Abstract

The debate over globalization and the environment can be given some much-needed focus by asking the specific empirical question: What is the effect of trade on a country’s environment, for a given level of GDP? There is an apparent positive correlation between openness to trade and some measures of environmental quality. But this could be due to endogeneity of trade, rather than causality. This paper uses exogenous determinants of trade – geographical variables from the gravity model – as instruments to isolate the effect of openness. The finding is that trade may indeed have a generally beneficial effect on these measures of environmental quality. This is particularly true of SO2 and organic water pollution. Across seven measures, the beneficial effect is only significant roughly half the time, but one can at least say that there is no evidence that trade has the detrimental effect on the environment that the race-to-the-bottom theory would lead one to expect. The primary effect appears to come via income itself: some of our results support the environmental Kuznets curve, which says that growth harms the environment at low levels of income and helps at high levels, and to support the proposition that openness to trade accelerates the growth process.

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

Jeffrey Frankel and Andrew Rose

Opponents of globalization usually do not argue that it is bad for economic growth, as measured by GDP. Rather they fear adverse effects on such “non-economic” objectives as environmental quality.1 If the term globalization is meant to capture the totality of industrialization, then there is little question that, at least at the early stages of economic development, environmental degradation is a consequence. If the human species still consisted of a few thousand hunter-gatherers, for example, man-made pollution would be close to zero. This is not the interesting question, however. The interesting questions are (1) whether economic growth eventually brings environmental improvement and (2) whether cross-border integration helps or hurts in this process. That first question is the much-studied environmental Kuznets curve, while the second is the focus of this paper.

The paper seeks to disentangle a variety of simultaneous causal relationships, on a cross-country data set. The question of central interest is the effect of international trade on the environment, for a given level of GDP. We consider certain causal relationships as already fairly well established:

1) Openness has a positive effect on countries’ real income per capita. Economists have long made the theoretical case, from the Smith-Ricardo idea of comparative advantage to the Helpman-Krugman model of trade under imperfect competition. The empirical case is also fairly strong, and holds up even after taking into account the important reverse causality that runs from income to trade.

2) Output has a positive effect on pollution through physical production, but at the same time,

3) At higher levels of income per capita, growth raises the public’s demand for environmental quality, which, given the right institutions, can translate into environmental regulation. People value both their economic standard of living as measured by GDP and the environment as well. Environmental regulation, if effective, then translates into a cleaner environment. While the effects described under propositions (2) and (3) go opposite directions, there is by now a rough conventional wisdom that the negative effect of growth on

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1 The quotation marks are necessary around “non-economic,” of course, because economists’ conceptual framework fully incorporates the objective of environmental quality, even though pollution is an externality that is not measured by GDP.
environmental quality dominates at low levels of income, while the positive effect dominates at higher levels. This proposition is:

4) The *environmental Kuznets curve*: the relationship between income per capita and some kinds of pollution is inverted-U-shaped. The World Bank (1992) and Grossman and Krueger (1993, 1995) brought to public attention this empirical finding. Growth is bad for air and water pollution at the initial stages of industrialization, but later on reduces pollution, as countries become rich enough to pay to clean up their environments. The standard theoretical rationale is that production technology makes some pollution inevitable, but that demand for environmental quality rises with income.  

To portray the Kuznets curve as claiming that if countries promote growth, the environment will eventually take care of itself, would be an unfair caricature. This optimistic view applies to pollution only if it is largely confined within the home or within the firm. Most pollution, such as SO2, NOx, etc., is external to the home or firm. For such externalities, higher income and a popular desire to clean up the environment are not enough. There must also be effective government regulation, which usually requires a democratic system to translate the popular will into action (something that was missing in the Soviet Union, for example), as well as the rule of law and reasonably

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2 Grossman and Kruger (1993, 1995) found the Kuznets curve pattern for urban air pollution (SO2 and smoke) and several measures of water pollution. Selden and Song (1994) found the pattern for SO2, suspended particulate matter (PM), NOx, and carbon monoxide. Shafik (1994) found evidence of the U shape for deforestation, suspended PM, and SO2, but less for water pollution and some other measures. Among more recent studies, Hilton and Levinson (1998) find the U-shaped relationship for automotive lead emissions and Bradford, Schlieckert and Shore (2000) find some evidence of the environmental Kuznets curve for arsenic, COD, dissolved oxygen, lead and SO2, while finding less evidence in the cases of PM and some other measures of pollution. Bimonte (2001) finds the relationship for the percentage of land that is protected area, within national territory.

3 Theoretical derivations include Andreoni and Levinson (1998), Jaeger and Kolpin (2000), Pfaff and Chaudhuri ( ), Selden and Song (1995) and Stokey (1998), among others. An alternative, though not inconsistent, explanation is that the pattern results from the stages of economic development, the transition from an agrarian economy to manufacturing to services (Arrow, et al, 1995; Panayotou, 1993)

4 Perhaps 80 percent (by population) of world exposure to particulates comes from cooking fire smoke in poor countries, which need not involve any externality. Chaudhuri and Pfaff (1998) find a U-shaped relationship between income and indoor smoke, across households. In the poorest households, rising incomes mean more cooking and more indoor pollution. Still-higher incomes allow a switch to cleaner fuels. Engel curves can produce the relationship, with no role for government regulation.
intelligent mechanisms of regulation. That is at the national level; the requirements for dealing with cross-border externalities are greater still.

We will be testing the environmental Kuznets curve, along with the other propositions on this list. But it is not the central focus of the paper.

The central focus of the paper is, rather:

5) 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 perhaps the most relevant fundamental question for policy. If it were established that trade had an adverse effect on the environment solely because openness raised countries’ incomes, and the higher incomes damaged the environment, few would conclude from this that we should try to turn back the clock on globalization. Few would choose deliberate self-impoverishment as a means to a clean environment.5

Secondly, the question is interesting because the answer is completely unknown. There are possible effects in both directions. Most widely discussed is the race to the bottom hypothesis, which says that countries that are open to international trade (and investment) will adopt looser standards of environmental regulation, out of fear of a loss in international competitiveness.

Less widely recognized is the possibility of an effect in the opposite direction, which we will call the gains from trade hypothesis. Trade allows countries to attain more of what they want, which includes environmental goods in addition to market-measured output. How could openness have a positive effect on environmental quality, even for a given level of GDP per capita? One widely identified possibility is an international ratcheting up of environmental standards via, for example, the practices of multinational corporations.6 A second possibility concerns technological and managerial innovation. We think that openness encourages ongoing innovation, that this may be why countries that trade more appear to experience a sustained increase in growth rather than just the one-time increase in the level of real income predicted by classical trade theory. Trade speeds the absorption of frontier technologies and best-practice management. It then seems likely that openness could encourage innovation that would be beneficial to environmental improvement as well as economic progress. A third possibility is that, because trade offers consumers the opportunity to consume goods of greater variety, it allows countries to attain higher levels of welfare (for any given level of domestically produced output), which, as under proposition (3) above, will raise the demand for environmental quality. Again, if the appropriate institutions are in place, this

5 Meadows, et al (1972), and Daly (1993), could, however, be interpreted as arguing that trade is necessarily bad because it raises measured GDP which in turn harms the environment. For a general survey of the issues, see Esty (2001).

Figure 1: Hypothesized causal relationships between trade and environment
demand for higher environmental quality will translate into effective regulation and the desired reduction in pollution. Whether the race-to-the-bottom effect dominates the gains-from-trade effect is an empirical question.

Figure 1 is a schematic illustration of the causal relationships that are hypothesized above, and several others as well. Two controversial propositions are:

6) The *pollution haven hypothesis*: a country that adopts lax environmental standards will attract multinational corporations and promote international trade, under which it exports goods that are produced in environmentally dirty ways.8

7) The *Porter hypothesis*: a tightening of environmental regulation stimulates technological innovation and thereby has positive effects on both the economy and the environment -- for example, saving money by saving energy.9 The analytical rationale for this view is not entirely clear. (Is the claim that any sort of change in regulation, regardless in what direction, stimulates innovation, or is there something special about pro-environment regulation? Is there something special about the energy sector?) Nevertheless the Porter hypothesis is sufficiently widely discussed that it merits a position on our list of propositions to be tested.

This list of propositions includes important possible causal arrows running in both directions among each pair out of the three key endogenous variables – trade, income, and the environment. In estimating a system of equations, the simultaneity problems are

7 A fourth possibility is that globalization offers interest groups that care particularly about the environment a new weapon -- threats to block movement toward free trade unless they are bought off. This is by analogy with the “embedded liberalism” identified by Ruggie (1982), a post-war quid pro quo that gave workers an increased level of social protection, in exchange for an open international trading regime.

8 It is worth noting one of the differences between the race-to-the-bottom hypothesis and the pollution haven hypothesis: while the former implies an overall world level of environmental regulation that is less than optimal, the latter does not. Some countries may choose high environmental standards for their own production, and import from others goods that embody pollution. But, in any case, some economists’ research suggests that environmental regulation is not a major determinant of firms’ ability to compete internationally. When deciding where to locate, multinational firms seem to pay far more attention to such issues as labor costs and market access than to the stringency of local environmental regulation. (Jaffe, Peterson, Portney and Stavins, 1995; Low and Yeats, 1992; Tobey, 1990.) Other empirical researchers, however, have found more of an effect of environmental regulation (Lee and Roland-Holst, 1997.) Theoretical analyses include Copeland and Taylor (1994, 1995, 2001) and Liddle (2001).

formidable. Let us say, for example, that we find a positive correlation between trade and environmental quality.\textsuperscript{10} Does this mean that trade is good for the environment? Not necessarily. It might be a result of the Porter hypothesis -- environmental regulation stimulates productivity -- together with the positive effect of income on trade. Antweiler, Copeland and Taylor (2001), which is perhaps the most careful existing study of the effects of trade on the environment, find a beneficial effect. But they make no allowance for the possible endogeneity of trade. Or let us say that we find a negative correlation between trade and environmental quality. Does this mean that trade is bad for the environment? Not necessarily. It might be a result of a negative effect of environmental regulation on growth, together with the positive effect of growth on trade.\textsuperscript{11}

We disentangle the simultaneous causality by means of two sets of instrumental variables. Most importantly, we take a set of geographical determinants of openness from the gravity model of bilateral trade. These are indicators of country size (GDP, population, and land area) and of distance between the pair of countries in question (physical distance as well as dummy variables indicating common borders, linguistic links, and landlocked status).\textsuperscript{12} Such gravity instruments has been used to isolate the effect of trade in studies of growth (Frankel and Romer, 1999; Irwin and Tervio, 2001), studies of currency union (Frankel and Rose, 1996, 2002), and studies of inequality (Chakrabarti, 2000, and Gurkaynak and Krashinsky, 2001). We also take a set of instrumental variables for income per capita from the growth literature: lagged income (the conditional convergence hypothesis), size (Frankel and Romer, 1999; Frankel and Rose, 2001), and rates of investment rates and human capital formation (the factor cumulation variables familiar from neoclassical growth equations: Solow, 1956; Barro, 1991; Mankiw, Romer and Weil, 1992).

As always, there is the possibility that some of our instrumental variables are in truth endogenous. This could be an issue with the factor cumulation variables in the income equation: Concern has been expressed that investment is endogenous, or human capital.\textsuperscript{13} To us, the geographic variables seem the least likely to be endogenous, not just

\textsuperscript{10} E.g., Eiras and Schaeffer (2001), p. 4, 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.”

\textsuperscript{11} The same ambiguity attaches to correlations among the other pairs of variables. For example, Esty and Porter (2001) find a positive correlation between income and environmental regulation. Their preferred interpretation is the Porter hypothesis, but they are obligate to admit that “These findings do not establish causality.” (p. 26).

\textsuperscript{12} Frankel (1997) offers a comprehensive review of the gravity model.

\textsuperscript{13} E.g., Bils and Klenow (1998) argue that investment in human capital is endogenous with respect to growth. It is also possible that the political variables are endogenous, with richer countries tending to become more democratic.
in a causal sense, but also in the econometric sense, i.e., correlated with the error term in the trade equation. These are the instruments we need for testing our question of central interest, the effects of trade on the environment for a given level of income.

We estimate a system of two equations:

**Growth equation:**

\[
\ln(Y/\text{Pop})_{90,i} = \beta_0 + \alpha([X + M]/Y)_{90,i} + \beta_1\ln(\text{Pop})_i + \phi Z_i \\
+ \gamma\ln(Y/\text{Pop})_{90,i} + \delta_1(I/Y)_i + \delta_2n_i + \delta_3(\text{School1})_i + \delta_4(\text{School2})_i + u_i
\]

(1)

where: the dependent variable is the natural logarithm of GDP (Y) divided by total population (Pop) at the end of 1990, measured in real PPP-adjusted dollars for country i; aggregate exports, aggregate imports, and gross investment are denoted “X”, “M” and “I” respectively; the growth rate of population is denoted “n”; “School1” and “School2” are estimates of human capital investment based, respectively, on primary and secondary schooling enrollment rates; “Z” denotes other controls; Greek letters denote coefficients; and “u” denotes the residual impact of other, hopefully orthogonal influences. We denote by “controls” the variables that derive from neoclassical growth theory and appear on the second line of the equation: initial income, investment, human capital and population growth.\(^{14}\) Variables other than GDP per capita and openness are computed as averages over the sample period. Following the norm in the growth literature, we measure openness as the ratio of trade to output.

**Environmental quality equation:**

\[
\text{Enviro}_i = \varphi_0 + \varphi_1(Y/\text{pop}_1)_{90,i} + \varphi_2(Y/\text{pop}_2)_{90,i} + \varphi_3(Y/\text{pop}_3)_{90,i} \\
+ \mu([X + M]/Y)_{90,i} + \pi(\text{Polity})_{90,i} + \lambda(\text{LandArea/Cap})_{90,i} + \epsilon_i
\]

(2)

where: the dependent variable is a variety of measures of environmental quality, each estimated as separate equations; the first three variables are the three segments of a spline (split at the .33 and .66 percentiles) fit to the natural logarithm of real 1990 GDP (Y)

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\(^{14}\) Frankel and Romer [1999] and Irwin and Tervio [2000] adopt a more stripped-down specification by omitting these controls, following Hall and Jones [1999]. They regress output per capita against distance from the equator and measures of country size, reasoning that the factor accumulation variables might be endogenous. Including the controls in the output equation might result in a downward-biased estimate of \(\alpha\), if some of the effect of openness arrives via factor accumulation. But inappropriately excluding these variables would also produce biased results and could be expected improperly to attribute too large an effect to trade. Our own preference is for the specification that includes the controls, in part because it is likely to avoid a possible upward bias in the openness coefficient.
divided by total population (Pop), taken from the Penn World Table 5.6 and so measured in real PPP-adjusted dollars, for country $i$; aggregate exports and aggregate imports as before are denoted “$X$” and “$M$”; Polity is a measure of how democratic is the structure of the government, ranging from -10 (“strongly autocratic”) to +10 (strongly democratic),\(^{15}\) and Land Area per capita is intended to allow for the likelihood that population density leads to environmental degradation (for a given level of per capita income).\(^{16}\) We report results for seven measures of environmental quality, including three measures of air pollution concentrations and four others:

SO$_2$: sulphur dioxide, mean (in micograms per cubic meter), 1995  
NO$_2$: nitrous dioxide, mean (in micograms per cubic meter), 1995  
PM: Suspended Particulate Matter, mean total (in micograms per cubic meter), 1995  
BOD: Biochemical oxygen demand -- Organic water pollutant emissions (in kg per day)  
Def: annual deforestation, average percentage change, 1990-95  
Energy: Energy depletion, in percent of GDP (“genuine savings”)\(^{17}\)  
CO$_2$/cap: Carbon dioxide emissions, industrial, in metric tons per capita

Results for the Growth Equation

We begin by estimating our output equation, equation (1), with OLS to replicate the common finding that there is a statistical association between trade and income. In Table I, we report OLS estimates of the impact of trade on output. The coefficient on initial GDP is a highly significant 0.71, representing a plausible degree of conditional convergence -- about 30 percent over a 20-year period. The estimated coefficient on trade, 0.33 in the OLS version, says that, holding constant for 1970 income, income in 1990 was 1/3 per cent higher for every 1.0 percentage point increase in the trade/GDP ratio. When multiplied by 3.45 (=1/(1-.71)) to convert to an estimated effect on long-run income, the effect on output is 1.14 per cent for every 1.0 percentage point increase in openness.

The effects of investment and both schooling variables are statistically significant and reasonable. Population growth has the negative sign hypothesized by the neoclassical model, but as in earlier work is the one growth determinant that is not statistically significant.

\(^{15}\) It is taken from the Polity IV at the University of Maryland. Described in Marshall and Jaggers ( ).

\(^{16}\) Cropper and Griffiths (1994) study deforestation and find that, in addition to the usual Kuznets curve effect of per capita income, population density has a further adverse effect.

\(^{17}\) 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.
The next step is to estimate the corresponding output equation using IV estimation to account for the possible endogeneity of openness. The instrumental variables we choose come from a simple gravity model that uses as controls an aggregation of: the log of distance, the log of partner country population, the log of area, and dummy variables for common language, common land border, and landlocked status. After estimating the gravity model for a large data set on pairwise trade, we aggregate the exponent of the fitted values across bilateral trading partners to arrive at an estimate of total trade for a given country. The correlation between actual trade shares and our generated instrument is a reassuringly high value of .72.\footnote{See Frankel and Rose (2001) for results of the estimation of the bilateral trade equation and details of the calculation of the gravity instrument, which corresponds closely to that used here. That paper also includes a response to a critique from Rodriguez and Rodrik (2001) and Rodrik (2000) regarding the gravity instruments. Part of the controversy is concerns whether trade can be assumed to have similar effects on growth when the “globalization” arises from deliberate policy (such as trade liberalization) as when it arises from geographic and technological factors (such as proximity or declining shipping costs).} The estimate of interest to us is $\alpha$, the coefficient on openness. When we include initial income and other controls, the effect of trade on output is 0.43. The implied steady state impact is $1.6 = \frac{0.43}{1 - 0.73}$.

**Results for the Environmental Degradation Equations**

Table 2 reports the results of OLS estimation of equation (2), where the dependent variable is represented by various measures of pollution and of other sorts of environmental damage. Our central interest is in $\mu$, the coefficient on openness.

The coefficient is negative for five measures -- insignificantly so for PM and energy depletion, borderline significant for NO2, and highly significant for SO2 and organic water pollution. It is positive for only two measures -- insignificantly so for deforestation and borderline-significant for CO2.

The Kuznets curve shows up fairly well for most of the measures. (We leave aside, for the moment, the equation for carbon dioxide.) That is, growth in the low-income countries increases environmental degradation, and growth in the high-income countries reduces it. The effect in the low-income range is insignificant for SO2, but is significant for energy depletion, borderline-significant for deforestation, and highly significant for suspended particulate matter. The effect in the high-income range is borderline significant for energy depletion and SO2, significant for suspended particulate matter, and highly significant for deforestation. The two measures that do not exhibit a clear Kuznets curve are NO2, where the positive effect does not show up until the middle third of the spline, and organic water pollution, where the positive effect appears at the highest-income level. In addition, growth continues to have a positive, indeed increasing, effect through all three segments in the case of CO2.
Thus the OLS results are overall fairly supportive of both the Kuznets curve and the proposition that openness is at least as likely to help the environment, for a given level of income, as to hurt it. The only case where growth appears always detrimental for the environment -- and openness to exacerbate the problem -- is CO2. This is the one gas on our list that is a purely global externality, where countries cannot expect to be able to address it by national regulation on their own, and indeed where fears of adverse effects on competitiveness are most acute.\footnote{Of course, we cannot rule out that emissions of CO2 also follow a Kuznets Curve, but that the peak is not reached until higher levels of income than yet experienced by rich countries. (E.g., Schmalensee, Stoker and Judson, 1996.)}

The contribution of this paper is to address the possibility that these apparent effects may be the spurious results of simultaneity. Table 3 estimates the environmental equation via instrumental variables, 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, but with a slightly different pattern across the various environmental measures. The coefficient on openness is again negative for five measures -- insignificantly so for CO2, borderline significant for energy depletion and NO2, and clearly significant for SO2 and organic water pollution. It is again positive for only two measures -- deforestation and PM -- without any statistical significance in either case.

We interpret the absence of a general positive effect of openness on environment degradation as evidence against the “race to the bottom” hypothesis. Trade, if anything, appears to have a generally beneficial effect on most of our measures of environmental quality, for given levels of income. But one might still be concerned about a possible “pollution haven” hypothesis according to which economic integration results in some countries exporting pollution to others, even if the overall level of pollution does not rise. The hypothesis would be that countries that have a particularly high demand for environmental quality -- the rich countries -- specialize in products that can be produced cleanly, and they let the poor countries produce and sell the products that require pollution.\footnote{E.g., Suri and Chapman (1998). Muradian, O’Connor and Martinez-Alier (2001) have found recent evidence that the imports of rich countries do embody more air pollution than their exports.} This hypothesis can be readily tested by adding to the equation the product of openness and income per capita. If rich countries take advantage of trade by exporting pollution-creating activities to poor countries, the interaction between openness and income should have a negative effect on the level of a country’s domestic pollution. When we tried this as an extension, we found that the estimated coefficient on the interactive term was positive in five out of seven cases, the opposite of the pollution haven hypothesis, and in no cases was statistically significant.
A parallel hypothesis would be that countries that are endowed with a particularly high supply of environmental quality -- those with high land area per capita -- import pollution from those that are more densely populated. We tested this by adding the product of openness and land area per capita. The sign was positive in five out of seven cases, but in no cases was significant. The only case of statistical significance was an apparent negative effect of the interactive term in the equation for CO2 emissions per capita, counterintuitively suggesting that sparsely populated open countries have lower emissions rather than higher. In any case, there is no evidence for the pollution haven effect. (Tables with the interactive terms are not reported here.)

The Kuznets curve continues to hold up under the IV estimation of Table 3. Growth worsens the environment in the low-income range in the case of five measures: insignificantly for deforestation, with borderline significance for organic water pollution and CO2, and with high significance for energy depletion and PM. The two measures that show growth reducing pollution in this range, NO2 and SO2, are not statistically significant. In the high-income range, growth improves the environment in five cases: insignificantly for NO2, PM and energy depletion, and significantly for SO2 and deforestation. The two cases where growth appears still to damage the environment in the high-income range, and significantly so, are again CO2 and water.21

The polity variable shows up with the expected negative sign in almost all cases: as expected, democracy is good for environmental protection. The effect is clearly significant statistically for NO2, SO2, PM, and energy depletion, under either OLS or IV estimation, and insignificant only for the case of water pollution. Even for CO2, the estimated effect is beneficial, though only significant under IV estimation. The one case of an apparent detrimental effect, deforestation, is not statistically significant. We note, in passing, that area per capita has the expected negative sign in five out of seven cases, though it is not always significant.

Conclusions and a Calculation

Trade can have several sorts of effects on the environment. We have found evidence that, for any given level of income, trade appears to have a generally beneficial effect on some measures of environmental quality, though not all. This is particularly true of SO2 and organic water pollution. Across seven measures, the beneficial effect is only significant roughly half the time, but one can at least say that there is no evidence that trade has the detrimental effect on the environment that the race-to-the-bottom theory would lead one to expect. In addition, trade helps promote economic growth, which in turn is an indirect channel of effect on the environment. At low levels of income this effect is detrimental to the environment, at high levels beneficial.

An interesting question is whether, within the class of low-income countries, the direct beneficial effect of openness is large enough to offset the indirect effect via income. The openness coefficient is too variable across measures of pollution and is

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21 For the case of water pollution, this apparent finding is surprising.
estimated too imprecisely to allow us to answer this question reliably. But an illustrative calculation may still be instructive. The environmentally damaging phase of the Kuznets curve is particularly strong for energy depletion, so let us take this case. Table 1 reports that for every 1 percentage point increase in openness, income rises by an estimated 0.3 percentage points (over the subsequent 20 years). The relevant coefficient from Table 2 implies that, in a poor country, this economic growth in turn induces energy depletion of 8.5*0.3= 2.6. At the same time, the 1 percentage point increase in openness diminishes energy depletion by an estimated 3.3 for a given level of income. Taking the difference of the two effects produces an estimated beneficial net effect.

We must be sure not read too much into this calculation of the net effect. The difference is not statistically significant. Furthermore, the net effect is much better than this for some of the measures of environmental damage, and much worse for others. But if it is necessary to attempt an overall verdict, it is also worth recalling two key points. Even if the two effects of trade on pollution cancelled out, that would still leave the country with a higher level of income and no change in environmental quality. Furthermore, once the country gets past the peak in the Kuznets curve, the two effects of openness, indirectly via income and directly, go the same direction.

This optimistic story does not hold for the case of CO2. Here there is no evidence that the Kuznets curve ever turns down on its own. Furthermore, openness is estimated under OLS to have a detrimental effect even for a given level of income, although, encouragingly, the latter effect disappears under IV estimation. Clearly growth alone won’t do it; international cooperation is also needed to address this sort of global environmental problem.

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References


Braithwaite, John, and Peter Drahos, Global Business Regulation, Cambridge University Press, UK.


Table 1: Income equations

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. *
. * Income equation with controls, OLS, and IV (gravity)
. *
. reg lrgdpch pwtopen lpop lrgdpchi invrat popg sch1 sch2, robust

Regression with robust standard errors
Number of obs = 106
F(7, 98) = 378.1
Prob > F = 0.000
R-squared = 0.940
Root MSE = 0.279

------------------------------------------------------------------------------
| Coef.  Std. Err.    t    P>|t|    [95% Conf. Interval]  
-------------+------------------------------------------------------------------
  lreal gdp/cap  | 0.003   .001   4.51    0.000   .0018752    .0048228
  pwtopen       | 0.065   .021   3.17    0.002   .024446    .106223
  lrgdpchi      | 0.711   .052  13.56    0.000   .6068329    .8148625
  invrat        | 0.016   .006   2.75    0.007   .0043862    .0270059
  popg          | -0.055  .050  -1.10    0.273  -.1540046    .0439813
  sch1          | 0.002   .002   1.04    0.273  -.0014603    .0047019
  sch2          | 0.007   .002   3.37    0.001   .0029775    .0115193
  _cons         | 1.019   .446   2.29    0.024  0.1344121   1.902896
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. ivreg lrgdpch (pwtopen = elhsfs) lpop lrgdpchi invrat popg sch1 sch2, robust

IV (2SLS) regression with robust standard errors
Number of obs = 102
F(7, 94) = 329.25
Prob > F = 0.0000
R-squared = 0.9382
Root MSE = 0.28273

------------------------------------------------------------------------------
| Coef.  Std. Err.    t    P>|t|    [95% Conf. Interval]  
-------------+------------------------------------------------------------------
  lrgdpch      | 0.004   .001   4.28    0.000   .0022838    .0062404
  pwtopen      | 0.078   .024   3.28    0.001   .0308508    .1253222
  lrgdpchi     | 0.726   .057  12.71    0.000   .612585    .8393506
  invrat       | 0.013   .006   2.17    0.032   .0011504    .0257221
  popg         | -0.047  .058  -0.82    0.416  -.1614204    .0673297
  sch1         | 0.001   .002   0.83    0.407  -.0020093    .0049089
  sch2         | 0.007   .003   2.82    0.006   .0022168    .0127724
  _cons        | 0.750   .496   1.51    0.135  -.238326    1.737495
------------------------------------------------------------------------------
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Table 2: Environmental degradation equations

* Splines for Real GDP per capita: Real income is replaced by a three-piece spline, split at the .33 and .66 percentiles.

OLS regressions

* Estimation of pollution equation, a function of income, trade, democracy and size

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. reg co2perc incl1-incl3 pwtopen polity lareapc, robust
Regression with robust standard errors                   Number of obs =     100
F(  6,    93) =   37.07
Prob > F      =  0.0000
R-squared     =  0.7526
Root MSE      =  2.4294
-------------+----------------------------------------------------------------
emissions of |               Robust
co2 / cap |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   incl1 |   1.037    .406       2.56   0.012      .2312251    1.842008
   incl2 |   2.113    .827       2.55   0.012      .4699467    3.755439
   incl3 |   7.049   1.282       5.50   0.000     4.503515     9.593509
   pwtopen |   .016    .008       1.97   0.052     -.0001296     .032725
   polity |  -.025    .022      -1.13   0.263     -.0696164     .0192251
  lareapc |   .161     .154       1.04   0.301     -.1459042     .4671842
    _cons |  -8.099       3.03       -2.67   0.009   -14.12257     -2.076243
-------------+----------------------------------------------------------------
. test incl1 incl2 incl3
( 1)  incl1 = 0.0
( 2)  incl2 = 0.0
( 3)  incl3 = 0.0
F(  3,    93) =   57.60    Prob > F =  0.0000

. reg defperc incl1-incl3 pwtopen polity lareapc, robust
Regression with robust standard errors                   Number of obs =      96
F(  6,    89) =    7.94
Prob > F      =  0.0000
R-squared     =  0.2670
Root MSE      =  1.1167
-------------+----------------------------------------------------------------
annual deforestation |               Robust
-------------+----------------------------------------------------------------
   incl1 |   .558    .338       1.65   0.102     -.1131407    1.228917
   incl2 |  -1.071    .460      -2.33   0.022    -1.984712    -.1568467
   incl3 |  -1.035    .338      -3.06   0.003    -1.706029    -.3630194
   pwtopen |   .002    .003       0.78   0.437     -.0033326     .0076449
   polity |   .033    .030       1.08   0.281     -.0274542     .0933718
  lareapc |  -.112    .076      -1.49   0.141    -.2628435     .0379788
    _cons |  -2.356    2.37      -0.99   0.323   -7.068778    2.357222
-------------+----------------------------------------------------------------
. test incl1 incl2 incl3
( 1)  incl1 = 0.0
( 2)  incl2 = 0.0
( 3)  incl3 = 0.0
F(  3,    89) =    7.88    Prob > F =  0.0001
```
. reg enrdam inc1-inc3 pwtopen polity lareapc, robust
Regression with robust standard errors
Number of obs = 98
F(  6,    91) = 3.07
Prob > F = 0.0089
R-squared = 0.1653
Root MSE = 6.8583

| energy depletion (%GDP) | Coef.  | Std. Err. | t    | P>|t|    | [95% Conf. Interval] |
|-------------------------|--------|-----------|------|--------|----------------------|
| inc1                    | 6.701  | 2.210     | 3.03 | 0.003  | 2.310476, 11.09073   |
| inc2                    | 4.288  | 2.902     | 1.48 | 0.143  | -1.47727, 10.05339  |
| inc3                    | -3.197 | 1.842     | -1.74| 0.086  | -6.855637, .4612429 |
| pwtopen                 | -.013  | .009      | -1.53| 0.130  | -0.0305804, 0.0039884|
| polity                  | -1.446 | .167      | -2.68| 0.009  | -1.7765009, -1.149375|
| lareapc                 | 2.49   | .419      | 0.59 | 0.554  | -.5835411, 1.081669  |
| _cons                   | -45.384| 15.583    | -2.91| 0.005  | -76.33765, -14.42956 |

.test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0  F(  3,    91) = 5.86  Prob > F = 0.0010

. reg no2m inc1-inc3 pwtopen polity lareapc, robust
Regression with robust standard errors
Number of obs = 36
F(  6,    29) = 7.13
Prob > F = 0.0001
R-squared = 0.2077
Root MSE = 39.866

| NO2     | Coef.  | Std. Err. | t    | P>|t|    | [95% Conf. Interval] |
|---------|--------|-----------|------|--------|----------------------|
| inc1    | -373.491| 209.562   | -1.78| 0.085  | -802.0938, 55.1116   |
| inc2    | 169.749 | 57.176    | 2.97 | 0.006  | 52.81202, 286.6866   |
| inc3    | -19.707 | 14.786    | -1.33| 0.193  | -49.93719, 10.5242   |
| pwtopen | -0.302  | .082      | -3.72| 0.001  | -.4690819, -.1377736|
| polity  | -3.854  | .975      | -3.15| 0.003  | -10.78989, -2.331318 |
| lareapc | -5.897  | 6.055     | -0.97| 0.338  | -18.28116, 6.486311  |
| _cons   | 2740.844| 1499.377  | 1.83 | 0.078  | -325.7254, 5807.414  |

.test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0  F(  3,    29) = 7.55  Prob > F = 0.0007

. reg sulfdm inc1-inc3 pwtopen polity lareapc, robust
Regression with robust standard errors
Number of obs = 41
F(  6,    34) = 40.04
Prob > F = 0.0000
R-squared = 0.6789
Root MSE = 23.351

| SO2     | Coef.  | Std. Err. | t    | P>|t|    | [95% Conf. Interval] |
|---------|--------|-----------|------|--------|----------------------|
| inc1    | 46.351 | 68.58| -0.68| 0.504  | -93.03795, 185.7394  |
| inc2    | -5.202 | 17.0379| -0.31| 0.756  | -5.421597, 63.82617  |
| inc3    | -16.540| 8.827  | -1.87| 0.066  | -34.47801, 1.598082  |
| pwtopen | -0.303 | .082   | -3.72| 0.001  | -.4690819, -.1377736|
| polity  | -6.561 | 2.081  | -3.15| 0.003  | -10.78989, -2.331318 |
| lareapc | -3.223 | 1.398  | -2.30| 0.027  | -6.064381, -0.3806328|
| _cons   | -248.434| 488.917| -0.51| 0.615  | -1242.032, 745.1641  |

.test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0  F(  3,    34) = 2.07  Prob > F = 0.1222
```latex
. reg suspm inc1-inc3 pwtopen polity lareapc, robust
Regression with robust standard errors
Number of obs = 38
F(  6,    31) = 13.45
Prob > F = 0.0000
R-squared = 0.7147
Root MSE = 52.835

|       | Coef. | Std. Err. | t     | P>|t|    | [95% Conf. Interval] |
|-------|-------|-----------|-------|--------|---------------------|
| inc1  | 332.443 | 100.885   | 3.30  | 0.002  | [126.687, 538.1996] |
| inc2  | -113.061 | 54.189    | -2.09 | 0.045  | [-223.5813, -2.541169] |
| inc3  | -46.614  | 22.426    | -2.08 | 0.046  | [-92.35144, -8.770822] |
| pwtopen | -2.256 | 0.323     | -7.99 | 0.045  | [-9140907, 0.402955] |
| polity | -7.459  | 3.378     | -2.21 | 0.035  | [-14.34902, -0.5689337] |
| lareapc | -10.514 | 4.576     | -2.30 | 0.028  | [-19.84621, -1.182096] |
| _cons | -2128.872 | 724.849  | -2.94 | 0.006  | [-3607.211, -650.5336] |

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0       F(  3,    31) = 10.86            Prob > F = 0.0000

. reg water inc1-inc3 pwtopen polity lareapc, robust
Regression with robust standard errors
Number of obs = 69
F(  6,    62) = 2.20
Prob > F = 0.0547
R-squared = 0.1877
Root MSE = 6.7e+05

|       | Coef. | Std. Err. | t     | P>|t|    | [95% Conf. Interval] |
|-------|-------|-----------|-------|--------|---------------------|
| inc1  | 462513.3 | 427084.3  | 1.08  | 0.283  | [-391216, 1316243] |
| inc2  | -348204.2 | 306688.4  | -1.14 | 0.261  | [-961265.5, 264857.1] |
| inc3  | 478785.8 | 246739.2  | 1.94  | 0.057  | [-14430.69, 920002.4] |
| pwtopen | -5403.064 | 2122.56   | -2.55 | 0.013  | [-9646.001, -1160.127] |
| polity | -20465.7 | 22229.98  | -0.92 | 0.361  | [-64902.79, 23971.39] |
| lareapc | -124713.4 | 56856.9   | -2.19 | 0.032  | [-238368.7, -11058.07] |
| _cons | -2215670.0 | 272127.0  | -8.1  | 0.419  | [-7655426, 3224085] |

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0       F(  3,    62) = 1.28            Prob > F = 0.2895
```
Table 3: Environmental degradation equations

IV regressions

* * Estimation of pollution equations, a function of income, trade, democracy and size

.ivreg co2perc (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors Number of obs = 96
F( 6,  89) = 43.49
Prob > F = 0.0000
R-squared = 0.7695
Root MSE = 2.1073

|                      | Coef. | Std. Err. | t     | P>|t| | 95% Conf. Interval |
|----------------------|-------|-----------|-------|-----|-------------------|
| emissions of CO2 per cap       |       |           |       |     |                   |
| inc1                  | .700  | .479      | 1.46  | .147| -.2506002 - 1.651539|
| inc2                  | 3.754 | 1.043     | 3.60  | .001| 1.680344 - 5.827068|
| inc3                  | 6.322 | 1.318     | 4.80  | .000| 3.702777 - 8.940313|
| pwtopen               | -.001 | .010      | -0.06 | .949| -.0213223 - .0199778|
| polity                | -.080 | .037      | -2.19 | .031| -.1529869 - -.0075785|
| lareapc               | .033  | .163      | 0.20  | .840| -.2904868 - .3563754|
| _cons                 | -.876 | 3.184     | -1.53 | .129| -11.20329 - 1.450801|

Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

.test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F( 3, 89) = 37.28 Prob > F = 0.0000

.ivreg defp (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors Number of obs = 92
F( 6,  85) = 10.69
Prob > F = 0.0000
R-squared = 0.2756
Root MSE = 1.1288

|                      | Coef. | Std. Err. | t     | P>|t| | 95% Conf. Interval |
|----------------------|-------|-----------|-------|-----|-------------------|
| annual deforestation |       |           |       |     |                   |
| inc1                 | .545  | .436      | 1.25  | .215| -.3218014 - 1.412437|
| inc2                 | -.736 | .593      | -1.24 | .218| -1.915416 - .4428395|
| inc3                 | -1.262| .510      | -2.48 | .015| -2.75795 - -.2486893|
| pwtopen              | .001  | .003      | 0.71  | .713| -.0055138 - .0080241|
| polity               | .027  | .027      | 1.00  | .320| -.0266874 - .0806927|
| lareapc              | -.078 | .084      | -0.94 | .351| -2.445592 - .087756|
| _cons                | -2.367| 3.035     | -0.78 | .438| -8.401125 - 3.666521|

Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

.test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F( 3, 85) = 11.24 Prob > F = 0.0000
. ivreg enrdam (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors
Number of obs = 93
F( 6, 86) = 3.57
Prob > F = 0.0033
R-squared = 0.1601
Root MSE = 7.0469

| energy depletion | Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval] |
|------------------|-------|-----------|---|------|----------------------|
| inc1             | 8.526 | 3.132     | 2.72 | 0.008 | 2.299406 14.75191 |
| inc2             | 4.257 | 3.654     | 1.16 | 0.247 | -3.006933 11.51994 |
| inc3             | -2.922 | 2.094   | -1.40 | 0.166 | -7.084741 1.240289 |
| pwtopen          | -0.033 | 0.020     | -1.67 | 0.099 | -0.0723321 0.0062907 |
| polity           | -0.521 | 0.190     | -2.74 | 0.007 | -0.8982336 -0.1435188 |
| lareapc          | 0.314 | 0.505     | 0.62 | 0.536 | -0.6895735 1.317237 |
| _cons            | -57.089 | 20.293   | -2.81 | 0.006 | -97.42937 -16.74794 |

Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F(  3,  86) = 6.84  Prob > F = 0.0003

. ivreg no2m (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors
Number of obs = 35
F(  5,  28) = .
Prob > F = 0.0000
R-squared = 0.2120
Root MSE = 39.012

| NO2 | Coef. | Std. Err. | t | P>|t| | [95% Conf. Interval] |
|-----|-------|-----------|---|------|----------------------|
| inc1 | -492.924 | 324.925   | -1.52 | 0.140 | -1158.503 172.6544 |
| inc2 | 207.138 | 100.288   | 2.07 | 0.048 | 1.706976 412.5686 |
| inc3 | -20.821 | 10.991    | -1.89 | 0.069 | -43.3357 1.694193 |
| pwtopen | -.324 | .186     | -1.75 | 0.092 | -.7043395 .0561261 |
| polity | -4.448 | 1.216     | -3.66 | 0.001 | -6.93888 -1.956846 |
| lareapc | -5.792 | 6.445   | -0.90 | 0.376 | -18.99402 7.40949 |
| _cons | 3593.957 | 2331.116  | 1.54 | 0.134 | -1181.117 8369.031 |

Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F(  3,  28) = 4.01  Prob > F = 0.0172
. ivreg sulfdm (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors
Number of obs = 40
F( 6,   33) = 7.78
Prob > F = 0.0000
R-squared = 0.6618
Root MSE = 24.318

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Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F(  3,   33) =  3.36
Prob > F =  0.0302

. ivreg suspm (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors
Number of obs = 37
F( 6,   30) = 9.80
Prob > F = 0.0000
R-squared = 0.7024
Root MSE = 54.128

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Instrumented: inc1 inc2 inc3 pwtopen
Instruments: polity lareapc elhsfs incf1 incf2 incf3

. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F(  3,   30) =  11.71
Prob > F =  0.0000
```
. ivreg water (inc1-inc3 pwtopen = elhsfs incf1-incf3) polity lareapc, robust
IV (2SLS) regression with robust standard errors
Number of obs =      66
F(  6,    59) =    2.18
Prob > F      =  0.0581
R-squared     =  0.0749
Root MSE      =  7.3e+05
------------------------------------------------------------------------------
organic water|               Robust
pollution BOD|      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
inc1 |  1339044     857329.6     1.56   0.124    -376468.5     3054557
inc2 |  -310917.9   382285.7    -0.81   0.419     -1075870    454034.1
inc3 |   645040.4   296639.3     2.17   0.034     51466.46     1238614
pwtopen |   -9960.8    3743.8    -2.66   0.010    -17452.07     -2469.6
polity |  -45944.98   35426.57   -1.30   0.200    -116833.4    24943.43
lareapc |  -168457.5    64550.7    -2.61   0.011    -297623.1   -39291.82
_cons |  -8185083    5717722    -1.43   0.158    -1.96e+07     3256052
------------------------------------------------------------------------------
Instrumented:  inc1 inc2 inc3 pwtopen
Instruments:   polity lareapc elhsfs incf1 incf2 incf3
```

```
. test inc1 inc2 inc3
( 1)  inc1 = 0.0
( 2)  inc2 = 0.0
( 3)  inc3 = 0.0
F(  3,    59) =  1.77  Prob > F =  0.1623
```