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Growing up and cleaning up: The environmental Kuznets curve redux

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A B S T R A C T

Borrowing from the Kuznets curve literature, researchers have coined the term "environmental Kuznets curve" or EKC to characterize the relationship between pollution levels and income: pollution levels will increase with income but some threshold of income will eventually be reached, beyond which pollution levels will decrease. The link between the original Kuznets curve, which posited a similar relationship between income and inequality, and its pollution-concerned offspring lies primarily with the shape of both curves (an upside-down U) and the central role played by income change. Although the EKC literature has burgeoned over the past several years, few concrete conclusions have been drawn, the main themes of the literature have remained constant, and no consensus has been reached regarding the existence of an environmental Kuznets curve. EKC research has used a variety of types of data and a range of geographical units to examine the effects of income levels on pollution. Changes in pollution levels might also be at least partly explained by countries' position in the demographic transition and their general population structure, however little research has included this important aspect in the analysis. In addition, few analyses confine themselves to an evaluation for one country of the long-term relationship between income and pollution. Using United States CO_2 emissions as well as demographic, employment, trade and energy price data, this paper seeks to highlight the potential impact of population and economic structure in explaining the relationship between income and pollution levels.

Introduction

The question whether environmental quality will improve or decline as countries develop continues to play a prominent role in environmental research and policy. In the 1970s and 1980s the debate centered on the limits to growth (Meadows, Meadows, Randers, & Behrens, 1972) and the roles that technology and population may play in overcoming those limits (Somin & Kahn, 1984). First, emphasis was placed on the adequacy of natural resources to sustain economic growth and development. Then, as scientific evidence about eutrophication, acid rain, stratospheric ozone depletion and global warming increased, focus shifted towards the limits to environmental waste absorption. Much of the early debate was played out with the use of large-scale systems dynamics models (Barney, Kreutzer, & Garrett, 1991), carefully selected empirical evidence (e.g. Barnett, 1979; Smith, 1979), or narrowly-conceived theoretical investigations (e.g. Solow, 1974). The 1990s and 2000s have seen a revival of the debate – this time driven by empirical investigations into relationships first between pollution and development and later between environmental degradation, more broadly defined, and development.

Borrowing from the Kuznets curve literature (Kuznets, 1955, 1998), which posits that the relationship between income and inequality follows an inverted U, researchers coined the term "environmental Kuznets curve" or EKC to characterize the relationship between pollution levels and income: pollution levels will increase with income but some threshold of income will eventually be reached, beyond which pollution levels will decrease (Grossman, 1995; Grossman & Krueger, 1995). The underlying logic behind the EKC presumed environmental quality to be a normal good, demand for which increases as income increases. Economies of scale, resource-saving technological change in the extractive and manufacturing sectors, trade liberalization leading to "out-migration" of dirty processes, and development of regulatory mechanisms and institutions to stimulate environmental protection, are all seen to contribute to a country's improved environmental quality as economic development takes place (Andreoni & Levinson, 2001; Ausubel, 1996; Komen, Gerking, & Folmer, 1997; Panayotou, 1993; Suri & Chapman, 1998).

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The policy implications of the EKC have aptly been described as "grow first, then clean up" (Beckerman, 1992; Dasgupta, Laplante, Wang, & Wheeler, 2002), a conclusion in stark contrast to the observation that economic growth itself is at the root of environmental harm (Hueting, 1991). The ensuing debate attracted more detailed empirical analysis as well as theoretical research in the hopes of either substantiating or refuting the postulated relationships between environmental quality and development. Academic and policy discourse over the validity of the EKC logic and the methods used to uphold it has generated a rich literature on the topic, too extensive to thoroughly review here. Several key themes, though, have emerged that cast doubt on past analyses.

First, the simple cross-sectional empirical work, on which much of the early EKC literature rested, has been dismissed by some for doing injustice to the unique development paths of individual countries or regions of a country (List & Gallet, 1999; Stern, 1998; Unruh & Moomaw, 1998). For example, while one group of countries or regions may undergo increases in pollution with increased development, others may exhibit the reverse behavior (Fig. 1). Grouping them together in a cross-sectional analysis will consequently lead to an inverted U pattern that does not adequately describe the behavior of *any* of the countries.

To ameliorate the shortcomings of simple cross-sectional analysis, panel data have been used to estimate EKC regression models of the forms such as

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \beta_t + \gamma_1 \ln\left(\frac{G}{P}\right)_{it} + \gamma_2 \ln\left(\frac{G}{P}\right)^2_{it} + \varepsilon_{it}$$

where E are annual emissions, P is population, G is income or GDP, and the first two terms on the right hand side of the equation are intercepts which vary across countries i and years t. The parameters γ capture influences of per capita GDP (G/P) and its squared values, α_i captures variation across all spatial units that does not change over time and β_t accounts for explanatory information that is time-varying but affects all spatial units. The error term of the equation is ϵ_{it} and, in a fixed effects model, the errors are assumed to be uncorrelated over time for each spatial unit. If α, β and the explanatory variables are correlated, then a model that treats α and β as components of the random disturbance ε (i.e. a random effects model) cannot be estimated consistently. Several studies have found this to be the case (see Stern, 2004 for a review, and Dijkgraaf & Vollebergh, 2005) and proceeded to estimate α and β as fixed effects regression parameters. Because the estimated parameters are conditional upon the country and time effects in the selected sample of data, however, they cannot be generalized to other samples of data (Hsiao, 1986), limiting the insights that can be generated from industrialized countries' behaviors for future emissions paths of developing countries.

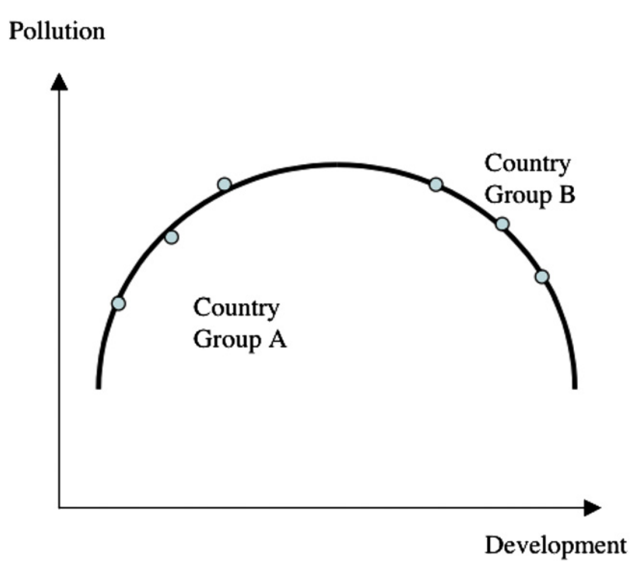

Fig. 1. The Kuznets curve in cross-sectional analysis.

Second, per capita GDP and per capita emissions (as well as their logarithmic transformations) are typically considered to be unit root non-stationary processes (Bradford, Fender, Shore, & Wagner, 2005) and methods for (non-stationary) panel data are usually used. However, as Wagner (2008) points out, the strong independence assumption required for the application of first generation methods for cross-sectionally independent panels may not hold, and regressors involving nonlinear transformations of unit root process behave differently from the linear unit root cases usually considered because the stochastic behavior is fundamentally changed by such transformations. Thus, despite considering potential unit root behavior, several papers (e.g. Perman & Stern, 2003) fail to acknowledge implications of nonlinear transformations. Developing and deploying adequate methods for nonlinear transformations of integrated regressors in non-stationary panels remains an area of active research (e.g. Breitung, 2000, 2005), whose findings may further challenge past EKC analyses.

A third important point lies in the distinction between local and transnational air pollutants. Presumably, developing countries are concerned more with immediate environmental quality related to urban air or drinking water rather than with global environmental quality related to stratospheric ozone depletion or the greenhouse effect. Wealthy consumers in industrialized nations, in contrast, may be more able to distance themselves from the environmental repercussions of their material and energy consumption and may show heightened concern about global environmental impacts. As industrialized countries push off dirtier processes to the developing world, environmental performance, as measured by emissions or concentrations of local pollution, may improve in these countries. The EKC would then suggest that the developing world could do so too in due course. The extent of such advancements will depend, in part, on the diffusion of cleaner technology to developing countries, which, in turn, may be driven by international environmental standards and on efforts by multi-national companies to raise standards in the countries in which they invest. Empirical evidence, however, seems to suggest the opposite – "transnationally controlled manufacturing within less-developed countries is relatively less ecoefficient and also contributes to the overall scale of environmental degradation" (Jorgenson, 2009, p. 71).

The choice of a particular environmental quality indicator or type of pollution – emissions or local concentrations, regional or trans-boundary pollutants – that is used in empirical analysis will determine whether an inverted U can be found and how it is shaped, and thus limit the generalizability of empirical findings across countries and time (Barbier, 1997; Kaufmann, Davidsdottir, Graham, & Pauly, 1998). Even if an inverted U exists for some kinds of pollution, such as the usual culprits SO_2, NO_x and CO_2, changes in technology and changes in demand for products may result in the rise of other pollutants (e.g. metals, dioxins), suggesting that, still, economic growth may not be compatible with long-term environmental improvement (e.g. Dasgupta et al., 2002, Perman & Stern, 2003).

Additional critiques have centered on differences in the quality of data used in cross-sectional studies (Dasgupta et al., 2002), the high degree of sensitivity of statistical results to variable choice and model specification (Harbaugh, Levinson, & Wilson, 2002), the