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ANALYSIS

Taking the "U" out of Kuznets
A comprehensive analysis of the EKC and environmental degradation

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ABSTRACT

Unlike most Environmental Kuznets Curve (EKC) studies which focus on narrow measures of pollution as proxies for environmental quality, we test the validity of the EKC using the Ecological Footprint (EF), a more comprehensive measure of environmental degradation. We find no empirical evidence of an EKC relationship between the EF and economic development, and only limited support for such a relationship among the components of the EF. In addition, we discover that energy is largely responsible for the lack of an EKC relationship, and that energy consumption levels would have to be cut by over 50% in order for a statistically significant EKC relationship to emerge from the data. Overall, these results suggest that growth alone will not lead to sustainable development.

1. Introduction

If the Environmental Kuznets Curve (EKC) is valid for all types of environmental degradation, then sufficient economic development alone will solve environmental problems in both developed and underdeveloped nations. Not surprisingly, this simple yet powerful implication has played an important role in the ongoing debate regarding appropriate economic growth and environmental policies (Ranjan and Shortle, 2007). Unfortunately, most of the empirical investigations of the EKC have focused on the narrow relationship between pollution output (as an inversely proportional proxy for environmental quality) and economic growth. These particular pollutants are only a small part of environmental concerns at the global level. Consequently, the analysis performed in this paper tests the validity of the EKC using a much more comprehensive measure of environmental degradation, the Ecological Footprint (EF).

Research on the validity, application, and measurement of the Environmental Kuznets Curve (EKC) has been prolific (Azomahou et al., 2006). Adapted from Kuznets' (1955) original study on the influences of economic development on income inequality, the EKC reflects the relationship between environmental quality and per capita income. The EKC asserts that

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environmental quality first declines (traditionally measured by an *increase* in pollution) in response to economic development, and improves (i.e. pollution levels *decline*) only after per capita income surpasses a critical threshold. This combination of falling then rising environmental quality (as measured by pollution output) during the course of economic growth and resulting development results in an inverted "U" shaped curve.

Research on the EKC began with the analysis of panel data on 42 countries to identify an EKC effect for different measurements of air quality (Grossman and Krueger, 1993). In the same genre, Selden and Song (1994) found support for an EKC for SO_2, while Grossman and Krueger (1995) andShafik and Banyopadhyay (1992) found water pollution to decline monotonically with income per capita while carbon emissions rise with income per capita. Since these initial studies, many have followed, focusing specifically on air pollution (i.e. List and Gallet, 1999; Heerink et al., 2001; Cole, 2003; Khanna, 2002; Bruvoll et al., 2003; Deacon and Norman, 2006; Merlevede et al., 2006; water pollution (Torras and Boyce, 1998; Paudel et al., 2005), deforestation (i.e. Culas, 2007; Rodriguez-Meza et al., 2003; Heerink et al., 2001; Barbier, 2001), hazardous waste and toxins (i.e. Gawande et al., 2001; Rupasingha et al., 2004), carbon dioxide (CO_2) (Azomahou et al., 2006) among others (see Cavlovic et al., 2000; Dasgupta et al., 2002; Copeland and Taylor, 2004 for reviews). One result of this expansive literature is that no simple, predictable relationship between an aggregate measure of environmental quality and per capita income has been identified; instead the EKC has been found to hold only for a subset of environmental measures (Stern, 1998; Plassmann and Khanna, 2006).

Several shortcomings along with inconsistencies in theoretical modeling have lead to strong criticisms of the EKC (Müller-Fürstenberger and Wagnerb, 2007; Perman and Stern, 2003). Critics have challenged both the findings (especially those based on cross-sectional data) and policy implications of these studies (Dasgupta et al., 2002); pointing out that the results are often sensitive to the nations (or states) chosen, the pollutant measurement (emissions versus ambient concentrations), trade effects, functional form, and methodological choice (Harbaugh et al., 2002; also see Cavlovic et al., 2000). And, since much of the analysis on the EKC is derived from reduced-form models, a variety of (sometimes conflicting), theoretical explanations can apply. For example, several studies have proposed the "new toxins" scenario may exist in which the traditional pollutants exhibit an inverted U-shape in relation to increases in income; however the pollutants that replace these do not, leading to an overall increase in environmental degradation (Stern, 2004). In addition, an important conclusion that can be drawn from a summary of the literature is that greenhouse gasses, in particular CO_2, exhibit an increasing—and even "U" (not inverted) shaped—relationship with growth (Galeotti et al., 2006; Azomahou et al., 2006).

Perhaps the greatest limitation of earlier EKC studies is their singular focus on one (or a small group of) pollutants as their measure of environmental quality. While the implications of single pollutants on health and the environment are important issues to address, the impact of individual decisions on the entire suite of pollutants along with potentially irreversible damage to ecosystems is of equal or greater importance since the substitution possibilities between different pollutants could negate any positive impacts on the environment noted for a single source. Notable exceptions to these studies on single pollutants include Rupasingha et al. (2004), Jha and Murthy (2003), and Boutaud et al. (2006).

Recently, greater effort has been made to construct comprehensive measures of environmental quality. For example, Jha and Murthy (2003) estimate global environmental degradation with an environmental degradation index (EDI) incorporating six environmental indicators: annual per capita fresh water withdrawal, annual fresh water withdrawal as a percentage of water resources, per capita paper consumption, per capita CO_2 emissions, share of world CO_2 emissions, and the average annual rate of deforestation. While broader than a single pollutant, the EDI is limited as a measurement of overall environmental quality by available data. Strong arguments could be made for the inclusion of a different or more inclusive set of environmental indicators. Finally, Boutaud et al. (2006) exam the relationship between the Ecological Footprint (EF) and Human Development Index (HDI) and growth. While Boutaud et al. (2006) include aggregate indices to test for an EKC, the authors rely on cross-sectional data for a single year and graphical representation of the data, resulting in analysis that is not conducive to hypothesis testing. This paper builds on this more inclusive approach with the development of a theoretical framework incorporating environmental capital into the carrying capacity of a nation and an empirical model utilizing a time series of 40 years of data on GDP and an aggregate measurement of environmental damage called the Ecological Footprint. More specifically, the goal of the analysis is to determine whether an EKC can be identified for this cumulative measurement of environmental degradation.

The remainder of the paper is organized as follows: Section 2 discusses the Ecological Footprint; Section 3 derives necessary conditions if both strong sustainability and balanced economic growth are to be achieved; Section 4 describes the data used in the panel regressions; Section 5 describes the various EKC panel models and their estimation results; and Section 6 concludes.

2. The Ecological Footprint

The Ecological Footprint (EF) was introduced by Rees (1992) and further developed in Wackernagel and Rees (1996) to determine how the environmental damage associated with human consumption compares to the biosphere regenerative capacity. The EF estimates the amount of natural capital (measured in biologically productive area) needed to support the resource demand and waste absorption requirements of a population and is expressed in global hectares or hectares of globally standardized bioproductivity (Wackernagel et al., 2004a,b). Specifically, the EF "measures the human demand on nature by assessing how much biologically productive land and sea area is necessary to maintain a given consumption pattern" (Wiedmann et al., 2006). In the basic calculation of the EF, consumption (categorized by food, services, transportation, consumer goods, and housing) is divided by the predetermined yield (biological productivity) by land type