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

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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.

Keywords: Openness, Growth, pollution, Kuznets, instrumental, variable, causality, simultaneity.

JEL Classification: F18

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

1: Introduction

Opponents of globalization often fear the 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.[7]

Our paper is part of a larger literature; a number of studies have sought to isolate the independent effect of openness on the environment. In addition to those already mentioned, 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.[8] 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.[9] 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.[10] But the existing research does not directly address the problem that trade may be simultaneously determined 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:

$$EnvDam_i = \varphi_0 + \varphi_1 \ln(y/pop_1)_{90,i} + \varphi_2 \ln(y/pop_2)_{90,i}{}^2$$
$$+ \beta([X+M]/Y)_{90,i} + \varphi_3 (Polity)_{90,i} + \varphi_4 \ln(LandArea/pop)_{90,i} + e_i$$

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 U-shaped relationship between income per capita and certain types of pollution, brought to 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.[11]

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.

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.[14] 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[15], 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 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 pollution.

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 working paper.[16]

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.[17]

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. This result could be viewed as one piece of evidence supporting the idea that the free-rider problem inhibits individual countries from curbing emissions of greenhouse gases on their own.[18] 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.[19]

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.[20] 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 the working paper version of this paper.

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.[21] 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 might 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.

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Table 1: [illegible]erminants of Air Pollution Concentrations

	OLS	OLS	OLS	IV	IV	IV
	NO_2	SO_2	PM	NO_2	SO_2	PM
Trade / GDP	-.29 (.17)	-.31 (.08)	-.37 (.34)	-.33 (.19)	-.23 (.10)	-.31 (.41)
Log real GDP per capita	409 (122)	287 (119)	567 (336)	461 (199)	296 (140)	681 (412)
Log real GDP p/c squared	-22.8 (6.9)	-16.6 (6.8)	-35.6 (19.1)	-25.6 (10.9)	-17.1 (7.7)	-42.0 (23.2)
Polity	-3.20 (1.47)	-6.58 (2.05)	-6.70 (3.42)	-3.77 (1.37)	-6.41 (2.27)	-7.78 (4.07)
Log of Area per capita	-5.94 (5.93)	-2.92 (1.39)	-13.0 (6.29)	-6.14 (6.43)	-1.54 (1.96)	-12.6 (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 (.008)	.000 (.010)
Deforestation	.002 (.003)	.001 (.004)
Energy Depletion	-.014 (.009)	-.034 (.020)
Rural Clean Water Access	.111 (.078)	-.067 (.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

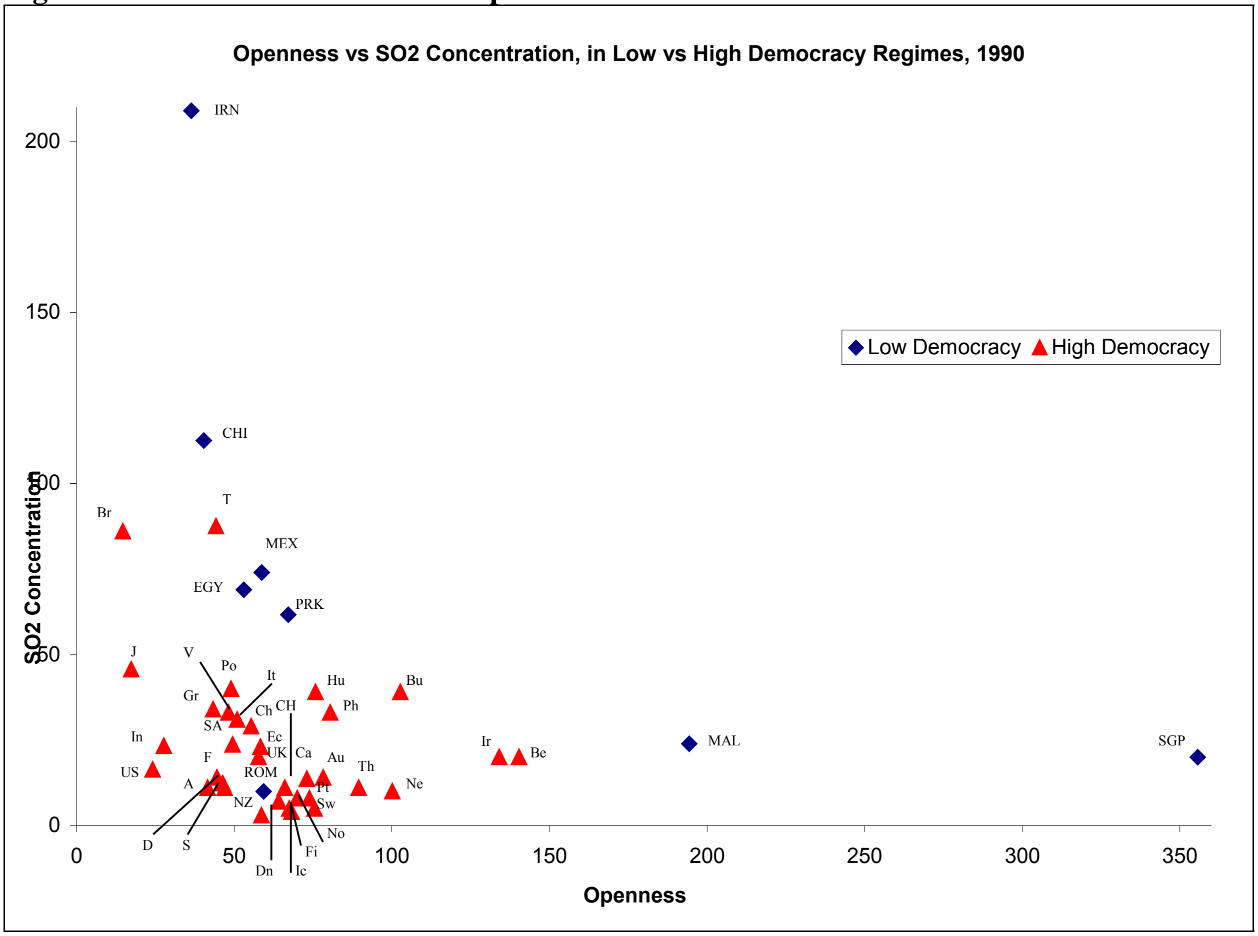
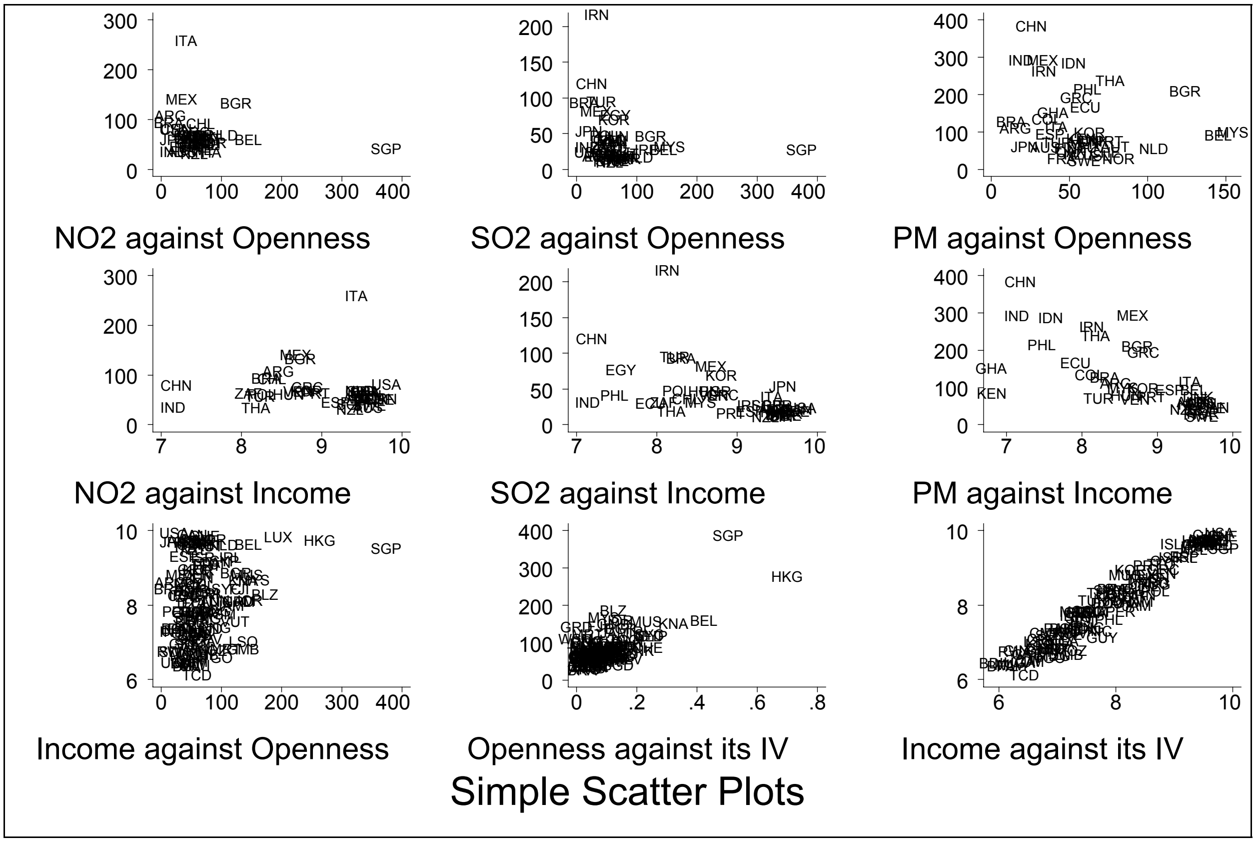


Table A1: Descriptive Statistics

	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 Simple Scatterplots of data on pollution and trade



Appendix tables
Results for interaction of income and trade (with income in quadratic form).

cited in published paper, but not reported there

```
. *
. * This  differs from pa4c in that interactions of openness with income p/c
. * and land area are added (the interaction with K/L is in pa4ac)
. *
. * This STATA program estimates a set of equations for:
. * a) income;
. * b) openness; and
. * c) pollution.
. *
. * This program uses IV and OLS methods.
. *
. * The new baseline uses quadratics, not a spline for income.
. *

. *
. * First interaction: with GDP p/c
. *
. * Add the interactions to the benchmark equation .  OLS then IV.
. *
. * CO2
. *
. reg co2perc inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                Number of obs =     100
                                                      F(  6,    93) =   40.99
                                                      Prob > F      =  0.0000
                                                      R-squared     =  0.7659
                                                      Root MSE      =  2.3632
---------------------------------------------------------------------------
             |               Robust
     co2perc |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |  -17.54647   4.202776    -4.17   0.000
       incsq |   1.247794   .2689828     4.64   0.000
     pwtopen |  -.1171033   .0728187    -1.61   0.111
      intery |   .0152322   .0089684     1.70   0.093
      polity |  -.0021871   .0295169    -0.07   0.941
     lareapc |   .2897612   .1886449     1.54   0.128
       _cons |   61.60089   16.40485     3.76   0.000
--------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0    ( 2)  incsq = 0
       F(  2,    93) =   14.32              Prob > F =    0.0000

. * Income Peak       1131.1588



ivreg co2perc (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =      96
                                                      F(  6,    89) =   24.50
                                                      Prob > F      =  0.0000
                                                      R-squared     =  0.5760
                                                      Root MSE      =  2.8579
---------------------------------------------------------------------------
             |               Robust
     co2perc |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------

         inc |  -20.42214   8.420988    -2.43   0.017
```

```
       incsq |   1.688672   .7398712     2.28   0.025
     pwtopen |   .4165342   .5465228     0.76   0.448
      intery |  -.0468285   .0616196    -0.76   0.449
      polity |   -.136495   .1089114    -1.25   0.213
     lareapc |  -.4210369   .7030166    -0.60   0.551
       _cons |   56.35638   21.74199     2.59   0.011
------------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
------------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    89) =    3.06    Prob > F =    0.0518

. * Income Peak   422.7599

. *
. * Deforestation
. *
. reg defp inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =     96
                                                       F(  6,    89) =    7.65
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2538
                                                       Root MSE      =  1.1267
------------------------------------------------------------------------------
             |               Robust
        defp |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------------
         inc |   4.379583   1.332433     3.29   0.001
       incsq |  -.3014252   .0816164    -3.69   0.000
     pwtopen |   .0268688   .0288845     0.93   0.355
      intery |  -.0028982   .0031489    -0.92   0.360
      polity |   .0330982   .0294806     1.12   0.265
     lareapc |  -.1405813   .0881114    -1.60   0.114
       _cons |  -14.57958   5.434964    -2.68   0.009
------------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0     ( 2)  incsq = 0
       F(  2,    89) =    9.1    Prob > F =    0.0002

. * Income Peak  1429.0891

ivreg defp (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =    92
                                                       F(  6,    85) =    2.98
                                                       Prob > F      =  0.0108
                                                       R-squared     =     .
                                                       Root MSE      =   1.958
------------------------------------------------------------------------------
             |               Robust
        defp |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------------
         inc |   .9473862   11.67173     0.08   0.935
       incsq |   .0808805   1.134537     0.07   0.943
     pwtopen |   .4140609   .9814517     0.42   0.674
      intery |  -.0468629   .1116816    -0.42   0.676
      polity |  -.0222205   .1338221    -0.17   0.869
     lareapc |  -.5637075   1.232651    -0.46   0.649
       _cons |  -12.55295   20.86813    -0.60   0.549
------------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
------------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0  ( 2)  incsq = 0
       F(  2,    85) =    0.85              Prob > F =    0.4313

. * Income Peak   .00286067
```

```
. *
. * Energy Depletion
. *
. reg enrdam inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =    98
                                                       F(  6,    91) =    3.22
                                                       Prob > F      =  0.0065
                                                       R-squared     =  0.1679
                                                       Root MSE      =  6.8478
---------------------------------------------------------------------------
             |               Robust
      enrdam |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   38.16656   9.120849     4.18   0.000
       incsq |  -2.206049   .5253217    -4.20   0.000
     pwtopen |    .024658    .105582     0.23   0.816
      intery |  -.0044884   .0119176    -0.38   0.707
      polity |  -.4570515   .1708018    -2.68   0.009
     lareapc |   .2441835   .4866501     0.50   0.617
       _cons |  -157.3793   38.71899    -4.06   0.000
-------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0     ( 2)  incsq = 0

       F(  2,    91) =    8.82              Prob > F =    0.0003

. * Income Peak   5712.609

ivreg enrdam (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =    93
                                                       F(  6,    86) =    0.94
                                                       Prob > F      =  0.4741
                                                       R-squared     =   .
                                                       Root MSE      =   13.47

---------------------------------------------------------------------------
             |               Robust
      enrdam |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   11.48796   53.26458     0.22   0.830
       incsq |   .6232899   4.809828     0.13   0.897
     pwtopen |    2.69875   3.787932     0.71   0.478
      intery |  -.3082474   .4290995    -0.72   0.474
      polity |  -.8342795   .5914198    -1.41   0.162
     lareapc |   -2.79859   5.125422    -0.55   0.586
       _cons |  -131.4493    124.399    -1.06   0.294
---------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0     ( 2)  incsq = 0
       F(  2,    86) =    2.30              Prob > F =    0.1063

. * Income Peak   .00009948

. *
. * NO2
. *
. reg no2m inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =     36
                                                       F(  6,    29) =    2.63
                                                       Prob > F      =  0.0370
                                                       R-squared     =  0.1574
                                                       Root MSE      =  41.111
---------------------------------------------------------------------------
             |               Robust
        no2m |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
```

```
         inc |   422.3331   171.3873     2.46   0.020
       incsq |  -23.73463   10.48264    -2.26   0.031
     pwtopen |  -.7230931   5.321866    -0.14   0.893
      intery |   .0459451   .5636627     0.08   0.936
      polity |  -3.200483   1.474742    -2.17   0.038
     lareapc |  -5.929677   6.017269    -0.99   0.333
       _cons |  -1746.937     670.61    -2.60   0.014
---------------------------------------------------------------------------
. test inc incsq     ( 1)  inc = 0     ( 2)  incsq = 0

       F(  2,    29) =    4.82                Prob > F =    0.0155

. * Income Peak       7309.8672

ivreg no2m (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     35
                                                       F(  6,    28) =    7.61
                                                       Prob > F      =  0.0001
                                                       R-squared     =  0.2287
                                                       Root MSE      =  38.595
---------------------------------------------------------------------------
             |               Robust
        no2m |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   645.1652   237.6681     2.71   0.011
       incsq |  -37.44308   14.49659    -2.58   0.015
     pwtopen |  -6.302414   6.453029    -0.98   0.337
      intery |   .6321251   .6943821     0.91   0.370
      polity |  -4.348285   1.010762    -4.30   0.000
     lareapc |  -7.102611   6.072446    -1.17   0.252
       _cons |  -2611.568   951.1994    -2.75   0.010
---------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0  ( 2)  incsq = 0
       F(  2,    28) =    4.22              Prob > F =    0.0250

. * Income Peak    5515.2865

. *
. * Sulfur Dioxide
. *
. reg sulfdm inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =     41
                                                       F(  6,    34) =    7.97
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7103
                                                       Root MSE      =  22.181
---------------------------------------------------------------------------
             |               Robust
      sulfdm |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   372.9109   142.1192     2.62   0.013
       incsq |  -22.60134   8.396773    -2.69   0.011
     pwtopen |  -3.559056   1.653811    -2.15   0.039
      intery |   .3531279   .1753988     2.01   0.052
      polity |  -6.301547   1.927016    -3.27   0.002
     lareapc |  -1.813289   1.711337    -1.06   0.297
       _cons |  -1405.922   581.1829    -2.42   0.021
---------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0     ( 2)  incsq = 0
       F(  2,    34) =    4.12               Prob > F =    0.0249

. * Income Peak      3826.6707

ivreg sulfdm (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =    40
```

```
                                                       F(  6,    33) =    7.04
                                                       Prob > F      =  0.0001
                                                       R-squared     =  0.6920
                                                       Root MSE      =  23.207
-------------------------------------------------------------------------
             |               Robust
      sulfdm |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------

         inc |   513.4604   210.9468     2.43   0.021
       incsq |  -31.61047   12.99536    -2.43   0.021
     pwtopen |  -7.005777   4.380388    -1.60   0.119
      intery |   .7217778   .4694786     1.54   0.134
      polity |  -6.518679    1.92014    -3.39   0.002
     lareapc |  -1.443263   2.194518    -0.66   0.515
       _cons |  -1929.897   829.4044    -2.33   0.026
---------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0    ( 2)  incsq = 0
       F(  2,    33) =    2.97               Prob > F =    0.0654

. * Income Peak       3366.6849

. *
. * Suspended Particles
. *
. reg suspm inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =     38
                                                       F(  6,    31) =   11.10
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6582
                                                       Root MSE      =  57.823
---------------------------------------------------------------------------
             |               Robust
       suspm |      Coef.   Std. Err.      t    P>|t|
-------------+-----------------------------------------------------------
         inc |   645.4215   307.3769     2.10   0.044
       incsq |  -42.93882   18.05398    -2.38   0.024
     pwtopen |  -8.707592   5.128309    -1.70   0.100
      intery |   .9440587   .5607545     1.68   0.102
      polity |  -7.081393   3.042012    -2.33   0.027
     lareapc |  -10.76527   5.808484    -1.85   0.073
       _cons |  -2124.038   1301.286    -1.63   0.113
---------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0  ( 2)  incsq = 0
       F(  2,    31) =    5.76              Prob > F =    0.0075

. * Income Peak 1836.4596

ivreg suspm (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =    37
                                                       F(  6,    30) =    9.48
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6767
                                                       Root MSE      =  56.411
---------------------------------------------------------------------------
             |               Robust
       suspm |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   729.4699   354.8551     2.06   0.049
       incsq |  -46.52108   20.75041    -2.24   0.033
     pwtopen |  -6.292212   4.968944    -1.27   0.215
      intery |    .643468   .5587868     1.15   0.259
      polity |  -8.003363   3.546252    -2.26   0.031
     lareapc |   -12.6961    6.64475    -1.91   0.066
       _cons |  -2559.111   1497.714    -1.71   0.098
--------------------------------------------------------------------------
```

```
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
------------------------------------------------------------------------------
. test inc incsq     ( 1)  inc = 0      ( 2)  incsq = 0
       F(  2,    30) =    4.41               Prob > F =    0.0209

. * Income Peak    2540.7345


. *
. * Rural access to clean water
. *
. reg ruralan inc incsq pwtopen intery polity lareapc, robust

Regression with robust standard errors                 Number of obs =    57
                                                       F(  6,    50) =   24.82
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.5979
                                                       Root MSE      =  18.331
------------------------------------------------------------------------------
             |               Robust
     ruralan |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------------
         inc |  -80.11559   37.75428    -2.12   0.039
       incsq |   6.037585   2.284809     2.64   0.011
     pwtopen |   .2180824   .6526446     0.33   0.740
      intery |  -.0138015   .0830803    -0.17   0.869
      polity |   -.319822   .5417517    -0.59   0.558
     lareapc |  -9.560386    2.22958    -4.29   0.000
       _cons |   330.8272    156.158     2.12   0.039
------------------------------------------------------------------------------
. test inc incsq    ( 1)  inc = 0     ( 2)  incsq = 0
       F(  2,    50) =    9.31               Prob > F =    0.0004

. * Income Peak    761.08012

. ivreg ruralan (inc incsq pwtopen = elhsfs incf incfsq) intery polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     55
                                                       F(  6,    48) =    0.17
                                                       Prob > F      =  0.9835
                                                       R-squared     =      .
                                                       Root MSE      =  128.67
------------------------------------------------------------------------------
             |               Robust
     ruralan |      Coef.   Std. Err.      t    P>|t|
-------------+---------------------------------------------------------------
         inc |  -636.2494   6635.896    -0.10   0.924
       incsq |   60.59561   649.4644     0.09   0.926
     pwtopen |     47.396   560.3881     0.08   0.933
      intery |  -5.878212   69.57319    -0.08   0.933
      polity |   .5363244   10.07493     0.05   0.958
     lareapc |  -68.44781   706.2894    -0.10   0.923
       _cons |   1409.271   12966.68     0.11   0.914
------------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   intery polity lareapc elhsfs incf incfsq
------------------------------------------------------------------------------
. test inc incsq     ( 1)  inc = 0      ( 2)  incsq = 0
       F(  2,    48) =    0.02                Prob > F =    0.9849

. * Income Peak      190.55917

* * * * * * * * *
```

Results for interaction of capital/labor and trade (with income in quadratic form). cited in R.Ec.Stat. paper

```
*
. * Benchmark as of 8-12-02.  OLS then IV.
. *
. * CO2
. *
. reg co2perc inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     55
                                                       F(  6,    48) =   35.18
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7753
                                                       Root MSE      =  2.6282
------------------------------------------------------------------------
             |               Robust
     co2perc |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------
         inc |  -14.71954   7.755569    -1.90   0.064
       incsq |   1.071597   .5011547     2.14   0.038
     pwtopen |   -.004053   .0195242    -0.21   0.836
     interkl |   1.08e-06   8.05e-07     1.34   0.187
      polity |  -.0095203   .0316964    -0.30   0.765
     lareapc |    .389474   .2660336     1.46   0.150
       _cons |   49.80053   29.69287     1.68   0.100
--------------------------------------------------------------------------
.. test inc incs
 ( 1)  inc = 0
 ( 2)  incsq = 0

       F(  2,    48) =   10.83                    Prob > F =    0.0001

. * Income Peak    961.06426

. ivreg co2perc (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =      54
                                                       F(  6,    47) =   32.59
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7898
                                                       Root MSE      =  2.1847
-----------------------------------------------------------------------
             |               Robust
     co2perc |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------
         inc |  -23.79231   8.417545    -2.83   0.007
       incsq |    1.72546   .5370915     3.21   0.002
     pwtopen |   .0102742    .029771     0.35   0.732
     interkl |  -8.85e-07   8.31e-07    -1.07   0.292
      polity |  -.0272206   .0535811    -0.51   0.614
     lareapc |   .3155784   .2587464     1.22   0.229
       _cons |   80.65656   32.46891     2.48   0.017
-----------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
-----------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    47) =   15.39      Prob > F =    0.0000

. * Income Peak    986.81776

. *
. * Deforestation
. *
. reg defp inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     53
                                                       F(  6,    46) =    6.41
                                                       Prob > F      =  0.0001
```

```
                                                       R-squared     =  0.3085
                                                       Root MSE      =  1.3138

------------------------------------------------------------------------
             |               Robust
        defp |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------
         inc |   2.075818   3.032319     0.68   0.497
       incsq |  -.1691247   .1790041    -0.94   0.350
     pwtopen |    .011594   .0166507     0.70   0.490
     interkl |  -1.58e-07   3.11e-07    -0.51   0.614
      polity |   .0262807   .0555139     0.47   0.638
     lareapc |  -.0103811   .1037993    -0.10   0.921
       _cons |  -5.331799   12.51526    -0.43   0.672
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    46) =    4.30                  Prob > F =    0.0194

. * Income Peak         462.63861

. ivreg defp (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     53
                                                       F(  6,    46) =    6.56
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1897
                                                       Root MSE      =  1.4222

-----------------------------------------------------------------------
             |               Robust
        defp |      Coef.   Std. Err.      t    P>|t|
-------------+---------------------------------------------------------
         inc |    4.86595   3.105405     1.57   0.124
       incsq |  -.3501681    .185161    -1.89   0.065
     pwtopen |  -.0137896   .0172789    -0.80   0.429
     interkl |   1.94e-07   3.17e-07     0.61   0.543
      polity |   .0161798   .0485191     0.33   0.740
     lareapc |  -.1292735   .1589866    -0.81   0.420
       _cons |   -14.2882   12.84746    -1.11   0.272
-------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    46) =    4.43           Prob > F =    0.0173

. * Income Peak      1041.0872

. *
. * Energy Depletion
. *
. reg enrdam inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     54
                                                       F(  6,    47) =    1.48
                                                       Prob > F      =  0.2046
                                                       R-squared     =  0.1137
                                                       Root MSE      =  8.2247
------------------------------------------------------------------------
             |               Robust
      enrdam |      Coef.   Std. Err.      t    P>|t|
-------------+------------------------------------------------------------
         inc |   44.56219   25.38554     1.76   0.086
       incsq |  -2.683721   1.491049    -1.80   0.078
     pwtopen |  -.0308318    .021687    -1.42   0.162
     interkl |   1.09e-06   7.12e-07     1.53   0.132
      polity |  -.4912701   .3470155    -1.42   0.163
```

```
     lareapc |   .2660432   .6980511     0.38   0.705
       _cons |  -176.6527   106.6154    -1.66   0.104
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    47) =    1.93              Prob > F =    0.1560

. * Income Peak     4033.1887

. ivreg enrdam (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     54
                                                       F(  6,    47) =    1.40
                                                       Prob > F      =  0.2346
                                                       R-squared     =       .
                                                       Root MSE      =   8.842
-----------------------------------------------------------------------
             |               Robust
      enrdam |      Coef.   Std. Err.      t    P>|t|
-------------+---------------------------------------------------------
         inc |    71.4296    25.8882     2.76   0.008
       incsq |  -4.415733   1.612883    -2.74   0.009
     pwtopen |  -.1803119   .1230837    -1.46   0.150
     interkl |   3.92e-06   2.73e-06     1.44   0.157
      polity |  -.5708394    .337686    -1.69   0.098
     lareapc |  -.4146897   1.042674    -0.40   0.693
       _cons |  -270.0651   99.52013    -2.71   0.009
--------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    47) =    3.81              Prob > F =    0.0293

. * Income Peak       3255.43

. *
. * NO2
. *
. reg no2m inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     30
                                                       F(  6,    23) =    1.94
                                                       Prob > F      =  0.1173
                                                       R-squared     =  0.1879
                                                       Root MSE      =  43.042
-----------------------------------------------------------------------
             |               Robust
        no2m |      Coef.   Std. Err.      t    P>|t|
-------------+---------------------------------------------------------
         inc |   410.8601   187.9997     2.19   0.039
       incsq |  -22.73852   10.73772    -2.12   0.045
     pwtopen |  -.5173574   .4053085    -1.28   0.215
     interkl |   4.71e-07   6.58e-06     0.07   0.944
      polity |  -2.728899   3.773059    -0.72   0.477
     lareapc |  -7.096475   6.678162    -1.06   0.299
       _cons |   -1717.05   808.8863    -2.12   0.045
-------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    23) =    2.73    Prob > F =    0.0861

. * Income Peak     8387.1107

ivreg no2m (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     30
```

```
                                                       F(  6,    23) =    1.20
                                                       Prob > F      =  0.3406
                                                       R-squared     =  0.1332
                                                       Root MSE      =  44.468
------------------------------------------------------------------------
             |               Robust
        no2m |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------
         inc |   391.1198   381.1072     1.03   0.315
       incsq |  -20.97587   21.99281    -0.95   0.350
     pwtopen |   .0783804   .6106091     0.13   0.899
     interkl |   -.000011   .0000114    -0.97   0.344
      polity |  -2.868655    4.96476    -0.58   0.569
     lareapc |  -6.755789   6.347687    -1.06   0.298
       _cons |  -1698.544   1634.537    -1.04   0.310
------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0          F(  2,    23) =    1.87     Prob > F =    0.1775

. * Income Peak   11193.506

. *
. * Sulfur Dioxide
. *
. reg sulfdm inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     32
                                                       F(  6,    25) =    3.57
                                                       Prob > F      =  0.0108
                                                       R-squared     =  0.5139
                                                       Root MSE      =   15.76
----------------------------------------------------------------------
             |               Robust
      sulfdm |      Coef.   Std. Err.      t    P>|t|
-------------+-----------------------------------------------------------
         inc |   303.3421   147.0133     2.06   0.050
       incsq |  -18.11208   8.846506    -2.05   0.051
     pwtopen |  -.3827739   .2273838    -1.68   0.105
     interkl |   3.92e-06   4.04e-06     0.97   0.342
      polity |  -1.730975   2.339441    -0.74   0.466
     lareapc |  -3.323324   1.480258    -2.25   0.034
       _cons |  -1188.958   607.9216    -1.96   0.062
------------------------------------------------------------------------

. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    25) =    2.26      Prob > F =    0.1250

. * Income Peak   4333.0456

. ivreg sulfdm (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     32
                                                       F(  6,    25) =    3.66
                                                       Prob > F      =  0.0095
                                                       R-squared     =  0.5088
                                                       Root MSE      =  15.842
----------------------------------------------------------------------
             |               Robust
      sulfdm |      Coef.   Std. Err.      t    P>|t|
-------------+--------------------------------------------------------
         inc |   334.4655   150.8396     2.22   0.036
       incsq |  -19.95198    9.01319    -2.21   0.036
     pwtopen |  -.3429395   .2848613    -1.20   0.240
     interkl |   3.54e-06   4.79e-06     0.74   0.467
      polity |  -1.486867   2.394407    -0.62   0.540
```

```
     lareapc |  -3.205778   1.549381    -2.07   0.049
       _cons |  -1323.283   627.9271    -2.11   0.045
---------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    25) =    2.46               Prob > F =    0.1059

. * Income Peak    4366.7006

. *
. * Suspended Particles
. *
. reg suspm inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     30
                                                       F(  6,    23) =    4
                                                       Prob > F      =  0.0067
                                                       R-squared     =  0.5523
                                                       Root MSE      =  56.432
----------------------------------------------------------------------
             |               Robust
       suspm |      Coef.   Std. Err.      t    P>|t|
-------------+--------------------------------------------------------
         inc |   551.3948   508.8648     1.08   0.290
       incsq |  -35.79599   29.24197    -1.22   0.233
     pwtopen |  -.6467419   .7005434    -0.92   0.365
     interkl |   9.64e-06   .0000133     0.73   0.475
      polity |  -2.355989   7.672784    -0.31   0.762
     lareapc |  -10.04963   5.408642    -1.86   0.076
       _cons |    -1889.7   2157.393    -0.88   0.390
---------------------------------------------------------------------------
. test inc incsq      ( 1)  inc = 0        ( 2)  incsq = 0
       F(  2,    23) =    5.39     Prob > F =    0.0120

. * Income Peak     2212.5653

ivreg suspm (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors       Number of obs =     30
                                                       F(  6,    23) =    3.93
                                                       Prob > F      =  0.0076
                                                       R-squared     =  0.5400
                                                       Root MSE      =  57.199
-------------------------------------------------------------------------
             |               Robust
       suspm |      Coef.   Std. Err.      t    P>|t|
-------------+-------------------------------------------------------------
         inc |   673.5513    612.294     1.10   0.283
       incsq |  -42.70518   35.24489    -1.21   0.238
     pwtopen |  -.2839184   .9247932    -0.31   0.762
     interkl |   4.46e-06   .0000192     0.23   0.818
      polity |  -2.768539    8.20899    -0.34   0.739
     lareapc |  -9.277383   5.315844    -1.75   0.094
       _cons |  -2436.355   2587.462    -0.94   0.356
--------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq
 ( 1)  inc = 0
 ( 2)  incsq = 0
       F(  2,    23) =    2.95              Prob > F =    0.0722

. * Income Peak     2659.9431
```

```
. *
. * Rural access to clean water
. *
. reg ruralan inc incsq pwtopen interkl polity lareapc, robust

Regression with robust standard errors                 Number of obs =     32
                                                       F(  6,    25) =   10.68
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6315
                                                       Root MSE      =  20.134
---------------------------------------------------------------------------
             |               Robust
     ruralan |      Coef.   Std. Err.      t    P>|t|
-------------+------------------------------------------------------------
         inc |  -33.88171   62.67165    -0.54   0.594
       incsq |   2.889868   3.786618     0.76   0.452
     pwtopen |   .0391187    .214443     0.18   0.857
     interkl |   3.71e-06   5.01e-06     0.74   0.466
      polity |   .1281525   .9003763     0.14   0.888
     lareapc |  -9.772383   3.517579    -2.78   0.010
       _cons |   165.3194   255.6344     0.65   0.524
--------------------------------------------------------------------------
. test inc incsq       ( 1)  inc = 0         ( 2)  incsq = 0
       F(  2,    25) =    3.61     Prob > F =    0.0420

. * Income Peak      351.48102


. ivreg ruralan (inc incsq pwtopen = elhsfs incf incfsq) interkl polity lareapc, robust

IV (2SLS) regression with robust standard errors umber of obs =     32
             F(  6,    25) =    9.87     Prob > F      =  0.0000
                                         R-squared     =  0.5625
                                         Root MSE      =  21.937
----------------------------------------------------------------------------
             |               Robust
     ruralan |      Coef.   Std. Err.      t    P>|t|
-------------+----------------------------------------------------------
         inc |   30.25503   78.07504     0.39   0.702
       incsq |    -1.3484    5.00639    -0.27   0.790
     pwtopen |  -.3831083   .4671899    -0.82   0.420
     interkl |   .0000108   9.99e-06     1.08   0.289
      polity |  -.1202621   .9388455    -0.13   0.899
     lareapc |  -11.92875   4.403313    -2.71   0.012
       _cons |  -46.92236   283.4336    -0.17   0.870
----------------------------------------------------------------------------
Instrumented:  inc incsq pwtopen
Instruments:   interkl polity lareapc elhsfs incf incfsq
---------------------------------------------------------------------------
. test inc incsq        ( 1)  inc = 0         ( 2)  incsq = 0
       F(  2,    25) =    1.00             Prob > F =    0.3810

. * Income Peak      74523.099


* * * * * * * * * * *
```

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, e.g., 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. Jaffe, Peterson, Portney and Stavins (1995) survey the literature with regard to direct investment in the U.S..

[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] 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.

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

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

[10] 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.

[11] 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 (2002), or in the working paper version of the present study.

[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, according to which a tightening of environmental regulation stimulates technological innovation and thereby raises productivity. (E.g., Porter and van der Linde, 1995.)

[14] The usual presumption is that environmental regulation, by raising business costs, slows economic growth. On the other hand the Porter Hypothesis (in which a tightening of environmental regulation stimulates technological innovation and thereby raises productivity) has the opposite implication. See e.g., Porter and van der Linde, 1995.

[15] 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.

[16] 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.

[17] 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.

[18] 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 EKC for CO_2.

[19] 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.

[20] E.g., Copeland and Taylor (2003) and Grossman and Krueger (1993, 1995), who suggest that the overall effect might be a reduction of pollution in the aggregate, contrary to the popular view of "eco-dumping" in poor countries.

[21] E.g., Frankel and Romer (1999), or Irwin and Tervio (2002), or the working paper version of this paper.