Dirty Exports and Environmental Regulation:

Do Standards Matter to Trade?

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Non-Technical Abstract: How to address the link between environmental regulation and trade was an important part of discussions at the Doha Ministerial of the World Trade Organization in November 2001. Trade ministers agreed to launch negotiations on trade and the environment, including clarification of WTO rules. This paper addresses an important part of the background context for deciding whether or how to link trade agreements to the environment, from a developing country perspective. We ask the question whether environmental regulations affect exports of pollution-intensive or "dirty" goods in 24 countries between 1994 and 1998. Based on a Heckscher-Ohlin-Vanek (HOV) model, net exports in five pollution-intensive industries are regressed on factor endowments and measures of environmental standards (legislation in force). The results suggest that, if country heterogeneity such as enforcement of environmental regulations is controlled for, more stringent environmental standards imply lower net exports of metal mining, nonferrous metals, iron and steel and chemicals. Moreover, we find that a trade agreement on a common environmental standard will cost a non-OECD country substantially more than an OECD country. Developing countries will, on average, reduce exports of the five pollution-intensive products by 0.37 percent of GNP. This represents 11 percent of annual exports of these products from the 24 studied countries.

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1. Introduction

The relationship between environmental standards and trade is at the forefront of policy debate. Disputes over linkages between trade and the environment have intensified over the past decade. The 1999 Seattle Ministerial of the World Trade Organization (WTO) ended in failure, at least in part, due to profound differences over tying environmental performance to competitiveness in exports. The issue of whether to link trade agreements to environmental standards was one of the factors for consideration at the WTO Ministerial in November 2001 in Doha, Qatar. There are only weak disciplines currently in the WTO agreements regarding environmental standards, as reflected in the Marrakech decision on trade and environment. The Technical Barriers to Trade Agreement and the Agreement on Sanitary and Phytosanitary Standards both include provisions related to environmental protection, however, there have been few formal disputes that were brought to the WTO. The question remains whether trade agreements are the best policy tool to affect change in environmental policy.[1]

If lax environmental standards provide additional incentives for export competition in pollution-intensive industries, and if developing countries do not place an emphasis on domestic environmental quality, then free trade may result in a "race to the bottom" in regulation. Private sector firms may exert pressure on governments in developed countries to scale back the most stringent environmental standards. Alternatively, if developed countries seek to harmonize environmental standards

[1] For a more detailed discussion of these issues see: Global Economic Prospects and the Developing Countries 2001, chapter 3, The World Bank, December 2000.

globally at increasingly high levels, then developing countries may confront lower growth rates of exports in pollution-intensive industries.

This paper empirically explores the link between trade and environmental standards by controlling for human capital as a technological variable. We also explicitly include a measure of the degree of enforcement of environmental regulations in the modeling. This enforcement mechanism is assumed to have a distinct role from environmental legislation in the analysis.

We study major pollution–intensive industries: metal mining, nonferrous metals, pulp and paper, iron and steel, and chemicals in 6 OECD and 18 non–OECD countries over the period 1994 to 1998. The analysis in large part follows the Hecksher–Ohlin–Vanek (HOV) model developed for econometric estimation by Tobey (1990), using data on environmental stringency from Dasgupta et al. (2001).

This paper is organized as follows: Section 2 reviews the existing theoretical and empirical works on trade and environmental regulation. Section 3 discusses the common and distinct characteristics of the pollution-intensive industries. Section 4 reviews the existing cross-country measures of the stringency of environmental regulation. Section 5 presents the data and the analytical framework. Section 6 reports the results, and Section 7 analyzes the results and their implication on trade policy.

2. Trade and Environmental Regulation

Most studies that trace the link between trade and the stringency of an environmental standard explore either the industrial flight (pollution–haven) or industrial specialization hypothesis. The industrial flight hypothesis centers on investigating the factors that determine industry location and whether environmental regulations influence foreign direct investment decisions by firms. These studies are largely concerned with the possibility of flight by pollution-intensive industries and foreign direct investment (FDI) from developed to developing countries. The industrial specialization hypothesis is explored by examining whether lax environmental standards lead to specialization in pollution–intensive industries by creating greater accessibility for industries to air and water resources.

The empirical evidence in the industry flight literature is mixed. Pearson (1987), Leonard (1988), Friedman, et al. (1992), and Levinson (1996) found little or no evidence that environmental regulations have a significant impact on the investment or location decisions of foreign firms. Mani, Pargal and Huq (1997), Gray (1997), and Wheeler (2000) offer a counter–argument for this hypothesis.

Levinson (1996) employed firm-level data on location choice and pollution abatement costs to assess the effect of state environmental regulations on new manufacturing plant locations in the U.S. Levinson indicates that the limited evidence of industry flight stems from firms that have plants in several states following the most stringent environmental regulations in all locations. Mani, Pargal and Huq's (1997) study of new plant locations in India indicate that environmental spending, presumably occurring as a result of more stringent regulation, is likely to be higher for more pollution-intensive industries. Gray (1997) note that firms want to locate where the markets are and that polluted areas may have shrinking markets, hence driving some firms away.

On the contrary, Lucas et al. (1990) and List and Co (1999) found some support for the industry-flight hypothesis. Lucas et al. suggest that implementation of progressively strict environmental regulations in the OECD countries have led to significant location displacement of pollution–intensive industries. List and Co study show that regulatory expenditures per manufacturer and the location decision of a new firm are inversely related in West Virginia.

Smarzynska and Wei (2001) also find some support for the industry-flight hypothesis. They control for corruption levels in a host country and use a firm level dataset for 25 transition economies to assess support for the industry flight hypothesis. Wheeler (2000) provides examples of the link between air pollution regulation and FDI in Mexico, Brazil, India, and the U.S. that illustrate the importance of community, or firm level efforts, to internalize the costs of pollution in developing countries.

The majority of studies that examine industrial specialization have found little or no empirical support (Tobey, 1990; Low and Yeats, 1992; Grossman and Krueger, 1993; Xu, 1999). Tobey (1990) investigates whether domestic environmental regulations have an impact on international trade patterns in five pollution-intensive industries for 23 countries. He found no statistical significance of his environmental regulation measures on the net exports of these industries. Grossman and Krueger (1993) find no evidence that a comparative advantage is being created by lax environmental regulations in Mexico. Xu (1999)'s study on bilateral trade found no evidence that a country with stricter environmental standards lowering their total exports of pollution–intensive goods.

Low and Yeats (1992) found that pollution-intensive industries account for a large and growing share of exports in the total manufacture of exports in some developing countries, and a decreasing share of exports in developed countries between 1965 and 1988. Grossman and Krueger argue that the difficulty in finding and supporting statistical evidence for the industrial specialization hypothesis lies in the fact that endowments such as physical and human capital, and investment remain dominant in determining a county's trade pattern.

On the contrary, Kalt (1988) finds that environmental regulations in the U.S. have led to a sharp reduction in net manufacturing exports in 1977 presumably due to a shift of output mix toward the production of clean air and water, and away from pollution-intensive outputs. In contrast, Antweiler et al. (1998) suggests that trade changes the composition of national output in a more polluting way for capital–abundant countries. This implies that the developed countries have comparative advantage in producing pollution–intensive goods.

3. Pollution–Intensive Industries

Various definitions have been used for pollution-intensive industries in the empirical literature. Grossman and Krueger (1993) measure environmental intensity by using the ratio of pollution abatement costs to the total amount of value added to a specific U.S. industry. Low and Yeats (1992), and Xu (1999) define pollution-intensive goods as products of industries that incurred abatement costs in the U.S. of approximately 1 percent or more of the total value of sales in 1988. This definition results in four industries: Iron and Steel, Metal Manufactures, Cement, and

Agricultural Chemicals. Smarzynska and Wei (2001) include in their analysis a set of pollution-intensive industries, which range from the low to high level of pollution. While the Smarzynska and Wei approach appears to be the most general in nature a certain level of aggregation is useful when the impact of environmental standards is compared across industries. Tobey defines pollution-intensive industries, as "those whose direct and indirect abatement costs in the U.S. are equal to or greater than 1.85 percent of total costs." According to the author, 1.85 percent is used, because it results—when commodities are aggregated—in a set of five industries that are generally considered the polluting: Metal Mining, Primary Nonferrous Metals, Pulp and Paper, Primary Iron and Steel, and Chemicals.

As there appears to be no definitive criteria yet adopted to define pollution intensive, we follow Tobey's definition of pollution-intensive industries in our analysis for comparison purposes. These five industries aggregate three-digit SITC industries in the following manner:

Metal Mining: SITC (Revision 1) 281, 283

Primary Nonferrous Metals[2]: 681, 682, 683, 684, 685, 686, 687, 689

Pulp and Paper: 251, 641, 642

Primary Iron and Steel: 671, 672, 673, 674, 675, 676, 677, 678

Chemicals[3]: 512, 513, 514, 581

[2] Tables 2 and 3 contain all of the relevant information about nonferrous metals.

[3] We added the Organic Chemicals industry to the Chemicals industry category, as it is also considered to be pollution–intensive.

Information about the pollutant releases presented in the paper is available from the most recent TRI reporting notebook for the year of 1993. The TRI system contains data on total toxic emissions during production. Table 2 provides a description of the chemicals causing pollution and different pollution prevention activities,[4] while Table 3 provides an overview of the amount of different pollutants released and transferred from each industry.

In the TRI notebook, total toxic emissions are divided into releases and transfers. Total releases are defined as "On-site discharge of a toxic chemical to the environment." This includes emissions to the air, discharges to water, and disposal to land. Transfers are defined as "Transfers of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI." The quantities reported represent a movement of the chemical away from the reporting facility." Unless the disposal is off-site, these waste products do not necessarily contribute to pollution.

In 1993, the total amount of releases and transfers of the Pulp and Paper industry was 218 million pounds of toxic chemicals, whereas the Chemicals industry released and transferred 2.5 billion pounds that accounted for 33 percent of all releases and transfers. Toxic chemical releases from the pulp and paper facility were approximately 550,000 pounds, i.e. five times as much as the mean amount of toxic chemical releases per facility across all of the industries in the TRI system. Table 3 shows that the maximum amount of pollution released (87 percent) by the Pulp and

[4] Information on the Mining industry is derived from the Mineral Waste Releases and Environmental Effects Summaries, since we do not have TRI reporting available for this industry.

Paper industry is emitted to the air, followed by approximately 10 percent of as water discharge.

A total of 438 million pounds of toxic chemicals were released and transferred by the Organic Chemical industry, representing 18 percent of the total releases and transfers by the entire chemical industry, and 6 percent of the releases and transfers by all the industries under TRI. In comparison, releases and transfers by the Inorganic Chemical industry totaled 249.7 million pounds in 1993. The Plastics industry releases were mainly air pollutants. The Chemicals industry comprises the Organic, Inorganic and Plastics industries. Historically, the Chemicals industries surpassed the other industries in TRI chemical releases. Emissions to the air, and discharges to water, are very significant in the Chemicals industry.

The Iron and Steel industry released and transferred a total of approximately 695 million pounds of pollutants containing a large proportion of metal-bearing wastes. About 70 percent of these wastes are transferred for offsite recycling in order to recover the metal content that results in increase in transfers in this industry. Waste disposal on land represents a very large proportion from the total releases of the Iron and Steel industry. When the transfers of different industries are compared, the Iron and Steel industry appears to have a very high amount of pollutants relative to the other industries. Moreover, emissions to the air and discharges to water are significantly lower than land disposal. The bulk of industrial wastes from the Iron and Steel industry are recycled.

4. Measuring Environmental Standards

It is essential to choose a reliable measure of an environmental standard. List and Co (1999) use four different measures of the stringency of environmental regulation for the U.S. The first two measures estimate money spent by different agencies within a state to control air and water pollution and solid waste disposal. The third measure they use is firm-level pollution abatement operating expenditures relative to abating air and water pollution and solid waste disposal. The fourth measure is an index that combines local, state and federal government pollution abatement efforts with firm-level abatement expenditures to assign a dollar-value ranking to each state. A higher value in the index implies more stringent environmental regulations. Tobey (1990) on the other hand, measures environmental stringency by using data from a 1976 UNCTAD survey. The degree of environmental stringency is measured from one to seven. Higher values imply more stringent regulations. Levinson (1996) includes six different measures of environmental stringency in his study. These measures are: (1) the Conservation Foundation index that measures each state's "effort to provide a quality environment for citizens" (Duerksen, 1983); (2) the FREE (Fund for Renewable Energy and the Environment) index, which measures the strength of state environmental programs; (3) the Green index which is an aggregate measure of the number of statutes that each state has from a list of 50 common environmental laws; (4) monitoring employment that measures the states' efforts and abilities in enforcing statutes; (5) aggregate abatement costs that show aggregate pollution abatement operating costs across industries deflated by the number of production workers in the state in 1982, and finally; (6) industry abatement costs which measure the amount the manufacturers are required to pay for pollution abatement in each state, provided that the characteristics of the manufacturer remain unchanged. Smarzynska and Wei (2001) measure environmental standards by a country's participation in international treaties (e.g. Convention on Long-range Transboundary Air Pollution), the quality of ambient air, water and emission standards, and finally observed actual reduction in various pollutants.

We use a cross-country index of the stringency in environmental regulation developed by Dasgupta et al. (2001) for our analysis. A higher score in this index reflects more stringent environmental standards. The authors randomly selected 31 UNCED reports from a total of 145. These 31 countries range from highly industrialized, to extremely poor. Based on these reports, they conducted a survey that considered the state of policy and performance in four environmental dimensions: air, water, land, and living resources. We analyzed the apparent state of policy as it affects the interactions between these four environmental dimensions and five activity categories: agriculture, manufacture, energy, transport, and the urban sector. Although many overlaps undoubtedly exist, we attempt to draw a separate assessment for the interaction of each activity category with each environmental dimension.

The Dasgupta survey employed 25 questions to categorize (1) the state of environmental awareness, (2) the scope of legislation enacted, and (3) the control mechanisms for environmental enforcement in place in each country. Environmental awareness in the Dasgupta survey is a measurement of a country's level of public concern about environmental quality. The legislation category of the Dasgupta survey measures the extent to which a country's environmental legislation provides broad protection of natural resources – such as protection of air, water, land, and other resources. A control mechanism for environmental enforcement measures the ability of regulators to enforce legislation. It reflects the history of environmental regulation, existence of regulating institutions and infrastructure, and power given to regulating agencies in each country.[5]

Due to its multi-dimensional property, the elements of this index can be disaggregated to construct variables that are useful for empirical analysis. The index is particularly useful for treating different aspects of environmental regulation separately, as they have a distinct, but interactive role in environmental regulation. Moreover, the data allow us to disaggregate the indices into the sectors, so that we focus only on the industries that are relevant to the analysis, namely manufacturing industries.

5. The Econometric Model

In addition to the choices of reliable measures of an environmental standard, we attempt to make an improvement in the econometric model by explicitly incorporating the key problems that the studies reviewed above had found. In summary, they suggest that the effect of environmental standards on exports is difficult to statistically observe because: (1) the variation of exports due to environmental standards is much subtler than the variation due to the basic factors of

[5] The status in each category is graded as high, medium, or low, with assigned values of 2, 1 and 0, respectively. For each UNCED country report, twenty-five questions are answered and total scores are developed for each country.

production, and other traditional determinants of trade patterns, FDI and location choice (Tobey, 1990; Low and Yeats, 1992; Dean, 1992; Grossman and Krueger, 1993; and Mani, Pargal and Huq, 1997); (2) omitted variables such as input quality and technological level make it difficult to obtain a reliable parameter estimate (Nordström and Vaughan, 1999); and (3) differences in a community or country's control mechanism for environmental enforcement may affect the effectiveness of environmental regulation (Wheeler, 2000; Smarzynska and Wei, 2001).

The first point does not necessarily imply that the effect of an environmental standard is insignificant. It is rather problematic if the standard variable is highly correlated with the other regressors. Using instrumental variables for the standard variable will mitigate this problem. The second point will be handled by including variables that measure the quality of factor endowments, as they are considered to be one of the important factors to cause the omitted variable effects. The third point will be addressed by explicitly incorporating the structure in which control mechanisms for environmental enforcement interact with an environmental standard.

We revisit the industrial specialization hypothesis with particular consideration of the above issues. Our conceptual model follows the Heckscher-Ohlin-Vanek (HOV) model, which was first developed by Leamer (1984). As commonly viewed in the industrial specialization literature, the environment is treated as a factor of production that is directly used for agricultural and industrial production as an input, or that the environment is degraded through air and water pollution as an end product of production processes. The Heckscher-Ohlin theorem, if it is extended in this context, suggests that countries that have lax environmental standards (thus, environmentally abundant) will, under a free trade regime, specialize in pollution-intensive goods.

We follow Tobey's cross-section multifactor HOV model, where multi-country data for environmental standards would fit well. We use the performance indices of countries in terms of environmental regulation developed by Dasgupta et al. (2001). These indices are used to construct two key variables for environmental regulation—the scope of environmental legislation—and the control mechanism for environmental enforcement.

Our analysis employs trade data on pollution-intensive industries from 24 OECD and non-OECD countries. The five pollution-intensive industries presented in Section 3 are used for our analysis. Net exports and factor endowments were obtained for the five-year period between 1994 and 1998. Following Tobey's HOV model, the regression model for an individual industry is specified as follows:

$$\begin{aligned} Y_{j,t} &= b_0 + b_1 cap_{j,t} + b_2 lab_{j,t} + b_3 coal_{j,t} + b_4 oil_{j,t} + b_5 arland_{j,t} \\ &\quad + b_6 schl_{j,t} + b_7 leg_{j,t} + b_8 cm \cdot leg_{j,t} + b_9 D_{OECD\,j,t} \cdot leg_{j,t} + b_{10} cm_{j,t} + e_{j,t} \end{aligned} \qquad (1)$$

where the subscripts *j* and *t* denote the country and the year, $Y_{j,t}$ is the value of net exports (US$ million) in country *j* in the year *t*. The parameter b_0 is the estimated coefficient for the intercept term. The parameters b_1 to b_{10} are the estimated coefficients for the explanatory variables. The term $e_{j,t}$ is the error term, which we will assume to follow the normality and the zero mean.

Capital stock (*cap*), labor (*lab*), coal (*coal*), oil (*oil*), and arable land (*arland*) are included, as they measure factor endowments of a country. Secondary school enrollment rate (*schl*) is included in our model, as it measures labor skills. Since this variable perhaps is likely to be correlated with quality of other factor endowments and technological levels, we hope the inclusion of this variable will generally mitigate omitted variable effects.

Capital stock (in US$ billions) is computed as an accumulated and discounted gross domestic investment flow in constant 1995 US dollars since 1980, assuming an average life of 15 years, and a constant depreciation rate of 13.3 percent per year.[6] Labor (in millions of people) is computed as the number of workers in the labor force who meet the International Labor Organization definition of an economically active population: all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed. While national practices vary in the treatment of such groups as the armed forces and seasonal or part-time workers, in general, the labor force includes the armed forces, the unemployed, and first-time job seekers. Arable land measures the area of arable land in hectares. Arable land includes land defined by the Food and Agriculture Organization (FAO) as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land left temporarily fallow. The value of the production of primary solid fuel in U.S. dollars is used to measure the endowment of coal. The value of oil and gas production in U.S. dollars is used to measure oil endowment.

[6] See Maskus (1991) for the discussion on this approach.

The variable *schl* follows the definition of the International Standard Classification of Education on a net secondary school enrollment ratio. It is the ratio (in percent) of the number of children at the official school age (as defined by the national education system) who are enrolled in school, to the population of the corresponding official school age. Secondary education completes the provision of basic education that began at the primary level, and aims to lay the foundation for lifelong learning and human development, by offering more subject- or skill-oriented instruction, with more specialized teachers.

Data on capital, labor, and secondary school enrollment were obtained from the World Development Indicators of the World Bank. Data on oil and gas production (in millions of barrels), and coal (in millions of short tons) were obtained from the U.S. Department of Energy (USDOE) database.

In our model, the state of legislation (*leg*) is constructed from the Dasgupta et al. (2001) dataset, and has been used as the measure of an environmental standard. It is measured by aggregating the scores on the scope of legislation enacted in the manufacturing sector (see Table 1 for the total scores on legislation). Similarly, the scores on the control mechanism for environmental enforcement (*cm*) are calculated by aggregating the scores on the control mechanism for environmental enforcement for the manufacturing sector.

As discussed earlier, the effect of legislation may differ according to the state of the control mechanism for environmental enforcement. As modeled in Smarzynska and Wei (2001), an inclusion of a product term between the legislation and a control mechanism variable is intuitive. The product term allows a slope for the legislation variable to vary across countries, particularly between developed and developing countries.

In addition, unobserved differences between developed and developing countries can be controlled by using a slope dummy for developed (or developing) countries. We use a dummy variable for OECD membership, D_{OECD}. How the state of a control mechanism for environmental enforcement, and the stage of development will affect the effectiveness of legislation can thus be tested by examining statistical significance of b_8 and b_9, respectively. The total effect of the state of legislation can be tested by investigating the statistical significance of $b_7 + b_8 cm + b_9$ for the OECD countries and $b_7 + b_8 cm$ for the non-OECD countries. Details of this effect will be explained later in Section 6.

Statistical independence between the explanatory variables is required for reliable parameter estimates, but Table 4 indicates possible multi-collinearity in some pairs of the variables. It is particularly problematic when key variables from which policy implication is to be derived are correlated with other explanatory variables. Notably, *leg* and *cm* are highly correlated, which will likely prevent deriving separate policy implications of each variable, thus, instrumental variables are used for each of these variables. Instrumental variables are chosen such that they are not correlated with the other instrumental variables, and also with the instruments for that variable. Data on these instruments are obtained from the Environmental Sustainability Index, developed jointly by the World Economic Forum's Global Leaders for Tomorrow Environment Task Force, the Yale Center for Environmental Law and Policy, and the Columbia University Center for International Earth Science Information Network

(2001), except for the data on a country's total government expenditure, which is obtained from the World Bank's World Development Indicators (1995–1998).

The instruments used for legislation are: (1) the number of memberships in environmental intergovernmental organizations (*eionum*); (2) percentage of cites reporting requirements met (*cites*); (3) levels of ratification under the Vienna convention for the protection of the ozone layer (*vienna*); (4) Montreal protocol multilateral fund protection (*monfun*); (5) the number of ISO 14001 certified companies per GDP (*iso14*); and (6) environmental strategies and action plans (*plans*). The instruments used for the control mechanism variable are (1) members of the International Union for Conservation of Nature and Natural Resources (IUCN) (*iucn*), (2) government expenditure per capita (*gov*), and (3) the number of sectoral EIA guidelines (*eia*).[7] While the choice of these instrumental variables is based on the logical linkage and causal relationship, we also chose them such that they were not strongly correlated with other explanatory variables in Equation (1) and their counterpart instrumental equation (see Table 4).

The two instrumental equations are assumed to take a linear form:

$$leg_{j,t} = a_0 + a_1 eionum_{j,t} + a_2 cites_{j,t} + a_3 vienna_{j,t} + a_4 monfun_{j,t} + a_5 iso14_{j,t} + w_{j,t} \tag{2}$$

$$cm_{j,t} = g_0 + g_1 iucn_{j,t} + g_2 gov_{j,t} + g_3 eia_{j,t} + V_{j,t} \tag{3}$$

A Non-Linear Two-Stage Least Squares (NL2SLS) method is used to estimate equation (1) for the five pollution-intensive good exports. NL2SLS method is used because a product term makes the model structure non-linear and also to account for the presence of instrumental variables in the product term. Kelejian (1991) offers an approach that estimates a system of non-linear equations. He suggests estimating first the slope parameters equation by equation, then calculating the gradients of these equations with respect to the slope parameters, and evaluating them at the estimated values of these parameters. Then use these gradient vectors as instruments for the dependent variables.

We have one non-linear equation and two instrumental equations. Thus, we have three dependent (or endogenous) variables. Amemiya (1976) indicates that a different set of gradients can be used for each equation. This allows us to have a rather simple equation system. We use the original 6 and 3 instrumental variables for *leg* and *cm*, respectively. We also use the explanatory variables in Equation (1) as instruments for *nex*. This makes Equations (1), (2) and (3) unchanged. But it is necessary to include an additional equation that has the product term, *leg cm*, as the instrumental variable. It is because this term is also a gradient, and consists of two dependent (or endogenous) variables. We use all 9 of the instrumental variables for *leg* and *cm*, and the product terms that pair each of the 6 instrumental variables for *leg* and each of the 3 instrumental variables for *cm*, as they logically follow. The instrumental equations for *leg*, *cm* and the product term, are fitted in the first stage. In the second stage, Equation (1) is estimated by replacing the corresponding variables with these fitted values. In this stage, we corrected for heteroscedasticity in

[7] While the use of these instrumental variables follow a logical order, a necessary assumption is made that the instrumental variables are unchanged over time.

Equation (1) by weighting the observations by the square root of the OLS estimated variances from the individual country.[8]

6. Results

The results are reported in Table 5. Capital is found to be significant for all of the five industries with a negative effect for the Mining and Nonferrous Metals industries and positive effect for the Pulp and Paper, Iron and Steel and Chemicals industries. Labor is positive and significant for the Chemicals industry, but it is insignificant for the Nonferrous Metal industry, and significantly negative for the Mining, Pulp and Paper and Iron and Steel industries. The coefficient estimate for coal is found to be positive and marginally significant for the Nonferrous Metals and Iron and Steel industries, while it is significantly negative for the Metal Mining industry. The effect of coal in the Pulp and Paper and Chemicals industries is insignificant. Arable land has a significant effect in all of the industries, with varying signs across industries. Oil is significant for the Mining and Chemicals industries, with a positive effect in the Mining industry, and a negative effect in the Chemicals industry. Oil is insignificant in the other three industries (Nonferrous Metals, Pulp and Paper, and Iron and Steel). Labor skills, as measured by the variable school, appear to have a positive significant relationship with net exports for all the industries, except for the Pulp and Paper industries, where it is insignificant. Negative coefficient estimates for the factor endowment variables, in some cases, are difficult to explain by real world observations. It is perhaps due to the high correlation among these variables.

[8] See Amemiya (1985) for the detail of this method.

Table 6 reports the results of a joint significant test of the effect of the state of legislation on net exports. The terms $b_7 + b_8 cm + b_9$ for the OECD countries and $b_7 + b_8 cm$ for non-OECD are found to be negative and significant in all industries, except for the Pulp and Paper industry in non-OECD countries. The results regarding the legislation variable generally support the industrial specialization hypothesis. More stringent environmental standards imply less net exports of pollution–intensive industries. This negative relationship is revealed once the control mechanism for environmental enforcement and the unobserved heterogeneous factors across countries are taken into account.

The total effect of legislation is, however, significantly different between OECD and non-OECD countries. As Table 5 shows, the estimated coefficient for b_9 is significant and negative in all cases. This means that environmental legislation has a more dramatic effect on net exports in OECD countries than in non-OECD countries. The role of a control mechanism for environmental enforcement in influencing the marginal effect of legislation on net exports is, however, not evident.

The estimated coefficient for the product term between *leg* and *cm* is insignificant in all industries. Unlike our prior expectation, the effect of legislation does not systematically vary with the control mechanism measure. Nevertheless, it is perhaps still useful to include this product term as a control variable in order to improve the estimate for the joint term $b_7 + b_8 cm + b_9$. The direct effect of the control mechanisms on net exports measured by b_{10} is positive and significant in the Mining, Nonferrous Metals and Chemical industries, while it is insignificant for the Pulp and Paper and Iron and Steel industries. The results regarding the control mechanism variable generally differ from the prior expectation. If the results are considered to reflect the true underlying relationship, the insignificant sign on the product term may reflect that the effectiveness of legislation may be enhanced more significantly by factors other than control mechanisms for environmental enforcement. The positive sign on the single term may reflect the fact that improved control mechanisms for environmental enforcement imply better compliance ability of the country to the environmental standards of its exporting partners.

7. Conclusions and Policy Implications

What do these findings suggest in regard to trade policy and multilateral disciplines on environmental protection? Our analysis suggests that environmental regulation can affect export competition. The negative relationship between the stringency of environmental standards and exports in the majority of industries examined may imply a possible trade-off between two goals—trade expansion and encouraging improvements in environmental standards. If developing countries do not place an emphasis on environmental quality, they are reluctant to tighten environmental standards. This could then result in a so-called “race-to-the-bottom” as with lack of international coordination pollution may become more concentrated in the developing countries.

If developed countries, instead, seek to harmonize environmental standards globally at high levels, through trade agreements, then developing countries may suffer from a greater loss in exports of the pollution-intensive products than a developed country. For example, suppose that all of the countries in our sample harmonize environmental standards at the most stringent level (Germany, Ireland, the Netherlands, and Switzerland). Based on our estimated slope parameters, a non-OECD country will, on average, reduce exports of the five pollution-intensive products by US$ 2.6 million each year, or 0.37 percent of the average GNP of the non-OECD countries in our study. This represents 11 percent of annual exports of these products from the 24 studied countries. In contrast, an OECD country, on average, will reduce annual exports by US$ 0.62 million, or 0.019 percent of the average GNP of the OECD countries in our study. This is 2.5 percent of annual exports of these products from the 24 studied countries.

This illustrates that global harmonization of environmental standards reduce developing country exports of pollution-intensive goods more than exports from developed countries. Our findings suggest tighten environmental standards in developing countries gradually with transition periods could avoid rapid decline in net exports of pollution-intensive products. It is also important to raise public environmental awareness in developing countries so that the loss of export competitiveness in these products are placed within the context of improved environmental benefits.

The implications of our analysis are more complex, but remain relevant, for questions of trans-boundary pollution that form the core agenda of the new WTO negotiations. The results do indicate a relationship between standards and trade. Developed countries are motivated to set a high global environmental standard in multilateral environmental agreements, as they tend to benefit more from reductions in trans-boundary pollution produced outside their borders. Some of the pollution generated by the industries studies here do cross national borders. International coordination to offset loss in export competitiveness shown here should be part of discussion at the WTO. Moreover, the targeting principle that suggests that addressing pollution emissions at the source through taxes and other direct domestic policy instruments—rather than through trade sanctions or limits on imports of goods by trading partners—remains the more rational policy prescription to suggest in this area, rather than embedding new obligations in trade agreements at the WTO.

References

Amemiya, T. 1976. Estimation in Nonlinear Simultaneous Equation Models. Paper presented at *Institut National de La Statistique et Des Etudes Ecnomiques,* Paris, March 10 and published in Malinvaued, E. (ed.), Cahiers Du Seminarire D'econometrie, no 19.

Amemiya, T. 1985. Advanced Econometrics. Cambridge: Harvard University Press.

Antweiler, W., B. Copeland, and S. Taylor. 1998. Is Free Trade Good for the Environment? *Discussion paper # 98-11,* Department of Economics, University of British Columbia, Canada.

Dasgupta, S., Mody, A., Roy, S., and D. Wheeler. 2001. Environmental Regulation and Development: A Cross-Country Empirical Analysis. *Oxford Development Studies,* Vol. 29(2):173-187.

Dean, J.M. 1992. Trade and the Environment, A Survey of the Literature in *World Bank Discussion Paper Series #159,* 15-28. Washington, D.C.: The World Bank.

Duerksen, C.J. 1983. Environmental Regulation of Industrial Plant Siting. Washington, D.C.: The Conservation Foundation.

Environmental Sustainability Index. 2001. World Economic Forum, Yale Center for Environmental Law and Policy. http://www.ciesin.org/indicators/ESI/downloads.html#report.

EPA Office of Compliance Sector Notebook Project. 1995. Washington, D.C.: U.S. Environmental Protection Agency.

Friedman, J., D. Gerlowski, and J. Silberman. 1992. What Attracts Foreign Multinational Corporations? Evidence from Branch Plant Location in the United States. *Journal of Regional Science* 32: 403-418.

Gray, W. 1997. Manufacturing Plant Location: Does State Pollution Regulation Matter? National Bureau of Economic Research (NBER) Working Paper # 5880. Boston, Massachusetts: NBER.

Grossman, G.M. and A.B. Krueger. 1993. Environmental Impacts of a North American Free Trade Agreement. In *The Mexico-U.S. free trade agreement*, ed. P.M. Garber. 13-56. Cambridge, Massachusetts and London: MIT Press.

Kalt, J.P. 1988. The Impact of Domestic Environmental Regulatory Policies on U.S. International Competitiveness. In *International Competitiveness*, A.M Spence and H.A. Hazard, eds. 221-262. Cambridge, Massachusetts: Ballinger.

Kelejian, H. 1971. Two-stage Least Squares and Econometric Systems Linear in Parameters but Nonlinear in the Endogenous Variables, *Journal of the American Statistical Association.* 66: 373-374.

Leamer, E.E. 1984. Sources of International Comparative Advantage: Theory and Evidence. Cambridge Massachusetts: MIT Press.

Leonard, H.J. 1988. Pollution and the Struggle for World Product. Cambridge, Massachusetts: Cambridge University Press.

List, J.A. and C.Y. Co. 1999. The Effects of Environmental Regulations on Foreign Direct Investment. *Journal of Environmental Economics and Management.* 40: 1-20.

Low, P. and A. Yeats. 1992. Do Dirt Industries Migrate? *World Bank Discussion Paper Series #159.* 89-103. Washington, D.C.: The World Bank.

Levinson, A. 1996. Environmental Regulations and Manufacturers Location Choices, Evidence from the Census of Manufacturers. *Journal of Public Economics* 62:5-29.

Lucas, R.E.B., D. Wheeler, and H. Hettige. 1990. Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution. Paper presented at the *Symposium on International Trade and the Environment*, Washington D.C.

Mani, M., S. Pargal, and M. Huq. 1997. Does Environmental Regulation Matter? Determinants of the Location of New Manufacturing Plants in India. *Policy Research Working Paper* # 1718. Washington, D.C.: The World Bank.

Maskus, K.E. 1991. Comparing International Trade Data and Product and National Characteristics Data for the Analysis of Trade Models. In *International economic transactions: Issues in measurement and empirical research*, P. Hooper and J.D. Richardson, eds. National Bureau of Economic Research Studies in Income and Wealth. 55: 17-56. Chicago, Illinois and London: University of Chicago Press.

Nordstrom, H. and S. Vaughan 1999. Trade and Environment. Geneva, Switzerland: World Trade Organization.

Pearson, C. 1987. Multinational Corporation, the Environment and Development. Washington, D.C.: World Resources Institute.

Smarzynska, B.and S. Wei. 2001. Pollution Havens and the Location of Foreign Direct investment: Dirty Secret or Popular Myth? June 10, 2001. Washington, D.C.: International Trade Team – Development Economics Research Group, The World Bank. Mimeo.

Tobey, J.A. 1990. The Effects of Domestic Environmental Policies. *Kyklos*, 43(2):191-209.

UNCED. 1990. Draft Format for National Reports. Geneva: United Nations Conference on Environment and Development.

World Bank. 2000. Global Economic Prospects and the Developing Countries 2001. Washington, D.C.: The World Bank.

Xu, X. 1999. International Trade and Environmental Regulation: A Dynamic Perspective. Huntington, New York: Nova Science Publishers, Inc.

Wheeler, D. 2000. Racing to the Bottom? Foreign Investment and Air Pollution in Developing Countries. *Policy Research Working Paper* #2524. Washington, D.C.: The World Bank.

Table 1. Scores for the State of Legislation (Max=24)

OECD country		Non-OECD country	
Finland	21	Bangladesh	9
Germany	24	Brazil	14
Ireland	24	Bulgaria	23
Korea	22	China	17
Netherlands	24	Egypt, Arab Rep.	11
Switzerland	24	India	16
		Jamaica	22
		Jordan	16
		Kenya	12
		Malawi	11
		Mozambique	9
		Paraguay	9
		Philippines	12
		South Africa	19
		Thailand	10
		Trinidad and Tobago	13
		Tunisia	21
		Zambia	12

Table 2. Major Pollutants and Pollution Prevention Activities

	Major chemicals contributing to pollution	Major pollution prevention activities	Pollution abatement costs as percentage of total costs
Metal Mining	Chlorine, Arsenic, Cadmium.	Flotation, leaching, tailing, metal parts cleaning, blasting and crushing.	1.92-2.03
Nonferrous Metal	Chlorine, Copper compounds, Zinc compounds, Lead compounds, and Sulfuric acid.	Process equipment modification, raw materials substitution or elimination, solvent recycling, precious metals recovery.	2.05
Pulp and Paper	Methanol, Hydrochloric acid, Sulfuric acid, Chloroform.	Extended delignification, enzyme treatment of pulp, chlorine dioxide substitution, improved chipping and screening, improved chemical controls and mixing.	2.40
Iron and Steel	Hydrochloric acid, Ammonia, Zinc compounds.	Reducing cokemaking emissions, reducing wastewater volume.	2.38
Inorganic Chemical	Hydrochloric acid, Chromium, Carbonyl Sulfide, Ammonia.	Substitution of raw materials, improve reactor efficiencies and catalyst, improve wastewater treatment and recycling.	2.89
Plastics	Trichloroethane, Acetone, Carbon disulfide.	Overall process to control for waste water, disposal and pellet release.	2.36
Organic Chemical	Sulfuric acid, Methanol and *ter*t-butyl alcohol.	Overall process to control for catalysts, raw materials e.t.c.	1.53-2.89

Source: U.S. EPA (1995) and Tobey (1990).

Table 3. Annual Releases and Transfers for Pollution-Intensive Industries in 1993

	Releases (in thousand pounds)				Transfers
Industry	Air Pollutant	Water Pollutant	Land Disposal	Total Releases	Total Transfers
Metal Mining	Not available				
Nonferrous Metal	79,861 (45%)	5,862 (3.3%)	91,868 (51.7%)	177,591	33,580
Pulp and Paper	148,272 (87.4%)	17,666 (10.4%)	3,727 (2.2%)	169,665	48,416
Iron and Steel	21,552 (25.1%)	18,479 (21.5%)	45,767 (53.4%)	85,798	609,540
Inorganic Chemical	25,104 (14%)	123,474 (69%)	31,064 (17%)	179,642	70,046
Plastics	117,702 (99.4%)	308 (0.26%)	394 (0.34%)	118,404	45,044
Organic Chemical	61,000 (40.2%)	88,450 (58.2%)	2,400 (1.6%)	151,850	135,700
TRI industry average	93%	1%	6%		

Source: U.S. Environmental Protection Agency (1995).

Table 4. Correlation Coefficient Matrix

	Explanatory variables								Instruments								
	cap	lab	arland	schl	coal	oil	leg	cm	eionum	cites	vienna	monfun	iso14	plans	iucn	gov	eia
cap	1.00																
lab	0.11	1.00															
arland	0.11	0.98	1.00														
schl	0.33	-0.17	-0.14	1.00													
coal	0.52	0.68	0.68	0.17	1.00												
oil	0.13	0.50	0.58	-0.02	0.29	1.00											
leg	0.36	-0.11	-0.09	0.76	0.19	-0.20	1.00										
cm	0.50	-0.13	-0.13	0.73	0.21	-0.20	0.86	1.00									
eionum	0.57	0.22	0.23	0.64	0.33	0.32	0.53	0.73	1.00								
cites	0.31	0.22	0.20	0.10	0.38	-0.22	0.18	0.24	0.21	1.00							
vienna	0.29	-0.37	-0.37	0.39	-0.23	0.03	0.41	0.30	0.32	-0.07	1.00						
monfun	-0.06	-0.23	-0.20	0.27	-0.06	-0.08	0.39	0.25	0.00	-0.24	0.38	1.00					
iso14	0.02	-0.04	-0.03	0.06	-0.08	0.05	0.06	0.07	0.15	0.19	-0.04	-0.06	1.00				
plans	-0.08	0.31	0.30	0.14	0.25	0.22	0.08	0.23	0.45	0.10	-0.14	-0.17	-0.22	1.00			
iucn	-0.19	-0.37	-0.34	0.27	-0.25	-0.37	0.45	0.49	0.11	-0.03	0.16	0.18	0.04	0.23	1.00		
gov	0.50	-0.17	-0.17	0.59	0.08	-0.16	0.67	0.93	0.79	0.26	0.28	0.13	0.17	0.30	0.44	1.00	
eia	0.07	0.47	0.46	0.09	0.51	0.50	-0.07	0.09	0.43	0.06	-0.26	-0.07	0.35	0.48	-0.21	0.18	1.00

Table 5. Coefficient Estimates for 5 Pollution-Intensive Goods' Net Exports (Non-linear 2SLS)

	Metal Mining	NFMetals	Pulp&Paper	Iron&Steel	Chemicals
Intercept	-1004.63***	-1211.35***	-824.21	-795.73	-7296.56***
	(170.68)	(287.06)	(724.05)	(935.18)	(1689.84)
Capital	-0.39***	-0.12*	0.47*	1.48***	2.96***
	(0.07)	(0.07)	(0.25)	(0.21)	(0.46)
Labor	-29.78***	0.75	-14.88***	-23.6***	49.29***
	(1.62)	(1.34)	(2.53)	(4.79)	(7.71)
Coal	-1.14***	0.49*	0.60	2.53*	1.78
	(0.42)	(0.28)	(0.65)	(1.44)	(2.22)
Oil	1.76***	0.09	-0.46	1.3	-3.28***
	(0.26)	(0.18)	(0.33)	(0.87)	(0.83)
Land	80.27***	-7.61**	33.61***	51.39***	-137.15***
	(3.95)	(3.2)	(6.62)	(12.2)	(17.46)
School	8.86***	5.26***	-0.82	12.91***	32.58***
	(1.7)	(1.68)	(1.52)	(4.55)	(7.59)
Legislation	-87.08***	-31.48**	6.18	-104.65*	-74.21*
	(9.04)	(12.67)	(15.86)	(39.04)	(42.00)
D_{OECD} *Legislation	-76.22***	-61.3***	-39.17*	-72.34*	-200.81***
	(7.47)	(11.03)	(20.72)	(42.61)	(64.83)
Legislation*Control Mechanism	-0.02	-0.03	-0.26	-0.02	0.31
	(0.13)	(0.04)	(0.25)	(0.11)	(0.29)
Control Mechanism	51.42***	37.87***	-24.26	37.12	165.77***
	(5.13)	(8.25)	(19.85)	(29.06)	(41.75)
Time dummy for 1995	-77.78	-42.9	-26.17	-103.4	-0.31
	(51.03)	(31.93)	(70.83)	(94.3)	(130.14)
Time dummy for 1996	-45.59	-25.00	-21.6	-61.00	-84.4
	(48.5)	(36.75)	(71.68)	(117.08)	(138.16)
Time dummy for 1997	-92.94*	-39.26	-2.94	-7.76	-83.31
	(51.08)	(37.07)	(71.9)	(119.47)	(140.64)
Time dummy for 1998	-77.98	-37.29	35.22	-37.1	-198.25
	(52.45)	(38.02)	(72.05)	(132.81)	(191.62)
Number of obs	77	93	111	97	97
Log-likelihood	-500.65	-594.38	-804.41	-745.32	-790.85

Note: Inside parentheses are standard errors. Notations "*", "**"and "***" signify significance at the 10, 5 and 1 percent levels based on a two-tailed test, respectively.

Table 6. Joint Hypothesis Testing on the Effect of Legislation

	Metal Mining	NFMetals	Pulp&Paper	Iron&Steel	Chemicals
OECD countries					
$E(ß_7 + ß_9 + E(cm)^* ß_8)$	-164.09	-93.93	-44.40	-177.81	-261.59
$SE(ß_7 + ß_9 + E(cm)^* ß_8)$	15.03	20.48	24.15	70.05	88.49
Assym. t value	-10.92	-4.59	-1.84	-2.54	-2.96
Statistical significance	1%	1%	5%	1%	1%
Non-OECD countries					
$E(ß_7 + E(cm)^* ß_8)$	-87.87	-32.63	-5.23	-105.47	-60.77
$SE(ß_7 + E(cm)^* ß_8)$	11.85	12.12	10.13	38.30	47.10
Assym. t value	-7.42	-2.69	-0.52	-2.75	-1.29
Statistical significance	1%	1%	ns	1%	10%

Note: “ns” means not significant.