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An Empirical Study of the Environmental Kuznets Curve in Sichuan Province, China

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Abstract

The empirical Environmental Kuznets Curve (EKC) literature is colorful but far from conclusive. The environmental Kuznets hypothesis (EKC) confirms an inverse U-shaped relationship between environmental pollution and per capita income. Many authors have analyzed the existence of an EKC for various pollutants. Others have used the EKC framework to identify country characteristics that help to explain the income–environment relationship. But for a local area, such as a province, studies are rare indeed. In this framework, based on the GDP per capita and emissions of industrial waste from 1985 to 2010 in Sichuan Province, China, the relationship is analyzed using regression between economic development and environment in Sichuan Province. Our evidence suggests that there exists a U-shaped or an inverted N-shaped relationship between environmental pollution and economic development in Sichuan Province, that is to say, the environmental Kuznets hypothesis is invalid in Sichuan Province. There are two possible reasons for this conclusion: firstly, KEC curve will not appear at any level of the economic development in Sichuan Province; secondly, the Environmental Kuznets Curve in Sichuan Province exists objectively, but the economic development in Sichuan Province at current stage is not sufficient enough to promote the appearance of KEC curve. However, more attention must be paid to the relation between environmental pollution and per capita income and appropriate environmental policies are required.

Keywords: environmental pollution, economic development, Environmental Kuznets Curve

1. Introduction

Through the analysis of economic growth and income gap in 18 countries, American economist Kuznets drew the following conclusions in the study of the relationship between economic growth and income distribution inequality: the inequality of income distribution is rapidly widening at early stages of economic growth, followed by the short-term stability, then it gradually declines at the later stages of growth, while the income inequality in developing countries at the early stages of development is more serious than developed countries, which is called the income Kuznets Curve (Researched by Kuznets, 1995). Suppose that the horizontal axis representing the economic growth and the vertical axis representing the inequality of income distribution, then KC curve is a parabola bent down after upwardly curved, usually referred as the "inverted U-shaped" curve. Based on the income Kuznets Curve theory, scholars Grossman and Krueger empirically analyzed the relationship between environmental quality and per capita income of the North American Free Trade Area for the first time in 1991. They concluded: pollution would increase with the rise in per capita GDP at low income levels, and decline with the growth of per capita GDP at the high-income level (Grossman & Krueger, 1991) .Panayotou first defined the relationship between environment-quality and per capita income as the Environmental Kuznets curve (EKC) using the inverted U-shaped curve in 1993. EKC reveals that the environmental quality would deteriorate with the increase in revenue at first, and then it would improve when income rises to a certain level, namely environmental quality and income show an inverted U-shaped relationship (Panayotou, 1993).

Different scholars hold different opinions about the environmental Kuznets curve hypothesis; some support the inverted U-shaped curve, while other studies show that it is U-shaped, N-shaped, monotonously rising and monotonously decreasing. Verbeke and Managi used empirical analysis to test the environmental Kuznets curve, and results showed that the EKC changing trajectory exists in most countries (Verbeke, 2006; Managi, 2006),

However, Richmond and Galeotti found that the EKC was not widespread by studying countries at different income levels, member countries in the Organization for Economic Cooperation and Development (OECD) generally show EKC relationship, while non-member countries do not show it (Richmond & Kaufmann, 2006; Galeotti et al., 2006). Khanna and Maddison doubted EKC, they believed that the increase of income is not the main factor of the improvement of the environment quality, economic growth and environment are mutual promoted and mutual influenced (Khanna & Plassmann, 2004; Maddison, 2006). Does the quality of the environment will be improved in the course of economic growth in a specific area, such as a province?

Given this issue, this paper adopts an econometric strategy to address this question. We propose a linear regression model which we will use in the fourth section to check the income-environment relationship with GDP Per capita and industrial three wastes, where industrial wastes, including industrial emissions, industrial wastewater and industrial solid waste. Whether the inverted U-shaped curve exists in Sichuan Province, the last section will conclude.

2. Economic Development and Environmental Pollution in Sichuan Province

2.1 Economic Development from 1985 to 2010 in Sichuan

GDP Per capita in Sichuan Province has almost shown exponential growth trend in the last 26 years from 1985 to 2010: it has increased to 21,361 Yuan, almost 36 times compared with 570 Yuan in 1985, and the annual average growth rate is 15.47%. GDP Per capita has grown rapidly since 2000, and the situation can be found in details in Figure 1 below. In the figure1 the horizontal axis represents the year.

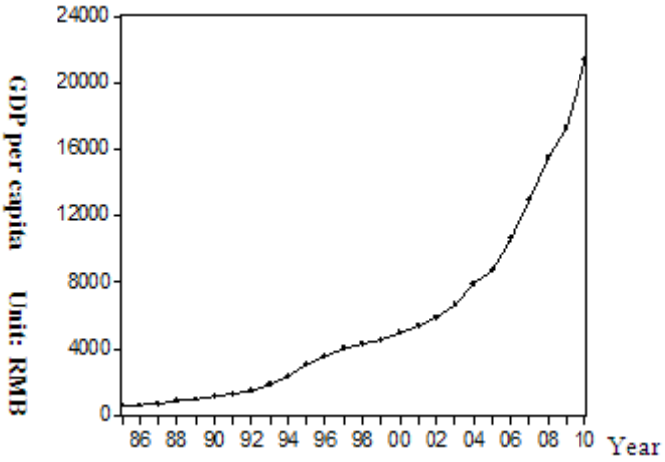

Figure 1. GDP per capita in Sichuan Province in 1985-2010

As shown in Figure 1, Sichuan province has experienced a period of rapid economic growth from 1985 to 2010.

2.2 Industrial Emissions in Sichuan

Industrial emissions in Sichuan generally showed an upward trend, which started from 378.7 billion standard m^3 in 1985 and reached 2.0107 trillion standard m^3 in 2010. Before 2002, industrial emissions were under 700 billion standard m^3, and then it increased rapidly, and reached the historical high of 2.297 trillion standard m^3 in 2007. It temporarily declined in 2008, pulled up again after 2009 and finally ended in 2.0107 trillion m^3 in 2010, as shown in Figure 2 below.

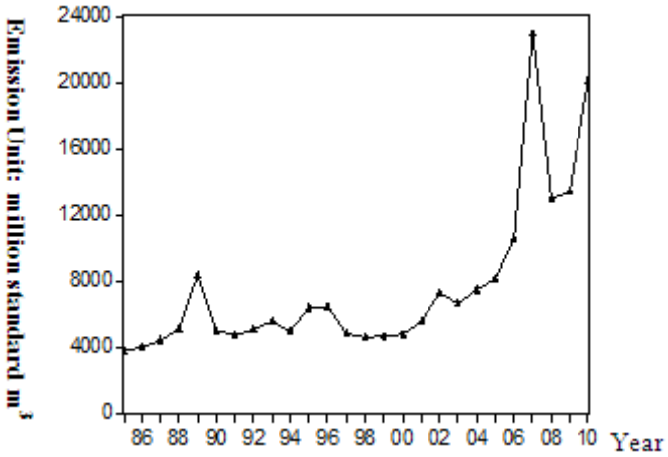

Figure 2. Industrial emissions in Sichuan Province

2.3 Industrial Wastewater Emissions in Sichuan

Sichuan industrial wastewater emissions in 1985 to 2010 roughly presented a "Λ+M+⌒" curve trend, where "Λ" presents the trend which first increased and then decreased , "M" means the trend of tow Λ, and "⌒" indicates the trend of convex shape, in the past 26 years Sichuan has made tremendous achievements in diminishing industrial wastewater emissions. In 1985, industrial wastewater emissions in Sichuan Province was 236830 ten thousand tons and its emissions in 2010 was 934.44 million tons, a net reduction of 1.43386 billion tons. In the meantime, the lowest emissions of 1.09701 billion tons appeared in 1989, in 1997 Sichuan industrial wastewater emissions were stabilized at low level and kept to the present, as shown in Figure 3.

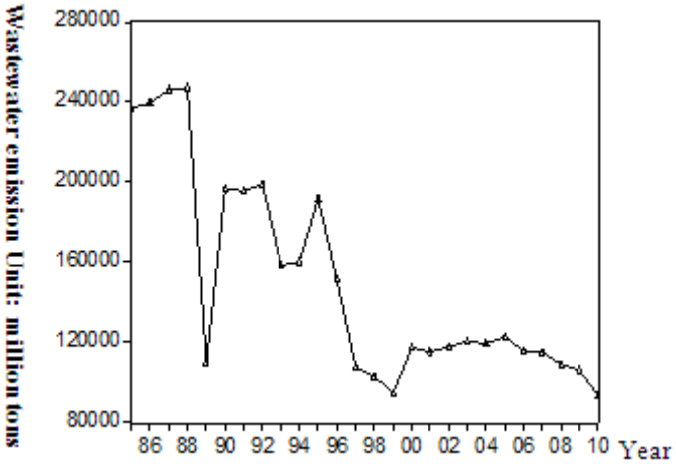

Figure 3. Industrial wastewater emissions in Sichuan Province

2.4 The Emissions of Industrial Solid Waste S in Sichuan

The emissions of industrial solid waste in Sichuan Province in the last 26 years roughly showed a downward trend, and this decreasing trend is very distinct, presenting a "M + ⌒" curve trend, where "⌒" signifies a trend of an decrease, it was 523 million tons in 1985, the highest in history was 9.98 million tons in 1998, later the emissions dropped steeply to 3.2 million tons in 2010, which was the lowest emission in history, as shown in Figure 4.

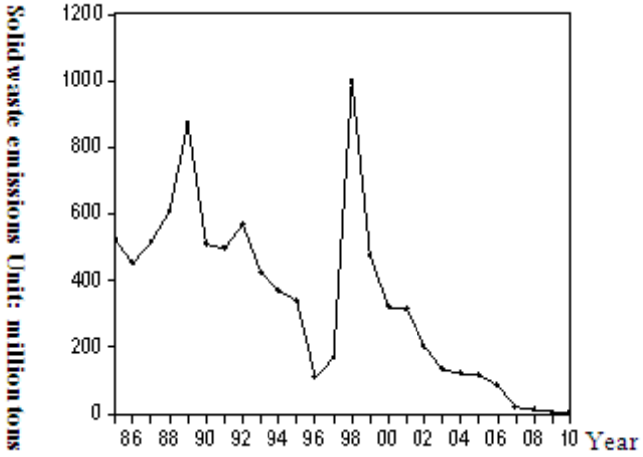

Figure 4. Industrial solid waste emissions in Sichuan Province

In general, great progress has been made in Sichuan's economic development from 1985 to 2010. Although environmental remediation has made some achievements, the environment problems are still very prominent, mainly caused by the ineffective control of industrial emissions.

3. Index Selections, Data Sources and Processing

3.1 Index Selections

Per capita GDP in Sichuan Province is selected as the indicator to measure the economic development, industrial emissions, industrial wastewater emissions, as well as industrial solid waste emissions are selected as indicators to measure the degree of environmental pollution in Sichuan Province.

3.2 Data Sources and Processing

This article selects the annual data of per capita GDP, industrial emissions, emissions of industrial waste water as well as the emissions of industrial solid waste in Sichuan Province from 1985 to 2010; they are derived from *Sichuan Statistical Yearbook*, *China Environment Statistical Yearbook*, *China City Statistical Yearbook* and *China's Regional Economic Statistical Yearbook*.

The two indexes used for environmental Kuznets empirical analysis are: per capita GDP index and environmental pollution index, which are obtained by processing the raw data. The per capita GDP Index is calculated on the basis per capita GDP in 1985, assume the per capita GDP is 1 in 1985, and divide each year's number by the per capita GDP in 1985 to get the yearly per capita GDP index. Index of environmental pollution is weighted and calculated from industrial waste gas emission index, industrial wastewater emission index and industrial solid waste emission index. Firstly, convert the three sequences of industrial emissions, industrial waste water emissions, emissions of industrial waste water, and industrial solid waste emissions in Sichuan to index. Specifically, the three sequences are all based on 1985, assume the indicators in 1985 as 100, divide emissions in each year by emissions in 1985 and multiply it by 100 to get the index. For example, industrial waste gas emission was 378.7 billion m^3 in 1985 and 397.9 billion standard m^3 in 1986, industrial emissions in 1985 is 100, then the indicator of industrial emissions in 1986 is (3979/3787) * 100 = 105. In this paper, the weight is determined using the principal component analysis method, the weights of the following three indicators: industrial emissions, industrial waste water, and industrial solid waste were 0.35, 0.31, and 0.34. So the Environmental Pollution Index in 1985 = 0.35×100+0.31×100+0.34×100 = 100. Likewise the environmental pollution index in subsequent years is calculated in the same way.

4. Empirical Analysis

Quadratic curve and cubic curve are used to fit in studying the relationship between economic development and environmental pollution in Sichuan Province, the quadratic curve fitting relationship is:

$$Y_t = \alpha + \beta_1 AGDP_t + \beta_2 AGDP^2_t + \varepsilon_t \quad (1)$$

The cubic curve fitting relationship is:

$$Y_t = \alpha + \beta_1 AGDP_t + \beta_2 AGDP^2_t + \beta_3 AGDP^3_t + \varepsilon_t \quad (2)$$

where α is constant, β_1 is the time coefficient, β_2 is the quadratic coefficient, β_3 is the cubic coefficient, ε_t is the regression error term, AGDP is per capita GDP index in Sichuan Province. For Equations (1) and (2), we assume that:

(a) $E(\varepsilon_t) = 0$,(t=1,2,3….,T).

(b) Var $(\varepsilon_t) = \sigma^2$,(t=1,2,3….,T).

(c) Cov $(\varepsilon_i, \varepsilon_j) = 0$, $(i \neq j)$.

(d) Cov $(\varepsilon_i, AGDP_t) = 0$.

For quadratic curves and cubic curves, different combinations of coefficient symbols have different curve forms.

Table 1. Curve shape of the relationship between environment and income

Model	**Value of β_i**	**Forms of the curve**
Model	$\beta_1 = \beta_2 = \beta_3 = 0$	no
Model 2 (linear)	$\beta_1 > 0$, $\beta_2 = \beta_3 = 0$	Linear monotonically increasing
Model 3 (linear)	$\beta_1 < 0$, $\beta_2 = \beta_3 = 0$	linear monotonically decreasing
Model 4 (quadratic)	$\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 = 0$	U-shaped relationship
Model 5 (quadratic)	$\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 = 0$	inverted U-shaped relationship
Model 6 (cubic)	$\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$	N-type relationship
Model 7 (cubic)	$\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$	inverted N-type relationship

As shown in Table 1, there are seven models for the curve, and the meanings vary from model to model, broadly speaking, linear monotonically increasing means that the environment quality deteriorates as income increases, linear monotonically decreasing means that the environmental quality improves with income increases. U-shaped relationship means that when income levels are in the lower stages, the environment quality improves as income rises, when the income level is at a high stage; the environment quality deteriorates as incomes rise. What's more, inverted U-shaped relationship means that when income levels are in the lower stages, the environment quality deteriorates as incomes rise and when income levels are in the high stages, the environment quality improves as income rises. Besides, N-type relationship is a kind of curve that as income levels rise gradually, the environment quality deteriorates before further improvement, and finally it falls into deterioration. On the contrary, inverted N-type relationship is totally opposite that as income levels raise gradually, the environment quality first improves before deterioration and at last improves.

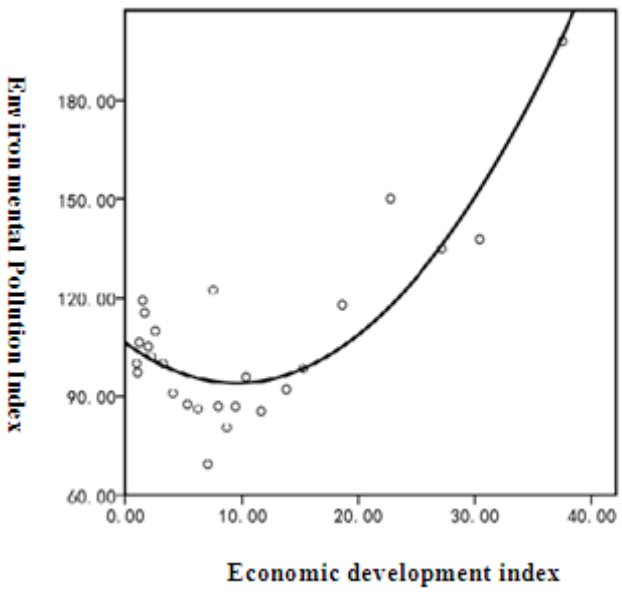

Figure 5. Quadratic curve fitting for the environmental pollution and AGDP

Figure 5 shows the quadratic curve fitting diagram for the environmental pollution and the per capita GDP in Sichuan Province.

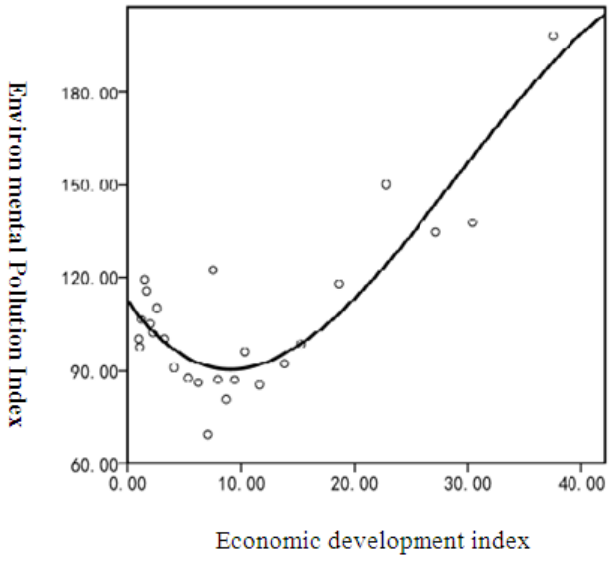

Figure 6. Cubic curve fitting for the environmental pollution and AGDP

Figure 6 shows the cubic curve fitting diagram for the environmental pollution and per capita GDP in Sichuan Province, the horizontal axis in this figure represents economic development index in Sichuan Province, and the vertical axis indicates the environmental pollution index.

It can be seen from the Figure 5 and Figure 6 that both quadratic curve and cubic curve fit well, the signs of the fitting coefficients are shown in Table 2 below:

Table 2. Fitting results for environmental pollution and per capita GDP

Model Form	Dependent variable	Model factors	Coefficient	T statistics	Coefficient of determination
Quadratic	environmental pollution degree	constant	108.77	24.2	0.803
		AGDP	-2.971	-3.8	
		$AGDP^2$	0.142	6.3	
Cubic	environmental pollution degree	constant	112.02	19.54	0.81
		AGDP	-5.202	-2.56	
		$AGDP^2$	0.34	3.08	
		$AGDP^3$	-0.04	-2.92	

As shown in Table 2, the t statistics of coefficients in the quadratic curve fitting are significant, coefficient of determination in the model is 0.803, the F-statistic is 37.51, indicating that the overall effect of the model is very good; t statistics of coefficients in the cubic curve fitting are also significant, the coefficient of determination in the model is 0.81, F statistics is 27.36, indicating the construction of the model is reasonable, so the quadratic formula for environment and income in Sichuan Province is:

$$Y = 0.142AGDP2-2.971AGDP+108.77 \quad (3)$$

The cubic relationship is:

$$Y = -0.04AGDP3+0.34AGDP2-5.202AGDP+112.02 \quad (4)$$

As the quadratic curve coefficients $\beta_1 < 0$, $\beta_2 > 0$, it determined that the environmental quality and income levels in Sichuan Province present "U-shaped" curve in the quadratic curve fitting, as the coefficients of its cubic curves $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$, it determined that the environmental quality and income levels in Sichuan Province present "И" type curve in the cubic curve fitting, that is the inverted "N" type curve, as shown in Figure 7 and Figure 8.

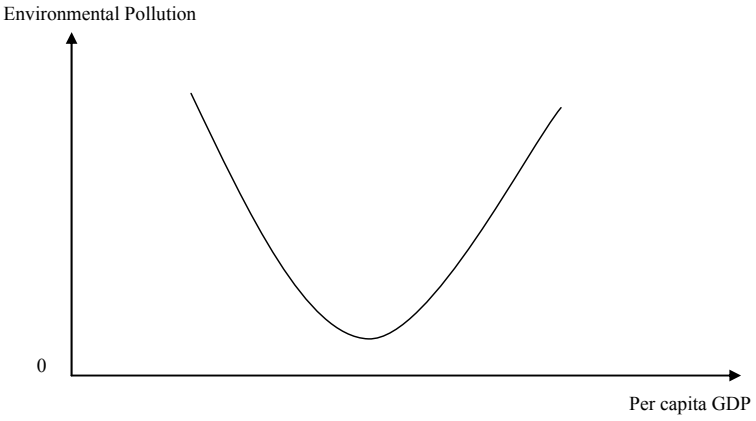

Figure 7. Curve for environment and income in Sichuan province

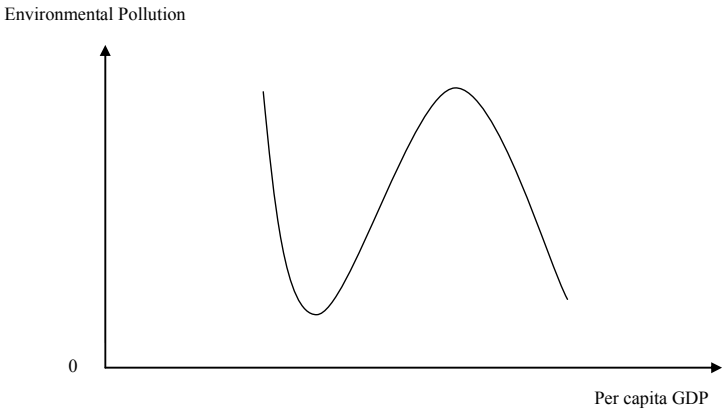

Figure 8. Curve for environment and income in Sichuan province

As shown in Figure 7 and Figure 8, neither quadratic curve fitting nor cubic curve fitting in Sichuan Province at current stage do not support the environmental Kuznets curve hypothesis, namely the KEC curve does not exist in Sichuan Province.

5. Conclusions and Solutions

Through empirical analysis, the relationship between environmental pollution and economic development in Sichuan Province support the environmental Kuznets curve hypothesis, which means the KEC curve does not exist in Sichuan Province. There are two possible reasons for this phenomenon: firstly, KEC curve will not appear at any level of the economic development in Sichuan Province objectively; secondly, the Environmental Kuznets Curve in Sichuan Province establishes objectively, but the economic development in Sichuan Province at current stage is not sufficient enough to promote the inflection point on KEC curve, that is to say the "И" shaped and "U" shaped relationship between environmental pollution and per capita income in Sichuan Province in this study are part of the KEC curve in Sichuan Province in the future.

Economic development provides more financial support for environmental remediation, but the increase in income is not the main incentive of the improvement in the environment quality. The environmental improvement is closely related to the environmental protection awareness of the people in Sichuan, the ideological quality of local people and the relevant policies of the government. Therefore, improvement of the environment should not only be built on the economic development. Sichuan Province must control the industrial emissions, so far industrial emissions is the biggest factor affecting the environment quality in Sichuan, Sichuan needs to phase out some industrial enterprises which are small-scale, high energy consumption, low-income or low production, especially those petrochemical enterprises. Most importantly, we need to promote the transformation of economic structure, shift from the domination of the secondary industry to the domination of the third industry, develop service industry vigorously, and improve people's awareness of environmental protection continuously.

Admittedly, this article has its own limitations and leaves more space for further researches in the future. Due to the lack of research data, it can't demonstrate the existence of Kuznets Curve in Sichuan province accurately. In addition, researchers need to explore a more scientific and effective method when confirm the weight in research. As for the study of Kuznets Curve in Sichuan province, latter researchers should collect more comprehensive and accurate data, amend the index of environment pollution, and make further discussion about the research methods.

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