Sources of Comparative Advantage in Polluting Industries*

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Abstract

We analyze the effects of environmental regulation on international trade flows. To guide empirical work we extend a standard model of international trade to incorporate pollution and environmental regulation. The model implies a simple cross-country, cross-industry empirical framework to study how environmental regulation and factor endowments combine to determine comparative advantage. We find that countries with weaker environmental regulation export relatively more in polluting industries, consistent with a *pollution haven effect*. Furthermore, this effect is quantitatively important and comparable in magnitude to traditional sources of comparative advantage such as skill and capital abundance.

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What are the sources of comparative advantage in polluting industries? This is an old question in the literature on international trade and the environment. Theory provides a straightforward answer. Everything else equal, countries with weak environmental regulation tend to have a comparative advantage in polluting industries. This result is known as the *pollution haven effect*.

Despite its theoretical appeal, there is still little direct empirical evidence supporting the existence of the pollution haven effect. Early studies focused on establishing *cross-country* trends. Between 1960 and the early 1990's pollution-intensive output as a percentage of total manufacturing fell in the OECD and increased in the developing world. In addition, those periods of rapid increase in net exports of pollution-intensive products from developing countries coincided with periods of rapid increase in the cost of pollution abatement in OECD countries.[1] Although consistent with the pollution haven effect, these trends could also be accounted for by other mechanisms. For example, capital accumulation in developing countries could lead to an increasing comparative advantage in capital-intensive goods, which only happen to be polluting.

More recent studies have sought to establish a direct link between environmental regulation, the location of polluting industries, and the resulting pattern of trade. These papers emphasize the *cross-industry* variation in U.S. environmental regulation and use pollution abatement costs as a proxy for regulation at the industry level. Overall, these studies have not found strong evidence in favor of the pollution haven effect.[2,3]

In this paper we follow a different approach. We study the determinants of comparative advantage by analyzing how country and industry characteristics interact to determine trade flows. We treat pollution intensity as a technological characteristic of an industry, like capital and skill intensity. At the same time, we treat environmental regulation as a country characteristic, like capital and skill abundance. To guide the empirical work, we extend the theoretical framework of Eaton and Kortum (2002), Romalis (2004), and Chor (2010) to incorporate pollution and environmental regulation. We do this by treating pollution as another factor of production as is standard in the literature on trade and the environment [Copeland and Taylor (2003)]. We assume that

[1] See Jaffe et al. (1995), and Mani and Wheeler (1999). These trends have accelerated since the early 1990s. For example, sulphur dioxide emissions have been reduced by half in both the US and Europe since the early 1990s (see United States Environmental Protection Agency Clearinghouse for Inventories and Emissions Factors and European Environmental Agency). On the other hand, sulphur dioxide emissions in China are estimated to have increased by 50% between 2000 and 2006 (see Lu et al., 2010).

[2] See Grossman and Krueger (1993), Brunnermeier and Levinson (2004), Copeland and Taylor (2004), and Levinson and Taylor (2008).

[3] As Levinson and Taylor (2008) point out, the use of pollution abatement costs presents a number problems. In particular, compositional effects within industries might make pollution abatement costs a poor proxy for policy. Also, environmental regulation at the industry level may be endogenous due to political economy factors. These problems can result in a variety of biases that may explain the negative results. Indeed, when Levinson and Taylor (2008) account for the endogeneity of environmental regulation they find a positive effect of changes in pollution abatement costs between 1977 and 1986 on changes in U.S. imports from Mexico and Canada. See also Ederington and Minier (2003).

environmental regulation affects the effective cost of polluting. As a result, the model predicts that countries with weak environmental regulation tend to have a comparative advantage in polluting industries. This framework allows us to exploit variation across industries in pollution intensity and variation across countries in environmental regulation stringency to estimate the effect of environmental regulation on comparative advantage in polluting goods, controlling for other sources of comparative advantage.

We find evidence in favor of the pollution haven effect. That is, we show that countries with weaker environmental regulation tend to export relatively more in polluting industries. Furthermore, in contrast with most of the extant literature, we find that these effects are quantitatively important. As an example, consider the following thought experiment. Take India, a country with average environmental regulation stringency in our sample. Now consider the effects of India adopting a more stringent environmental policy, say to the level of Taiwan which is one standard deviation above the mean of cross-country regulatory stringency. We find that Indian exports to the U.S. in pollution-intensive industries would decrease significantly. For example, in steel products manufacturing, which is one standard deviation more pollution intensive than the typical industry, India would decrease its exports by 14 percent. Moreover, this effect is comparable in magnitude to more traditional determinants of comparative advantage. In particular, in an analogous experiment, increasing capital (skill) abundance would yield an increase in exports in capital (skill) intensive industries of 15 and 25 percent respectively. Given the large variation of pollution intensity across industries, the pollution haven effect is particularly important for a number of highly polluting industries. For example, in an analogous counterfactual calculation, if China were to adopt the environmental regulations of Germany, which is the most stringent country, it would decrease its exports in industry 'pulp paper and paperboard mills,' the most polluting industry in terms of sulfur dioxide emissions, by 67 percent. Taken together, our results suggest that differences across countries in environmental regulation are an important determinant of comparative advantage.

One potential concern regarding the causal interpretation of our results is that comparative advantage in polluting industries might influence environmental regulation.[4] We attempt to address this concern by analyzing the effect of an institutional determinant of environmental regulation, namely democratic institutions. Democratic institutions can affect environmental regulation in two ways. First, electoral incentives increase the willingness to provide environmental quality along with other public goods [List and Sturm (2006)]. Institutions that align the incentives of governments and citizens, in particular representativeness and constraints on the executive,

[4] This concern is not as serious as in the existing literature that uses abatement costs at the industry level as a measure of industry-specific environmental regulation. The reason is that country-level environmental regulation is less likely to be influenced by industry lobbies.

are likely to be important in this dimension. Second, past democratic institutions have been shown to be related to higher current state capacity, or the ability to carry out the functions of government such as collecting taxes [Besley and Persson (forthcoming)]. Similarly, state capacity likely increases the ability to enforce environmental regulation. These findings motivate our use of democratic institutions as a source of variation in environmental regulation. This has the advantage of limiting reverse-causality concerns. However, democratic institutions are likely to influence comparative advantage through other channels. For example, democratic societies might invest more in education, gaining a comparative advantage in skill-intensive industries. We try to isolate the effect of democratic institutions on comparative advantage in polluting goods by controlling for interactions of democratic institutions with other industry characteristics. The results suggest that democracy induces a comparative advantage in polluting goods through its effect on environmental regulation and not through its effect on skill and capital abundance.

We find that countries weak environmental regulation have a comparative advantage in polluting industries even without controlling for other sources of comparative advantage. This result, referred to in the literature as the *pollution haven hypothesis*, is usually considered to be stronger than the *pollution haven effect*.[5] As countries with weak environmental regulation are usually capital scarce and capital intensive sectors tend to be polluting, there is potentially an effect going in the opposite direction: capital abundant countries could specialize in polluting industries. Our evidence suggests that the magnitude of the pollution heaven effect is large enough to dominate this potentially countervailing effect.[6]

The evidence in this paper helps reconcile the effects of environmental regulation on international trade flows, traditionally viewed as weak, with a large body of evidence documenting a strong effect of environmental regulation on plant location and FDI flows.[7] The paper also contributes to the literature on the effects of institutions on international trade. The literature to date has highlighted the importance of financial development, the strength of legal institutions, and labor market flexibility.[8] Instead, we emphasize the role of environmental regulation and its possible dependence on democratic institutions as a determinant of comparative advantage in polluting industries.

[5] For a more detailed discussion of the *pollution haven hypothesis* and the *pollution haven effect* see Copeland and Taylor (2004).

[6] Still, it is important to emphasize that even the *pollution haven hypothesis* does not imply that international trade with countries with weak environmental regulation should increase global pollution. In particular, several papers have argued that trade liberalization can lead to growth which in turn might induce countries to enact more stringent environmental regulation or adopt cleaner technologies [Grossman and Krueger (1993), Antweiler, Copeland, and Taylor (2001), and Levinson (2009)].

[7] See for example Becker and Henderson (2000), Greenstone (2002), Keller and Levinson (2002) and List et al. (2003).

[8] See Antras (2003), Beck (2003), Levchenko (2007), Nunn (2007), Manova (2008), Costinot (2009), and Cuñat and Melitz (forthcoming).

The paper is organized as follows. Section 1 presents the theoretical framework and derives the estimating equation. Section 2 describes the data in detail. Section 3 presents our empirical results. Section 4 concludes.

1 Pollution and environmental regulation in a standard model of trade

In this paper we analyze the effects of environmental regulation on the pattern of international trade. To do this we need to control for other sources of comparative advantage. In this section, we describe a model in which environmental regulation and factor endowments combine to determine comparative advantage.

Our analysis combines two strands of the literature. On the one hand, the last few years have seen the development of a number of models that allow to assess the importance of different channels of comparative advantage.[9] These models have not yet analyzed the role of environmental regulation. On the other hand, there is a well established literature in environmental economics that analyzes the effects of environmental regulation on the location of polluting activities and international trade.[10] This literature has shown that pollution, or the use of environmental resources, can be treated as a factor of production. Building on this insight, we show next how environmental regulation can be incorporated into existing models of trade along with other factor endowments.

Our starting point is Chor's (2010) extension of Eaton and Kortum (2002). Chor incorporates factor endowments and institutional variables as sources of comparative advantage in addition to technological differences. There are many tradable industries, which are characterized by their intensity in the use of factors of production (and, below, by their pollution intensity).[11] These intensities are the same in all countries. Within each industry there exist many varieties, whose total factor productivity vary across industries and countries. There are many countries, which are characterized by their factor abundance (and, below, by the strength of their environmental regulation). There is perfect factor mobility within countries, but factors are immobile across countries. All markets are competitive, but transporting goods across countries is costly.

The central equation of the model gives the price that country c would charge for exporting

[9] See for example Eaton and Kortum (2002), Beck (2003), Romalis (2004), Levchenko (2007), Nunn (2007), Manova (2008), Costinot (2009), Chor (2010), and Cuñat and Melitz (forthcoming).

[10] See for example Pethig (1976), McGuire (1982), Chichilnisky (1994), Copeland and Taylor (1994, 1995, and 2003), Rauscher (1997), and Levinson and Taylor (2008).

[11] For brevity, we do not introduce here differences in intensity in the use of institutions. It is immediate to show, following Chor (2010), that institutional variables can be added to the regressions as additional interaction terms.

variety j of industry i to country c':

$$p^i_{c'c}(j) = \frac{\prod_{f=0}^{f=F} (w_{cf})^{s^i_f}}{A^i_c(j)} \cdot d^i_{c'c}. \tag{1}$$

The price equals the cost of producing one unit of the good in country c times the fraction of the good that is not lost in transit to country c', $d^i_{c'c}$. The cost of production depends on factor prices w_{cf} in country c and also on total factor productivity $A^i_c(j)$.[12]

Productivity, in turn, depends on country-specific and industry-specific factors and is heterogeneous across varieties within each industry:

$$\ln A^i_c(j) = \lambda_c + \mu_i + \gamma_0 \cdot \epsilon^i_c(j). \tag{2}$$

The term $\epsilon^i_c(j)$ is interpreted as a stochastic component i.i.d. across countries and industries and with cumulative density function $F(\epsilon) = \exp(-\exp(-\epsilon))$.[13]

Chor (2010) shows that under this production structure trade flows are characterized by the following gravity-type equation:

$$\ln X^i_{c'c} = \sum_{f=1}^{f=F} \beta_f \cdot \ln \frac{w_{cf}}{w_{c0}} \cdot s^i_f - \beta_d \cdot D_{c'c} + \alpha_c + \alpha^i_{c'} + \eta_{c'c} + \varepsilon^i_{c'c}. \tag{3}$$

The first term reflects comparative advantage resulting from factor endowments. The second term reflects the effect of generalized distance, $D_{c'c}$, and includes, for example, physical distance and common language. The equation includes an exporter fixed effect. It captures λ_c and reflects the fact that countries that are larger and/or more productive will tend to export more in all industries. It also includes an importer-industry fixed effect. and the error term can be correlated across industries for each exporter-importer pair.

We modify Chor's (2010) model by assuming that production creates pollution as a by-product, denoted $Z^i_c(j)$. In addition, we assume that firms can allocate a fraction of the resources they employ to abatement, which results in a reduction in the pollution intensity of production. Our treatment follows closely Copeland and Taylor (2003). Production and abatement technologies are

[12] This equation corresponds to Equation (4) in Chor (2010) for the case of Cobb-Douglas technology.

[13] Chor (2010) also allows productivity to depend on the interaction between country and industry attributes. In particular, he includes financial development times dependence on external finance (Beck, 2003; Manova, 2008), strength of legal institutions times input-use concentration (Levchenko, 2007), strength of legal institutions times relationship-specific inputs (Nunn, 2007), strength of legal institutions times industry complexity (Costinot, 2009), skill endowment times industry complexity (Costinot, 2009), and labor market flexibility times volatility of sales (Cuñat and Melitz, forthcoming).

characterized by the the following two equations:

$$Q_c^i(j) = \left(1 - \theta_c^i(j)\right) \cdot A_c^i(j) \cdot \prod_{f=0}^{f=F} \left(V_{cf}^i\right)^{s_f^i}, \tag{4}$$

$$Z_c^i(j) = \varphi^i\left(\theta_c^i(j)\right) \cdot \prod_{f=0}^{f=F} \left(V_{cf}^i\right)^{s_f^i}. \tag{5}$$

The variable $\theta_c^i(j) \in [0,1]$ denotes the fraction of resources allocated to abatement and $\varphi^i(\cdot)$ determines the resulting pollution generated. The function $\varphi^i(\cdot)$ is decreasing and satisfies $\varphi^i(1) = 0$, so that an industry that produces no output does not generate any pollution.[14] We further assume

$$\varphi^i\left(\theta_c^i(j)\right) = Z_0^i \cdot \left(1 - \theta_c^i(j)\right)^{1/s_p^i}, \tag{6}$$

where Z_0^i determines how much pollution is generated in the absence of abatement, i.e. $\theta_c^i(j) = 0$, and s_p^i measures the cost of abatement in industry i. For example, the case $s_p^i \to 0$ corresponds to the case in which abatement in industry i is costless. In fact, the model in Chor (2010) corresponds to the particular case in which $s_p^i = 0$ for all industries. Combining Equations (4), (5), and (6), we obtain

$$Q_c^i(j) = A_c^i(j) \cdot \left(Z_0^i\right)^{-s_p^i} \cdot Z_c^i(j)^{s_p^i} \cdot \prod_{f=0}^{f=F} \left(V_{cf}^i\right)^{s_f^i \cdot (1-s_p^i)}. \tag{7}$$

Thus, we can reinterpret pollution as being another input in production with share s_p^i. [15] Note that the total factor productivity $A_c^i(j) \cdot \left(Z_0^i\right)^{-s_p^i}$ is still distributed as in Equation (2) since the factor $\left(Z_0^i\right)^{-s_p^i}$ is absorbed by the industry fixed effect.

What is the price of pollution? Since pollution is an externality, its cost depends to a large extent on policy. We assume that pollution policy is characterized by a pollution tax τ_c, which is redistributed lump-sum to consumers.[16] As a result, we rewrite Equation (3) incorporating pollution as an additional input:

$$\ln X_{c'c}^i = \sum_{f=1}^{f=F} \beta_f \cdot \ln \frac{w_{cf}}{w_{c0}} \cdot s_f^i \cdot \left(1 - s_p^i\right) + \beta_p \cdot \ln \frac{\tau_c}{w_{c0}} \cdot s_p^i - \beta_d \cdot D_{c'c} + \alpha_c + \alpha_{c'}^i + \eta_{c'c} + \varepsilon_{c'c}^i. \tag{8}$$

In this first draft of the paper we only use data on U.S. imports. As a result, we will be

[14] Note that we assume that the abatement technology has the same factor intensities as production in each sector.

[15] This is true as long as the constraint $\theta_c^i(j) \geq 0$ is not binding, i.e. as long as there is positive abatement. When the cost of pollution is so low that this constraint is binding, small changes in this cost have no effect on pollution.

[16] Environmental policies are multidimensional, involving pollution taxes, pollution caps, regulation of production processes, control on the establishment of production facilities, etc. We take τ_c to be an effective tax, reflecting all these policies.

estimating the equation

$$\ln M_c^i = \sum_{f=1}^{f=F} \beta_f \cdot \ln \frac{w_{cf}}{w_{c0}} \cdot s_f^i \cdot \left(1 - s_p^i\right) + \beta_p \cdot \ln \frac{\tau_c}{w_{c0}} \cdot s_p^i + \alpha_c + \alpha^i + \varepsilon_c^i, \tag{9}$$

where M_c^i denotes U.S. imports of industry i from country c, the distance term and the error term $\varepsilon_{c'c}$ are absorbed in the exporter fixed effect, and the importer-industry fixed effect becomes an industry fixed effect.

What are the counterparts in the data of the objects in Equation (9)? For industry factor intensities, $s_f^i \cdot \left(1 - s_p^i\right)$, we use the corresponding factor shares in the U.S. For industry pollution intensities, s_p^i, we use U.S. industry "pollution factors." Pollution factors are equal to pollution generated in an industry divided by value added in that industry. In other words, the pollution factor of industry i in country c is given by:

$$z_c^i = \frac{Z_c^i(j)}{Q_c^i(j) \cdot p_c^i(j)}, \tag{10}$$

where $p_c^i(j)$ is the price of variety j of industry i in country c. Perfect competition and Equation (7) implies that, in equilibrium, $\tau_c \cdot Z_c^i(j) = s_p^i \cdot Q_c^i(j) \cdot p_c^i(j)$. Rearranging, we obtain that for the U.S.

$$s_p^i = \tau_{US} \cdot z_{US}^i. \tag{11}$$

Thus, industry pollution intensities, s_p^i, are proportional to U.S. industry pollution factors, z_{US}^i. Since the constant τ_{US} is absorbed by the coefficient β_p in Equation (9), we simply use z_{US}^i in the regressions.

Let us emphasize that our model does not imply that pollution factors, z_c^i, are common across countries. Instead, common technology across countries implies

$$z_c^i = \frac{s_p^i}{\tau_c}, \tag{12}$$

so that pollution factors are higher in countries with weaker environmental regulation, i.e. low τ_c. What is preserved across countries are relative pollution factors, so that if in one country industry i is more polluting than industry i' then industry i is more polluting than industry i' in all countries. In particular, we use U.S. pollution factors only because the U.S. had the most comprehensive cross-industry data, but in principle we could have used pollution factors from any other country.[17]

[17] This applies to all factors of production. For example, countries in which capital is abundant have high capital/output ratios in all industries, and those industries that are particularly capital intensive in one country are particularly capital intensive in all countries.

For country characteristics we are limited by the absence of good cross-country data on factor prices. We thus follow the literature and proxy relative factor prices w_{cf}/w_{c0} using relative factor endowments V_{cf}/V_{c0}. Likewise, we also proxy the relative cost of pollution τ_c/w_{c0} using our measure of environmental regulation E_c.

2 Data

In this section we introduce novel measures of an industry's air pollution intensity and the strictness of a country's air pollution regulations. We describe each of these measures in detail below and then combine them with U.S. bilateral trade flows to take a first look at the evidence: is cross-country variation in the strictness of air pollution regulations an important determinant of comparative advantage in polluting industries?

The remaining sources of data used in the paper are standard in the literature. The data on bilateral trade flows with the U.S. is from Feenstra, Romalis and Schott (2002), updated till 2006. We source data on cross-country stocks of human capital and physical capital from Hall and Jones (1998). Data on skill and capital intensity at the industry level is available for the manufacturing sector only and is sourced from Bartelsman and Gray's (1996) NBER-CES manufacturing data, updated to 2005.

2.1 A measure of air pollution intensity

Our measure of air pollution intensity at the industry level is drawn from data compiled by the U.S. Environmental Protection Agency's (EPA) in their Trade and Environmental Assessment Model (TEAM).[18] TEAM's air emissions baseline data is based on the EPA's 2002 National Emissions Inventory.[19] From this dataset, we obtain - for a host of air pollutants - the total amount of air pollution emitted by 4-digit NAICS industries in the US in 2002. Throughout, we focus our analysis on industry level emissions data of three common air pollutants: Carbon Monoxide (CO), Nitrogen Oxides (NOx) and Sulfur Dioxide (SO2).

Given information on the value of sales in each industry we can then compute the corresponding pollution emission intensity (per dollar of sales in a given industry). In total, we have pollution intensity data for 112 industries, 17 of which are in agriculture, 9 in mining and 86 in manufacturing.[20] Across these broad sectors, agriculture is clearly the most pollution intensive in nitrogen

[18] This data is assembled by the EPA and Abt Associates. See Abt Associates (2009) for a complete description.

[19] Specifically, for each pollutant, we sum across point (i.e. those deriving from large polluting facilities), area and mobile source measurements at the national level.

[20] We also have information on 180 service sector industries but we do not exploit this here given that disaggregated service trade data is unavailable.

oxides and sulfur dioxide (an order of magnitude more intensive than manufacturing) and mining the most pollution intensive in carbon oxide (differing again by an order of magnitude with respect to agriculture and manufacturing).[21] Within manufacturing, metal manufacturing, mineral (non-metallic) products manufacturing, paper manufacturing, chemical manufacturing and petroleum and coal products make it to the top of the list in every pollutant ranking displayed in Table 1.

Our list of most pollution intensive manufacturing industries is broadly consistent with the ranking "dirty industries" in Mani and Wheeler (1999) which uses an alternative indicator of pollution intensity based on the Industrial Pollution Projection System (IPSS) dataset assembled by the World Bank.[22,23] More generally, as Hettige et al (1995) had noted for IPSS data, there is extreme sectoral variation in emission factors, the distribution being very fat tailed. As an example, the least pollution intensive manufacturing sector in Carbon Monoxide - Tobacco manufacturing- is 24 times less polluting than the most CO intensive industry within manufacturing, Alumina and aluminum production. The upshot of this is that the ten most pollution intensive manufacturing sectors account for a significant amount of total manufacturing air pollution emissions in every pollutant, ranging from 38% for CO to 66% in SO2. Further, despite differences in the exact ordering of sectors across pollutant categories, computing a rank correlation reveals a high average correlation: highly pollution intensive industries in a given pollutant tend to be pollution intensive in all pollutants (see Table 2). Table 3 reports the correlation of our measures of pollution intensity and industry level factor intensities of production (skill and capital intensity). Across all pollutants, pollution intensive industries tend to be capital intensive and unskilled intensive[24].

2.2 A measure of air pollution regulation

As our primary measure of air pollution regulation we use survey data underlying the World Economic Forum's 2004 Global Competitiveness Report. This survey builds on questionnaire responses

[21] In particular this is driven by NAICS sectors grouped under Crop Production. For mining sectors this is mostly due to Metol Ore Mining and Oil and Gas Extraction.

[22] The IPPS data also gives pollution intensity per sector across a range of pollutants. However this data refers to 1987 measurements. Thus our EPA-TEAM data is based on a newer vintage data. Furthermore, as Abt Associates (2009) note, the data used in developing the IPPS pollutant output intensity coefficient, and the 1987 Toxic Release Inventory (TRI) database in particular, "have been the subject of substantial concerns regarding their reliability. This [1987] was the first year the TRI data were self-reported by facility. A 1990 EPA report found that 16 percent of releases reported in the 1987 database were off by more than a factor of ten, and 23 percent were off by a factor of two."

[23] At this degree of sectoral disaggregation, it is difficult to find comparable data for other countries. Still, Cole et al (2004) and Dean and Lovely (2008), when reporting 3-digit ISIC manufacturing pollution intensities for, respectively, the UK during the 1990s and China in 1995 and 2004, single out the same highly polluting industries as we do here: metal manufacturing, non-metallic mineral products, coke and petroleum and paper manufacturing. Reliable data at this more aggregated level is available for at least a handful more of European countries and Canada. In the future we plan to conduct a more systematic cross-country comparison of pollution intensity measures at the industry level.

[24] The positive correlation between pollution intensive and capital intensive industries is again in accordance with the discussion of Mani and Wheeler (1999) for the IPSS dataset. See also Antweiler et al (2001).

from more than 8000 business, government and non-governmental organization leaders in 102 countries.[25] Specifically we use the parts of the survey that deal with the perceived stringency of environmental pollution standards and in particular of the subcategory "Air Pollution Regulations". The latter gives, for each of the 102 countries, an index measure - ranging from 1 to 7 - that averages across the answers of respondents in a given country to the following question: "the air regulations in your country are (1) lax compared with those of most other countries - (7) among the world's most stringent)?". A list of the ten least and ten most stringent regulation countries according to this measure is provided in Table 4.

The fact that pollution regulation is stringent in a given country does not necessary imply that this regulation is enforced. To assess the latter we use an index - again from the Global Competitiveness Report (2004) survey- that takes the maximum value (7) if environmental regulations in a given country are "enforced consistently and fairly" and the minimum value (1) when they are "not enforced or enforced erratically". While there are differences across rankings - e.g. Singapore ranks 15th in air pollution stringency but 3rd in terms of enforcement; Venezuela drops 11 positions in the ranking to fourth worst in the world when we consider enforcement - we observe a high correlation between the stringency of a country's air pollution regulation and environmental regulation enforcement (correlation is 0.94)

It is difficult to find comparable data on cross-country regulatory measures that permits a cross-validation of our measures of perceived stringency and enforcement as measures of actual strictness of air pollution regulation. When it exists, the latter data is mainly available for developed economies. One exception to this are the indices of environmental policy put forth in Dasgupta et al (2001). Drawing from national environmental reports submitted by 145 countries to the United Nations - in preparation for the U.N. Conference on Environment and Development (UNCED, 1992) - these authors randomly selected 31 such reports and built an index of air pollution policy and performance. If, as it seems reasonable to assume, the relative stringency of environmental policy is persistent through time, our measure of policy stringency based on the Global Competitiveness Report survey should be highly correlated with the air pollution policy index devised by Dasgupta et al (2001). Indeed for the 29 countries that are common across both policy indices we find a high correlation of 0.85.[26,27]. Another alternative is to compare our broad measure of air pollution

[25] This gives an average of 80 respondents per country with a maximum of 264 respondents for the Russian Federation and a minimum of 21 for Israel. See Global Competitiveness Report (2004), Chapter 3.1 for a full description of this survey.

[26] The correlation of Dasgupta et al (2001) measure with the Global Competitiveness Report (2004) measure of environmental regulation enforcement is 0.76.

[27] Interestingly, our air pollution regulation also correlates with actual environmental outcomes. In particular, we use two measures of air pollution, SO2 concentration and Total Suspended Particulates, both normalized by urban population in a given country. This data is sourced from the Environmental Sustainability Index (Esty et al 2005). For

regulation with an actual, if narrow, policy measure that is available for a broad cross-section of countries: the lead content per gallon of gasoline. As Hilton and Levinson (1998) and Damania el al (2003) discuss, lead emissions are precursors to local air pollutants and have been subject to differential regulation across countries. Thus, countries with stricter environmental policy according to our measure of air pollution regulation should have a lower lead content per gallon of gasoline. We obtain data for 1995 from Associated Octel (1996) "Worlwide Gasoline Survey" and are able to match 85 countries across the two datasets. We find a negative correlation of -0.71, significant at the 1 percent level. Taken together these correlations suggest a high degree of consistency between our air pollution regulation measure and previously used proxies.

2.3 The pollution content of US imports: a first look at the data

We now deploy our measures of industry level air pollution intensity and country level air pollution regulation to take a first look at the pollution content of US imports. We are interested in characterizing the magnitude of aggregate pollution imports and documenting its sources both at the country and industry level. Further, we build on this information to provide a first assessment of whether, in the raw data, there is evidence that strict air pollution regulation is associated with comparative advantage in polluting industries.

First, recall that the industry level pollution intensity measure introduced above gives only a measure of the pollution directly generated at a specific stage of production and does not take into account whether a given industry will require inputs that may themselves be polluting. When looking at the pollution content of imports of the U.S. this may be misleading: if we observe an import of a final good that is not itself very polluting but requires pollution intensive inputs we would be biasing downward our estimates of the pollution content of imports.[28] We take into account these indirect emissions arising from intermediate stages of production by computing total emission intensities thus:

$$\tilde{\mathbf{p}}_j = \mathbf{p}'_j (I - B)^{-1}$$

where $\mathbf{p}_j$ is a vector that collects the TEAM data direct emission intensity coefficients for all industries in a given pollutant j. B is the 2002 direct requirements input-output matrix, where entry B_{ij} gives the share of input i in the gross output of industry j.[29] Thus, each element $\tilde{p}_{ij}$

the 52 countries we are able to match across the two datasets, both air pollution measures are negatively correlated with our index of air pollution regulation (-0.45 for SO2 and -0.54 for Particulates) and with overall environmental regulation enforcement (-0.41 and -0.48 respectively). All correlations are significant at the 1% level.

[28] See Levinson (2009) for a similar point in another application of Leontieff's (1970) input-output approach to the pollution content of U.S. trade.

[29] We obtain B from the Bureau of Economic Analysis' benchmark input-output tables for 2002 and bridge the BEA's own classification to the NAICS classification used by the EPA. Notice that here we do take into account

of $\tilde{\mathbf{p}}_j$ gives us the total - directly and indirectly- increase in pollutant j necessary to produce one extra unit of shipments in industry i.

To obtain the pollution content of U.S. trade, we combine this information with US bilateral trade data assembled by Feenstra, Romalis and Schott (2002). This gives, for each NAICS sector, the value of imports and exports between the US and its trading partners in year 2005. Denoting total imports from country c in industry i by M_{ic} we obtain the pollution content of imports in pollutant j, PM_j, as:

$$PM_j = \sum_c \sum_i \tilde{p}_{ij} \cdot M_{ic}$$

PM_j thus gives us the total air pollution content embedded in aggregate US imports for pollutant j. Notice that, when computing this measure, we are implicitly assuming that technology is the same across countries and time.

We find that in 2005, summing across all industries, the US imported 4.6 million tons of NOx, 3.3 million tons of SO2 and 10 million tons of CO. Further, we find that the US is a net importer in all pollutants (with a deficit of 2.5, 1.6 and 4.4 million tons in NOx, SO2 and CO respectively). As a reference point, from the TEAM-EPA data we can back out the totals emitted in the US for 2002 (for the same set of industries): 11.3 million tons of NOx, 13.5 million tons of SO2 and 23.1 million tons of CO. This suggests that, across all pollutant categories considered here, the US is importing a large fraction of pollution relative to what it produces[30].

Looking at the industry sources of these imports reveals that the bulk of pollution imported is accounted for by a handful of industries (see Table 5). Further, it is interesting to note that many of the largest industries that have the highest pollution content of imports are also those whose technology is the most pollution intensive. Indeed, extending the analysis across all industries, the correlation between the amount of pollution imported and the pollution intensity of the industry is positive for all pollutants considered here (NOx :0.19, significant at the 10 percent level; SO2: 0.35, significant at the 1 percent level; CO, 0.04 but not statistically different from zero).

We've seen that overall, the US is importing a substantial amount of pollution relative to what is producing and furthermore, it tends to do so precisely in industries that are more polluting intensive. The next step is then to look at what countries are on the other side of this pollution intensive trade. We begin by analyzing this country dimension by specializing the measure above to

$$PM_{cj} = \sum_i \tilde{p}_{ij} \cdot M_{ic}$$

pollution indirectly generated by service sector inputs: p_j includes entries for the service sector, again sourced from TEAM-EPA data.

[30] This is also true if we look within the manufacturing sector alone.

Thus, PM_{cj} gives the pollution content of total imports from country c in pollutant j. Table 6 presents a ranking of the top 10 countries in terms of the total pollution exported to the US. Not surprisingly, these rankings are dominated by the largest trading partners of the US. As is the case for goods exports to the US, the largest 10 pollution exporters to the US account for roughly two thirds of all pollution exported to the US in 2005.

Since it reflects mostly the importance of a country as a trading partner of the US, the measure above does not capture whether a country tends to export in polluting industries. Anticipating the more detailed analysis in the next section, and as a first look at the raw data, we ask whether the share of exports in pollution intensive industries is larger for countries with weak air pollution regulations. To do this, we divide the sample into weak versus strict air pollution regulation countries, defined as those with a measure of air pollution regulation that is, respectively, below and above the sample median. Similarly, we group industries into those that are pollution intensive and those that are not. We define an industry i to be pollution intensive in pollutant j if the corresponding $\widetilde{p_{ij}}$ is in the top quartile of the distribution of total pollution intensities for that pollutant. We find that, for weak regulation countries, 48 percent of their exports are in NOx intensive industries while for strict air pollution regulation counties 33 percent of exports are in NOx intensive industries. The pattern repeats itself for SO2 (61 and 51 percent respectively) and CO (52 versus 36 percent respectively).[31] Thus, countries with weak air pollution regulations tend to export relatively more in pollution intensive industries to the US. The next section assesses this relationship more thoroughly, taking as a reference the cross-country, cross-industry regression derived in Section 1.

3 Determinants of Comparative Advantage in Polluting Goods

In this section we investigate whether lax environmental regulation can be a source of comparative advantage in polluting goods. For this purpose, we exploit variation across industries in pollution intensity and variation across countries in environmental regulation stringency to estimate Equation (9). In the model, pollution intensity is treated as a technological characteristic of each industry, like capital and skill intensity. In addition, differences in the stringency of environmental regulation across countries lead to differences in the shadow price of pollution. This treatment of environmental

[31] Qualitatively, the results are unchanged if we instead define a pollution intensive industry to be an industry with a $\widetilde{p_{ij}}$ coefficient above the median. For example, in the case of NOx, we find that according to this definition, 94 percent of exports of weak regulation countries to the U.S. are in polluting industries versus 80 percent for strong regulation countries. The pattern is the same across the other pollutants. The overall high numbers are the immediate consequence of the fact documented above: the bulk of US imports tend to happen in relatively high pollution intensive industries.

regulation parallels the treatment of capital and skill abundance as sources of differences in the price of capital and the skill premium across countries. Thus, to implement an empirical test of Equation (9), we follow Romalis (2004) and proxy for differences in factor prices across countries using differences in factor abundance. This leads to the following empirical counterpart of Equation (9):

$$\ln M_{ic} = \beta_1 \; E_c \times z_i + \beta_2 \; K_c \times k_i + \beta_3 \; H_c \times h_i + \alpha_c + \alpha_i + \varepsilon_{ic}, \tag{13}$$

where M_{ic} are imports into the U.S. from country c in industry i; E_c is a measure of the stringency of air pollution regulation in country c; z_i is a measure of the pollution intensity of industry i; K_c and H_c denote country c´s endowments of capital and human capital; k_i and h_i are industry i´s capital and skill intensity; α_c and α_i are country and industry fixed effects. We estimate this equation for the year 2005.

We measure the technological characteristics of industries using U.S. factor shares in value added. This is consistent with the model where in equilibrium these shares are constant across countries. Note that this holds despite the presence of Hicks neutral technology differences across countries and differences in factor and pollution prices, because we assume a Cobb-Douglas production function.

As discussed in Section 1, we do not observe the price of pollution. Thus, we cannot directly measure the share of pollution in value added in the U.S., $s_p^i = \tau_{US} \cdot \frac{Z_{US}^i}{Q_{US}^i \cdot p_{US}^i}$. As an alternative, we use the pollution intensity measure: $z_{US}^i = \frac{Z_{US}^i}{Q_{US}^i \cdot p_{US}^i} = \frac{s_p^i}{\tau_{US}}$. Note that, under the assumptions in the model, this does not lead to biases in the estimation of Equation (13) because the use of z_{US}^i amounts to dividing the independent variable s_p^i by a constant (τ_{US}). Note that this also implies that differences in environmental regulation across countries do not alter the relative pollution intensities across industries, which then are accurately measured by US (or any other country's) pollution intensities. This is an implication of the assumptions of the model that can be tested by looking at the correlation of relative pollution intensities across countries.

3.1 Baseline Results

As measures of pollution intensity we use the simple average of pollution emitted per unit of output for three air pollutants sulfur dioxide (SO2), nitrogen oxides (NOx) and carbon monoxide (CO). Table 7 reports estimation of Equation (13) for the average pollution intensity measure and also for each of the three air pollutants separately, without controlling for capital and skill interactions. Panel A reports results for the sample of all industries producing goods, namely agriculture, mining and manufacturing and Panel B restricts the sample to manufacturing industries. The first row reports the estimate of β_1 for the interaction of pollution intensity of the industry with the air pollution regulation stringency index. The remaining columns report the analogous estimation for the rest of the pollutants. The estimated β_1 coefficient on the environmental regulation and pollution intensity interaction ($E_c \times z_i$) are negative and statistically significant at 1 percent for each pollutant and the pollution intensity index. Thus, to simplify the exposition, in what follows we only report estimates for the pollution intensity index.

Estimation of Equation (13) with controls for factor endowments as determinants of comparative advantage is reported in Table 8. As the available measures of capital and skill intensity only cover manufacturing industries, results are only reported for manufacturing. Columns 1 and 2 show that adding controls for capital and skill interactions ($K_c \times k_i$ and $H_c \times h_i$) does not significantly affect the estimated coefficients, which suggests that the environmental regulation and pollution intensity interaction ($E_c \times z_i$) is not capturing other classical determinants of comparative advantage. In addition, the magnitude of the effect of the pollution intensity interaction is similar to the factor intensity interactions. The estimated coefficient on the average measure of pollution intensity implies that a country with one standard deviation below the mean environmental regulation would sell 14 percent more of an industry that is one standard deviation above mean pollution. In turn, a country with one standard deviation above the mean capital intensity would sell 15 percent more of an industry that is one standard deviation above mean capital intensity. Finally, a country with one standard deviation above the mean skill intensity would sell 25 percent more of an industry that is one standard deviation above mean skill intensity.

3.2 Robustness

A potential problem in the estimation of Equation (13) is that environmental regulation is partially determined by other country characteristics. In particular, it is possible that richer citizens demand more stringent environmental regulation [Grossman and Krueger (1993), Copeland and Taylor (1994)]. Alternatively, it is possible that countries with better legal institutions are more efficient at enforcing environmental regulation. This leads to a positive correlation between environmental regulation and those country characteristics. If pollution intensity is also correlated with other industry characteristics, the omission of these other determinants of comparative advantage might bias the estimated effect of environmental regulation on comparative advantage.

We follow two different strategies to address these concerns. First, we estimate Equation (13) including controls for other sources of comparative advantage. For example, if developed countries tend to have more stringent environmental regulation and polluting industries tend not to be the most technologically advanced, we need to control for the possibility that more technologically advanced countries specialize in R&D intensive industries. Thus, we include an interaction between GDP per capita and industry-level TFP growth. This does not significantly affect the estimated coefficient on the pollution interaction, as reported in Columns 3 and 4 of Table 8. We also control for institutional determinants of comparative advantage. In particular, the recent trade literature (Antras, 2003, Nunn, 2007, Levchenko, 2007, Costinot, 2009) has highlighted the role of contracting institutions for the production and trade of products for which relationship-specific investments are important. Column 5 shows that the coefficient on the pollution interaction remains negative and statistically significant after the inclusion of an interaction of the efficiency of legal institutions and the measure of contracting intensity of the industry developed by Nunn (2007) in column 5.[32]

A potential problem with the first strategy to deal with omitted sources of comparative advantage discussed above is that we do not have precise measures for all the industry characteristics that might be correlated with pollution intensity. Thus, the interaction of environmental regulation with pollution intensity might still capture the effects of other country-level variables on comparative advantage. We follow a second strategy to address this concern. Table 9 shows that the estimated coefficient on the interaction of environmental regulation and pollution intensity remains negative and statistically significant after the inclusion of controls for interactions of pollution intensity with the following country-level variables: fertile land per capita, efficiency of legal institutions, skill abundance, capital abundance and income per capita. These results suggest that environmental regulation is not capturing the effect of other country characteristic that interacts with unobserved industry characteristics correlated with pollution intensity.

3.3 Reverse Causality

Can we interpret the results presented in Table 8 as the causal effect of environmental regulation on comparative advantage? An alternative interpretation is that comparative advantage in polluting industries influences environmental regulation. This reverse causality channel could upwards or downwards bias the estimate of the effect of environmental regulation on comparative advantage. This is because countries with a comparative advantage in polluting industries might have both a larger income cost and a larger clean air benefit from enacting environmental regulation.

To fully address this concern we need an instrument for environmental regulation. That is, a source of variation in environmental regulation that is not determined by comparative advantage in polluting industries (exogenous) and does not affect comparative advantage through other channels

[32] As a measure of the efficiency of legal institutions we use the total number of procedures mandated by law or court regulation that demand interaction between the parties or between them and the judge or court officer from World Bank (2004).

(exclusion restriction). As a first step in this direction, we analyze the effect of an institutional determinant of environmental regulation, namely democratic institutions. Sturm and List (2006) present a model where a secondary policy issue like environmental regulation can be influenced by electoral incentives. They test the model's predictions using variation in term limits across U.S. states as a measure of electoral incentives. We follow a similar approach and use country-level measures of constraints on the executive and democracy from Polity IV as measures of electoral incentives.[33]

Note that democratic institutions are less likely to be determined by comparative advantage in polluting industries than environmental regulation, which minimizes reverse causality concerns. However, they are likely to influence comparative advantage through other channels. For example, democratic societies might invest more in education, gaining a comparative advantage in skill-intensive industries. Alternatively, constraints on the executive could reduce the risk of expropriation inducing more capital accumulation (Acemoglu and Johnson, 2005). In sum, the exclusion restriction is not satisfied thus we do not pursue an instrumental variable estimation. Still, we can try to isolate the effect of democratic institutions on comparative advantage in polluting goods by estimating the following specification:

$$\ln M_{ic} = \gamma_1 \; D_c \times z_i + \gamma_2 \; D_c \times k_i + \gamma_3 \; D_c \times h_i + \gamma_4 \; D_c \times c_i + \delta_c + \delta_i + \varepsilon_{ic}, \tag{14}$$

where D_c is a measure of democratic institutions in country c, z_i is the pollution intensity of industry i, k_i and h_i are industry i´s capital and skill intensity and c_i is the contracting intensity of industry i. The coefficient of interest (γ_1) is meant to capture the effect of democratic institutions on comparative advantage in polluting industries. Similarly, the interactions of democratic institutions with other industry characteristics attempt to control for the effects of democratic institutions on comparative advantage operating through the other channels mentioned above.

Estimation results for Equation (14) are reported in Table 10. The first column shows that countries with stronger executive constraints tend to export less in polluting industries, that is γ_1 is negative and precisely estimated. Columns 2 and 3 show that the coefficient is not significantly affected by the inclusion of controls for interactions of executive constraints and other industry characteristics. This result suggests that democracy induces a comparative advantage in polluting goods through its effect on environmental regulation and not through its effect on skill and capital abundance.

[33] As a measure of democratic institutions we use the share of years between 1950 and 2000 in which the country had a positive score in the polity2 variable from the Polity IV database. As a measure of executive constraints we use the average over the 1990s of the constraints on the executive variable from the same database.

4 Final Remarks

In this paper we have shown that environmental regulation is an important determinant of comparative advantage in polluting industries. This result is robust to a variety of controls, including factor endowments and quality of institutions. We also present suggestive evidence that weak democratic institutions are also associated with comparative advantage in polluting industries.

In ongoing work, we are extending the analysis in some directions. First, we are planning to include emissions of green house gases. Second, we are exploring alternative measures of environmental regulation that are based on actual policy measures, such as the lead content of gasoline [Associated Octel (1996)].

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Table 1: Ten most pollution intensive manufacturing industries for each pollutant. Emission Factors are in Tons per million of dollars shipped.

	NOx			S02			CO		
Rank	Industry	EF	%Total	Industry	EF	%Total	Industry	EF	%Total
1	Lime and gypsum	6.68	1	Pulp/paper/paperboard mills	5.17	14	Alumina and aluminum	14.2	7
2	Cement and concrete	5.42	10	Lime and gypsum	4.85	1	Iron/Steel Mills and Ferroalloy	7.94	7
3	Glass and glass products	3.8	3	Nonferrous Metal(not Aluminum)	4.67	4	Lime and Gypsum	7.08	1
4	Pulp/paper/paperboard mills	3.67	10	Cement and concrete	4.22	7	Pulp/paper/paperboard mills	5.56	7
5	Pesticide & fertilizer	2.22	2	Alumina and Aluminum	4.19	4	Other Nonmetallic Mineral	4.81	1
6	Basic Chemicals	1.96	8	Pesticide & fertilizer	3.18	2	Steel Products	4.62	1
7	Petroleum and Coal Products	1.42	12	Basic Chemicals	2.69	11	Cement and Concrete	4.44	3
8	Veneer/Plywood/Eng. Wood	1.19	1	Petroleum and Coal Products	2.30	18	Basic Chemicals	4.36	8
9	Iron/Steel Mills and Ferroalloy	1.14	2	Other Chemical Products	1.89	3	Veneer/Plywood/Eng.Wood	3.29	1
10	Clay Product and Refractory	1.08	1	Veneer/Plywood/Eng. Wood	1.72	3	Nonferrous Metal(not Alum.)	3.24	1
% of Total Accounted by top 10			50	% of Total Accounted by top 10		66	% of Total Accounted by top 10		38

Emission Factors are in Tons per million of dollars shipped. "% Total" gives the industry's share of total emissions in manufacturing.

Table 2: Rank correlation of pollution intensity ranking of industries.

	NOx	SO2	CO
NOx	1	-	-
SO2	0.58***	1	-
CO	0.90***	0.44***	1

*** indicates significance at the 1 percent level.

Table 3: Correlation between Pollution, Skill and Capital Intensities.

	NOx	SO2	CO
	1	-	-
Skill Intensity	-0.24**	-0.19*	-0.25**
Capital Intensity	0.33***	0.52***	0.53***

* indicates significance at the 10 percent level,** indicates significance at the 5 percent level, *** at 1 per cent level.

Table 4: Ten least and ten most stringent countries according to air pollution regulation index.

Rank	Most Stringent Regulation	Index	Least Stringent Regulation	Index
1	Germany	6.7	Haiti	1.3
2	Sweden	6.6	Angola	1.5
3	Switzerland	6.5	Paraguay	2
4	Finland	6.5	Chad	2.1
5	Denmark	6.5	Bolivia	2.1
6	Netherlands	6.2	Nigeria	2.1
7	Norway	6.2	Ethiopia	2.1
8	Austria	6.1	Mali	2.2
9	Luxembourg	6.1	Guatemala	2.2
10	Belgium	5.9	Zimbabwe	2.2

Median is 3.5, mean is 3.8. Source Global Competitiveness Report (2004).

Table 5: Ranking of industries with the ten highest pollution content of imports.

	NOx		S02		CO	
Rank	Industry	%Total	Industry	%Total	Industry	%Total
1	Oil and gas extraction	32	Oil and gas extraction	13	Oil and gas extraction	18
2	Petroleum and Coal Products	10	Petroleum and Coal Products	8	Motor Vehicle Manufacturing	6
3	Motor Vehicle Manufacturing	5	Basic Chemical Manufacturing	6	Petroleum and Coal Products	6
4	Basic Chemical Manufacturing	4	Motor Vehicle Manufacturing	6	Basic Chemical Manufacturing	4
5	Motor Vehicle Parts Manufacturing	3	Nonferrous Metal (except Aluminum)	6	Iron and Steel Mills and Ferroalloy	4
6	Cut and Sew Apparel Manufacturing	2	Motor Vehicle Parts Manufacturing	4	Motor Vehicle Parts	4
7	Iron and Steel Mills and Ferroalloy	2	Forging and Stamping	3	Cut and Sew Apparel	3
8	Semiconductor/Electronic Component	2	Alumina and Aluminum	3	Alumina and Aluminum	3
9	Other Miscellaneous Manufacturing	2	Iron and Steel Mills and Ferroalloy	3	Other Miscellaneous Manufacturing	3
10	Forging and Stamping	2	Semiconductor/Electronic Component	3	Computer and Peripheral Equipment	3
% of total accounted by top 10		64	% of total accounted by top 10	62	% of total accounted by top 10	52

Table 6: Ranking of the ten largest pollution exporters to the US in 2005.

	NOx		S02		CO	
Rank	Country	%Total	Country	%Total	Country	%Total
1	Canada	21	Canada	21	Canada	20
2	Mexico	10	China	11	China	11
3	China	9	Mexico	9	Mexico	10
4	Japan	5	Japan	7	Japan	6
5	Venezuela	5	Germany	5	Germany	4
6	Saudi Arabia	4	United Kingdom	3	Venezuela	3
7	Nigeria	4	Venezuela	3	United Kingdom	3
8	Germany	3	Korea	2	Saudi Arabia	2
9	United Kingdom	3	Russia	2	Korea	2
10	Korea	2	Brazil	2	Brazil	2
% of total accounted by top 10		64	% of total accounted by top 10	65	% of total accounted by top 10	64

Table 7
Environmental Regulation and Comparative Advantage in Polluting Goods

Panel A: All Industries

	(1)	(2)	(3)	(4)
Air Pollution Regulation Stringency				
× Pollution intensity	-0.332***			
	[0.0245]			
× NOx intensity		-0.334***		
		[0.0228]		
× SO2 intensity			-0.165***	
			[0.0222]	
× CO intensity				-0.300***
				[0.0208]
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	7,068	7,068	7,068	7,068
R-squared	0.607	0.610	0.596	0.608

Panel B: Manufacturing Industries

	(1)	(2)	(3)	(4)
Air Pollution Regulation Stringency				
× Pollution intensity	-0.166***			
	[0.0301]			
× NOx intensity		-0.168***		
		[0.0311]		
× SO2 intensity			-0.112***	
			[0.0228]	
× CO intensity				-0.186***
				[0.0336]
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	6,347	6,347	6,347	6,347
R-squared	0.648	0.648	0.647	0.648

Robust standard errors in brackets. *** indicates $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8
Determinants of Comparative Advantage in Polluting Goods – Baseline Results
Manufacturing Industries

	(1)	(2)	(3)	(4)	(5)
Air Pollution Regulation × Pollution Intensity	-0.130***	-0.129***	-0.127***	-0.128***	-0.0873**
	[0.0312]	[0.0356]	[0.0312]	[0.0357]	[0.0361]
Skill Abundance × Skill Intensity		9.936***		9.756***	9.286***
		[1.128]		[1.152]	[1.167]
Capital Abundance × Capital Intensity		0.281***		0.275***	0.321***
		[0.0691]		[0.0705]	[0.0707]
Income per capita $_c$ × TFP growth $_i$			0.465***	0.0818	0.00321
			[0.129]	[0.138]	[0.140]
Efficiency of Legal Institutions$_c$ × Contract Intensity$_i$					0.0860***
					[0.0168]
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	5,226	5,226	5,226	5,226	4,896
R-squared	0.657	0.664	0.658	0.664	0.672

Robust standard errors in brackets. *** indicates p<0.01, ** p<0.05, * p<0.1

Table 9
Determinants of Comparative Advantage in Polluting Goods- Robustness
Is the air pollution regulation index just capturing development?

All Industries

	(1)	(2)	(3)	(4)	(5)	(6)
Pollution Intensity $_i$						
× Air Pollution Regulation $_c$	-0.332***	-0.329***	-0.333***	-0.273***	-0.215***	-0.177***
	[0.0245]	[0.0244]	[0.0301]	[0.0379]	[0.0370]	[0.0435]
× Fertile Land per capita $_c$		0.00244***				
		[0.000269]				
× Eff. Legal Institutions $_c$			-0.000286			
			[0.00407]			
× Skill Abundance $_c$				-0.215		
				[0.224]		
× Capital Abundance $_c$					-0.174***	
					[0.0386]	
× Income per capita $_c$						-0.273***
						[0.0609]
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,068	7,068	6,152	5,838	7,068	7,068
R-squared	0.611	0.607	0.616	0.614	0.608	0.608

Robust standard errors in brackets. *** indicates $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10
Determinants of Comparative Advantage in Polluting Goods – Endogeneity
Role of political institutions as ultimate determinants of environmental regulation

Manufacturing Industries

	Constraints on Executive			Democracy		
Political Institutions $_c$						
× Pollution Intensity $_i$	-0.163***	-0.177***	-0.145***	-0.361***	-0.424***	-0.348***
	[0.0218]	[0.0274]	[0.0293]	[0.0969]	[0.121]	[0.127]
× Skill intensity $_i$		0.428***	0.276*		3.060***	2.702***
		[0.119]	[0.142]		[0.549]	[0.645]
× Capital intensity $_i$		0.102**	0.112***		0.615***	0.642***
		[0.0425]	[0.0425]		[0.190]	[0.191]
× Contract intensity $_i$			0.255**			0.634
			[0.106]			[0.470]
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,607	7,607	7,607	7,649	7,649	7,649
R-squared	0.675	0.676	0.676	0.673	0.674	0.674

Robust standard errors in brackets. *** indicates p<0.01, ** p<0.05, * p<0.1