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Environmental Kuznets Curve in China: New evidence from dynamic panel analysis ☆

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HIGHLIGHTS

- We apply dynamic panel estimations to study the EKC hypothesis with Chinese panel data.
- Our study covers three indicators: carbon dioxide, waste water, and waste solid emissions.
- We find robust support for the EKC hypothesis for all three indicators of pollution.
- Energy consumption has significantly positive effects on all three pollutant emissions.
- Trade and urbanization may have harmful environmental impacts in the long run.

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ABSTRACT

This paper applies a panel of 28 provinces of China from 1996 to 2012 to study the impacts of economic development, energy consumption, trade openness, and urbanization on the carbon dioxide, waste water, and waste solid emissions. By estimating a dynamic panel model with the system Generalized Method of Moments (GMM) estimator and an autoregressive distributed lag (ARDL) model with alternative panel estimators, respectively, we find that the Environmental Kuznets Curve (EKC) hypothesis is well supported for all three major pollutant emissions in China across different models and estimation methods. Our study also confirms positive effects of energy consumption on various pollutant emissions. In addition, we find some evidence that trade and urbanization may deteriorate environmental quality in the long run, albeit not in the short run. From policy perspective, our estimation results bode well for Chinese government's goal of capping greenhouse emissions by 2030 as outlined in the recent China-US climate accord, while containing energy consumption and harm effects from expanding trade and urbanization remains some environmental challenges that China faces.

1. Introduction

China has experienced a period of extraordinary economic growth since the economic reform in 1978. When viewed in totality of both its magnitude and its duration, the average growth rate of around 9% in (real) per capita GDP from 1978 to 2012 is truly miraculous. Along with this remarkable economic growth process, China has also witnessed a considerable and rapid rise in pollution. China surpassed the U.S. as the largest carbon dioxide emitter in year 2008 and remained at the No. 1 spot ever since, reaching 9208.05 million tons of carbon dioxide emission in year 2012 (26.72% of the world's total).[1] The massive run up of pollution emission has brought about serious environmental problems in China, as well as heated debate on how economic growth affects environmental quality and whether China's high growth is sustainable once more environment-friendly policies are implemented. Of particular interest to this debate is the study of the Environmental Kuznets Curve (EKC), according to which environmental quality deteriorates with economic development at low levels of income but improves with further economic development

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[1] See BP's Annual Statistical Review of World Energy, available from the website: http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy-2013.html.

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at high levels of income.

In the seminal work of the EKC literature, using a cross-country dataset at city level, Grossman and Krueger (1991) found that the air pollution measures (SO_2, dark matter, and suspended particles) increase with income at first but decreases once per-capita GDP reaches a certain threshold value. By examining additional indicators of air pollution and a dataset at country level, Selden and Song (1994) and Holtz-Eakin and Selden (1995) found a similar inverted-U relationship between per-capita income and air pollutant emissions. Grossman and Krueger (1995) further expanded their previous work by considering more comprehensive measures of environmental (both air and water) quality and confirmed the EKC hypothesis.

Subsequent studies on the environment-growth nexus often incorporated other factors (other than per-capita income) that may affect environmental quality in order to mitigate the omitted variables biases in the earlier EKC studies. This multivariate framework helps us understand both how these non-income factors contribute to environmental degradation individually and whether the EKC hypothesis still survives after controlling for these relevant variables. Some frequent variables that researchers introduced into the EKC study include, among others, energy consumption, international trade, and urbanization (see, e.g., Torras and Boyce, 1998; Farzin and Bond, 2006; Jalil and Mahmud, 2009; Qu and Zhang, 2011; Wang et al., 2011; and Jayanthakumaran et al., 2012).[2]

The inclusion of energy consumption in studying environmental conditions is an obvious choice, given its well-known, scientific impacts on generating pollution. It comes as no surprise that researchers have consistently found that the effects of energy consumption on a variety of environmental pollutants are significantly positive in previous EKC estimations (as in, for example, Ang, 2009; Baek and Gweisah, 2013; Liu, 2005 and Nasir and Rehman, 2011).

While openness to trade is also regarded as an important determinant of environmental quality, its impact is generally less clear. As articulated in Grossman and Krueger (1991), there are three major environmental effects associated with trade openness: a scale effect arising from the ensuing expansion of production; a composition effect due to the shifting of “dirty” industries to developing countries; and a technique effect because of the better abatement technology brought about through trade. From a developing country's perspective, the first two effects tend to bring environmental deterioration while the third effect tends to improve its environment quality. This ambiguity in environmental impact of trade is well reflected in the literature. Some studies found negative effects of trade on environmental quality (Ang, 2009; Jalil and Feridun, 2011; Nasir and Rehman, 2011); others reached the opposite conclusion (Birdsall and Wheeler, 1993; Ferrantino, 1997; Grether et al., 2007); while still others obtained insignificant long-run effects of trade from estimating ARDL models (Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012).

Similarly, urbanization has been taken into account in previous EKC studies and shown to have mixed effects on environmental conditions. On the one hand, a higher level of urbanization tends to raise the per capita pollutant emissions due to industrial concentration and congestion in urban areas (Panayotou, 1997); on the other hand, urbanization can be beneficial for environment protection due to the economies of scale advantage in abatement technology in urban relative to rural areas (Torras and Boyce, 1998), and because it is more conducive in mobilizing people's effort in urban areas to influence environmental protection policies (Rivera-Batiz, 2002; Farzin and Bond, 2006). Meanwhile, the role of urbanization turned out to be insignificant in the study by Qu and Zhang (2011).

The fast economic growth in China, coupled with its enormous demand for energy consumption to fuel the economy and rapidly-rising environmental pollution, has made it an interesting subject of investigation in a number of recent EKC studies. By estimating autoregressive distributed lag (ARDL) models with time-series data and different control variables, Jalil and Mahmud (2009); Jalil and Feridun (2011), and Jayanthakumaran et al. (2012) supported the existence of long-run inverted-U relationship between carbon dioxide (CO_2) emissions and per-capita GDP in China. Song et al. (2008) applied the bias-corrected OLS and the fully modified OLS estimations and confirmed the EKC hypothesis for waste gas, waste water, and solid wastes indicators with Chinese province-level panel data. However, the estimation of a simultaneous equation model with Chinese panel data in Shen (2006) found evidence supporting EKC only for water pollutants but not for air pollutants; while the panel cointegration estimation by Wang et al. (2011) did not support the EKC hypothesis for CO_2 emissions in China.[3]

As Chinese economy continues to grow, surpassing the U.S. as the world's largest economy in 2014 in purchasing-power-parity (PPP) adjusted terms, and as China emerges as one of the world's largest energy consumers, the investigation into how environmental conditions in China are affected by this process has important implications not only for China itself but, indeed, for the world as a whole.[4] Given the inconclusive nature of the results from existing studies and the fast-changing environmental conditions in China, the current research aims at providing additional evidence regarding the EKC hypothesis by applying dynamic panel estimation techniques to Chinese data. Specifically, using a province-level panel dataset of China from 1996 to 2012 and a multivariate EKC framework that includes energy consumption, trade, and urbanization as auxiliary control variables, we estimate both the dynamic specification of the EKC equation by system GMM and the long-run EKC relationship by alternative estimators based on the ARDL model. Our empirical estimations yield robust results in supporting an invert U-shaped relationship between environmental quality and economic development across the alternative indicators measuring air, water, solid pollutants in China. In addition, consistent with previous studies, our estimation reveals that energy consumption has a significantly positive effect on various pollutant emissions, while the effects of trade and urbanization on pollution are more mixed across different models and estimation methods.

The current paper contributes to the literature on EKC studies with Chinese data in terms of both methodology and scope. From the methodological perspective, to the best of our knowledge, this paper is the first to apply system GMM estimator and panel ARDL model estimators to study EKC with Chinese provincial panel data. In this regard, the study of dynamic EKC specification with lagged dependent variable has been largely unexplored in the existing literature.[5] However, environmental quality evolves cumulatively

[2] However, none of these previous studies included all of these three variables simultaneously in their estimations as in the current paper.

[3] Although evidences of EKC are found in many previous studies, there is by no means a unanimous consensus in the existing literature. In fact, a considerable amount of disparate conclusions has been reached in EKC studies, resulting from different data samples, different estimation methods, and across different pollution indicators (see, for example, Roca et al., 2001; Stern, 2004; and Brajer et al., 2011 for more details).

[4] According to the latest World Economic Outlook database released in October 2015 by International Monetary Fund (IMF), the PPP-adjusted GDP of China is $18088.05 (billion) in 2014 compared with $17348.08 (billion) for the U.S. in the same year.

[5] Our literature search has returned two exceptions. One is the paper by Ren et al. (2014) that applies GMM estimator to study the EKC for CO_2 emissions in