Is Trade Good or Bad for the Environment? Sorting Out the Causality *

Jeffrey A. Frankel
Kennedy School of Government
Harvard University, 79 JFK Street
Cambridge MA 02138-5801
Tel: (617) 496-3834
Fax: (617) 496-5747
jeffrey_frankel@harvard.edu

Andrew K. Rose
Haas School of Business
University of California
Berkeley, CA 94720-1900
Tel: (510) 642-6609
Fax: (510) 642-4700
arose@haas.berkeley.edu

Abstract

We seek to contribute to the debate over globalization and the environment by asking: What is the effect of trade on a country's environment, for a given level of GDP? We take specific account of the endogeneity of trade, using exogenous geographic determinants of trade as instrumental variables. We find that trade tends to reduce three measures of air pollution. Statistical significance is high for concentrations of SO_2, moderate for NO_2, and lacking for particulate matter. While results for other environmental measures are not as encouraging, there is little evidence that trade has a detrimental effect on the environment.

Is Trade Good or Bad for the Environment? Sorting Out the Causality

1: Introduction

Opponents of globalization often fear adverse effects of trade on environmental quality. Should they? In this short empirical paper, we use cross-country data to show that there is little evidence that openness increases air pollution, holding other things (such as income) constant. Our modest and incremental contribution to the literature is to take special care to account for the fact that income, trade, and environmental quality are determined simultaneously.[1]

The simultaneity issue is potentially important. As Figure 1 shows, a rough inverse correlation between SO2 concentrations and trade is visible.[2] Eiras and Schaeffer (2001, p. 4), for example, find: "In countries with an open economy, the average environmental sustainability score is more than 30 percent higher than the scores of countries with moderately open economies, and almost twice as high as those of countries with closed economies." Does this mean that trade is good for the environment? Not necessarily. Causality could run in other directions. The observed correlation might be a result of the Porter hypothesis -- which claims that environmental regulation stimulates productivity -- together with the positive effect of income on trade. Or it might be because democracy leads to higher levels of environmental regulation, and democracy is causally intertwined with income and trade.

The central focus of the paper is to estimate the effect of trade on the environment *for a given level of income per capita.* This is an interesting question for two reasons. First, it is the most fundamental question for policy. If it is established that trade has an adverse effect on the environment solely because openness raise countries' incomes, which in turn damages the environment, few would conclude that we should try to turn back the clock on globalization. Not many would choose deliberate self-impoverishment as a means to a clean environment.

The question is also interesting because, although the topic is the subject of a rapidly growing area of research, the answer is not settled. Indeed, the effect of trade on the environment is theoretically ambiguous.[3]

Many believe that openness harms the environment. Most widely discussed is the *race to the bottom hypothesis*, which says that open countries in general adopt looser standards of environmental regulation, out of fear of a loss in international competitiveness. Alternatively, poor open countries may act as pollution havens, adopting lax environmental standards to attract multinational corporations and export pollution-intensive goods.[4]

But less widely recognized is the possibility of an effect in the opposite direction, which we call the *gains from trade hypothesis*. If trade raises income, it allows countries to attain more of what they want, which includes environmental goods as well as more conventional output. Openness could have a positive effect on environmental quality (even for a given level of GDP per capita) for a number of reasons. First, trade can spur managerial and technological innovation, which can have positive effects on both the economy and the environment. Second, multinational corporations tend to bring clean state-of-the-art production techniques from high-standard source countries of origin to host countries. Third is the international ratcheting up of environmental standards through heightened public awareness.[5] While some environmental gains might tend to occur with any increase in income, whether taking place in an open economy or not, others may be more likely when associated with international trade and investment.[6] Whether the race to the bottom effect in practice dominates the gains from trade effect is an empirical question.

Our paper is part of a larger literature; a number of studies have sought to isolate the independent effect of openness on the environment. Lucas, et al. (1992), study the toxic

intensity implied by the composition of manufacturing output in a sample of 80 countries, and

find that a high degree of trade distorting policies increased pollution in rapidly growing

countries.[7] Harbaugh, Levinson, and Wilson (2000) report in passing a beneficial effect of trade

on the environment, after controlling for income.   Dean (2002) finds a detrimental direct of

liberalization for a given level of income, via the terms of trade, though this is outweighed by a

beneficial indirect effect via income.[8]   Antweiler, Copeland and Taylor (2001) and Copeland

and Taylor (2003) represent an extensive body of theory and empirical research explicitly

focused on the effects of trade on the environment.   They conclude that trade liberalization that

raises the scale of economic activity by 1 per cent works to raise SO_2 concentrations by ¼ to ½

% via the scale channel, but that the accompanying technique channel reduces concentrations by

1 ¼ to 1 ½%, so that the overall effect is beneficial.

Antweiler, et al, point out that endogeneity could be a potential weakness of their work;

and a number of authors have sought to address some aspects of endogeneity.[9] But the existing

research does not directly address the problem that trade may be determined simultaneously with

income and environmental outcomes. Allowing for the endogeneity of trade and income is the

main new contribution of this paper.

2: Methodology

We turn directly to the empirics.

Equation to be estimated

We estimate the following cross-country equation:

$$EnvDam_i = j_0 + j_1 \ln(y/pop_1)_{90,i} + j_2 \ln(y/pop_2)_{90,i}^2$$
$$+ b([X+M]/Y)_{90,i} + j_3 (Polity)_{90,i} + j_4 \ln(LandArea/pop)_{90,i} + e_i$$

where:

- $EnvDam_i$ is one of three measures of environmental damage for country i,

- $\{\varphi_i\}$ is a set of control coefficients,

- $ln(y/pop)_{90,i}$ represents the natural logarithm of 1990 real GDP per capita for country i,

- $(X+M)/Y$ represents the ratio of nominal exports and imports to GDP ("openness"),

- $Polity$ is a measure of how democratic (vs. autocratic) is the structure of the government,

- $LandArea/pop$ is a measure of per capita land area, and

- e is a residual representing other causes of environmental damage.

The coefficient of interest to us is β, the partial effect of openness on environmental degradation.

Income plays a strong role in determining environmental outcomes. We incorporate into our analysis -- without relying on -- the "environmental Kuznets curve" (EKC). This is a rought U-shaped relationship between income per capita and certain types of pollution, brought to public attention by the World Bank (1992) and Grossman and Krueger (1993, 1995). Growth increases air and water pollution at the initial stages of industrialization, but later on can reduce pollution given the right institutions, as countries become rich enough to pay to clean up their environments. The EKC hypothesis predicts that the coefficient on the squared income term is negative, so that the pollution curve eventually turns down.[10]

The market does not address externalities left to itself. Higher income is unlikely to result in an improved environmental regulation absent appropriate political institutions. Thus it is important to control also for the latter, which we do by including *polity* in our equation.[11]

Addressing endogeneity

The endogeneity of trade is a familiar problem from the empirical literature on openness and growth.[12] What is needed is a good instrumental variable, which is exogenous yet highly correlated with trade. The gravity model of bilateral trade offers a solution. It states that trade between a pair of countries is determined, positively, by country size (GDP, population, and land area) and, negatively, by distance between the countries in question (physical distance as well as cultural distance in the form of, e.g., difference languages). Geographical variables are plausibly exogenous. Yet when aggregated across all bilateral trading partners, these variables are highly correlated with a country's overall trade, and thus make good instrumental variables, as first noted by Frankel and Romer (1999). Thus we construct an instrumental variable for openness by aggregating up across a country's partners the prediction of a gravity equation that explains trade with distance, population, language, land border, land area, and landlocked status.

We use a cross-country approach, thus choosing not to follow Grossman and Krueger (1993) and Antweiler et al (2001) in using panel data. We realize that a pure cross-section approach means that we cannot control for unobservable heterogeneity. But our key instrument is driven by cross-country geographical variation, which does not change over time, so there seems little advantage for us in a panel study.

Income per capita too is endogenous. Both trade and environmental regulation may affect income.[13] We thus use a second set of instrumental variables for income, taken from the growth literature. These include: lagged income (thus we incorporate the conditional convergence hypothesis), population size, and rates of investment and human capital formation (the factor accumulation variables familiar from neoclassical growth equations).

Data

We focus on results for three 1990 measures of air pollution, all measured as concentrations in micrograms per cubic meter (simply averaged across a country's measuring stations and cities, in cases where more than one observation was available):

- SO_2: mean sulphur dioxide,

- NO_2: mean nitrogen dioxide, and

- PM: mean total suspended particulate matter.

We have also looked at four other measures of environmental quality:

- CO_2: Industrial carbon dioxide emissions per capita, in metric tons

- Deforestation: average annual percentage change, 1990-95

- Energy depletion: "genuine savings" as a percentage of GDP[14], and

- Rural Clean Water Access: as percentage of rural population, 1990-1996.

Of these seven, the three measures of local air pollution – SO_2, NO_2, and particulates –are the most relevant. CO_2 is a purely global externality, and unlikely to be addressed by regulation at the national level. Deforestation and energy depletion are not measures of pollution, and measuring them involves some serious problems of composition and data reliability, as does water access. Still, it seems worthwhile to look as well at these broader measures of environmental quality.

Per capita income is defined as 1990 GDP per capita (measured in real PPP-adjusted dollars), taken from the Penn World Table 5.6. The Penn World Table also supplies our measure of openness. Polity ranges from -10 ("strongly autocratic") to +10 (strongly democratic), and is taken from the Polity IV project. Land area is taken from the CIA's website and is intended to allow for the likelihood that higher population density leads to environmental degradation (for a

given level of per capita income).   Descriptive statistics are included in an appendix table, and simple scatterplots are portrayed in the appendix figure.

3: Results

Table 1 reports our key estimation results, where the dependent variable is represented in turn by the three measures of air pollution. The three columns at the left of the table are the OLS estimates, while the IV estimates are on the right.

The estimated effect of the polity variable on pollution is always negative, suggesting that improved governance has a beneficial effect.   It is generally significant statistically. The same is true of land area per capita, evidence that population density has an adverse effect on concentration of pollutants.

Of greater interest is the relationship with per capita income. The estimated coefficient on the quadratic term is negative for all three measures of air pollution, confirming the EKC hypothesis: after a certain point (recorded at the bottom of the table as "income peak"), growth reduces these environmental indicators.   Statistically, it is highly significant in the case of SO_2 and NO_2, and moderately so in the case of PM.

Our central interest is β, the coefficient on openness.   The OLS estimate is negative for all three kinds of air pollution – insignificantly so for PM, moderately significant for NO_2, and highly significant for SO_2. Apparently any adverse "race to the bottom" effect on air pollution is outweighed by a positive "gains from trade" effect.

The main contribution of this paper is to address the possibility that these apparent effects may be the spurious results of simultaneity.   The right part of the table reports instrumental variables estimates, where the gravity-derived prediction of openness is the instrument for trade and the factor accumulation variables are the instruments for income. The IV results are

generally similar to the OLS results, though with somewhat diminished significance levels in some cases. The EKC is still there for all three pollutants, and the coefficient on openness is negative for all three pollution measures. As in the OLS results, statistical significance is high for SO_2, moderate for NO_2, and lacking for particulates.

As an alternative to our quadratic functional form for the EKC, we have also tried a three-segment spline, with "knots" at the .33 and .66 percentiles of the logarithm of per capita income. Results are comparable, and are reported in the NBER working paper.[15]

Results for Other Environmental Measures

Air pollution is only one kind of measure of environmental quality. We also produced analogous estimates for other measures of environmental degradation. Table 2 reports our OLS and IV estimates of β for carbon dioxide, deforestation, energy depletion, and access to clean water.[16]

Beneficial OLS effects of openness show up only for energy depletion and clean water access (an increase in clean water access indicates a beneficial environmental effect, the reverse of the other six indicators), and are of borderline statistical significance. The case that would give an environmentalist the greatest concern is CO_2. The coefficient on openness is positive and of moderate significance.[17] This result could be viewed as one piece of evidence supporting the idea that the free-rider problem and fears of lost competitiveness inhibit individual countries from curbing emissions of greenhouse gases on their own. CO_2 is a purely global externality, so there is no reason to expect individual countries to address it without some mechanism of international cooperation.

When instrumental variables are used, the detrimental effect of openness on carbon dioxide emissions loses all significance, while the apparently beneficial effect on energy depletion becomes significant at the 10% level. On the other hand, the beneficial OLS effect on water access disappears. Evidently the use of instrumental variables to correct for simultaneity can make an important difference to some results.

To summarize: the results are generally supportive of the environmental Kuznets curve, and of the positive effect of democracy on environmental quality. More importantly, there is some evidence that openness reduces air pollution and little evidence that openness causes significant environmental degradation, other things equal. The most important exception is carbon dioxide.

Do Some Countries Have a "Comparative Advantage" in Pollution?

We also test the "pollution haven" hypothesis according to which economic integration results in some open countries exporting pollution to others, even if there is no systematic effect on the world environment in the aggregate.

One version of the hypothesis is that open countries that have a particularly high demand for environmental quality – rich countries – specialize in products that can be produced cleanly, letting poor open countries produce and sell the products that require pollution. This hypothesis can be readily tested by adding the interaction of openness and income per capita to our equation. If rich countries take advantage of trade by transferring the location of pollution-creating activities to poor countries, the interaction between openness and income should have a negative effect on pollution. When we tried this, the coefficient on the interactive term was insignificant for most of the seven environmental measures. The exceptions are particulates and

SO_2. With either OLS or IV estimation, openness interacted with income has a positive effect on these two types of pollution, opposite of that predicted by the standard pollution haven hypothesis.[18]

A second version of the pollution haven hypothesis is that countries endowed with a high supply of environmental quality – e.g., those with high land area per capita – become pollution havens, exporting dirty goods to more densely populated countries. We tested this by adding the product of openness and land area per capita. Again, signs were divided between negative and positive, and the coefficients were usually insignificant. The only two cases with significant interaction coefficients (IV for particulates, and OLS for CO_2) have the "wrong" sign, suggesting that more sparsely populated countries have lower emissions than they otherwise would, not higher. Again, there is no evidence supporting the pollution haven hypothesis.

A third possible source of "comparative advantage" derives from traditional trade theory. If some countries have a comparative advantage in capital-intensive sectors such as mining or heavy manufacturing, and these sectors produce comparatively more pollution, then trade may lead to an increase in pollution among the capital-endowed countries and a decrease among the labor-endowed countries.[19] We tested this version by including interactive terms defined as openness times the country's capital/labor ratio. The signs are mixed, and standard errors large; the interactive term is not statistically significant.

To summarize: there is no evidence that poor, land-abundant, or capital-abundant countries use trade to exploit a comparative advantage in pollution. The only cases where the coefficient on the interactive term appears significant are of the wrong sign. The details of estimates for all three versions of the pollution haven hypothesis are available in a working paper version of this paper.

10

4: Conclusions

Trade can have several sorts of effects on the environment. In this short paper, we have modeled the effect of trade on the environment, controlling for income and other relevant factors. The primary contribution of the paper is to address the endogeneity of income and especially trade, the latter by means of instrumental variables drawn from the gravity model. While the use of instrumental variables did not radically reverse the results of earlier OLS studies, it could have; and it did make a substantive difference to the estimates in some cases.

We have found that trade appears to have a beneficial effect on some measures of environmental quality, though not all, ceteris paribus. The effect is particularly beneficial for some measures of air pollution, such as SO_2. Our examination of seven different measures of environmental quality provides little evidence that trade has a detrimental effect overall. We reject the hypothesis of an international race to the bottom driven by trade. There is also no evidence for the pollution haven hypothesis, which claims that trade encourages some countries to specialize in dirtier environments.

Other evidence shows that trade promotes economic growth.[20] Thus trade also has an indirect effect on the environment. Given the environmental Kuznets curve, at low levels of income this effect increases pollution, but at high levels reduces it.

The major example where trade and growth may have the detrimental effects feared by environmentalists is carbon dioxide. Greenhouse gases are global externalities, and there is no reason to expect individual countries to be able to address them in the absence of an international agreement.

References

Antweiler, Werner, Brian Copeland and M. Scott Taylor, 2001, "Is Free Trade Good for the Environment?" <u>American Economic Review</u>, 91, no. 4, September, 877-908.

Barrett, Scott, and Kathryn Graddy, 2000, "Freedom, Growth, and the Environment," <u>Environment and Development Economics</u> 5, 433-456.

Bradford, David, Rebecca Schlieckert and Stephen Shore, 2000, "The Environmental Kuznets Curve: Exploring a Fresh Specification," NBER Working Paper no. 8001. Forthcoming, <u>Topics in Economic Analysis and Policy</u>.

Copeland, Brian, and M. Scott Taylor, 2003, <u>Trade and the Environment: Theory and Evidence</u> (Princeton University Press: Princeton).

Dean, Judy, 1992, "Trade and the Environment: A Survey of the Literature," in Patrick Low, ed., *International Trade and the Environment*, World Bank Discussion Paper No. 159.

Dean, Judy, 2001, "Overview," in <u>International Trade and the Environment</u>, J. Dean, ed., *International Library of Environmental Economics and Policy Series*, (Ashgate Publishing: UK).

Dean, Judy, 2002, "Does Trade Liberalization Harm the Environment? A New Test," <u>Canadian Journal of Economics</u>, November 35, no. 4, 819-842.

Eiras, Ana, and Brett Schaefer, 2001, "Trade: The Best Way to Protect the Environment," *Backgrounder*, The Heritage Foundation no. 1480, September 27.

Eskeland, Gunnar, and Ann Harrison, 2002, "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis," NBER WP No. 8888, April.

Esty, Daniel, and Bradford Gentry, 1997, "Foreign Investment, Globalisation, and the Environment," <u>Globalization and the Environment</u>, edited by Tom Jones (Organization for Economic Cooperation and Development: Paris).

Frankel, Jeffrey, 2003, "Globalization and the Environment," NBER Working Paper No. __; forthcoming in <u>Globalization: What's New</u>, edited by Michael Weinstein (Council on Foreign Relations, New York).

Frankel, Jeffrey, and David Romer, 1999, "Does Trade Cause Growth?" <u>American Economic Review</u>, 89, no. 3, June, 379-399.

Grossman, Gene, and Alan Krueger, 1993, "Environmental Impacts of a North American Free Trade Agreement," in The U.S.-Mexico Free Trade Agreement, Peter Garber, ed., Cambridge MA, MIT Press.

Grossman, Gene, and Alan Krueger, 1995, "Economic Growth and the Environment," Quarterly Journal of Economics, 110, no. 2, May 1995, pp. 353-77.

Harbaugh, William, Arik Levinson, and David Wilson, 2000, "Reexamining the Empirical Evidence for an Environmental Kuznets Curve," NBER W P No. 7711, May.

Levinson, Arik, 1999, "State Taxes and Interstate Hazardous Waste Shipments," American Economic Review, 89(3) June.

Lucas, Robert E.B., David Wheeler, and Hemamala Hettige, 1992, "Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: l960-88," in P. Low (ed.), International Trade and the Environment, World Bank Discussion Paper No. l59.

Porter, Michael, and Claas van der Linde, 1995, "Toward a New Conception of the Environment-Competitiveness Relationship," Journal of Economic Perspectives 9, No. 4.

Rodríguez, Francisco, and Dani Rodrik, 2001, "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence," *NBER Macroeconomics Annual 2001* (Cambridge, MA: MIT Press).

Rodrik, Dani, 1995, "Getting Interventions Right: How South Korea and Taiwan Grew Rich," Economic Policy, April (20), 53-97.

Vogel, David, 1995, Trading Up: Consumer and Environmental Regulation in a Global Economy, Harvard University Press.

World Bank, 1992, *Development and the Environment*, World Development Report (Oxford University Press: NY).

Table 1: Determinants of Air Pollution Concentrations

	OLS	OLS	OLS	IV	IV	IV
	NO$_2$	SO$_2$	PM	NO$_2$	SO$_2$	PM
Trade / GDP	-.29	-.31	-.37	-.33	-.23	-.31
	(.17)	(.08)	(.34)	(.19)	(.10)	(.41)
Log real GDP per capita	409	287	567	461	296	681
	(122)	(119)	(336)	(199)	(140)	(412)
Log real GDP p/c squared	-22.8	-16.6	-35.6	-25.6	-17.1	-42.0
	(6.9)	(6.8)	(19.1)	(10.9)	(7.7)	(23.2)
Polity	-3.20	-6.58	-6.70	-3.77	-6.41	-7.78
	(1.47)	(2.05)	(3.42)	(1.37)	(2.27)	(4.07)
Log of Area per capita	-5.94	-2.92	-13.0	-6.14	-1.54	-12.6
	(5.93)	(1.39)	(6.29)	(6.43)	(1.96)	(6.84)
Observations	36	41	38	35	40	37
R^2	.16	.68	.62	.18	.67	.63
Income Peak	$7665	$5770	$2882	$8015	$5637	$3353

Cross-country estimation across countries in 1990.
(Robust standard errors in parentheses.)
Regressands are averages per cubic meter. Intercept included but not reported.
Instrument for trade constructed by aggregating predicted bilateral gravity equation of trade on: distance, population, area, and dummies for language, land border, and landlocked status. Instruments for income (and square) constructed from regression of income on: lagged income, population, openness, investment, population growth, and primary and second school enrollments.

Table 2: Effect of Openness on Other Types of Environmental Degradation

	OLS	IV
CO_2	.016	.000
	(.008)	(.010)
Deforestation	.002	.001
	(.003)	(.004)
Energy Depletion	-.014	-.034
	(.009)	(.020)
Rural Clean Water Access	.111	-.067
	(.078)	(.266)

Estimation across countries in 1990.
(Robust standard errors in parentheses.)
Income, income squared, polity score, log area per capita, and intercept were included in the regression, but are not reported here, to save space.
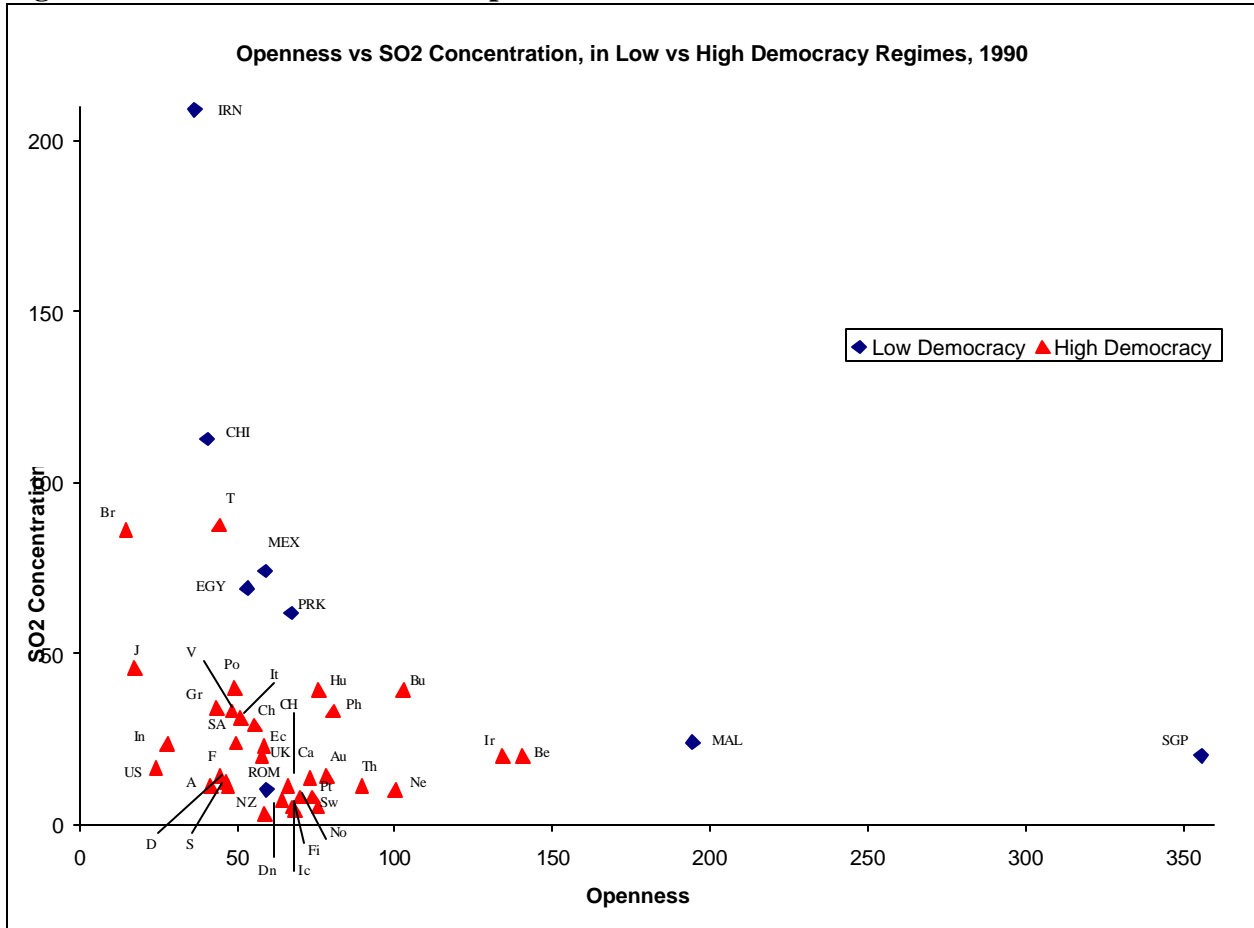
Figure 1: SO2 versus measure of openness to trade

Openness vs SO2 Concentration, in Low vs High Democracy Regimes, 1990

Table A1: Descriptive Statistics

	Obs.	Mean	Standard Deviation	Min	Max
NO_2	42	55.4	39.5	5	248
SO_2	48	31.9	35.9	1	209
Particulate Matter	44	103.1	84.8	9	368.9
CO_2	147	4.1	6.0	.0	31.3
Deforestation	137	.5	1.2	-2.7	7.2
Energy Depletion	144	4.7	12.7	0	104.3
Rural Clean Water Access	70	7.5	5.5	.2	26.9
Trade / GDP	113	73	49	13	373
Log real GDP per capita	113	8.0	1.1	6.0	9.8
Polity	133	.8	7.7	-10	10
Log of Area per capita	112	3.0	1.5	-1.8	6.6

Figure A1: Simple Scatterplots of data on pollution and trade

Simple Scatter Plots
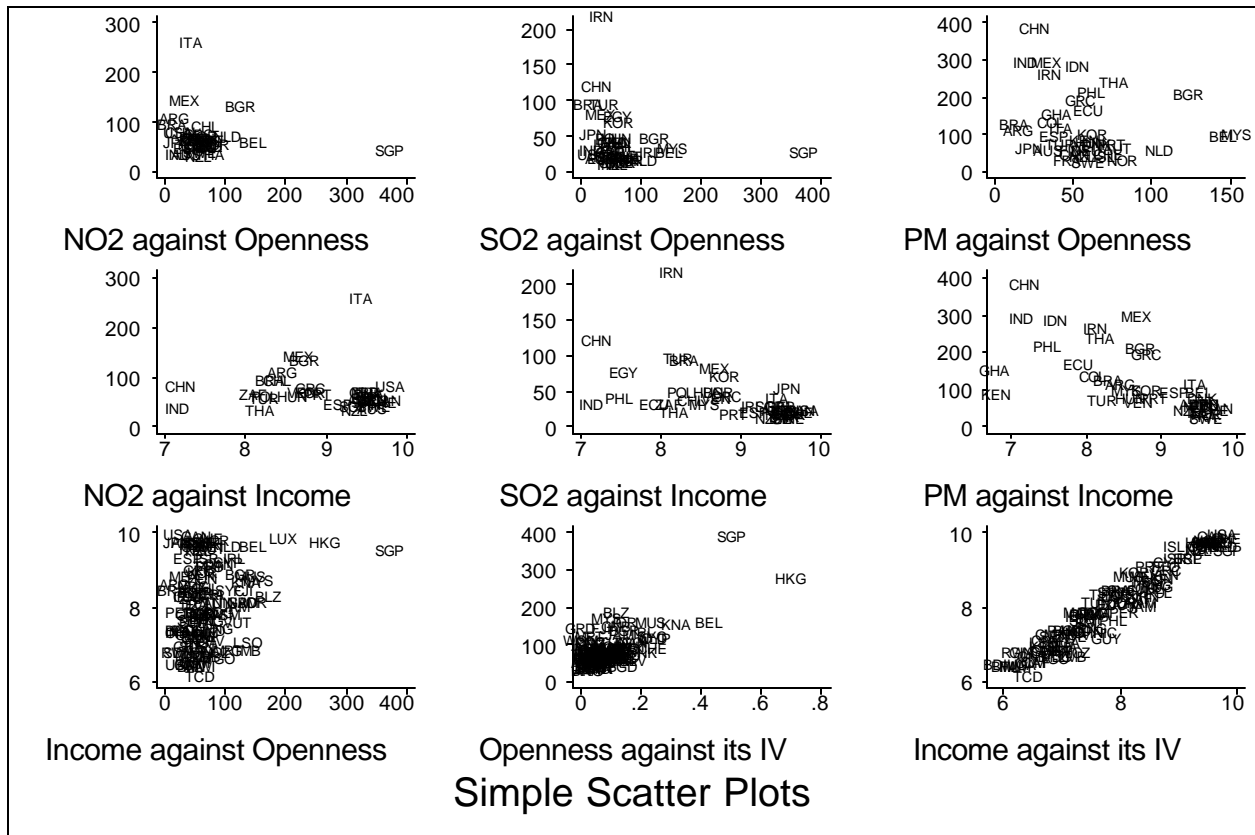
Endnotes

[1] References in the wider debate on globalization and the environment are given in Frankel (2003).

[2] Appendix Figure A1 shows the graph for all three measures of air pollution used in this study.

[3] One way to see the ambiguity is to distinguish three channels whereby trade, like any other determinant of real income, can affect the environment. The *scale* effect is the obvious channel whereby higher GDP leads to higher pollution. But in the language of Copeland and Taylor (2003) and Grossman and Krueger (1993), there is also a *composition* effect (e.g., agriculture vs. manufacturing vs. services have different effects on the environment) and a *technique* effect (any given sector can use cleaner or dirtier techniques of production). The question is whether the latter two effects can outweigh the first. The literature is surveyed in Dean (1992, 2001).

[4] It is important to emphasize a key difference between the race to the bottom hypothesis and the pollution haven hypothesis: while the former implies a negative effect on the overall world level of environmental regulation, the latter does not. Some countries may choose high environmental standards for their own production, and import from others goods that embody pollution. The second group can be said to exploit or develop a comparative advantage in pollution. The pollution haven hypothesis with respect to trade is tested toward the end of this paper.

[5] References for these three interrelated hypotheses include Braithwaite and Drahos (2000), Eskeland and Harrison (2002), Esty and Gentry (1997), Schmidheiny (1992), and Vogel (1995).

[6] The environmental gains from trade, even for a given level of GDP per capita, would occur particularly if measured GDP does not adequately capture the increase in welfare arising from enhanced variety of consumption.

[7] They use the Dollar index of trade distortion, a measure of relative prices, which has been heavily criticized by Rodriguez and Rodrik (2001).

[8] Rodriguez and Rodrik (2001) also criticize the measure of trade distortion she uses, the black market premium.

[9] Levinson (1999) shows that controlling for endogeneity of environmental regulation can change results, in his study of hazardous waste trade. Dean (2002) treats income as endogenous in her study of the effect of trade liberalization on water pollution across Chinese provinces.

[10] While a number of studies have confirmed the EKC, especially for SO_2 and Particulate Matter, the results are not always favorable; e.g., Bradford, Schlieckert and Shore (2000) get mixed answers. Many more EKC references are available there, in Frankel (2003), or in the working paper version of the present study.

[11] Notice in Figure 1 that the low-democracy countries tend to have higher SO2 pollution. Barrett and Graddy (2000) also find that an increase in civil and political freedoms significantly reduces some measures of pollution.

[12] Rodrik (1995) and Rodriguez and Rodrik (2001) are among those critical of previous studies on the grounds of simultaneity.

[13] The usual presumption is that environmental regulation, by raising business costs, slows economic growth. But we should also consider the Porter Hypothesis, in which a tightening of environmental regulation is said to stimulate technological innovation and thereby raise productivity. E.g., Porter and van der Linde, 1995.

[14] Energy depletion is a measure computed for the World Bank's *World Development Indicators*. It is equal to the product of unit resource rents and the physical quantities of fossil

fuel energy extracted (including coal, crude oil, and natural gas). Table 3.15, available at

http://www.worldbank.org/data/wdi2001/pdfs/tab3_15.pdf, explains the data computations.

[15] That is, it is estimated that increases in income in the low-income countries increase pollution,

and in the high-income countries reduce it. The coefficient on openness is again negative for all

three measures of air pollution.

[16] In most cases, the effects of polity, area, and quadratic income -- not reported here, to save

space -- go in the same direction as with the air pollution indicators. The EKC shows up highly

significant for deforestation, energy depletion, and rural water access.

[17] Further, the coefficient on quadratic income is positive and highly significant, while in the

spline version income has a positive effect through all three segments in this case. This confirms

others' findings of no Environmental Kuznets Curve for CO_2.

[18] The significance level for SO_2 is 5% under OLS and 10% under IV (and for PM is more

marginal; all results available in a working paper). This is consistent with the finding of

Antweiler, Copeland and Taylor (2001) that trade has a significantly less favorable effect on SO_2

emissions in rich countries than in poor countries. Their explanation is that, because rich

countries have higher capital/labor ratios, the factor-based pollution-haven effect -- the third

hypothesis, considered below -- tends to outweigh the income-based pollution-haven effect.

[19] E.g., Copeland and Taylor (2003) and Grossman and Krueger (1993, 1995), who suggest that

the overall effect of reduced pollution in the labor-intensive country and higher pollution in the

capital-intensive country might be a reduction of pollution in the aggregate. Grossman and

Krueger (1993) find that industries' pollution-intensity does not affect the composition of US

imports from Mexico, contrary to the popular view of "eco-dumping" in poor countries, but their

labor intensity does.

---

[20] E.g., Frankel and Romer (1999), or the working paper version of this paper.