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The environmental Kuznets curve hypothesis for water pollution: Do regions matter?

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ABSTRACT

This study revisits the environmental Kuznets curve (EKC) hypothesis for water pollution by using a recent dynamic technique, which is the generalized method of moments (GMM) approach, for a board sample of 97 countries during the period 1980–2001. On a global scale, as we cannot obtain the EKC relationship between real income and biological oxygen demand (*BOD*) emissions, this paper further classifies these countries into four regional groups – Africa, Asia and Oceania, America, and Europe – to explore whether the different regions have different ECK relationships. The empirical results show evidence of the inverted U-shaped EKC relationships' existence in America and Europe, but not in Africa and Asia and Oceania. Thus, the regional difference of EKC for water pollution is supported. Furthermore, the estimated turning points are, approximately, US$13,956 and US$38,221 for America and Europe, respectively.

1. Introduction

As countries develop their economies, their citizens obtain higher living standards, yet during their process of economic development and industrialization, pollution problems will arise. Many goods produced are usually accompanied by flare gas and wastewater, which cause air and water pollution, respectively. Additionally, when countries attempt to simulate their economic growth, they should also pay attention to the problems of pollution produced during the process of production to not harm their residents. Earlier studies about the relationships between income and environmental degradation are "unfortunately blurry" due to there being different results for different countries in the same region, different time periods within the same country, and different methodologies in different regions (see Table A1). Moreover, the few research efforts on the environmental Kuznets curve (EKC) hypothesis for water pollution use a dynamic panel framework. This paper contributes to the literature by employing the recent dynamic panel generalized method of moments (GMM) method to overcome econometrics limitations and to address the problem of irreversibility. We further use the regional panels to overcome the lumping problem.

The purposes of this study are as follows. First, this study uses a panel dataset spanning the period 1980–2001 to investigate the EKC relationship between real income and water pollution indicator – i.e., biological oxygen demand (*BOD*) emissions for a board sample of 97 countries – by utilizing the dynamic panel GMM technique. As such, this is one of our major contributions and differs from previous studies. Second, this study classifies 97 countries into four regions (Africa, Asia and Oceania, America, and Europe) to re-examine the EKC hypothesis for *BOD* emissions. One thing worth noting is that using panel data creates another problem in which different countries as a whole are treated as an entity and not as a separate unit (see Lee and Lee, 2009). As a result, we cannot identify the difference in the EKC hypothesis among countries.

Due to a lack of available data, previous studies utilize cross-sectional datasets to examine the EKC hypothesis. The estimators of the purely cross-sectional model, however, produce econometric problems resulting from country-specific effects and endogeneity, and the conclusions reached may not carry forward to differences within countries over time. To control for country-specific effects, recent studies test for the EKC hypothesis using panel data techniques. Although the traditional "static" panel data models (fixed effect and random effect models) solve the problem of not considering the country-specific effect, the potential endogeneity of all explanatory variables still exists and does not take the processes of dynamic adjustment into account. Coondoo

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and Dinda (2002) and Dinda (2004) determine that the EKC hypothesis is actually the result of the dynamic process of change. Chimeli and Braden (2005) specify that the advantage of focusing on a dynamic economy's steady state rather than a simpler static model is that we can put the cross-sectional EKC into stark relief by analyzing economies whose environmental quality exhibits a monotonic path to the steady state. As such, we may obtain inefficient estimates of the long-run parameters in the static regressions (Banerjee et al., 1993; Baltagi, 2008).

Coondoo and Dinda (2002) argue that a change in the level of economic activity causes a change in the environmental quality as well as vice versa. The direction of causality between the level of income and environmental quality is not always unidirectional causality from the level of income to environmental quality. Furthermore, when environmental degradation shows irreversibility, higher levels of economic growth cannot be sustained (Arrow et al., 1995). Therefore to reduce biases of estimators, real income per capita should be treated as an endogenous variable, and real income and environmental quality should be considered simultaneously when we examine the EKC hypothesis (Coondoo and Dinda, 2002; Ewijk and Wijnbergen, 1995; Stern et al., 1996; Tahvonen and Kuuluvainen, 1993).

To improve the above econometric problems, this study applies a dynamic panel GMM technique developed by Arellano and Bond (1991), of which to our knowledge, no existing studies use the dynamic GMM technique to examine the relationship between real income and water pollution. The EKC process may be dynamic, with current realizations of the dependent variable influenced by past ones. The general estimators are designed for situations with few time periods and many countries, with independent variables that are not strictly exogenous, with fixed effects, and with heteroskedasticity and autocorrelation within countries.

The environmental quality of countries may be influenced by their neighboring countries (Ansuategi, 2003; Helland and Whitford, 2003; Gray and Shadbegian, 2004; Maddison, 2006; Sigman, 2002). Sigman (2002) investigates the effects of spillover on *BOD* concentrations and indicates that monitoring stations on international borders may have higher *BOD* concentrations. Helland and Whitford (2003) find that establishments located on border of the US have air and water emissions that are 604% and 55% higher than ones located not on the border of the US. Thus, another contribution of this study is to resolve the "lump-together" problem in using panel data (Huang et al., 2008), and we assess whether the EKC hypothesis is supported depending on countries classified by region. It is expected that the empirical results will lead to different policy implications and strategies for all four regions.

The remainder of this paper is organized as follows. Section 2 reviews previous research in the empirical literature that examines the EKC hypothesis for various environmental degradation indictors. Section 3 introduces the dynamic panel GMM technique. Section 4 establishes the EKC empirical model and illustrates the variables' definitions and data sources. Section 5 provides the empirical results. Section 6 provides policy implications, and a conclusion is offered in Section 7.

2. Literature review

The degrees of water pollution become more acute over time and damage human and livestock health. Reddy and Behera (2006) illustrate that high levels of water pollution have adverse effects on human and livestock health and on crop production. Russell and Vaughan (1982) and Massey et al. (2006) state that water quality improvements lead to an increase in fish population, as fish living in polluted water may easily die. Koshal (1976) argues that an increase in the use of 'pure' water will decrease death rates due to certain diseases. Mara (2003) also finds that the macroeconomic toll of water- and excreta-related disease is incredible. Alemagi (2007) argues that oil membrane on the surface of water hinders oxygen in the air from dissolving in water, and thus oxygen deficiency in water is mortal to underwater life.

This section reviews the empirical study of the EKC relationship between real income and various environmental degradation indicators. An increase in real income can influence the environmental quality through three effects: scale, composition, and technique effects (Copeland and Taylor, 2004; Grossman, 1995; Grossman and Krueger, 1995). The scale effect means that when the economy is scaled up, more pollution will be generated. The composition effect specifies that the composition of output moves among those sectors which have different pollution intensity of output as the real income increases. The technique effect is that the sectors of the economy adopt less-polluting technologies to produce goods, and thus a decrease in emission intensity will reduce pollution. In brief, as the economy grows, pollution will increase via the scale effect, but decrease via the composition and technique effects. Therefore, the EKC hypothesis means that as countries' economies develop, in the early stage their environmental quality may decrease (the scale effect is larger than the composition and technique effects) and then improve (the composition and technique effects are larger that the scale effect) at a later stage.

In recent years, many empirical studies have appeared that test the EKC hypothesis. These studies utilize many different environmental degradation indictors, different estimated countries as well as regions, and different econometric techniques to examine the EKC hypothesis (Ekins, 1997). However, they do not always find evidence of the EKC relationship between real income and environmental quality, implying that the EKC's empirical results are fragile in terms of consistency with the views of Harbaugh et al. (2002). Harbaugh et al. (2002) find that the relationship between pollution and *GDP* is sensitive to sample selection and empirical specification, and that there is little empirical support for the EKC.

The pioneering study of Grossman and Krueger (1991) investigates the EKC hypothesis, and they find evidence of an inverted U-shaped relationship between real income and environmental degradation with the estimated turning points at US$4772 to US$5965. Following Grossman and Krueger (1991), there have been plenty of empirical studies in the literature in recent years (see Table A1). Based on the adopted data type, these existing studies in the literature can be classified into three categories: cross-sectional data, time series data, and panel data.

By using cross-sectional data, Panayotou (1993) estimates the relationship between *GDP* and four environmental quality indictors – i.e., sulphur dioxide (SO_2), nitrous oxides (NO_x), suspended particulate matters (SPM), and deforestation – and finds an inverted U-shaped relationship between income and environmental degradation. Torras and Boyce (1998) find evidence of N-shaped relationships in the case of SO_2 and smoke, whereas inverted N-shaped relationships exist in the case of heavy particles and dissolved oxygen (DO). After utilizing time series data, Friedl and Getzner (2003) and Focacci (2005) estimate the relationship between real income and carbon dioxide (CO_2) emissions. Friedl and Getzner (2003) show an N-shaped relationship between real income and CO_2 in Austria, whereas Focacci