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EKC Analysis for Economic Growth and Environmental Quality: A Case of Beijing

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Abstract: In recent years, with the gradual deterioration of environmental quality, more and more researchers devote to determining the relationship between environmental equality and economic growth. The Environmental Kuznets Curve (EKC) hypothesis contends pollution increases initially as a country develops its industry and thereafter declines after reaching a certain level of economic progress. Based on the EKC theory, the study develops a regression model to investigate the relationship between environmental quality and economic growth in Beijing based on the data from 2000 to 2009. The empirical study doesn't always support a conventional inverted U-shaped relationship. The results reveal four relationship types between selected pollution indices and GDP per capita, including (1) An inverted U-shaped pattern, (2) An increasing linear pattern (3) A decreasing linear pattern and (4) A complex relationship that can't portrayed by a specific graph.

Key words: Environmental kuznets curve, economic growth, E

INTRODUCTION

Since, the reform and the opening to the outside world, rapid industrialization and urbanization have played an important role for economic development in China. The Chinese economy has achieved an average growth rate of 12% from 1979-2007 which makes China one of countries with fastest growth rate. However, the developing route in China heavily depends on high investment and high energy consumption to realize high growth and achieve economies of scale in production which brings serious consequences to sustainable development and natural environment. From practices of developed countries and regional economic development, most of them once have experienced environmental deterioration during the process of economic development. Can we sustain economic growth while the environment is continually degraded? So, it is imperative for researchers to study the relationship between them and provide valuable information for decision makers to formulate economic growth strategies for China.

In recent years, with the development of economy and the living standard, the problems related to resource destruction and environmental pollution become more and more serious and the well-known debate between economic growth and environmental quality has attracted more and more practitioners and researchers who have devoted to this field. Considerable literatures on this subject, both theoretical and empirical, have grown in the recent two decades. For example, a group of researchers established extended endogenous economic growth models considering influencing factors to energy consumption and environment (Peng and Bao, 2006; Yu *et al*., 2006). Among the vast studies an important finding is the Hypothesis of Environmental Kuznets Curve (EKC) that contends pollution increases initially as a country develops its industry and thereafter declines after reaching a certain level of economic progress.

The EKC concept is emerged in the early of 1990s with Grossman and Krueger who used a structural equation to examine the reduced-form relationship between per capita income and four environmental indicators and made the initiative contribution. They find little evidence that environmental quality deteriorates steadily with economic growth. Instead, there is an inverted U-shaped relationship between economic growth and environmental quality and when a country's per capital income is up to $8000 (1985 dollars), a turning point for most pollutant, economic growth will be associated with alleviating environmental deterioration (Grossman and Krueger, 1995). Due to its similarity to the pattern of income inequality and economic development described by Kuznets (1955), this environmental pattern has been called EKC. Some empirical studies reveal that in most cases there exists EKC between environmental pollution and economic growth. Shen (2006) showed that there is an inverted U-shaped relationship between income and pollution indictors selected in China.

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Ahmed and Long (2012) found an inverted U-shaped relationship between CO_2 emission and growth in Pakistan. Park and Lee (2011) studied EKC model for air pollution (SO_2, NO_2, CO) of 16 metropolitan regions in Korea and found that EKC curve varied according to different regions and different pollutant, so environmental should consider regional characteristics and the type of pollutant. Similar results also appear in studying the EKC between different regional economic growth and pollutants in China. Guo *et al.* (2007) examined the relationship between per capita income and 8 pollution indictors by panel data of 29 provinces in China and finds that not all the pollution indicators has an inverted U-shape relationship with economic growth and some appear an inverted N-shape or a linear relationship. Diao *et al.* (2008) did reach on a case of Jiaxing of Zhe Jiang in China and finds that there exist three patterns, such as an inverted U-shape, an increasing linear pattern and a weak N-shape.

Over all, the existence and shape of EKC might vary depending on data and index selection, etc. This study adapts EKC analysis to assess the nature of the long-term relationship between per capita income and Beijing's measures of environmental degradation and to determine whether increases in per capita income are associated with reductions in environmental degradation in Beijing in order to provide valuable information for policy makers to enhance their decision-making. This article is organized as follow. Section 2 gives a brief introduction on the method of study and data used in EKC analysis. Then, in Section 3, the regression results are presented and analyzed. Finally, Section 5 concludes the study.

DATA DESCRIPTION AND STUDYING METHOD

Data description: Environmental quality has different dimensions. Environmental equality is mainly related to air quality, water quality. The air quality variables in our study, Sulfur Oxide Discharged (SOD) and Soot and Industrial Dust Discharged (SIDD), are the most commonly used indicators of air pollution in cities and other densely populated areas. As for water quality, we focus on three categories of indicators, including Chemical Oxygen Demand (COD), Industrial Solid Waste Produced (ISWP) and total Wastewater Discharged (WD) including industrial wastewater discharged and non-industrial wastewater discharged. So, in this study, we select these five pollution indicators to measure environmental quality and GDP per capita (PCGDP), an index that indicates the level of economic growth. PCGDP is adjusted on the base of CPI, setting CPI in 2000 equal to 100. The study period is from 2000 to 2009. GDP are collected from Beijing Statistical Yearbook and National Bureau of statistics and pollution indices are released by Beijing Municipal Environmental Protection Bureau. Indices of economy and pollution are listed in Table 1.

Method of study: Most empirical studies of EKC share common characteristics with respect to the data and methods employed. In this study, a following reduced form model adapted is used to test the possible relationship between pollution indices and GDP per capita:

$$Y_t = \beta_0 + \beta_1 x_t + \beta_2 x_t^2 + \beta_3 x_t^3 + \varepsilon_t \quad (1)$$

where, Y refers to environmental indicator, x is GDP per capita and ε is error items. Here, t is time and β_k is the coefficient of the k explanatory variable which can reflect the relationship between environmental quality and economic growth. In the above equation, we don't consider other variables of influence on environmental degradation. Model 1 provides us to test several forms of environment-economic relationships:

- $\beta_1 = \beta_2 = \beta_3 = 0$. A flat pattern or no relationship between x and v
- $\beta_1>0$ and $\beta_2 = \beta_3 = 0$. A monotonic increasing relationship or a linear relationship between x and y
- $\beta_1<0$ and $\beta_2 = \beta_3 = 0$. A monotonic deceasing relationship between x and y
- $\beta_1>0$, $\beta_1<0$ and $\beta_3 = 0$. An inverted-U-shaped relationship, i.e., a conventional EKC. We can obtain the turning points at $x^* = -\beta_1/2\beta_2$ by setting derivatives of Eq. 1 equals to zero
- $\beta_1<0$, $\beta_2<0$ and $\beta_3 = 0$. A U-shaped relationship. We can obtain the turning points at $x^* = -\beta_1/2\ \beta_2$ by setting derivatives of Eq. 1 equal to zero
- $\beta_1>0$, $\beta_1<0$ and $\beta_3>0$. A cubic polynomial or N-shaped curve
- $\beta_1<0$, $\beta_2>0$ and $\beta_3<0$. Opposite to the N-shaped curve

We can see that EKC is only one possible result. Different curves are achieved from different regression equation.

Table 1: Economy and indices of pollution

Indices	Symbol
GDP per capita (10000 RMB yuan)	lgdp
Chemical oxygen demand (10000 tons)	lcod
Sulfur oxide discharged (10000 tons)	lso_2
Soot and industrial dust discharged (10000 tons)	lsmoke
Industrial solid waste produced (10000 tons)	lsolid
Total waste water discharged (10000 tons)	lwater

Symbols are used in regression equations

EMPIRICAL STUDY

Qualitative analysis: As the capital of China, Beijing has realized rapid economic growth since entering into the new Millennium. The average growth rate of Beijing economy from 2000-2009 is 14.4% which is higher than the national average rate. GDP per capita in 2009 (70452.35 RMB yuan) is nearly three times of GDP per capita in 2000 (24127.44 RMByuan).

From the practices of developed countries, environmental degradation is an inevitable consequence during the process of economic development. So, Beijing's environmental quality deteriorates necessarily during the later period of industrialization. But, due to Beijing take various measures in ameliorating environment in the later decade, especially, with the success in the application for the hosting city of the Olympic Game, Beijing's environmental quality have achieved great improvement. The following line charts (Fig. 1-3) can demonstrate the variable trend of GDP per capita and the five pollution indices.

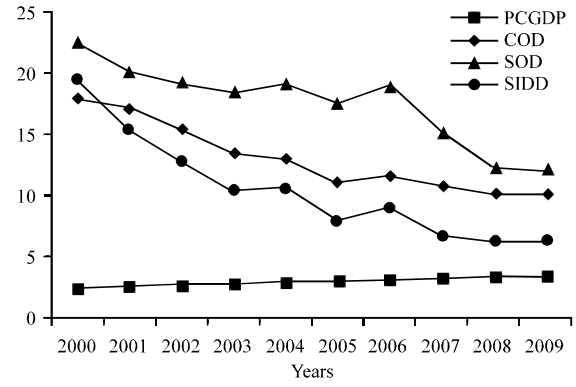

Fig. 1: GDP per capita (PCGDP), chemical oxygen demand (COD), sulfur oxide discharged (SOD) and soot and industrial dust discharged (SIDD) in Beijing

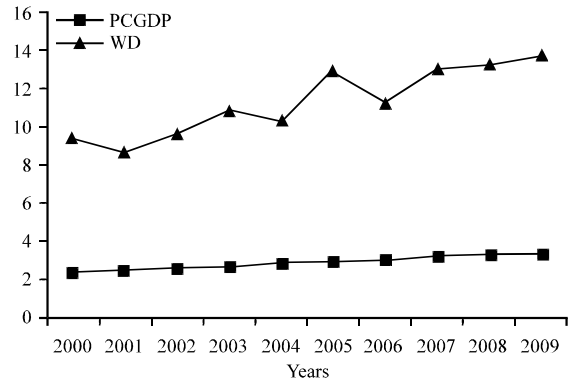

Fig. 2: GDP per capita (PCGDP) and wastewater discharged (WD) in Beijing

We can see from the Fig. 1 that GDP per capita of Beijing increase stably. The three pollution indices mainly take on downtrend from 2000-2009 but the declining speed begins to slow from 2007.

We can find from Fig. 2 that the changing trend of wastewater discharged is the same as that of GDP per capita in Beijing.

The changing trend of Industrial Solid Waste Produced (ISWP) is more complex which takes on decline, increase, once again decline and increase (Fig. 3).

EKC analysis: Based on Eq. 1, the relationship between five pollution indices and PCGDP are tested by regression calculation. First, it estimates the equation that includes quadratic term and cubic term of PCGDP and then a significant judgment is carried out for coefficients estimation by t-test. If coefficients of cubic terms aren't significant, it needs eliminate these cubic terms to estimate again. If coefficients of quadratic terms aren't significant, it needs further eliminate these quadratic terms to estimate again. Finally, we can get different estimation equations by coefficients that pass significant test. These equations can help us to examine whether the EKC relationship exists between pollution indicators and GDP per capita.

In our study, we do Durbin-Watson test (DW test), a test statistic used to detect the presence of autocorrelation in the residuals from a regression analysis. The results are listed in Table 2. The results denote that stochastic errors have no serial autocorrelation.

Regression analysis on chemical oxygen demand: The dependent variable is the Chemical Oxygen Demand (COD) and the regression model is shown in Eq. 2. The regression model exhibits that a linear downtrend relationship between COD and PCGDP:

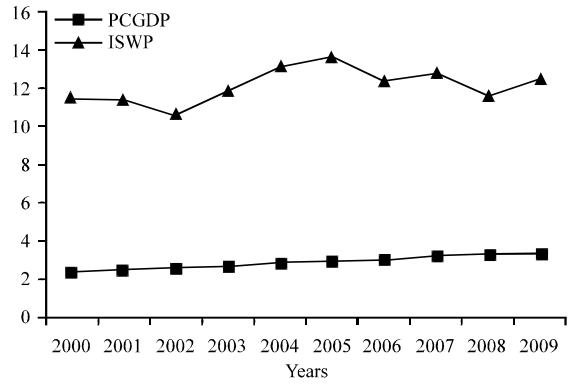

Fig. 3: GDP per capita (PCGDP) and industrial solid waste produced (ISWP) in Beijing

Table 2: Regression results of pollution indices on PCGDP

	lcod	lso_2	lsmoke	lwater	lsolid
Constant	4.415**	/	5.622**	10.296	/
lgdp	-1.745**	10.399*	-3.116**	1.238**	/
$lgdp^2$	/	-5.618*	/	/	/
$lgdp^3$	/	/	/	/	/
adj.R^2	0.958	0.814	0.951	0.823	/
DW test	2.22	2.51	2.71	2.21	/
Curve shape	Downtrend straight line	Inverted U-shaped curve	Linear downtrend	Uptrend straight line	/
Turning point	/	2.523	/	/	/

Asterisks ** and * denote 5% and 10% significant level, respectively

$$lcod = 4.415\text{-}1.745 \lg dp \quad (2)$$

During the selected period, the relationship between COD and PCGDP is not a conventional inverted U-shaped relationship, i.e., EKC which is different from previous studies [9] in which it proclaims that the relationship of COD and PCGDP is suitable for explanation by EKC. In our study, at least in the selected period, it is revealed that EKC does not apply to this kind of pollutant. Instead, the relationship of COD and PCGDP exhibits strongly negative linear correlation. The discharged quantity of COD decreases with the rising PCGDP and there no turning point in GDP per capita for COD.

Regression analysis on sulfur oxide discharged: The regression model shown in Eq. 3 exhibits an inverted U-shaped relationship that exists in SOD and PCGDP which is same as previous studies. The coefficient estimate reaches 10% significant level. From the Eq. 3, we can obtain a turning point at PCGDP = 25, 230, indicating that the values of SOD begin to decrease when PCGDP exceeds 25230 RMB Yuan, the values of SOD increase with the rising PCGDP. Due to the turning point that occurred at the interval between 2001 and 2002, Beijing has passed the turning point of the EKC for several years. The SOD of Beijing has arrived at the right side of EKC. Accordingly, with the further development of Beijing development, SOD will be alleviated:

$$lso_2 = 10.399 \lg dp\text{-}5.6181 \lg dp^2 \quad (3)$$

Regression analysis on soot and industrial dust discharged: The regression model shown in Eq. 4 exhibits a linear downtrend relationship between SIDD and PCGDP:

$$lsmoke = 5.622\text{-}3.1161 \lg dp \quad (4)$$

During the selected period, a conventional inverted U-shaped relationship, i.e., EKC, doesn't exist between SIDD and PCGDP. In our study, at least in the selected period, it is revealed that EKC does not apply to this kind of pollutant. Instead, the relationship of SIDD and PCGDP exhibits strongly negative linear correlation. The discharged quantity of SIDD decreases with the rising PCGDP.

Regression analysis on wastewater discharged: The regression model shown in Eq. 5 exhibits a linear uptrend relationship between WD and PCGDP:

$$lwater = 10.296\text{+}1.2381 \lg dp \quad (5)$$

During the selected period, a conventional inverted U-shaped relationship, i.e., EKC, doesn't exist between WD and PCGDP. In our study, at least in the selected period, it is revealed that EKC does not apply to this kind of pollutant. Instead, the relationship of WD and PCGDP exhibits strongly positive linear correlation. The discharged quantity of WD increases with the rising PCGDP. We can achieve from regression analysis that the relationship between COD and PCGDP displays downtrend and the ratio of industrial wastewater discharged to total wastewater discharged is less than 10%, so the increase of non-industrial wastewater discharged mainly contributes to the increase of wastewater discharged. The working emphasis of Beijing will focus on this field in the future.

Regression analysis on industrial solid waste produced: During the selected period, a conventional inverted U-shaped relationship, i.e., EKC, doesn't exist between ISWP and PCGDP. More over, the relationship between ISWP and PCGDP is very complex which can observe from Fig. 3. We can't obtain any results by linear, quadratic term and cubic term regression test which exists divergence from previous literatures (Wu *et al*., 2002) in which it finds that the relationship of ISWP and PCGDP can be portrayed by EKC. So, we should conduct further study for the relationship between industrial solid waste produced and GDP per capita.

Based on the above analysis, the relationship between economic growth and environmental pollution in Beijing shows little evidence for existence of environmental Kuznets curve for most selected pollution indices, except sulfur oxide discharged. The results reveal four types, including (1) An inverted U-shaped pattern, (2) An increasing linear pattern, (3) A decreasing linear pattern and (4) A complex relationship that can't portrayed by a specific graph.

CONCLUSION

The study make an empirical study used data of Beijing from 2000 to 2009 on Environmental Kuznets Curve (EKC) hypothesis. We examine the reduced-form relationship between environmental quality and GDP per capita. The empirical evidence demonstrates that the hypothesis of EKC only holds for Sulfur Oxide Discharged (SOD). Because the SOD of Beijing has arrived at the right side of EKC, with the further development of Beijing development, SOD will be alleviated. As for the other three pollutants, the empirical study shows little evidence in supporting EKC. Our conclusion has divergence for selected pollution indices compared with previous studies. We should acknowledge that different verification methods may give different conclusions. The further study on EKC hypothesis should find more effective verification methods.

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