introduce the difference in GNP per capita $DY_{ij} = [(Y_i/N_i) - (Y_j/N_j)]$, this variable presumably capturing the effects of the regulatory gap across countries. In addition, we include time dummies that capture common time-dependent shocks (e.g. changes in the price of oil), and country dummy variables that capture bilateral specific effects. This leads to the second specification, estimated in double-log (except for the dummy variables):

$$\begin{aligned} \ln M_{ijt} = & \alpha_0 + \alpha_t + \alpha_{ij} + \alpha_1 \ln Y_{it} + \alpha_2 \ln Y_{jt} + \alpha_3 \ln INF_{it} + \\ & \alpha_4 \ln INF_{jt} + \alpha_5 \ln RER_{ijt} + \alpha_6 BOR_{ij} + \alpha_7 LL_i + \alpha_8 LL_j + \\ & \alpha_9 \ln DY_{ijt} + \beta_1 \ln DT_{ij} + \eta_{ijt} \end{aligned} \quad (9)$$

variables that include country-specific characteristics, and variables that capture time-dependent costs (e.g. the price of oil). Since here we are only interested in country-specific characteristics, time-dependent shocks are captured by time dummies.

¹³ The index is itself a weighted sum of four indices computed each year: road density, paved roads, railway and the number of telephone lines per capita.

where α_9 is expected to be positive, α_0 is an effect common to all years and pairs of countries (constant term), α_t an effect specific to year t but common to all countries, α_{ij} an effect specific to each pair of countries but common to all years and η_{ijt} is the error term

For estimation purposes, equation (9) can be rewritten as:

$$\ln M_{ijt} = X_{ijt}\phi + Z_{ij}\delta + u_{ijt} \quad \text{with } u_{ijt} = \mu_{ij} + v_{ijt} \quad (10)$$

where X (Z) represents the vector of variables that vary over time (are time invariant) and a random error-component is used because the within-transformation in a fixed-effects model removes the variables that are cross-sectional time invariant. To deal with the possibility of correlation between the explanatory variables and the specific effects, we use the instrument variable estimator proposed by Hausman and Taylor (1981) but also report fixed-effects estimates which correspond to the correct specification under the maintained hypothesis (columns 1 & 2 of table 4).

Because the null hypothesis of correlation between explanatory variables and the error-term cannot be rejected, we re-estimated the random effect model treating the GDP variables as endogenous. The results are reported in columns 3-6 of table 4. Coefficient estimates are robust and after instrumentation, the coefficient estimates are quite close in value to those obtained under the fixed-effects estimates.

Insert table 4 here:

Gravity model: panel estimates

First note that all coefficients have the expected signs and, as usual in gravity models with large samples, are robust to changes in specification.¹⁴ Notably, the dummy variables for infrastructure have the expected signs and are highly significant. So is the real exchange rate variable which captures, at least partly, some of the effects of trade liberalization that would not have already been captured in the time dummy variables (not reported here). Income variables are also, as expected, highly significant. Overall then, except for the landlocked variables, which are at times insignificant, all coefficient estimates have expected signs and plausible values.

Compare now the results between the panel estimates for all manufactures --except polluting products--(ALL2-HT column) with those for the five polluting industries (POL2-HT column). Note first that the estimated coefficient for distance is a third higher for the group of polluting industries compared to the rest of manufacturing.¹⁵ Second, note that the proxy for the regulatory gap captured by the log difference of per capita GNPs is negative for non-polluting manufactures (as one would expect from the trade theory literature under imperfect competition) while it is insignificant (though positive) for polluting industries. Now, if indeed the regulatory can be approximated by differences in per capita GDPs across partners, presence of pollution havens would be reflected in a significant positive coefficient for this variable.

Compositional effects for the coefficients of interest are shown in table 5. Non-ferrous metals (and to a lesser extent iron & steel) stand out with low elasticity estimates for

¹⁴ We also experimented with other variants by including population variables that gave virtually identical estimates for the included variables, so we do not report results here).

distance. If one were to take seriously cross-sector differences in magnitude, one would argue that the South-North 'reverse' (in the sense of the pollution havens hypothesis) delocalization of non-ferrous metals according to comparative advantage in response to the reduction in protection would have occurred because of fewer natural barriers to trade. Of course, there are other factors as well to explain the developments in sectors, including the heavy protection of these industries in the North.

Insert table 5 here:

Panel estimates by industry

The sectoral pattern of estimates for α_9 indicates that the regulatory gap would have had an effect on bilateral trade patterns for two sectors: non-metallic minerals and iron & steel, and marginally for the pulp & paper industry. Again, the non-ferrous metals stands out, suggesting no effect of differences in the regulatory environment, once other intervening factors are controlled for.

In sum, the pattern of trade elasticities to transport costs obtained here makes sense. Most heavy polluting sectors are intermediate goods, so proximity to users should enter into location decisions more heavily than customs goods that are typically high value, low weight industries that can be shipped by airfreight. Interestingly, after controlling for a number of factors that influence the volume of bilateral trade, we find little evidence of the presence of a regulatory gap, thus broadly supporting (indirectly) the 'pollution halo' hypothesis.

¹⁵ One could note that the coefficient estimates on infrastructure are much higher for these weight reducing activities which is also a plausible

5. Conclusions

Concerns that polluting industries would 'go South' was first raised in the late eighties at the time when labor intensive industries like the garment industries were moving South in response to falling barriers to trade worldwide, but especially in developing countries. Such delocalization could be characterized as a continuous search for 'low-wage heavens' by apparel manufacturers, in an industry that has remained labor-intensive. Fears about pollution havens were then expressed notably because of the possible impact of the regulatory gap between OECD economies where polluters paying more would lead them to search for 'pollution havens' analogous to 'low-wage havens'. Later with the globalization debate, the hypothesis gained new momentum by those who have read into globalization a breakdown of national borders, making it difficult to control location choices by multinationals. This paper has reviewed the now substantial evidence surrounding this debate and given new evidence.

Three rather distinct families of evidence were reviewed. Aggregate comparisons of output and trade trends based on a classification of pollution industries based on US emissions revealed very marginal delocalization to the South. On the other hand, firm-level estimates of FDI location choices by and large found at best marginal evidence either of location choice in the US in response to cross-State differences in environmental regulations or of location choices of multinational firms across developing countries in response to differences in environmental regulations. Reasons for this lack of response to the so-called regulatory gap was found in the last piece of evidence largely patched from developing-country case studies taking into account political economy determinants

result signifying another brake on North-South delocalization.

of multinational behavior in host countries and the internal trade-offs between leveling up emission standards (to avoid dealing with multiple technologies) and cutting abatement expenditures.

Drawing on a large sample of countries accounting for the bulk of worldwide production and trade in polluting products over the period 1980-98. The paper also produced new evidence. Globally, we found that revealed comparative in polluting products fell as one would expect if the environment is a normal good in consumption, while at the same time the period witnessed a trend towards relocation of all (but one) polluting industries to the South. A reverse delocalization was detected for non-ferrous metals, as one would expect according to comparative advantage-driven response to trade liberalization in a sector where barriers-to-trade turn out to be relatively small. Finally, in the aggregate, we found no evidence of trade flows being significantly driven by the regulatory gap, although some positive evidence was found for the non-metallic and iron & steel sectors.

In conclusion, we find only moderate support for the 'pollution havens' hypothesis and identify natural barriers-to-trade in the typical heavy polluting industries as a factor accounting for this less-than-expected delocalization. One should keep in mind of two important caveats with respect to the 'pollution havens' debate. First, we only examined manufacturing and hence did not take into account resource extracting industries that may have sought pollution havens. Second, even within the narrow confines of trade pattern quantification, a fuller evaluation of the debate on trade, globalization and the environment would also have to examine the direct and indirect energy content of trade.

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