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Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve

Mariano Torras, James K. Boyce *

Department of Economics, Thompson Hall, University of Massachusetts at Amherst, Amherst MA 01003, USA

Abstract

Improvements in some measures of air and water quality can accompany rising per capita income, as illustrated by the so-called environmental Kuznets curve. For pollution variables which show such a relationship, we hypothesize that a more equitable distribution of power contributes to these outcomes, by enhancing the influence on policy of those who bear the costs of pollution, relative to the influence of those who benefit from pollution-generating activities. An empirical analysis of international variations in seven indicators of air and water quality supports this hypothesis. Literacy, political rights, and civil liberties are found to have particularly strong effects on environmental quality in low-income countries. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

Mounting public concern over environmental issues has sparked efforts to understand more clearly the reasons for variations in the extent of environmental degradation. One way to address this question, made possible by recent data, is through international comparisons, in which the dependent variable is some measure of environmental quality, and an array of variables which theory suggests might impact on this measure—directly or otherwise—is included on the right-hand side of the regression equation. The few studies (e.g. Selden and Song, 1994; Shafik, 1994; Grossman and Krueger, 1995) which have attempted this have had per capita income as the chief explanatory variable of interest.

The relationship between per capita income and environmental quality depends on scale, composition and technology effects[1]. If the pollution in-

* Corresponding author. Tel.: +1 413 5453815; fax: +1 413 5452921; e-mail: boyce@econs.umass.edu

[1] For a more detailed explanation of these effects, see Grossman (1995) or Grossman and Krueger (1995).

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tensity of aggregate output was fairly constant across countries, we would expect environmental quality to worsen with income, as greater output generates more pollution (the scale effect). On the other hand, environmental quality could improve with income if this scale effect were eclipsed by the combination of the two other effects. With increasing per capita income, the composition of output shifts among sectors which differ in their pollution intensity of output. For instance, the service sector may grow relative to the manufacturing sector. This composition effect can alter the pollution intensity of output. Furthermore, the various sectors of the economy may adopt less-polluting technologies, either because of market-driven technological advance (spurred in part by the internal benefits of resource conservation) or government regulation (including standards, taxes and the creation of tradable emissions permits). There is no a priori reason to assume the relationship between income and environmental quality to be strictly monotonic. Instead, environmental quality may worsen with income within some ranges of income, but improve over others. Also, we should not necessarily expect the same relationship to hold for all dimensions of environmental quality. It is plausible, for example, that government regulatory responses are stronger when the effects of pollution lie primarily within national borders than when their impact is primarily transnational or global (Arrow et al., 1995; Max-Neef, 1995).

Grossman and Krueger (1995), among others, find that for a number of environmental variables, the relationship between per capita income and environmental degradation takes an inverted U-shaped form—that is, environmental quality initially worsens but ultimately improves with income. This apparent empirical relationship has been dubbed the 'environmental Kuznets curve,' because of its similarity to the relationship between per capita income and income inequality first suggested by Simon Kuznets (1955). Grossman and Krueger (1995) found evidence for such a relationship for 12 of the 14 air and water quality variables in their study.

Regrettably, the same incautious policy inference that was often drawn from the original Kuznets curve can be derived from the so-called environmental Kuznets curve. That is, if rising per capita income will ultimately induce countries to clean up their environments, then economic growth itself can be regarded as a remedy to environmental problems. As distributional concerns were subordinated to growth by proponents of 'trickle-down' economic development, so environmental concerns may be downplayed as a transitional phenomenon which growth in due course will resolve[2].

Grossman and Krueger, like Kuznets before them, caution against such a reading of their findings. "Even for those dimensions of environmental quality where growth seems to have been associated with improving conditions", they write (Grossman and Krueger, 1995, p. 371–372), "there is no reason to believe the process is an automatic one…there is nothing at all inevitable about the relationships that have been observed in the past". They suggest that 'an induced policy response' in the form of more stringent and more strictly enforced environmental standards, driven by citizen demand, has provided the strongest link between income and pollution. In so doing, they echo Kuznets (1955, p. 28) original conclusion with respect to income distribution: "Effective work in this field necessarily calls for a shift from market economics to political and social economy".

This insight provides the starting point for the present study. In particular, we investigate possible causal linkages between changes in income distribution, studied by Kuznets and many subsequent authors, and changes in pollution levels—a connection hitherto remarkably absent from discussions of the 'environmental Kuznets curve'. We hypothesize that changes in the distribution of

[2] This concern has been voiced by various critics. For example, Arrow et al. (1995) caution that economic growth is 'no substitute' for environmental policy. Ayres (1995) considers this an understatement and dismisses as 'false and pernicious nonsense' the idea that economic growth is good for the environment. Kaufmann and Cleveland (1995) raise the important related point that long-run sustainability depends not simply on the level of emissions (and resource depletion) but also on the capacity of natural systems to absorb and process wastes (and renew resources).

power are central to the connections between the two phenomena.

Section 2 of this paper briefly recaps the theory behind environmental Kuznets curves, summarizes our approach and presents a model based upon it. Section 3 reviews the data and methodology utilized in our empirical analysis, and Section 4 presents the results. Section 5 examines the peaks and troughs in the relation between income and pollution, and their implications for the relationship between income growth and environmental quality. Section 6 summarizes our findings and offers some concluding remarks.

2. The political economy of environmental Kuznets curves

The environmental Kuznets curve is a 'reduced-form' relationship, in which the level of pollution is modeled as a function of per capita income without specifying the links between the two. Grossman and Krueger (1995, p. 359) characterize these missing links as 'environmental regulations, technology and industrial composition'. In addition to eliminating the need for data on intervening variables, an advantage of the reduced-form approach is that it provides a direct estimate of the net effect of per capita income on pollution.

Two features of Grossman and Krueger's underlying structural model deserve mention. First, while the industrial-composition effect, which accompanies rising per capita income, may lower the marginal pollution intensity of output, it cannot fully offset the scale effect (i.e. the environmental impact resulting from the level of aggregate output) unless more pollution-intensive sectors shrink absolutely. This could happen only if these sectors produce inferior goods, whose consumption falls with rising income, or if their products were replaced by imports. In general, the former condition seems unlikely to hold. The latter simply relocates pollution to other countries.

Second, following on this point, if total pollution declines with rising income, technological change is likely to play a key role. Hicks (1932) distinguished between 'autonomous' and 'induced' innovation: the former is exogenous, the latter endogenous to economic forces. If the technology effect is strong enough to cause total pollution to decline systematically across countries as per capita income rises, induced innovation is the likely cause. Market signals can contribute to the inducement process; for example, rising resource costs may encourage resource-conserving technological change, and a 'greening' of consumer demand may prompt firms to adopt cleaner technologies. But we suspect that government policies—including regulatory standards, pollution taxes and the creation of tradable emission permits—have been the most potent spur to pollution-reducing technological change.

Grossman and Krueger (1995, p. 372) likewise speculate that 'the strongest link between income and pollution in fact is via an induced policy response', and that these policies are in turn induced by popular demand:

> As nations or regions experience greater prosperity, their citizens demand that more attention be paid to the noneconomic aspects of their living conditions. The richer countries, which tend to have relatively cleaner urban air and relatively cleaner river basins, also have relatively more stringent environmental standards and stricter enforcement of their environmental laws than the middle-income and poorer countries. (Emphasis added).

The public-good character of environmental quality means that effective demand requires solutions to market failure. Implicit in such policy-based explanations of the environmental Kuznets curve, then, is a simple theory of induced innovation: as per capita income rises, societies become better able to redress market failure. If this is empirically true, we can ask what it is about higher-income societies that facilitates solutions to market failures. Is it per capita income per se, or other variables historically associated with it?

Grossman and Krueger (1996, p. 120) hint at an answer in a recent comment:

> If environmental improvements are mediated by changes in government policy, then growth

and development cannot be a substitute for environmental policy. In the absence of vigilance and advocacy in each and every location, there is always the possibility that greater output will mean greater consumption of (or waste of) scarce resources. (Emphasis added).

Why might 'vigilance and advocacy' (hereafter 'vigilance' for short) in a society increase with per capita income? One possibility is that individual demand for environmental quality rises. Another is that individuals gain greater power to make that demand effective through the political process.

Not everyone favors policies to reduce all sorts of pollution. Some individuals benefit from economic activities which generate pollution: otherwise these activities would not occur. The beneficiaries are producers who receive a 'pollution subsidy' (Templet, 1995, p. 143) consisting of unspent pollution control dollars, and consumers who reap part of this subsidy via lower prices. In welfare-analytic terms, these benefits take the forms of producers' surplus and consumers' surplus, respectively. Other individuals adversely affected by pollution bear net costs. While the latter exercise vigilance in an attempt to establish or strengthen environmental controls, the beneficiaries exercise counter-vigilance in an attempt to prevent or weaken them.

Define b_i as the net benefit (net cost if $b_i < 0$) to the ith individual from a pollution-generating activity. The normative rule prescribed by benefit-cost analysis is to set the level of pollution so as to maximize aggregate net benefits, that is:

$$\max \sum_i b_i$$

Given declining marginal benefits from the pollution-generating activity, and rising marginal costs from pollution, the socially efficient level of the activity is given by the familiar condition equating marginal benefit to marginal cost.

Boyce (1994, 1996) describes actual policy outcomes by means of a positive 'power-weighted social decision rule' (PWSDR) in which what are maximized are net benefits weighted by power of those to whom they accrue:

$$\max \sum_i \pi_i b_i$$

where π_i = the power of the ith individual (here taken to be exogenous). Becker (1983) ascribes a comparable role to 'influence' in the determination of fiscal policy.

The PWSDR corresponds to the benefit-cost norm only in the special case where all individuals have equal power. When those who benefit from pollution-generating activities are more powerful than those who bear the costs, the PWSDR predicts inefficiently high levels of pollution. The opposite can occur too: if those who bear the costs of pollution are more powerful than those who derive the benefits, the PWSDR predicts inefficiently low levels of pollution.

Which situation is more prevalent depends on the relationship between b_i and π_i. If these are positively correlated, such that those who benefit from pollution-generating activities tend to be more powerful than those who bear the costs, then greater power inequality will be associated with more pollution.

There is reason to expect that net benefit from pollution-generating activities (b_i) is positively associated with individual income. Individuals with higher incomes generally own more assets, and consume more commodities, than those with lower incomes. Hence, they can be expected to enjoy more producers' and consumers' surplus, including that created in pollution-generating activities. This is not to say that higher-income individuals want to breathe dirty air or to drink polluted water. But the vigilance with which they pursue these by public action is muted, if not overwhelmed, by the other arguments in their utility functions. The tension between their taste for environmental quality on the one hand, and for consumer goods and profits on the other, can be eased by channeling their demand for environmental quality into such private and semi-private goods as luxury housing, country clubs and vacations in relatively pollution-free places[3].

[3] It is possible (though not certain) that within a given society, the marginal pollution intensity of consumption (including pollution generated in the production and transport of consumer goods and services, as well as in the act of consump-

Power (π_i), too, is likely to be correlated with income. While this may seem evident to most people, remarkably few modern economists have seen fit to mention it. Simon Kuznets was among the exceptions. In 1963 he suggested that power inequality is a function of both income inequality and per capita income:

> One may argue that not only the welfare equivalents but also the power equivalents of the same relative income spread show a much wider range when the underlying average income is low than when it is high (Kuznets, 1963, p. 49).

We will refer to this as Kuznets' 'unsung hypothesis', since it has received far less attention than his earlier hypothesis of an inverted U-shaped relation between income inequality and per capita income.

Other variables, apart from income distribution, may also affect the distribution of power. These include individual attributes such as race, ethnicity and gender, and the political framework by which these attributes and income are mapped to power. Adding these to Kuznets' unsung hypothesis, we get:

$$\pi = \pi(G, Y, \boldsymbol{X}), \quad \pi_G > 0, \quad \pi_Y < 0 \tag{1}$$

where π = power inequality, G = income inequality, Y = per capita income, and the vector $\boldsymbol{X}$ consists of non-income determinants of power.

The foregoing reasoning leads us to predict that greater power inequality will be associated with higher levels of pollution, as those who benefit from pollution-generating activities are better able to prevail against those who bear the costs. In this paper we test this hypothesis. Our underlying structural model is:

$$POL = f(Y, \pi, \boldsymbol{Z}) \tag{2}$$

where POL = the level of pollution, and $\boldsymbol{Z}$ is a vector of non-economic determinants of pollution levels. Per capita income (Y) is included to allow for possible effects on pollution aside from those mediated by power inequality. In the absence of direct measures of power inequality, we use variables drawn from the right-hand side of Eq. (1) as proxies for π.

We will test the empirical validity of these propositions by means of the following model:

$$POL = \alpha + \beta_1 Y + \beta_2 Y^2 + \beta_3 Y^3 + \delta_1 GINI + \delta_2 LIT + \delta_3 RIGHTS + \gamma_i \boldsymbol{Z}_i + \mu, \tag{3}$$

where POL = the pollution variable being tested; Y = per capita income; $GINI$ = the Gini coefficient of income inequality; LIT = the literacy rate; $RIGHTS$ = political rights and civil liberties; and $\boldsymbol{Z}_i$ is a vector of other (primarily geographical) covariates, such as dummy variables for central cities and coastal zones which are used in the subnational-level regressions and urbanization which is used in the national-level regressions.

All equations are estimated by ordinary least squares (OLS)[4]. For five of our pollution variables we have data from the same sites for several years, but it is not possible to use a fixed-effects model to control for omitted country-specific variables since the power inequality variables (*GINI*, *LIT* and *RIGHTS*) have unique values for each country. An attempt to control for fixed effects would hence result in perfect linear dependence. This problem could be mitigated by compiling time-series data for the power inequality variables, but this is beyond the scope of the present study. Furthermore, the drawback to any fixed-effects estimation is that its focus is on time-series

tion itself) declines with rising individual income. Even were this so, greater income inequality (i.e. redistribution of income from poor to rich) could be associated with greater pollution, if the industrial-composition effect of this redistribution were outweighed by its adverse impact on power inequality and thereby on vigilance, regulation and pollution-reducing technological change. This would be depicted graphically by an outward shift of the curve relating the marginal pollution intensity of consumption to individual income. Our expectation that income inequality is associated with higher levels of pollution is premised on the hypothesis that such technology effects do, in fact, outweigh any distribution-driven industrial composition effects.

[4] Generalized least squares (GLS) estimation yields, without exception, regression coefficients which are virtually identical to the OLS coefficients, but with much smaller standard errors, and hence even higher statistical significance. More important, in our view, is the economic significance of the estimated coefficients (McCloskey and Ziliak, 1996, p. 98).

changes. In contrast, cross-country variations are of primary interest in this analysis[5].

3. Data

3.1. Dependent variables

Altogether we test seven distinct pollution variables. Three atmospheric pollution variables and two water pollution variables are taken from the Global Environment Monitoring System (GEMS) data set, which includes observations from more than 1000 locations worldwide. The other two variables are national-level data on the percentages of the population with access to safe water and sanitation facilities, aspects of environmental quality of particular relevance to the well-being of the poor in low-income countries. A complete variable list is provided in the Appendix.

3.1.1. The GEMS data set

The three atmospheric pollution variables—sulfur dioxide, smoke and heavy particles—and two water variables—dissolved oxygen and fecal coliform—from the GEMS data set were also investigated by Grossman and Krueger. We employ the same data, which cover years spanning 1977–1991. The GEMS air pollution data contain observations from 18–52 cities in 19–42 countries (varying depending on the pollutant). The GEMS water pollution data contain observations from up to 287 stations in 58 countries. All these data are location-specific; the GEMS data set contains no aggregate national measures of pollution. In all cases except for dissolved oxygen, higher values indicate inferior environmental quality; in the case of dissolved oxygen the reverse is true.

Each of the dependent variables we test represents some concentration level, with the exception of fecal coliform. As done by Grossman and Krueger (1995), for fecal coliform we use log $(1+\mu)$ where μ is the concentration level. The reasons are 3-fold: (1) The coliform grow exponentially; (2) the distribution is positively skewed; and (3) we cannot simply use log (μ) because there exist many zero readings (where coliform is below minimum detectable level) and one cannot take the log of zero.

3.1.2. National-level pollution variables

Our national-level variables are the percentage of the population with access to safe water and the percentage with access to sanitation. These data are taken from the United Nations Development Programme (1994). Unlike the GEMS data, these contain no time-series dimension.

3.2. Explanatory variables

3.2.1. Income

Per capita income is measured in real purchasing power parity (PPP) adjusted dollars. Like Shafik (1994) and Grossman and Krueger (1995), we use a cubic functional form for the per capita income variable. An attraction of the cubic form is that while it permits a simple quadratic (U-shaped) relationship (when the estimated coefficient on the cubic term is ~ 0), it allows for second turning point (when it is nonzero). In the case of the GEMS data set, we use the same income data as Grossman and Krueger, taken from Summers and Heston (1991). In the case of the national-level variables, we use 1991 income from the United Nations Development Programme (1994).

3.2.2. Income inequality

As a measure of income inequality we use Gini ratios reported by the World Bank (1996)[6].

[5] Year-to-year variations in income inequality, literacy, or rights within a given country would be unlikely to have strong effects on the level of pollution. In any event, our interest is longer-term determinants of inter-country variations in pollution levels.

[6] The Gini ratio is a standard measure of income inequality employed by economists. It ranges from 0 (perfect equality) to 1 (all income received by one individual). For details on its derivation, see Kakwani (1980). In the case of the OECD countries, we computed Gini ratios from the quintile data reported in the same source.

Three limitations of the available data should be noted. First, there remain many countries for which income distribution data are not available. Hence, using this variable has the effect of diminishing our sample size. Second, despite recent efforts at the World Bank to standardize the data, methodological inconsistencies remain. For example, for some countries the Gini ratios refer to expenditure rather than income. Finally, the accuracy of some of these data is open to doubt. We find it surprising, for example, that the Gini ratio reported for Peru is lower than that reported for Costa Rica, a country with a history of social democracy which is rare among Latin American nations.

3.2.3. Literacy

As another proxy for power equality, we use adult literacy rates for males and females in the year 1992, as reported by the United Nations Development Programme (1994). To the extent that literacy brings greater access to information, and access to information is correlated with power, countries with higher literacy rates can be said to enjoy a more equitable distribution of power.

3.2.4. Political rights and civil liberties

As a further measure of power equality, we employ an aggregate of two variables reported in Finn (1996): political rights and civil liberties in the year 1995. Each is measured on a 1–7 scale, with one meaning the most freedom, and seven the least. We add the two, and subtract this sum from 14 to obtain a 0–12 scale with higher values representing greater freedom.

3.2.5. Urbanization

We include the urbanization rate as an explanatory variable in our national-level regressions. This is the percentage of the country's population living in urban areas, as reported by the United Nations Development Programme (1994). Though urbanization is often associated with greater levels of pollution, it may also facilitate some environmental improvements, for example, through economies of scale in the provision of sanitation facilities.

3.2.6. GEMS control variables

The control variables included in the GEMS air pollution data set are the monitoring stations, proximity to a coastline, the type of area (industrial, residential, commercial) in which the station is found, the cities' population density and the year in which the measurement was taken. The control variables for the water pollution data set are mean water temperature and the year in which the measurement was taken[7].

4. Results

We have estimated Eq. (3) for each of the pollution variables described in the previous section. For comparative purposes, we first estimated the equation with only income and the geographical control variables on the right-hand side. We then included the three power-inequality variables—the Gini ratio of income distribution, literacy and political and civil rights—as additional regressors.

Table 1 presents our regression results, excluding the inequality variables, for the five pollution variables drawn from the GEMS data set. These results are similar to those of Grossman and Krueger (1995)[8]. In the cases of sulfur dioxide and smoke, we obtain the 'Kuznetsian' inverted-U relation: pollution initially rises with per capita income and then declines[9]. However, the statisti-

[7] Following Grossman and Krueger, missing mean temperature observations are estimated from a regression of temperature on latitude for those observations (the majority) for which data are available.

[8] In addition to current income, Grossman and Krueger include average income in the preceding 3 years as a lagged measure. We have not done so here, since lagged income is strongly collinear with current income. Grossman and Krueger themselves note (pp. 361) that 'including just current (or just lagged) GDP per capita does not qualitatively change the results'. Our total numbers of observations differ slightly from those reported by Grossman and Krueger for reasons which are not clear.

[9] Note that in the overwhelming majority of the instances in which we find statistical significance, it is at the 1% rather than the 5% level.

Table 1
The determinants of pollution (GEMS variables): Excluding inequality

Explanatory variable	Sulfur dioxide	Smoke	Heavy particles	Dissolved oxygen	Fecal coliform
Income	$9.71E^{-3}$	$2.69E^{-2}$	$-6.38E^{-2}$	$2.55E^{-4}$	$3.94E^{-4}$
	(4.22)**	(2.51)**	(−7.29)**	(2.01)*	(2.46)**
Income squared	$-1.60E^{-6}$	$-4.37E^{-6}$	$4.67E^{-6}$	$-3.84E^{-8}$	$-2.23E^{-8}$
	(−5.10)**	(−2.51)**	(4.01)**	(−2.06)*	(−0.94)
Income cubed	$6.06E^{-11}$	$1.96E^{-10}$	$-1.17E^{-10}$	$1.99E^{-12}$	$-3.58E^{-13}$
	(5.07)**	(2.24)*	(−2.75)**	(2.63)**	(−0.37)
Central city	13.42	11.86	15.44	—	—
	(6.01)**	(2.74)**	(2.13)*		
Coast	−6.77	−21.15	−51.33	—	—
	(−3.43)**	(−5.63)**	(−8.57)**		
Industrial	3.66	1.91	30.96	—	—
	(1.38)	(0.40)	(3.56)**		
Residential	−2.11	−5.18	7.15	—	—
	(−0.82)	(−1.18)	(0.84)		
Population density	$-1.46E^{-6}$	$1.43E^{-4}$	$-1.38E^{-4}$	—	—
	(−0.07)	(4.59)**	(−1.70)*		
Year	−1.65	−0.77	0.50	−0.06	0.02
	(−5.48)**	(−1.45)	(0.50)	(−2.21)*	(0.46)
Mean water temperature	—	—	—	−0.16	0.09
				(−11.22)**	(4.68)**
Adjusted R^2	0.15	0.27	0.61	0.21	0.06
N	1188	405	854	1931	1484

t-ratios in parentheses.
* Statistically significant at 5% level.
** Statistically significant at 1% level.

cally significant positive coefficients on the cubic term imply that these pollutants eventually resume a rising trend (a point to which we return in the next section). Sulfur dioxide pollution also shows a secular trend to diminish over time (indicated by the statistically significant negative coefficient on the year). Airborne heavy particles monotonically diminish with income (a plot of the curve shows a flattening in the middle-income range due to the positive coefficient on income squared). As expected, central city locations are associated with higher levels of these air pollutants and coastal locations with lower levels.

Table 2
The determinants of pollution (National-Level variables): Excluding inequality

Explanatory variable	Safe water %	Sanitation %
Income	$8.98E^{-3}$	$1.74E^{-2}$
	(3.46)**	(5.42)**
Income squared	$-6.99E^{-7}$	$-1.31E^{-6}$
	(−2.48)**	(−3.76)**
Income cubed	$1.79E^{-11}$	$3.14E^{-11}$
	(1.90)*	(2.69)**
Urbanization rate	0.31	0.17
	(2.78)**	(1.25)
Adjusted R^2	0.64	0.69
N	82	79

t-ratios in parentheses.
* Statistically significant at 5% level.
** Statistically significant at 1% level.

Dissolved oxygen in water improves with income (recall that more dissolved oxygen indicates better water quality). Fecal coliform pollution displays an inverted-U pattern, first rising with income and then declining, though the quadratic and cubic term here are not statistically significant. Higher water temperatures are associated, as expected, with poorer water quality.

Table 2 presents the comparable results for the two national-level environmental quality variables. The percentages of the population with access to safe water and sanitation initially rise with income, then dip slightly, and then resume rising[10]. Urbanization is associated with better access to safe water and sanitation (though not statistically significant for the latter), indicating that in this important respect it tends to have a positive effect on environmental quality.

In testing the impact of the inequality variables, we allow for the possibility that their effects may differ in low-income and high-income countries, as suggested by Kuznets in his unsung hypothesis. Using a $5000 per capita income (in PPP-adjusted dollars) as a dividing line, we create dummy variables for low- and high-income countries. By interacting these with the inequality variables, we estimate separate coefficients for the latter for the two sets of countries.

Our results are reported in Table 3[11]. Comparing these with the results in Tables 1 and 2, we find that the statistical significance of the income effects generally diminishes when the inequality variables are included as regressors. The most striking cases are those of smoke and heavy particles, where the income effects recede into statistical insignificance.

Income inequality, measured by the Gini ratio, has mixed effects. In the cases of sulfur dioxide and smoke, greater income inequality is associated with more pollution in the low-income countries, but not in the high-income countries. Similarly, in low-income countries, income inequality negatively affects the percentage of the population with access to safe water. These findings are consistent with our hypothesis as to the relation between inequality and pollution, and with Kuznets' unsung hypothesis. In the cases of heavy particles and dissolved oxygen, however, we obtain contrary results: greater income inequality in the low-income countries appears to be associated with less pollution. Given the questionable quality of the income-distribution data, however, we do not place great confidence in these findings.

The impact of literacy is, in general, quite consistent with our hypothesis. In the low-income countries, literacy is statistically significantly associated with better environmental quality (less pollution) in the cases of sulfur dioxide, heavy particles, dissolved oxygen and sanitation; in the high-income countries, too, it has statistically significant favorable effects on heavy particles, dissolved oxygen and fecal coliform pollution. Only in the case of smoke in the high-income countries do we obtain a statistically significant coefficient on literacy with the 'wrong' sign.

The estimated coefficients on political rights and civil liberties lend further support to our hypothesis. In the low-income countries, a higher rights score is associated with statistically significant improvements in levels of sulfur dioxide, smoke, heavy particles, dissolved oxygen and fecal coliform; in no case do we find statistically significant contrary effects. In the high-income countries, the impact of the rights variable tends to be weaker: we find statistically significant favorable effects on smoke and fecal coliform, but a statistically significant opposite effect on dissolved oxygen.

For each of our seven pollution indicators, one or more of the power inequality variables thus turns out to have a statistically significant effect in the predicted direction. Their inclusion in the regressions generally reduces the statistical significance of per capita income as a determinant of environmental quality. Literacy and rights show stronger and more consistent effects than the Gini ratio, suggesting that these are better proxies for power inequality[12]. The inequality effects tend to be strongest in the low-income countries, suggesting that Kuznets' insight—that the 'power equivalents' of a given income distribution show a wider range when average income is low—applies to the power equivalents of literacy and rights as well. In sum, our results provide fairly robust support for the hypothesis that greater inequality in the distribution of power leads to more pollution.

[10] Shafik (1994) reports similiar results for access to safe water and for urban sanitation.

[11] For reasons of space we omit the coefficients on the geographical control variables from Table 3.

[12] This could be because literacy and rights are intrinsically more important determinants of the distribution of power, or because the Gini data are unreliable, or both.

Table 3
The determinants of pollution: Including inequality

Explanatory variable	Sulfur dioxide	Smoke	Heavy particles	Dissolved oxygen	Fecal coliform	Safe water (%)	Sanitation (%)
Income	0.01**	0.01	0.02	$-8.00E^{-5}$	$3.89E^{-4}$	0.01	0.02
	(3.28)	(0.46)	(1.27)	(−3.16)**	(1.12)	(4.06)**	(4.02)**
Income squared	$-1.81E^{-6}$	$-2.52E^{-6}$	$-1.76E^{-7}$	$9.88E^{-8}$	$-4.15E^{-8}$	$-9.72E^{-7}$	$-1.07E^{-6}$
	(−3.91)**	(−0.79)	(−0.11)	(3.17)**	(−0.99)	(−3.08)**	(−2.81)**
Income cubed	$6.42E^{-11}$	$1.21E^{-10}$	$-2.37E^{-11}$	$-2.64E^{-12}$	$8.99E^{-13}$	$2.39E^{-11}$	$2.35E^{-11}$
	(3.87)**	(0.83)	(−0.44)	(−2.26)*	(0.57)	(2.32)*	(1.89)*
Gini ratio (low-income)	114.20	106.66	−508.1	6.17	−1.52	−48.00	−10.84
	(5.69)**	(2.92)**	(−5.80)**	(4.84)**	(−0.83)	(−2.58)**	(−0.47)
Gini ratio (high-income)	−87.07	−40.09	96.35	−2.89	−6.64	−30.51	−23.96
	(−3.51)**	(−0.90)	(1.28)	(−1.33)	(−2.37)**	(−0.96)	(−0.63)
Literacy (low-income)	−0.72	−0.46	−4.61	0.02	0.01	−0.12	0.38
	(−4.13)**	(−0.99)	(−10.42)**	(2.25)*	(1.24)	(−1.07)	(2.81)**
Literacy (high-income)	−0.38	2.20	−10.42	0.11	0.07	−0.41	0.13
	(−1.13)	(3.00)**	(−9.07)**	(4.67)**	(2.42)**	(−1.29)	(0.35)
Rights (low-income)	−5.24	−6.18	−16.67	0.08	−0.19	$2.33E^{-3}$	−0.34
	(−8.36)**	(−4.48)**	(−10.50)**	(2.02)*	(−3.43)**	(0.00)	(−0.45)
Rights (high-income)	1.42	−18.59	2.88	−0.51	−0.48	1.18	1.73
	(0.92)	(−4.28)**	(0.63)	(−4.13)**	(−3.13)**	(0.69)	(0.84)
Adjusted R^2	0.22	0.35	0.74	0.23	0.08	0.66	0.72
N	1188	405	854	1931	1484	82	79

t-ratios in parentheses.
* Statistically significant at 5% level.
** Statistically significant at 1% level.

Table 4
Peaks and troughs of pollution functions

Variable	Specification	Peak	Trough
Sulfur dioxide ($)	Excluding inequality	3890	15 425
	Including Inequality	3360	14 034
Smoke	Excluding inequality	4350	10 510
	Including inequality	Income not statistically significant	
Heavy particles	Excluding inequality	Monotonic decrease	
	Including inequality	Income not statistically significant	
Dissolved oxygen	Excluding inequality	Monotonic increase	
	Including Inequality	19 865	5085
Fecal coliform	Excluding inequality	Monotonic increase	
	Including inequality	Income not statistically significant	
Access to safe water	Excluding inequality	11 255	14 925
	Including inequality	6900	20 215
Access to sanitation	Excluding inequality	10 957	16 852
	Including inequality	Monotonic increase	

5. Peaks and troughs: A cautionary note on high-income countries

The results presented in the preceding section suggest that rising per capita income can be accompanied by improvements in air and water quality, and that improvements in the distribution of power play an important role in this outcome. Does this imply that we can be complacent about environmental problems in those countries which have successfully made the transition to high income and declining pollution levels? We think not. An interesting feature of the literature on the environmental Kuznets curve, which marks a departure from the original Kuznetsian literature on income distribution, is the common use of a cubic functional form for income. This allows for the possibility that a downturn in pollution (at the peak of the inverted U) can be followed by a later upturn, that is, a reversal of the tendency for pollution levels to decline with further increases in per capita income.

In many cases, this is precisely what we observe. Table 4 presents the relevant peaks and troughs calculated from our regression results. For example, the levels of sulfur dioxide and smoke peak at a per capita income in the neighborhood of $4000 (in PPP$). Grossman and Krueger (1995, p. 367) report similar results. If we consider per capita income values only up to $15000, we see evidence of the 'Kuznets U', but considering values of income greater than $15000 yields a quite different story: beyond a trough around this income level, the levels of both pollutants rise with income. Grossman and Krueger do not comment on these subsequent upturns, which are apparent for eight of the 12 pollution variables for which they find support for the environmental Kuznets curve hypothesis. These upturns can hardly be called irrelevant; the income levels at which they occur are not terribly high—indeed, many industrialized countries have already exceeded them.

These findings imply that beyond some point, high income levels, rather than being conducive to further improvement in air and water quality, can have the opposite effect. Whether this is true, and if so, why, are questions which deserve further study. One possibility is that the scale effect overshadows the composition and technology effects, as the scope for further improvements in the distribution of power is depleted, or as these generate diminishing returns in terms of pollution-reducing technological change. Another possibility is that rising capita income in the high-income countries has been associated with increasing power inequality. In either event, our results do not offer grounds for complacency regarding the environmental impacts of growth in the high-income countries.

6. Concluding remarks

This study brings 'political and social economy', in Kuznets (1955) phrase, to bear on the analysis of the relationship between per capita income and pollution. We believe, like Grossman and Krueger (1995, 1996), that citizens' demand and 'vigilance and advocacy' are often critical in inducing policies and technological changes which reduce pollution. However, we do not regard these as a simple function of average income. Following Boyce (1994), we hypothesize that more equitable distributions of power tend, ceteris paribus, to result in better environmental quality.

Our regression results generally are consistent with this hypothesis. Literacy and rights appear to be particularly strong predictors of pollution levels in the low-income countries. The estimated effects of per capita income on pollution generally weaken once we account for inequality effects, but they do not disappear altogether. In those cases where higher per capita income continues to be associated with less pollution, there are at least three possible explanations. First, it is likely that our proxy variables do not fully capture income-related changes in power inequality; better controlling for these might further weaken the pure income effects. Second, individual demand for environmental quality may rise with income—and rise more strongly than demand for other goods and services, the production and consumption of which generate pollution—such that even with an unchanged distribution of power, there is greater politically effective demand for environmental quality[13]. Finally, as average income in a given country rises, pollution-intensive production may be relocated to lower-income countries. If so, this may reflect power inequalities among countries, as well as within them[14].

One policy implication of our findings is that, in the developing countries, the growth of per capita income can be accompanied by improvements in at least some important dimensions of environmental quality. We agree with Grossman and Krueger (1996, p. 122) that 'putting brakes on economic growth in the developing world is not an acceptable, or even a wise, response to the pressing environmental concerns of our time'. To this, however, we would add two further policy implications.

First, promoting more equitable power distributions in the developing world is a wise response. Our findings indicate that efforts to achieve a more equal distribution of power, for example, via more equitable income distribution, wider literacy, and greater political liberties and civil rights, can positively affect environmental quality. The effects of these variables appear to be particularly strong in low-income countries. From an environmental standpoint, then, the distribution of power is not a peripheral concern.

Second, we cannot assume that environmental improvements will continue to accompany further growth of per capita income in those countries which have already attained high average incomes. For countries in the upper-income range, there is evidence that rising average income is associated with renewed deterioration in some dimensions of environmental quality. The extent to which this trade-off can be relaxed through social, political and technological changes remains an open question.

[13] Note that politically effective demand for public goods requires institutional solutions to the free-rider problem.

[14] As Arrow et al. (1995), p. 92) observe, 'reductions in one pollutant in one country may involve increases in other pollutants in the same country or transfers of pollutants to other countries'. In a study of industrial composition effects, Rock (1996) finds evidence that developing countries with more outward-oriented trade policies tend to have higher pollution intensities of GDP. Inequality across nations and its consequences for the global environment is a promising area for future empirical work.

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Appendix A. Variable list

Variable	Mean	N	Source
SO_2 median ($\mu g/m^3$)[a]	33.23	1297	GEMS
Smoke median ($\mu g/m^3$)	42.56	484	GEMS
Heavy particles median ($\mu g/m^3$)	149.68	916	GEMS
Dissolved O_2 mean (mg/l)[b]	7.9	2054	GEMS
Fecal coliform mean log ($1+\mu$ /100ml)	5.58	1569	GEMS
% Access to safe water	72.38	142	United Nations Development Programme (1994)
% Access to sanitation	65.24	139	United Nations Development Programme (1994)
Per-capita income ($)	6859.25	—	Summers and Heston (1991)[c]; United Nations Development Programme (1994)
Coast (1 = close to coast; 0 = not)	0.56	—	GEMS
Central city (1 = central city; 0 = not)	0.54	—	GEMS
Industrial (1 = industrial; 0 = not)	0.29	—	GEMS
Residential (1 = residential; 0 = not)[c]	0.36	—	GEMS
Population density (pop./sq. mile)	34 970.5	—	GEMS
Year	—	—	GEMS
Mean water temperature (°C)[d]	19.58	—	GEMS
Gini coefficient	0.41	—	World Bank (1996)
% Literate	75.4	—	United Nations Development Programme (1994)
Political rights and civil liberties (0–12 scale)	6.35	—	Finn (1996)
% Urbanized	50.1	—	United Nations Development Programme (1994)

[a] Micrograms per cubic meter.

[b] Milligrams per litre.

[c] Includes extrapolations made by Grossman and Krueger for years after 1988.

[d] For missing values temperature was estimated from latitude data.

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