Applying Kuznets Theory to the Analysis of Relation between Economic Growth and Environmental Quality in Chongqing

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Abstract. In the process of economic development, the state of the environment is an important factor to be considered. The environmental Kuznets curve reflects the relationship between environmental quality and per capita income, which is of great significance to study the above problems. Based on the Kuznets theory of environment, this paper analyzes the data about the economy and environment in Chongqing, which is from China's National Bureau of Statistics. The regression model of Chongqing's economic growth and environmental level is explored through regression analysis, which provides the basis for judging the environmental status and improving the government's policy on the environment. The results show that the four environmental pollution indicators selected in this paper are consistent with the EKC curve of per capita GDP. The author found that the discharge of two types of pollutants is on the rise, which requires active measures to control pollution. The discharge of the other two types of pollutants is declining. This situation requires people to continue to control to prevent the discharge of pollutants from rising again.

Keywords: Environmental Kuznets theory; Economic growth; Environmental pollution; Regression analysis

1 Introduction

Nowadays, the concept of sustainable development has become one of the important principles of economic development, emphasizing that economic development must consider population, resources, environment and other factors. After the reform and opening-up, the Chinese economy has developed rapidly and industrial production has increased. Various environmental problems have also emerged. Environmental pollution has gradually become a bottleneck factor for the sustainable development of the social economy. In this respect, the environmental Kuznets theory provides a useful empirical exploration on a macro scale. Chongqing is regarded as one of the major cities in the upper reaches of the Yangtze River. Therefore, analyzing the relationship between economic growth and environmental quality in Chongqing and exploring the scientific methods of its environmental governance have important meanings. These can not only promote t sustainable economic development, but also effectively strengthen the ecological barrier in the upper reaches of the Yangtze River. This paper makes a basic introduction to environmental Kuznets theory and clarifies the basic model selected in the subsequent data analysis. Then, based on selecting appropriate economic growth and environmental quality

ICEMME 2022, November 18-20, Nanjing, People's Republic of China

DOI 10.4108/eai.18-11-2022.2326752

evaluation indexes, this paper conducts regression analysis on the data. According to the numerical results and images of regression analysis, the corresponding conclusions of the changing trend of each environmental index are given. Finally, this paper puts forward the situation and improvement measures that need to be paid attention to in the process of Chongqing's economic growth for environmental governance. These measures involve governments, businesses and the public who are supposed to make more joint efforts together.

2 Overview of Environmental Kuznets theory and its basic models

2.1 Introduction to environmental Kuznets theory

The Kuznets Curve, first proposed by economist Robert Kuznets, is an inverted U-shaped Curve between the difference in per capita wealth and the increase in per capita wealth. After Grossman and Krueger (1995) studied the relationship between environmental quality and per capita income, the above theory developed into a theory used to describe the correlation between economic development and environmental pollution, namely the Environmental Kuznets curve (EKC) hypothesis [1]. The study shows that there is also an inverted U-shaped relationship between environmental quality and per capita income levels: In the initial stage of economic development, economic growth will bring serious environmental damage. However, after economic development reaches a certain level, environmental quality will reach a turning point. A higher level of economic status can reduce environmental pollution and improve environmental quality [2,3,4]. The environmental Kuznets hypothesis has been widely recognized since it was put forward, and has been widely used in the related fields of the relationship between resources, environment and economic development.

2.2 Introduction of EKC model

Internationally, there are two types of commonly used models derived from environmental Kuznets theory. One is based on time series data analysis, and the other is based on panel data analysis. Since the data types in this paper change with time, it is more appropriate to choose the first type model as the fitting model. The Kuznets model based on time series data is described in detail below.

The EKC model is based on the analysis of time series data, which is the most classical and the commonly used simplified econometric model. It is the quadratic polynomial function relationship model [5]:

$$E_t = \beta_0 + \beta_1 * Y_t + \beta_2 * Y_t^2 + u_t \quad (1)$$

In the above relation, Y_t is the independent variable, which represents the economic output of a region at time t. This variable is usually expressed as GDP or per capita GDP; E_t is the dependent variable of the equation, which represents the environmental pressure that the region bears at time T. This variable is usually expressed by pollutant discharge, environmental assessment indicators, etc.; $\beta_0, \beta_1, \beta_2$ are parameters; u_t is the random error term. When β_2 is above zero, the function curve is u-shaped; When β_2 is under zero, the curve of the function is inverted u-shaped. In addition, the turning point of environmental quality can be obtained by using the first derivative of the function, which is

$$Y = -\frac{\beta_1}{2\beta_2} \quad (2)$$

The above model was further expanded to cubic function type:

$$E_t = \beta_0 + \beta_1 * Y_t + \beta_2 * Y_t^2 + \beta_3 * Y_t^3 + u_t \quad (3)$$

In the new relation, the meanings of the independent variable Y_t and dependent a variable E_t remain the same. $\beta_0, \beta_1, \beta_2, \beta_3$ are parameters, but when β_3 is above zero, the curve is N-shaped; When β_3 is under zero, the curve is inverted N-shaped. What is more, the turning point of environmental quality can also be obtained by using the first derivative of the function.

The relationship between economic growth and four kinds of pollution indicators in Chongqing

This article selects Chongqing's per capita GDP (X) as an economic indicators, and this economic indicator is used as an independent variable in the regression. There are four environmental indicator in this paper. They are the total discharge of industrial wastewater (Y1), the total discharge of industrial waste gas (Y2), the total discharge of industrial sulfur dioxide (Y3) and the discharge of industrial oxygen demand (Y4). Each of them is respectively taken to indicate the environmental pressure in Chongqing, and used as dependent a variable in the regression. The software R was used to simulate quadratic and cubic regression curves between X and each Yi(i =1,2,3,4), and the one with better fitting results was selected as the final fitting equation from the two regression curves. Among them, the respective cubic fitting effect of Y1, Y2, Y3 and X is better than the quadratic one, so the relevant data of the cubic fitting curve of these three variables are included in the below table. However, the quadratic fitting effect of Y4 and X is better than the cubic fitting effect, so the relevant data of the quadratic fitting curve of Y4 are included in the table. The final specific fitting results and images are as follows:

Table 1. Simulation results between per capita GDP and different environmental indicators

Environmental indicators	Model coefficients				correlation coefficients	
	β_0	β_1	β_2	β_3	Adjusted R-squared	The p-value of the equation significance test
Total industrial waste water discharge (tons)	63865	- 71895.	- 8704.	31132	0.6825	0.0004008
Total industrial waste gas discharge (100 million standard cubic meters)	5699.3	11902.3	4059.4	3542.7	0.935	8.28 e-07
Industrial Sulphur dioxide emissions (tons)	589732	- 202122.	- 87486.	110836	0.8211	0.0002901
Industrial chemical oxygen demand emissions (tons)	11.1517	0.7981	1.2903	-	0.8016	0.04106

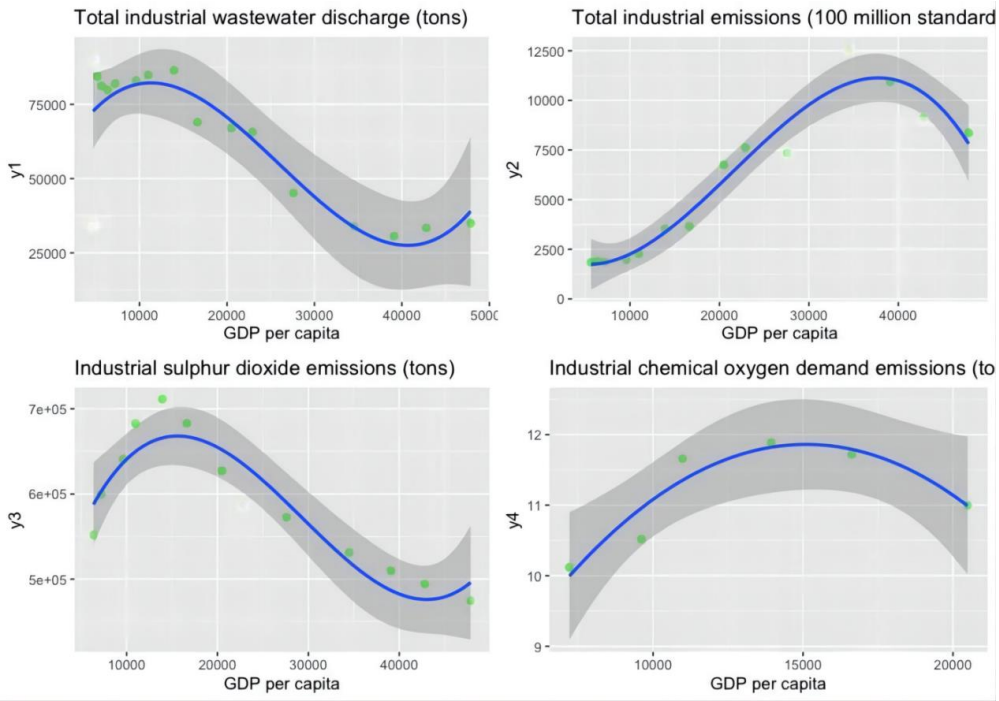

Figure 1. Regression curve between per capita GDP and different environmental indicators

According to the above table and images, the following conclusions can be drawn:

(1) The EKC model fitting equation between the total amount of industrial wastewater discharge and per capita GDP of Chongqing is

$$y_1 = 63865 - 71895 * x - 8704 * x^2 + 31132 * x^3 \quad (4)$$

The corresponding curve graph is N-shaped. According to the image, the equation has two inflections. And it can be seen that the discharge of industrial wastewater with per capita GDP appeared the trend of first up and then down in the initial period. However, the current economic situation of Chongqing is located on the right side of the second inflection point. So, it is possible that in the next few years, the discharge of industrial wastewater in Chongqing will increase with the rise of per capita GDP. Therefore, relevant government departments should take preventive measures to promote the positive interaction between economic growth and the water environment.

(2) The EKC model fitting equation between the total industrial waste gas emission and per capita GDP of Chongqing is

$$y_2 = 5699.3 - 11902.3 * x - 4059.4 * x^2 - 3542.7 * x^3 \quad (5)$$

The corresponding curve graph is inverted N-shaped. Due to the problem of sample size, the image mainly shows the part after the first inflection point. It is being shown that with the increase of per capita GDP, industrial waste gas rises first and then declines. At present, the

industrial waste gas emission of Chongqing city is in a downward trend, so we need to continue to maintain this good state and try to prevent the deterioration.

(3) The EKC model fitting equation between the total industrial sulfur dioxide emission and per capita GDP of Chongqing is

$$y_3 = 589732 - 202122 * x - 87486 * x^2 + 110836 * x^3 \quad (6)$$

The corresponding curve graph is N-shaped, which means the total industrial sulfur dioxide emission increases at first, then decreases and then increases. Therefore, relevant measures should be taken as soon as possible to control its growth trend.

(4) The EKC model fitting equation between industrial oxygen demand emissions and per capita GDP in Chongqing is

$$y_4 = 11.1517 - 0.7981 * x - 1.2903 * x^2 \quad (7)$$

The corresponding curve graph is inverted U-shaped. The development of the economy initially led to a certain increase in industrial oxygen demand emissions, but the increased strength of the economic level made it effectively controlled and gradually declined.

3 Discussion

The four indicators of environmental pressure in Chongqing selected in this paper all showed a trend of first rising and then decreasing with the development of the economy. However, at present, the total discharge of industrial wastewater and the total discharge of industrial sulfur dioxide are on the rise, so timely measures should be taken to prevent the further increase of pollutant discharge. Total industrial waste gas emissions and industrial oxygen demand emissions are in the stage of decline. It is very important to maintain this situation and inhibit it from increasing again. In order to realize the sustainable development strategy of Chongqing municipality and the harmony between environment and economic growth, effective measures should be taken to control environmental pollution in time. This paper suggests three aspects: source control, treatment technology and environmental awareness [6]. Firstly, control of pollution sources. Actively adjust the industrial structure to reduce the proportion of natural resource-intensive and pollution-intensive industries in the industry; Promote clean products and increase the proportion of clean industry. Secondly, improve pollutant treatment technology. The investment in science and technology should be increased, through the assistance and restraint of government macro-control. Improve the utilization rate of natural resources and reduce the generation of pollutants through technological progress. At the same time, for the inevitable waste caused in the production process, factories should achieve the maximum degree of harmless treatment. Finally, enhance the awareness of participation in environmental protection. The degree of participation of enterprises and residents in environmental protection depends on their environmental protection awareness. Government departments should guide enterprises to establish a green corporate culture and prevent enterprises from destroying the environment in order to pursue profit maximization. In addition, it is vital to actively promote environmental protection knowledge to the citizens and encourage them to participate in environmental protection.

4 Conculsion

In general, the environmental quality of Chongqing meets the environmental Kuznets curve with its economic status. At the same time, through the analysis of above analysis it can be seen that one as the main areas of the upper Yangtze river in Chongqing, the current environmental conditions in some aspects such as industrial emissions and chemical oxygen demand (cod) in good condition, but in other areas such as industrial waste water discharge and sulfur dioxide emissions and its environment is not very ideal. Therefore, in order to balance economic development and environmental protection, the government's macro-control is very important, which will guide enterprises to establish a green corporate culture and lead people to improve their awareness of environmental protection.

In addition, there are still some deficiencies in this paper. The selection of environmental assessment index lacks some strong theoretical basis. There are many indicators of environmental conditions in a region, and this paper fails to make a detailed investigation on which to choose and how many to choose. In addition, the sample number of some indicators in this paper is not enough, so the data quantity should be appropriately increased to improve the fitting effect of the regression curve.

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