

**Have Countries with Lax Environmental Regulations a Comparative Advantage in
Polluting Industries?¹**

Miguel Quiroga*

Department of Economics, University of Gothenburg, Sweden

Department of Economics, University of Concepción, Chile

Martin Persson

Department of Energy and Environment, Chalmers University of Technology, Sweden

and

Thomas Sterner

Professor at the Department of Economics, University of Gothenburg, Sweden

RFF university fellow

¹ The authors would like to thank Brian Copeland, Jorge Dresdner, Renato Aguilar, Fredrik Carlsson, Håkan Eggert, and Lennart Hjalmarsson for comments. The usual disclaimers apply. Financial support from Sida, the MISTRA program on trade and environment and the Swedish Energy Agency is also gratefully acknowledged.

*Corresponding author. Telephone: +56 41 2204503 Fax: + 56 41 2254591. *E-mail adress:*
mquirog@udec.cl

Have Countries with Lax Environmental Regulations a Comparative Advantage in Polluting Industries?

Miguel Quiroga, Thomas Sterner, and Martin Persson

Abstract

We study whether lax environmental regulations induce comparative advantages, causing the least-regulated countries to specialize in polluting industries. The study is based on the Trefler and Zhu [24] definition of the factor content of trade. For the econometrical analysis, we use a cross-section of 71 countries to examine the net exports in the most polluting industries in the year 2000. We try to overcome three areas in the empirical literature: the measurement of environmental endowments or environmental stringency, the possible endogeneity of the explanatory variables, and the influence of the industrial level of aggregation. As a result, we find that industrial aggregation matters and we do find some evidence in favor of the pollution-haven effect.

Key Words: comparative advantage, environmental regulation, trade, pollution haven, Porter hypothesis

JEL Classification: F18, Q56

Have Countries with Lax Environmental Regulations a Comparative Advantage in Polluting Industries?

Miguel Quiroga, Martin Persson, and Thomas Sterner

1. Introduction

In the last two decades, environmental concern has emerged as a relevant issue in trade liberalization. The debate has been induced by the fear that countries use less stringent environmental policies to gain a comparative advantage in polluting industries.

We investigate to what extent differences in environmental policy among countries are a source of comparative advantage. The subjacent hypothesis asserts that lax environmental standards extend the availability of environmental inputs in the production process, reducing environmental control costs and increasing net exports in pollution-intensive sectors—the so-called “pollution-haven effect” described by Copeland and Taylor [6]. Although some theoretical research supports this proposition (see Chilchilnisky [3], Copeland and Taylor [5], McGuire [12], Siebert [20], Pethig [16]), empirical studies have not found robust results corroborating the hypothesis.²

The Heckscher-Ohlin-Samuelson (HOS) theorem is a natural framework to analyze this issue. Scholars use Vanek’s factor-content prediction (HOV) to study input services—say capital, labor, land, or natural resources—included in a country’s net exports. In a branch of this literature, Tobey [22] accommodated the comprehensive empirical study published by Leamer [11] to analyze whether differences in the stringency of environmental regulations influence the comparative advantages in five pollution-intensive industries. Tobey’s research was based on a cross-section analysis of net exports in

² The literature has been reviewed by Jaffe *et al.* [10], Rauscher [19], and recently by Copeland and Taylor [6].

these industries, with country measures of factor endowments and a qualitative measure of environmental stringency as explanatory variables. He did not find evidence that environmental regulation determined net exports in any of the industries studied. The study, however, was constrained by the low number of degrees of freedom (Copeland and Taylor [6]). In response, most contemporaneous studies increased the number of observations in the estimations. For instance, Murrell and Ryterman [13] include East European economies, and Cole and Elliott [4] use a more updated dataset that includes 60 countries for 1995.

The endogeneity of the variable measuring strictness of environmental regulations has also been a concern in the literature, as countries could reduce the stringency of environmental policy when their net exports are being threatened by international competition.³ As recognized by Cole and Elliott [4], however, it is improbable that this problem could be serious in Tobey's set up because net exports in a specific industry are not likely to influence the environmental regulation at a country level. Even so, Cole and Elliott [4] estimated the net exports in a polluting industry and the stringency of the environmental regulation using simultaneous equations. Evidence of pollution-haven effect has not been found in any of these extensions of Tobey either.

In this paper, we follow Tobey's approach, but we aim to overcome three areas in which we believe there is room for improvement: the measure of environmental stringency, endogeneity due to dissimilarity in the consumption patterns across countries, and the level of aggregation of the industries considered in the analysis.

Measuring the stringency of environmental regulations is a task laced with many difficulties. Van Beers and van den Bergh [27] distinguish two main categories of indicators: input and output oriented. Input-oriented indicators relate to a country's efforts in environmental protection—for example, legislation, expenditures on environmental research, and pollution abatement and control, among others.

³ Governments could use the environmental policy as a second-best trade policy when they face limitations on pursuing trade goals using trade policy (e.g. Trefler [23] and Ederington and Minier [8]).

Output-oriented indicators capture the *effect* of environmental regulations. To the best of our knowledge, most empirical research based on the HOV model has been grounded on input-oriented indicators.⁴ However, the level of environmental control cost does not only depend on the stringency of regulations “on paper,” but also on the nature of enforcement, gains in efficiency (e.g. Porter and van de Linde [17]), and offsetting subsidies supporting pollution-intensive industries (see Baumol and Oates [2], Eliste and Fredriksson [9]). As a result, Jaffe *et al.* [10, page 144] claim that the scarce evidence of pollution haven “...could be due to no more than the failure of the ordinal measure of environmental stringency to be correlated with true environmental control costs.” We believe that output-oriented indicators might be a better measure than input-oriented indexes because they take account of not only the stringency but also the enforcement of environmental regulations and of any subsidy or domestic policy offsetting some of the effect of stricter regulations. Therefore we incorporate a measure directly based on emissions to capture the environmental endowment in the empirical analysis. We expect that a more stringent environmental policy will reduce environmental endowments available for use in production and emissions. Reduced availability of environmental services will increase the use of primary factors to control pollution, increase production costs and reduce the net exports of goods that use environmental services intensively.

The second area in which we believe we can provide a contribution is related to the research on the factor content of trade (Vanek [28]), which is based on the claim that international trade is an indirect way of exchanging abundant factors. Thus, the factor content of the goods exchanged in the international trade is the difference between the factor content of goods produced and consumed in the country. Trefler and Zhu [24] formulated a more general definition of the factor content of trade that allows trade in intermediate input and variation in the technology across countries. The authors show that this definition is not consistent with Vanek’s factor content prediction. In our paper, we use this result to show that even when it is assumed that technology is the same across countries, the less restrictive definition of the factor content of trade includes a

⁴ See Walter and Ugelow [26], Tobey [22] and Murrell and Ryterman [13]. The index developed by Dasgupta *et al.* [7], used in the empirical work of Cole and Elliott [4], is also based almost exclusively on input-oriented indicators.

dissimilarity consumption term that researchers have not been controlling for. We think that the consumption condition could be positively correlated with the environmental endowment, which could make the Ordinary Least Square (OLS) parameters downward biased, reducing the ability to identify evidence of a pollution haven. We therefore use Instrumental Variables (IV). To the best of our knowledge, this source of endogeneity has not been empirically analysed earlier.⁵

The third aspect we address is the level of aggregation. Earlier studies examine trade in aggregate commodity groups. As these groups include a wide array of industries with different pollution intensities and levels of environmental control costs, the effect of environmental policy on trade might not be detected because control costs could be canceled out when these heterogeneous units are pooled. Thus, aggregation may mask shifts in the division of labor between polluting and non-polluting activities within an industry sector. In the paper, we estimate the empirical specification at a more disaggregated level.

Our empirical analysis is based on a cross-section of 71 developed and developing countries in 2000.⁶ Previously published studies used cross-sections of countries for the years 1995 or 1975 (Cole and Elliott [4], Murrell and Ryterman [13], Tobey [22]). The fact that we use more up-to-date data is an important advantage because considerable progress has been made lately in tariff reduction and reduced barriers to trade around the world. According to the World Trade Organization (WTO) (<http://www.wto.org>), developed countries have cut their tariff on industrial products by 40 percent between 1995 and 2000. The value of the imported industrial products rose from 20 to 44 percent, and the proportion of imports facing tariff

⁵ Although another source of endogeneity could come from the fact of using emissions as explanatory variables, we believe that this problem is not serious because we are considering national emissions as explanatory variable but net export in a particular industry.

⁶ Countries included in the analysis: Algeria, Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Denmark, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Gabon, Germany, Ghana, Greece, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Italy, Japan, Jordan, Kenya, Republic of Korea, Luxembourg, Macau, Madagascar, Malaysia, Mauritius, Mexico, Morocco, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Senegal, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Syrian Arab Republic, Thailand, Tunisia, Uganda, United Kingdom, United States, Uruguay, Venezuela, and Zimbabwe.

rates above 15 percent fell from 7 to 5 percent. This enhances the importance of trade and comparative advantage as determinants of the pattern of trade. This is illustrated by the world's openness to trade: the sum of exports and imports as a percentage of gross domestic product (GDP). In 1975, trade openness was 33 percent but in the following 20 years, it increased to 42 percent and then to 49 percent in the following 5 years, from 1995 to 2000, (World Bank's website, 2006). We believe that this dramatic increase in world trade (as well as increases in environmental regulation) might increase the probability of finding evidence of pollution havens, especially if polluting industries have been more affected by barriers to trade in the past.

We choose to analyze the most polluting industries and to work at a more disaggregated (3-digit) level.⁷ We estimated a model in which the net exports were regressed on the endowments of inputs, including two environmental variables based on emissions of sulfur dioxide (SO₂) and organic matter in wastewater, measured as biological oxygen demand (BOD).

Preliminary analysis of this data at the aggregate level, using OLS, only finds evidence of the pollution-haven effect in the non-metallic minerals sector. Some of the other subsectors even exhibited evidence in the opposite direction. Such positive effects of environmental regulation are known in the literature as the Porter hypothesis, interpreted as the result of technological innovation triggered by regulation (Porter and van de Linde [17]). In this case, the stricter environmental policy increases profitability and net exports for the industries concerned. Many economists find the Porter hypothesis flouts logic since it is not clear why companies fail to undertake profitable improvements before being forced by the regulator (e.g. Palmer *et al.* [15]). To look carefully at the evidence we disaggregate data and use IV to correct for endogeneity. As we will see, this modifies the results.

In the following section we present the conceptual framework. In the third section, we discuss our empirical strategy. In the last two sections, we present an analysis of the results and conclusions.

⁷ The industries are classified according to the Standard International Trade Classification (SITC) revision 3.

2. Conceptual Framework⁸

Trefler and Zhu [24] showed that if we include intermediate trade inputs and allow technologies to vary across countries, factor services exchanged through international trade will contain differences in endowment and consumption patterns across countries. Equation 1 summarizes this relationship. F_i^{T-Z} is the $K \times 1$ vector of net factor services exported by country i . V_i denotes the $K \times 1$ vector of factor endowments, and C_{ij} is the $G \times 1$ vector of country i consumption of goods produced in country j . Subscript w symbolizes the variable aggregated at the world level. ϕ_i is country i 's share of world consumption. The $K \times G$ factor intensity matrix A_j describes the production technology for country j .⁹

$$F_i^{T-Z} = (V_i - \phi_i V_w) - \sum_{j=1}^N A_j (C_{ij} - \phi_i C_{wj}) \quad (1)$$

In general, studies have directly considered emissions of pollutants as one of the factors in the production process. The basis for introducing the environment as an input in the production process comes from a seminal paper written by Ayres and Kneese [1]. Thus, environmental services included in country i 's net exports (E^z) are, employing equation (1), the result of two factors: abundance of environmental inputs and differences in the pattern of consumption (see equation 2).¹⁰

$$E^z = e' F_i^{T-Z} = (E_i - \phi_i E_w) - \sum_{j=1}^N \sum_{g=1}^G \alpha_{egj} (C_{gij} - \phi_i C_{gwj}) \quad (2)$$

⁸ A detailed version of this section can be found in Quiroga *et al.* [18].

⁹ The k -input requirement per unit of product g , denoted α_{kg} , is a generic element of A_j . It includes the direct and indirect factor requirements to produce g in country j . The direct factor requirements are the primary factors used in the production of g , and the indirect factor requirements are the primary factors used in the production of intermediate inputs employed in the elaboration of g .

¹⁰ E symbolizes the endowments of environment inputs. e' denotes the transpose of a $K \times 1$ vector that contains only zeros, but the e th element, the environment, is equal to 1. α_e' denotes the transpose of a $G \times 1$ vector, which indicates the *environment*-requirements per unit of product g .

Therefore, a country is a net exporter of environmental services if and only if $E^z > 0$ which is decided by the sum of 2 components. The first is the conventional requirement that the country's share in the world environmental endowment must be larger than its share in the world expenditure of income ($E_i/E_w > \phi_i$). The second term is a measure of consumption similarity. In this less constrained framework, the abundance of environmental endowments does not determine by itself the comparative advantage of a country: heterogeneity in the consumption patterns across countries also plays a role in the factor content of trade.

Econometric Specification

Starting from equation 1 and assuming that countries have similar factor intensity matrices, we obtain equation 3 that is the base of our empirical work.¹¹ According to this equation, net exports of good g from country i are a linear function of factor endowments minus country i 's importance in the consumption of good g . The last component is a "consumption adjustment", denoted q , that reflect deviation of the country i 's share in the consumption of good g from its share in the world consumption.. The coefficient γ_{kg} can be interpreted as the effect that an increment in the endowment of the input k will have on the exports of good g , *ceteris paribus*.

$$T_{gi} = \sum_{k=1}^K \gamma_{kg} V_{ki} - (C_{gi} - \phi_i C_{gw}) \quad (3)$$

This expression looks very similar to the empirical specification that has been estimated by Leamer [11], Tobey [22], Murrell and Ryterman [13] and Cole and Elliott [4], except for the term capturing differences in patterns of consumption, q . This factor has not appeared in those studies because the assumption of identical homothetic preferences in HOV models is a sufficient condition to make $C_{gi}/C_{gw} = \phi_i$ (Trefler and Zhu [24]).

¹¹ C_{gi} and C_{gw} represent country i and world consumption of good g , respectively.

Industrial Aggregation

Earlier studies have used highly aggregated data which might have hidden any evidence of pollution havens. To illustrate this point, consider equation 4 which shows equation 3 expressed at an arbitrary industrial level.

$$T_{il} = \sum_{g \in I} T_{ig} = \sum_{k=1}^K \left(\sum_{g \in I} \gamma_{gk} \right) V_{ik} - \left(\sum_{g \in I} C_{ig} - \phi_i \sum_{g \in I} C_{wg} \right) \quad (4)$$

The coefficient γ_{Ik} , which can be interpreted as the effect of an increment in the endowment of input k on the exports of industry I , will be the sum of the coefficients associated to each good that belongs to I . Clearly, if one of the coefficients for one good is big – but not the others then there would be an effect in that single sub-sector but it might not show up at the aggregate level¹².

3. Empirical Strategy

We estimated the parameters of equation 5, which is based on equation 3, for a subset of highly polluting industries. E_k stands for the variables measuring environment endowments, V_k denotes other endowment variables, and ε is the error term.

$$T_g = \alpha + \sum_{k=1}^p \gamma_{gk} V_k + \sum_{k=p+1}^q \delta_{gk} E_k + \varepsilon \quad (5)$$

The main hypothesis is that the parameters associated to environmental comparative advantages can be estimated as positive at a reasonable level of statistical significance. We conduct three independent estimations based on equation 5. These are intended to illustrate what we perceive of as unresolved issues from previous studies. First, we estimate the empirical specification used by previous studies as a

¹² Moreover the industrial aggregation might also be related to the endogeneity problem discussed above.

benchmark¹³. In the next step, we assume that q is nonnegative and positively correlated with environmental endowments such that the parameters estimated using OLS are inconsistent. We assume there is no variable to control for dissimilarities in the consumption condition and thus we use IV estimation to get consistent estimates in the HOV equations. In the third and final step, we follow do the same estimations at a more disaggregated level.

Environmental Variables

A suitable environmental indicator, based on pollution, should at least fulfill the following base criteria: (i) be emitted as a result of production; (ii) be subject to regulation due to its direct effects on humans or the environment; (iii) have well-known abatement technologies available for implementation; and (iv) have data available for a wide set of developed and developing economies. Two pollutants that satisfy these criteria are atmospheric SO₂ and BOD.

SO₂ is a precursor for acidification and urban smog. The main source of SO₂ emissions is combustion of coal and oil, accounting for about 85 percent of global anthropogenic emissions (UNDP [25, page 64]). It is possible to reduce SO₂ emissions by various well-known methods (fuel substitution, desulfurizing or flue gas scrubbing etc). A country's emissions of SO₂ mainly depend on three variables: The amount of coal and oil consumed, the sulfur content of those fuels, and the use of abatement technologies. The latter two factors are easiest to influence and we therefore choose as our indicator of policy stringency, a *country's SO₂ emissions from fossil fuel use, divided by the share of coal and oil in the country's total energy use*. This indicator thus corrects for the fact that some countries have very low emissions just because they derive a large share of their energy use from natural gas, hydro or nuclear power.

¹³ This means that we assume the error term is iid, normally distributed, with finite and constant variance; therefore, we can use OLS on a cross-section of countries. We assume countries fulfill the consumption similarity condition ($q = 0$), or, if they do not, this condition is not correlated with the regressors.

Organic matter and chemicals, emitted through wastewater, are by-products of various industrial activities and are a major source of surface water pollution. The released organic material is consumed by naturally occurring bacteria, using up the oxygen dissolved in the water. With high enough releases of organic matter, the oxygen levels in the waters may drop to levels so low that fish and other aquatic organisms perish. A low oxygen level is often considered the single most important factor when determining the extent of pollution in a water body (Nemerow and Dasgupta [14, page 4]).

The rate at which the oxygen is consumed can be measured in various ways; one common method is BOD. Organic matter can quite easily be reduced through end-of-pipe treatment of the wastewater which removes more than 90 percent of original BOD. The technologies are well developed and readily available, although at noticeable costs.

Other Endowment Variables Considered in the Estimation

This study adopts a model with endowments in capital, labor, land, and natural resource endowments. We have tried to follow the endowments considered in the basic studies first conducted by Leamer [11]. Labor endowment is split up into three groups based on level of education: illiterate workers, literate workers with secondary education, and professional and technical workers. Information about land is divided into tropical and non-tropical forest areas, and cropland. The natural resource endowments include production of minerals (copper, iron, lead, and zinc) and solid fuels (coal and liquid and gaseous fuels—i.e. crude oil and natural gas). A more detailed description of the sources of information is given in Table 1. Table 2 provides summary statistics.

4. Results

We first estimate benchmark parameters of equation 8 for each aggregate industry using OLS, see Table 3. Because the hypothesis of homoscedasticity was rejected in some industries, we use White standard errors to estimate heterocedasticity-robust t statistics.¹⁴

As mentioned, two alternative assumptions are consistent with this method of estimation. Either that countries fulfill the consumption similarity condition ($q = 0$) and net exports are determined by abundance of their endowment factors¹⁵ or q is uncorrelated with the regressors.

Several explanatory variables are highly correlated, and various diagnostic tests suggest that multicollinearity can be severe in our estimations (e.g. the mean variance inflation factor is 48 and the condition number 68). Part of this problem can be due to the fact that we have redundant variables characterizing the skills of labor force. One of these variables is the number of literate non-professional workers. This variable is not statistically different to zero in any of our regressions. Moreover, when we drop this variable, we do not observe any change in the signs or the level of significance of the main variables, and the severity of the multicollinearity is considerably reduced (the mean variance inflation is 13 and the condition number 26). Therefore, the reported results do not include this variable. The sign of the parameters looks reasonable, and the sign and the significance of the parameters associated to the environmental endowment are robust to changes in the data and in the specification of the regression model. For instance, most of the industries considered in the analysis are based in natural resources, and we should expect that these factors could be a source of comparative advantage. This is exactly what we

¹⁴ The White standard errors were multiplied by $n/(n-k)$. This degrees-of-freedom adjustment, suggested by Davidson and MacKinnon (1993), improves the White estimator for OLS in small samples. Furthermore, this modus operandi guarantees to get the usual OLS standard errors if the variances of the disturbances were constant across observations.

¹⁵ Although this seems restrictive, Trefler and Zhu [24] show that there are many models consistent with this condition—e.g. models with taste for variety or ideal variety; North-South models with differences in technology; and models consistent with production specialization as Heckscher-Ohlin, scale returns, and failures of factor price equalization.

observe in these sectors. The production of iron has a direct influence in the net export of the iron and steel industry. The production of copper and zinc determines a comparative advantage in the nonferrous metals.¹⁶ Finally, the exports in the pulp and paper industry are considerably influenced by the availability of forest and negatively influenced by the area of cropland.

In general, we observe a rather high coefficient of determination in our results despite the fact that we use a cross-section sample. The independent variables explain a high percentage of the variation in the net exports. The exception is the chemical industry, where we can explain only half of the variation in net exports. An analysis of these results by sector shows that industries differ considerably in their sources of comparative advantage. In most cases, net exports are directly influenced by the abundance of unskilled workers and, in others, by the abundance of capital. Summing up, our estimation results look quite reasonable and are a good starting point for our analysis.

Table 3 shows that only in non-metallic minerals do we find evidence of a pollution haven: The statistically significant positive coefficient associated to BOD suggests that a higher level of organic water pollutant emissions, which is attributable to a lax environmental regulation in our study, will increase the exports in this industry. In the other cases, the parameters show that the availability of the environmental amenities does not influence the export in a country—or that the effect goes in the opposite direction. In effect, emissions of SO₂ in the nonferrous metals, chemical, and pulp and paper industries (as well BOD in the chemical industry) negatively affect industrial exports. This can be seen as support for the Porter hypothesis that stricter environmental policy will increase net exports of these industries.

¹⁶ Lead has a counterintuitive sign. However, this is only because different subsectors coexist in nonferrous metals. In a more disaggregate analysis, lead net exports are directly influenced by lead production, although the coefficient is not statistically different to zero.

Endogeneity and IV Estimation

As mentioned, we believe that if countries do not fulfill the consumption symmetry condition, and we do not control for q , then the estimated parameters could be inconsistent if q is correlated with some of the explanatory variables. We suspect that q could be correlated with environmental endowment because we are considering the most polluting industries. In this case, a consumption of good g higher than the share in the world consumption could generate a higher level of pollution. Then, if environmental endowments and q are positively correlated using OLS, we underestimate the true value of the parameters, and the asymptotic bias could be negative (thus a bias against evidence of pollution havens). Our hypothesis is that OLS parameters are inconsistent and thus we use IV estimation.

To do IV estimation we need instrumental variables and our candidate instruments are the number of fish species (fishno), the number of fish species threatened (fishthrea), total road network (road), and the number of vehicles per thousands people (vehicles).¹⁷ First, we evaluated the relevance of the instruments using the first-stage regressions reported in Table 4. The Shea partial R^2 suggests that the instruments have the adequate relevance to explain all the endogenous regressors, and the Anderson canonical correlation likelihood-ratio test indicates that we reject the hypothesis that the model is underidentified.¹⁸ The comparison of the Cragg-Donald statistic with the critical value reported in Stock and Yogo [21, Table 2] does not allow us to reject the null of weak instruments. As a consequence, weak instruments could result in size distortion of at least 20 percent (*ibid.*). To overcome the weakness of our instruments, we use a Limited Information Maximum Likelihood estimator (LIML) instead of Two Stages Least Squares (2SLS), because LIML has proven to be less affected by weak instruments. In our case, the maximal size distortion is below 10 percent when we use LIML (Stock and Yogo [21, Table 2]).

¹⁷ The instruments were highly correlated with environmental endowment. In some cases, they could reflect the effect that high levels of pollution can have on biodiversity and in the other the influence that mobile sources of pollution have on our environmental endowments. We tried another instruments as well, but they were irrelevant.

¹⁸ The rule of thumb in this literature indicates that the instruments are weak to explain all the endogenous variables if the value of the partial R^2 is large, but the Shea partial R^2 is small.

The lack of consistency in OLS estimations when we suspect that some of the regressors are endogenous has to be balanced with the loss of efficiency when we use IV. A common practice is to check the endogeneity of the regressors. We tested the hypothesis that BOD and SO₂ are exogenous, making use of different versions of Durbin-Wu-Hausman's test of endogeneity. The outcomes were robust to the choice of the statistic.¹⁹ The results of one of these tests are in the penultimate row of Table 5. In chemical and pulp and paper industries, and in non-metallic mineral production, it was not possible to reject the exogeneity of the environmental explanatory variables.

Furthermore, in choosing the estimator, we must consider whether the assumption of homoskedasticity is valid or not, because the Generalized Method of Moment (GMM) provides a more efficient estimation in the presence of heteroskedasticity of unknown form. If the variance is not constant, IV estimators will be consistent, but less efficient, and OLS will be less efficient than GMM. Therefore, if we reject the hypothesis of homoskedasticity and the regressors are endogenous, we will make use of the orthogonality conditions to estimate the GMM generalization of the LIML estimator to allow for heteroskedasticity. It is called "continuously-updated GMM" estimator (HLIML-GMM). On the other hand, if the regressors are exogenous and heteroskedasticity is present, we estimate a Heteroskedastic OLS estimator (HOLS). It uses the additional moments available to generate the OLS residuals that will constitute the first-step in the feasible two-step GMM (Wooldridge [29]).

Table 5 displays the results of our estimations when we consider the possibility of endogenous regressors and apply more efficient methods of estimation when disturbances are not homoskedastic. Only in the iron and steel and nonferrous metals sectors did we reject the hypothesis of exogeneity of the environmental variables. However, in the chemical industry and pulp and paper sector, we employed the HOLS estimator, because when we estimated the HOV equation using OLS we rejected the assumption of

¹⁹ If we could not reject the assumption of conditional homoskedasticity, a special form of the test was calculated.

homoskedasticity (see Table 3). Overidentification tests suggest that the instruments were valid. They are exogenous—i.e., uncorrelated with the error term.

The results show that, as expected, there is a downward bias in the OLS parameters when regressors are endogenous. We can see this if we compare the parameters associated to the environmental variables in the iron and nonferrous industries in Tables 3 and 5. In almost all the cases, the value of the parameters was larger if we use instrumental variables to control for the endogeneity of the regressors.

Employing these more efficient and consistent methods of estimation we found additional evidence of pollution haven in the iron and steel sector. Therefore, the net export in the iron and steel industry and in the non-metallic minerals production are directly influenced by lax environmental regulations, while evidence supporting the Porter hypothesis is now only found in the chemical industry.

Disaggregated Analysis

In this section, we analyze the influence that the industrial level of aggregation has on our results. We follow the same procedure as in the previous section to estimate the HOV equation at a more disaggregated level employing methods that are consistent when regressors are endogenous and more efficient in the presence of heteroskedasticity. Table 6 summarizes the effect of environmental endowments on the net exports in all the industries.²⁰

We detected a more extended presence of the endogenous regressors in the analysis. Moreover, we found more evidence of pollution havens. Most of this evidence comes from the variable measuring water pollution, which suggests that more stringent water pollution regulations that are effective in reducing water contamination will reduce the net exports in the industries where the BOD estimated coefficient is positive and statistically different from zero. Only in three disaggregated industries: semi-finished products of iron and steel (672), glassware (665), and pottery (666), did we find evidence that lax

²⁰ Tables reporting detailed result for each industry can be consulted in Quiroga *et al.* [18].

air pollution regulations will increase the export in this industries. There was however more evidence of the Porter hypothesis from the variable capturing air pollution regulations.

5. Conclusions and Discussion

The main goal of this study was to capture the effect that differences in environmental policy have on trade. Consistent with previous literature, we use cross-section country data on net exports in the most polluting industries and control for the endowments of the country to investigate the hypothesis that lax environmental regulations constitute a source of comparative advantage, causing the least-regulated countries to “specialize” in polluting industries. The most distinctive aspect of our paper is the link to the literature on factor endowment content, which analyzes missing trade when scholars try to explain global trade using the HOV model, emissions to capture the intensity of the regulation, and estimations made at a more disaggregated industrial level. We believe that the earlier literature has generally not been controlling for differences in consumption patterns across countries. This fact could make regressors endogenous in our setup. We estimate the parameters using instrumental variables to deal with this trait. Our results indicate that in most cases, the environmental endowments are endogenous and the level of industrial aggregation matters for evidence of a pollution haven.

Empirically the evidence is still mixed. Using more advanced methods and recent data still do not give a very clear picture. We do however find that the introduction of instrumental variables to deal with the bias caused by consumption asymmetries together with more disaggregated data analysis extends the number of cases in which we find the pollution haven, while the evidence in favor of the Porter hypothesis only remains in the chemical industry and for air pollution regulations.

6. References

- [1] R.U. Ayres, and A.V. Kneese, Production, Consumption, and Externalities. *Amer. Econ. Rev.* 59 (1969) 282-297.
- [2] W.J. Baumol, and W. Oates, *The Theory of Environmental Policy*, Cambridge University Press, 1988.
- [3] G. Chilchilnisky, North-South Trade and the Global Environment. *Amer. Econ. Rev.* 84 (1994) 851-874.
- [4] M. Cole, and R. Elliott, Do Environmental Regulations Influence Trade Patterns? Testing Old and New Trade Theories. *World Economy* 26 (2003) 1163-1186.
- [5] B.R. Copeland, and M.S. Taylor, North-South Trade and the Environment. *Quart. J. Econ.* 109 (1994) 755-787.
- [6] B.R. Copeland, and M.S. Taylor, Trade, Growth, and the Environment. *J. Econ. Lit.* 42 (2004) 7-71.
- [7] S. Dasgupta, A. Mody, S. Roy, and D. Wheeler, Environmental Regulation and Development: A Cross-country Empirical Analysis. *Oxford Devel. Stud.* 29 (2001) 173-187.
- [8] J. Ederington, and J. Minier, Is environmental policy a secondary trade barrier? An empirical analysis. *Can. J. Econ.* 36 (2003) 137-154.
- [9] P. Eliste, and P.G. Fredriksson, Environmental Regulations, Transfers, and Trade: Theory and Evidence. *J. Environ. Econ. Manage.* 43 (2002) 234-250.
- [10] A.B. Jaffe, S.R. Peterson, P.R. Portney, and R.N. Stavins, Environmental Regulation and the Competitiveness of U. S. Manufacturing: What Does the Evidence Tell Us? *J. Econ. Lit.* 33 (1995) 132-163.
- [11] E. Leamer, *Sources of International Comparative Advantage: Theory and Evidence*, The MIT Press, Cambridge, Massachusetts, 1984.
- [12] M.C. McGuire, Regulation, factor rewards, and international trade. *J. Public Econ.* 17 (1982) 335-354.

- [13] P. Murrell, and R. Ryterman, A methodology for testing comparative economic theories: Theory and application to East-West environmental policies. *J. Compar. Econ.* 15 (1991) 582-601.
- [14] N.L. Nemerow, and A. Dasgupta, *Industrial and Hazardous Treatment*, Van Nordstrand Reinhold, New York, 1991.
- [15] K. Palmer, W.E. Oates, and P.R. Portney, Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *J. Econ. Perspect.* 9 (1995) 119-132.
- [16] R. Pethig, Pollution, welfare, and environmental policy in the theory of Comparative Advantage. *J. Environ. Econ. Manage.* 2 (1976) 160-169.
- [17] M.E. Porter, and C. van de Linde, Toward a New Conception of the Environment-Competitiveness Relationship. *J. Econ. Perspect.* 9 (1995) 97-118.
- [18] M. Quiroga, T. Sterner, and M. Persson, Have Countries with Lax Environmental Regulations a Comparative Advantage in Polluting Industries?, RFF Discussion Paper 07-08, Resources for the Future, 2007.
- [19] M. Rauscher, *International Trade, Factor Movements, and the Environment*, Clarendon PressOxford, 1997.
- [20] H. Siebert, Environmental Quality and the Gains from Trade. *Kyklos* 30 (1977) 657-673.
- [21] J.H. Stock, and M. Yogo, *Testing for Weak Instruments in Linear IV Regression*, Harvard University, 2004.
- [22] J. Tobey, The Effects of Domestic Environmental Policies on Patterns of World Trade: An empirical test. *Kyklos* 43 (1990) 191-209.
- [23] D. Trefler, Trade Liberalization and the Theory of Endogenous Protection: An Econometric Study of U.S. Import Policy. *J. Polit. Economy* 101 (1993) 138-160.
- [24] D. Trefler, and S.C. Zhu, The Structure of Factor Content Predictions, NBER Working Paper No. 11221, National Bureau of Economic Research, 2005.
- [25] UNDP, *World Energy Assessment: Energy and the Challenge of sustainability*, New York, 2000.

- [26] I. Walter, and J. Ugelow, Environmental Policies in Developing Countries. *Ambio* 8 (1979) 102-109.
- [27] C. van Beers, and J.C.J.M. van den Bergh, An Empirical Multi-Country Analysis of the Impact of Environmental Regulations on Foreign Trade Flows. *Kyklos* 50 (1997) 29-46.
- [28] J. Vanek, The Factor Proportion Theory: The N-Factor Case. *Kyklos* 21 (1968) 749-756.
- [29] J.M. Wooldridge, *Econometric Analysis of Cross Section and Panel Data*, The MIT Press, Cambridge, Massachusetts; London, England, 2002.

Table 1: Definitions and Data

Variable	Definition and Source
Net Export	Thousands U.S. dollars of net export year 2000, <i>UN Comtrade Database</i> (2000).
Capital	Physical capital stock, thousand of millions of dollars, year 2000. The sum of annual GDI, (average life of 15 years and constant depreciation rate of 13.3%), <i>World Development Indicators</i> 2004.
Labor	Economically active population (thousands) year 2000, <i>Ibid.</i>
Illiteracy	Illiteracy adult rate year 2000 ^a , <i>Ibid.</i>
Tertiary	Professional and technical workers (% of labor force) year 2000 or the closest year with information available. International Labour Office (various years), <i>Yearbook of Labour Statistics</i> .
Qualified labor	Labor*Tertiary.
Illiterate labor	Illiterate workers (thousands) are calculated as: Labor*(100- Illiteracy)/100.
Tropical	Millions hectares of tropical forest year 1996, <i>World Resources Institute. Earth Trends: The Environmental Information Portal</i> , http://earthtrends.wri.org .
Crop	Thousands of square kilometers of cropland years 1992-1993, <i>Ibid.</i>
Nontropical	Millions hectares of non-tropical forest year 1996, <i>Ibid.</i>
Copper, Iron, Lead, and Zinc	Thousands metric tons of mine production for each of these metals year 2000, <i>US Geological Survey</i> , Commodity statistics and information, 2004.
Coal	Coal production (millions short tons) year 2000, Energy Information Administration (Official Energy Statistics from the US Government), <i>International Energy Annual</i> 2003, table 25.
Gasoil	The sum of world production of crude oil, NGPL, and other liquids (thousand barrels per day) and world dry natural gas production (trillion cubic feet) year

	2000, million tonnes of oil per year, <i>Ibid</i> , table G.1.
BOD	Organic water pollutant (BOD) emissions (thousands of kg per day) year 2000. <i>World Development Indicators 2004</i> .
SO₂	Sulfur emissions divided by share of oil and coal in total energy. Sulfur emissions compiled by Stern, D. (available on http://www.rpi.edu/~sternd/datasite.html).
Fish-diversity	Fish species, number, refer to the total number of freshwater and marine fish identified, documented, and recorded in a particular country or region. Total numbers include both endemic and non-endemic species. Most marine fish are excluded from country totals, years 1992-2003, <i>World Resources Institute. Earth Trends: The Environmental Information portal</i> , http://earthtrends.wri.org .
Fish-threat	Fish, number threatened, includes all species of both freshwater and marine fish that are recorded as threatened and that are known to occur in the territory of a given country, year 2004, <i>Ibid</i> .
Vehicles	Total number of vehicles per 1000 people, year 1996, <i>Ibid</i> .
Road	Total road network, thousands kilometers, includes motorways, highways, main or national roads, and secondary or regional roads, year 2000, but they mostly come from 1999, <i>Ibid</i> .

^a For purposes of calculating, a value of 1% was applied in Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Japan, Luxembourg, Netherlands, New Zealand, Norway, Slovak Republic, Sweden, Switzerland, United Kingdom, and United States.

Table 2. Summary of Statistics, Year 2000

Variable	Observations	Mean	Stan. Dev.	Minimum	Maximum
Capital	71	630	1819	3	1,07e+04
Qualified labor	71	4605	11589	17	85424
Illiterate labor	71	6465	26396	2	192763
Tropical	71	13	40	0	301
Crop	71	145	326	0	1753
Nontropical	71	14	58	0	404
Copper	71	153	593	0	4602
Iron	71	12677	42250	0	223000
Lead	71	41	132	0	739
Zinc	71	112	322	0	1780
Coal	71	57	208	0	1314
Gasoil	71	52	125	0	902
BOD	71	280	795	2	6204
SO₂	71	792	1946	2	12197

Table 3: HOV Estimation Results using Robust Ordinary Least Square

(Dependent variable: thousands of U.S. dollars of net export in 2000)

	Iron and Steel	Nonferrous Metals	Industrial Chemical	Pulp and Paper	Non-metallic Minerals Products
Capital	1 (0,2) ***	-0,4 (0,2) **	0,6 (0,2) ***	-0,1 (0,1)	0,3 (0,3)
Qualified labor	-105 (97)	-39 (69)	140 (140)	-31 (43)	-213 (119) *
Illiterate labor	42 (19) **	11 (11)	-35 (38)	45 (16) ***	20 (11) *
Tropical	-1 (6)	-11 (5) **	-42 (24) *	21 (9) **	3 (6)
Crop	-4 (2)	-0,7 (1)	2 (4)	-5 (2) ***	0,3 (1)
Nontropical	-2 (5)	0,8 (6)	-46 (31)	60 (13) ***	1 (6)
Copper	98 (221)	1574 (190) ***	864 (343) **	526 (156) ***	-192 (281)
Iron	27 (7) ***	31 (7) ***	46 (28)	-1 (11)	-4 (11)
Lead^a	-6 (7)	-15 (8) *	-76 (41) *	14 (15)	4 (10)
Zinc^a	2 (3)	7 (3) **	28 (16) *	-7 (6)	-0,5 (4)
Coal^a	-2 (5)	6 (4)	27 (9) ***	4 (5)	-8 (6)
Gasoil^a	-4 (2) *	5 (3) *	6 (5)	-6 (4)	-3 (2)
BOD	0,4 (0,8)	-0,7 (0,6)	-5 (3) *	1 (1)	2 (0,8) ***
SO₂	-541 (561)	-1396 (483) ***	-2550 (907) ***	-1098 (374) ***	322 (755)
Const^a	215 (186)	310 (106)	573 (347)	373 (221) *	101 (164)
R²	0,85	0,91	0,48	0,76	0,84
Observations	71	71	71	71	71
Homocedasticity^b	0,03	4,32**	34,88***	8,60***	0,08

Notes: Heterocedasticity-robust standard deviation is reported in parenthesis. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. ^aCoefficients and standard deviation are expressed in thousands. ^bIt reports the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (with one degree of freedom), the null hypothesis (H₀) is constant variance.

Table 4: First-stage Regressions of Instrumented Variables BOD and SO₂

	(1) OLS BOD	(2) OLS SO ₂
Capital	0,2 (0,0) ***	-0,0 (0,0)
Qualified labor	16 (11)	0,0 (0,0) *
Illiterate labor	3 (4)	-0,0 (0,0)
Tropical	-2 (1)	-0,0 (0,0)
Crop	1 (0,2) ***	0,0 (0,0) **
Nontropical	-2 (1,3) *	-0,0 (0,0) **
Copper	13 (10)	0,4 (0,0) ***
Iron	-0,3 (4)	0,0 (0,0)
Lead	-4590 (2164) **	-6 (3) **
Zinc	1621 (662) **	2 (0,7) ***
Coal	3373 (510) ***	4 (0,9) ***
Gasoil	328 (267)	2 (0,8) **
Fish-diversity	41 (46)	-0,4 (0,1) ***
Fish-threat	544 (1068)	8 (3) **
Road	-795 (137) ***	0,3 (0,2)
Vehicles	268 (106) **	-0,0 (0,2)
Constant	-34058 (23544)	36 (52)
Observations	69	69
Partial R²	0,59	0,33
Shea Partial R²	0,54	0,30
Anderson canonical correlation likelihood-ratio test^a	21,2***	
Test of weak instruments^b	4,7	

Notes: Heterocedasticity-robust standard deviation is reported in parenthesis. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. ^aDistributed Chi-sq(3). ^bCragg-Donald statistic (critical values are reported in Stock and Yogo [21]).

Table 5: HOV Estimation Results under Hypothesis of BOD and SO₂ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 2000)

	Iron and Steel		Nonferrous Metals		Industrial Chemical		Pulp and Paper		Non-metallic Minerals Products	
Method	LIML		LIML		HOLS ^e		HOLS		OLS	
Capital	1	(0,2) ***	-0,6	(0,2) ***	0,6	(0,2) ***	-0,1	(0,1)	0,3	(0,3)
Qualified labor	-38	(97)	-26	(89)	103	(99)	-61	(55)	-213	(119) *
Illiterate labor	32	(17) *	17	(15)	-25	(19)	53	(19) ***	20	(11) *
Tropical	12	(9)	-0,3	(6)	-35	(11) ***	24	(8) ***	3	(6)
Crop	-4	(2) *	-2	(1)	2	(2)	-6	(2) ***	0,3	(1)
Nontropical	4	(6)	11	(6) *	-37	(12) ***	61	(10) ***	1	(6)
Copper	60	(303)	1410	(244) ***	770	(290) **	342	(159) **	-192	(281)
Iron	50	(15) ***	36	(14) **	36	(14) **	-6	(23)	-4	(11)
Lead^a	-2	(9)	-2	(10)	-63	(16) ***	19	(14)	4	(10)
Zinc^a	-2	(4)	1	(4)	23	(6) ***	-8	(5) *	-0,5	(4)
Coal^a	-7	(5)	-3	(4)	24	(5) ***	0,2	(4)	-8	(6)
Gasoil^a	-5	(2) **	3	(3)	5	(5)	-7	(3) **	-3	(2)
BOD	1	(0,7) *	0,6	(0,7)	-4	(1) ***	1	(0,9)	2	(0,8) ***
SO₂	-585	(729)	-1004	(606)	-2311	(741) ***	-503	(362)	322	(755)
Const^a	87	(188)	149	(118)	521	(193) ***	146	(138)	101	(164)
Centered R²	0,85		0,91		0,48		0,76		0,84	
Observations	69		69		69		69		71	
Overidentification^b	1,1		0,2		0,3 ^h		2,4 ^h			
Exogeneity^c	13,5***		18,5***		0,4		1,1		1,1	
Homocedasticity^d	8,4		5,5		14,61		7,3		8,6	

Notes: All the estimations have a correction due to small samples. Heterocedasticity-robust standard deviation is reported in parenthesis. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. ^aCoefficients and standard deviation are expressed in thousands. ^bAnderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript h indicates that Hansen J statistic was reported instead. ^cC-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. ^dIV heterocedasticity test, Pagan-Hall general test of homoskedastic disturbance using levels of IVs only [chi-sq (16)]. ^eIt uses fishno and road as additional moment conditions.

Table 6: Effect of the Environmental Endowment on Net Export

Industry	Environmental Endowment		Sub-sector	Environmental Endowment	
	BOD	SO ₂		BOD	SO ₂
Iron and Steel	+	0	671	++	0
			672	0	+
			673	0	0
			674	0	-
			676	+++	0
			677	+++	--
			678	0	0
			679	+++	0
Nonferrous Metals	0	0	681	+++	0
			682	0	0
			683	+	-
			684	0	--
			685	0	-
			686	+++	0
			687	+++	0
Chemical	---	---	689	+++	0
			512	0	--
			513	0	0
			514	0	--
Pulp and Paper	0	0	581	---	--
			251	--	0
			641	++	0
Non-metallic Minerals Products	+++	0	642	0	0
			661	+++	0
			662	0	0
			663	+++	0
			664	0	0
			665	++	+++
			666	+++	+
667	++	0			

Notes: The sign indicates the impact of the variable on net exports: “+” indicates “pollution haven effect” and “-” denotes “Porter hypothesis”. The number of signs in a cell specifies the level of confidence of the parameter in the econometric analysis: 99%, 95% and 90%. “0” indicates that the variable is not statistically different from zero.