Research Progress in Chinese Environmental Kuznets Curve

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Keywords: Environmental Kuznets Curve, environmental quality, economic growth.

Abstract: With the development of China's economy, the research on the relationship between economic growth and environmental quality has become a hot issue in ecological economics. The analysis of Chinese Environmental Kuznets Curve (EKC) was conducted from the perspective of empirical research and theoretical research, and the problems and deficiencies in existing research were explored in this paper. The following can be found from the review of the academic literatures related to Chinese Environmental Kuznets Curve. Firstly, there are different conclusions in different regions. EKC of most provinces is inverted U-shape, some provinces are inverted N-shape and inverted U-shape + positive U-shape, and the results of eastern, central and western provinces are also different. Secondly, different indicators lead to different conclusions such as inverted U-shape, inverted N-shape, inverted U-shape + positive U-shape. Thirdly, different econometric models lead to different conclusions. In research using quadratic polynomial and logarithmic equation, the EKC appears to be inverted U-shape, while the model combined with cubic equation and multiple equations has both inverted U-shape curve and inverted N-shape curve. Fourthly, the existing research lacks the discussion of the formation mechanism of EKC. This paper points out that Chinese scholars should strengthen the theoretical and methodological research on Environmental Kuznets Curve, and forecasts the further relevant key areas.

1. Introduction

China's economic growth has been so remarkable in recent years that since the 1990's it has been with a higher long-term growth rate. However, when people focus on China's success in the field of economy, they ignore the environmental issues behind its economic growth. China's rapid economic growth is accompanied by serious environmental pollution, which causes the environmental resources to be increasingly scarce. Faced with more and more environmental restrictions, people begin to pay more attention to the relationship between economic growth and environmental pollution. In addition, the relationship between environmental quality and economic growth also becomes the hot topic in the academic circles. More and more scholars begin to be engaged in the research on environmental economics, with the sustainable development as a research focus.

Since the 1990s, there have been more and more theoretical and empirical literatures in this area. The most important discovery in empirical research is the Environmental Kuznets Curve (EKC). The earliest research on the EKC hypothesis was conducted by Grossman-Krueger, Shafik and Panayotou. In 1991, Grossman-Krueger analyzed the urban atmospheric quality data of GEMS and found that SO_2 and smoke conform to the inverted U - shape curve [1]. In 1992, based on data provided by the World Bank, Shafik used three different forms of equations (linear logarithm, logarithmic square sum logarithmic cubic) to fit the relationship between environmental indicators and per capita GDP. In 1993, Panayotou borrowed the inverted U-shape curve between per capita income level and income inequality as defined by Kuznets in 1955 and named the relationship between environmental quality and per capita income level the Environmental Kuznets Curve [2] for the first time. Like fair distribution, EKC discusses the relationship between national per capita income and environmental pressure. The theory holds that the relationship between national per capita income and environmental pressure should be an "inverted U-shape" curve.

In recent years, many scholars have done a lot of similar empirical analysis, but there are still many uncertainties for the situation in China. Environmental quality will deteriorate in the early

stages of economic growth, and then will be improved with economic growth. It can be known that there will be a situation for environment that it will first deteriorate and then improve, which has also been confirmed in the development of many developed and industrialized countries. It means that economic growth will ultimately improve the adverse effects on environment in the early economic development, and that growth can be sustained, getting rid of the idea in the *Limits to Growth* (1984) written by Meadows that economic growth is unstainable restricted by the environment. On this basis, the economic growth is necessary for improving environmental quality.

It is believed in most literature that Environmental Kuznets Curve is a kind of experience, a kind of description of empirical data. The shape of EKC fitted in different countries and systems is not the same, which does not mean the inevitable relationship between economic growth and environmental pollution. In order to strengthen the association of theory with empirical analysis, this paper pointed out the problems and defects existing in the research in China at present based on summarizing the predecessors' research, which can provide scientific basis for further research.

2. Literature Review

2.1 Empirical Research

2.1.1 Research Area

According to the geographical scope of the research, the empirical research mainly follows the following four ideas:

1) Throughout the country. The empirical research on EKC conducted from the perspective of the country originated from 1999. Zhang Xiao [3] examined the existence of China's Environmental Kuznets Curve with the econometric regression method. In this paper, the Environmental Kuznets Curve between China's economy and the environment shows a weak u-shape relationship, but the turning point is lower than that of developed countries. Lin Boqiang and Jiang Weijun [4], Yang Wanping and Yuan Xiaoling [5] also conducted research from the perspective of China's overall panel data. The research results of Lin Boqiang and Jiang Weijun verified that EKC follows the inverted U shape and predicted that China would reach the turning point in 2040. But research results of Yang Wan Ping and Yuan Xiaoling's suggested that EKC showed a positive U shape.

2) Provinces comparison. Gao Hongxia et al [6], Luo Lan and Deng Ling [7], Wu Yuming and Tianbin [8] stuided 31 provinces and autonomous regions in China; Chen Dehu and Zhangjin [9], Zhang Jin [9], Han Jun [10], GaoJing[11], Bao Qun and Peng Shuijun [12] conducted studies based on panel data of 30 provinces and autonomous regions in China; Li Rui’e and Zhang Haijun [13], Xu Shichun and He Zhengxia [14] conducted studies based on panel data from 28 provinces and autonomous regions in China. Liu Huajun et al. [15] conducted studies based on panel data of 27 provinces and regions in China. According to the results of many scholars, inverted U-shape curves were found in most provinces, but in some provinces, the regular U-shape, inverted N-shape or linear were also found

3) Comparative study of the Eastern, Central and Western China. Zhou Qian [16], Xu Guangyue and Song Deyong [17], Li Fei and Zhuang Yu [18] discussed the EKC from the perspective of the Eastern, Central and Western China. It is found in the study that in the Eastern and central China, it tends to be U-shape, and in the Western China, it tends to be U-shape. According to other studies, the economic growth and environmental pollution in the Eastern, Central and Western regions show "N-type" development, and at the same time due to the imbalanced economic growth in the Eastern, Central and Western regions, the turning point of each region will be different. East>Central>Western.

4) Single province or city. Many scholars have verified the hypothesis of EKC with a single province or city as the research region. It can be found from the research literature that the research on provinces and cities in developed regions is more than that in the central and western provinces, however, the empirical conclusions of various provinces and cities are relatively confused, and the

U-shape, N-shape, inverted-N-shape, linear and other relations have been found in the research [19-39].

2.1.2 Research Index

Seen from the perspective of research indicators, the conclusions of empirical research in China show the following rules and characteristics:

1) Chinese scholars have made a large number of empirical analysis on the data of industrial "three wastes" discharge. The research results are inconsistent (Shown in Table 1).

Table 1. Empirical research on the relationship between environmental quality and economic growth

Environmental index	Conclusion	Reference
Three Wastes	Inverted U	[3,7-8,12,14,30,33,40]
Three Wastes	N type	[32]
Three Wastes	Positive U type	[26,41]
Three Wastes	Inverted U type + positive U type	[18,22,29,31]
Three Wastes	Inverted N type + N type + U type	[42]
Three Wastes	N type + inverted U type	[24,43]
Three Wastes	Inverted N type + inverted U type	[27,35]
Three Wastes	Inverted U type + linear	[28]
Three Wastes	Concave type	[37]
Three Wastes and Dust	Inverted N type + U type; U type + inverted U type + N type	[34]
Three wastes, SO_2	U type + inverted U type; inverted U type + inverted N type; inverted U shape	[13,19,38]
Three Wastes, SO_2, Smoke and Dust	Inverted U type + linear	[36]
Dust, SO_2 and Emission of Industrial Smoke and Dust	Inverted U	[6,10]
SO_2, CO_2	Inverted U	[11]
Municipal wastes	Inverted U	[44]
Industrial waste water	Invert U+U	[45]

In addition to the inverted U shape found in the results, inverted U-shape + positive U-shape, inverted N-shape and U-shape are also often found. In the empirical study of industrial "three wastes", the conclusion of the inverted U-shape curve accounted for about 35%, inverted U type + positive U type conclusion accounted for 17%; N type + inverted U type, inverted "N" type + inverted "U" and positive U shape each accounted for 9%, other conclusions accounted for 21%. In the empirical study of the three wastes and other environmental indexes, the inverted U-shape curve accounts for the majority. In addition to the inverted U-shape, the conclusions of the inverted N-shape curve were also found in studies. In a word, the conclusions drawn by Chinese scholars on the relationship between "three wastes" and economic development are inconsistent, for example, there is inverted U shape, inverted N shape, inverted U shape + positive U shape and concave shape.

2) In recent years, Chinese scholars have conducted empirical analysis of the relationship between the carbon emission and economic development with a large amount of data and the existing research results have inconsistent conclusions. Some scholars believe that the relationship between China's carbon emissions and economic growth shows inverted u-shaped curve, [4, 9, 15, 20]. While

Wu Zhenxin and Wan Bulei [21], Lv Zhipeng [23] found in their research that the relationship between carbon emissions and economic development in Beijing and Liaoning Province shows an inverted n-shaped curve. Xu Guangyue and Song Deyong [17] studied the relationship between carbon emissions and economic development in China and in the Eastern, Central and Western China and found that inverted U-shaped curves appeared in the Eastern and Central regions, while positive U-shaped curves appeared in the Western regions.

3) In addition to the relationship between economic growth and environment, Chinese scholars also conducted researches involving other aspects.

(1) Research on the relationship between forest resources and economic growth in China [39, 46-49]. Some scholars have proposed in 2000 that the deforestation rate of China's forest resources has shown an upward trend, and only by lowering the curvature of the Environmental Kuznets Curve can the existing forest resources be kept [46]. Some scholars have summarized the laws of economic development and changes in forest resources in various countries and proposed the U-shaped theory of forest resources changes [47]; while more scholars believe that China's forest resources and economic growth show an inverted U-shaped curve.

（2）Research on the relationship between the tourism economic development and environmental pollution. Some scholars discussed the trend of EKC in the process of tourism economic development from the perspective of tourism economic development. Li Fengsheng and Wang Lipeng [50] took Guilin tourism industry as an example to discusses the relationship between economic development and environmental pollution, and put forward that before the EKC of Guilin tourism industry reaches its peak, preventive measures should be taken to reduce the curve so as to make the curve changed from an "inverted U" shape to "--" shape, thus realizing a "win-win situation" between tourism economic development and environmental protection. Zhang Jinhe et al. [51] believe that in the process of tourism economic development, there is an Environment Kuznets inverted U-shaped curve between the emission of solid and liquid tourism waste and tourism development in Huangshan Mountain Scenic Area, while the relationship between the emission of gaseous waste and tourism economic development is uncertain.

In addition to the above research, scholars have also verified EKC from the aspects of low-carbon aquaculture, soil erosion and farmland surface pollution, and the research conclusions are inconsistent, including inverted U-shaped inverted U-shaped + positive U-shaped [52-54]

2.1.3 Research Model

The econometric research model plays an important role in the EKC research. In the empirical research in China, it seems that there is not much progress in econometric methods in recent years. It can be seen from Table 2 that the fitting model of cubic equation is most used in empirical research (Table 2) and that different econometric models will lead to different EKC research results. It is shown that the EKC presented by using quadratic polynomial and logarithmic equation is basically inverted U, and the combination of cubic equation and multiple equations lead to both U and N curves. Some scholars use entropy and factor methods to obtain positive U-shaped and positive N-shaped. Therefore, in addition to rational selection of major factors of environmental stress, it is also necessary to establish an accurate econometric model that comprehensively reflects the relationship between environment and economic growth.

2.2 Theoretical Research

As the empirical research goes deeper and deeper in China, the theoretical explanation of EKC phenomenon has gradually attracted the attention of researchers. People have discussed it from the perspectives of the economic structure, technology, international trade environment demand and national policies [56-57].

2.2.1 Economic Structure

Niu Haipeng et al. [58], Qian Xueya and Wang Weiwei explained the EKC phenomenon from the change of economic structure, and believed that with the improvement of economic structure, pollution emissions showed a gradual downward trend. However, the improvement of economic

structure may make the economic development slow down or even decline in the short term, or may promote economic development in the short term. In the boom phase, the proportion of the secondary industry has increased, and industrialization and urbanization have brought serious ecological and environmental problems. When the main economic activities shift from high energy consumption and high-pollution industries to low-pollution and high-output service industries and information industries, the pressure of production on resources and the environment will be reduced and the relationship between environmental damage and economic development will show an inverted U-shaped curve.

2.2.2 Scientific and Technological Progress

Wang Guoyin [60], He Lihua and Jin Jiang [61] explained the EKC phenomenon from the perspective of scientific and technological progress. They believed that scientific and technological progress was an indispensable condition for the turning point of the Environmental Kuznets Curve. Therefore, the solution to environmental problems requires the innovative research and development to promote technological progress.

2.2.3 International Trade

Gao Jing and Huang Fanhua [62], Hu Liang and Pan Li [63], Zhu Shubin and Gao Wei [64] studied EKC from the effect of trade on the environment, and believed that developed countries shifted high-pollution, high-energy and resource-based industries to developing countries, as a result, the environmental quality of developed countries has improved and the that of developing countries has been further damaged.

2.2.4 Environmental Requirements

The environmental demand consists of environmental consumption demand and investment demand. Zhu Zhijie [66] studied EKC from the effect of environmental demand on the environment and believed that as people have deeper and deeper understanding of development, there is an interaction between environmental demand and economic development.

2.2.5 National Policy

The national environmental policy will change the shape of the EKC to become flat or to make the peak point appear earlier. Zhang Xuegang and Wang Yujing [66] believe that the government's regulation of the environment has an important impact on environmental quality improvement.

In addition to the above-mentioned theoretical research, some scholars have also discussed EKC from the perspectives of preferences, social welfare functions, environmental damage, pollution control costs, and capital productivity [67-73].

3. Deficiency and Prospects of EKC Research

3.1 Deficiency of Environment Kuznets Model

Since Grossman used econometric tools to study the relationship between economic growth and environmental quality, a large number of econometric models have emerged, which more or less have some deficiencies in the arguments mainly in the following aspects:

3.1.1 Deficiencies of Model Presupposition

(1) Model unidirectionality. There is an interactive two-way relationship between economic development and environmental quality. However, most current EKC studies assume that there is only one-way impact of the economy on the environment, ignoring the adverse effects of environmental changes on economic growth, which will bring about the problem of endogenous Bias.

(2) Isomorphic assumption. At present, the data of the EKC rising segment in the empirical test comes from the developing country or the backward development area, and the data in the descending segment of the curve comes from the developed countries or the advanced development regions. In fact, this method simply "splices" the data from developing economies and developed

economies, while ignoring the differences in economic structure, resource endowment, political system, infrastructure and other aspects of countries (regions) [18]. This method which simply assumes that all economies are isomorphic, and the relevant conclusions are doubtful. [18].

3.1.2 Arbitrariness of Variable Selection

There are numerous factors that affect the environment, such as economic structure (including input structure and output structure), technical level, trade conditions, environmental demand elasticity of income, national environmental policies and so on. At present, most EKC studies only have a single variable of per capita income. Although income levels as well as other variables are used in a few models to study EKC, generally speaking, the variables are selected with arbitrariness. They do not seriously consider whether the selected variables are important and complete, which will lead to the result that variables are omitted or the selected variables are non-critical issues, resulting in incomplete model and econometric bias.

3.1.3 Econometric Methods

(1) Just as the model unidirectionality problem mentioned above, most of the current models are single-equation econometric models, which assume that the environment has no feedback effect on economic growth. This unidirectional effect of economy on environment is not suitable, which will lead to the inaccurate estimation. Therefore, some scholars have avoided the problem of model form.

3.2 Prospects

(1) According to the current research status quo both at home and abroad, it is necessary for us to first strengthen the EKC research within a country or a region. Because the economic structure, system, culture, and statistical data more consistent in a country or a region, which basically meet the isomorphic EKC hypothesis. Larger samples of panel data within a country, for example in the county level or regional administrative division unit in China, not only can basically satisfy the assumptions of ergodic hypothesis, but also can avoid the existing influencing factors between countries in international panel data, as a result, it will bring about more meaningful and persuasive conclusions.

(2) In terms of models, it is necessary to actively adopt the combination of time series and cross-section, that is, the parallel data model of non-classical data types. It can not only reflect the development and change of environmental quality and economic development in time, but also reflect the differences between regions over the same time period. It is better to reflect the environmental quality with one or fewer indicators to accurately, reflect the economic development with green GDP, and quantify and add other major influencing factors into the model, to make the relationship between them simplified, clarified and real.

(3) Since there is no theoretical basis for EKC, in addition to a large number of empirical studies, the formation mechanism of EKC in theory must be widely discussed and strictly proved. In the initial stage of theoretical discussion, it is allowed to learn from the mature theories of other disciplines, such as system theory, thermodynamics theory and so on.

(4) It is expected that more scholars will conduct research in this area to confirm the authenticity of EKC in order to determine the environmental pollution trend in the whole country, provinces and cities based on science, so as to deal with the critical point of environmental pollution peak and the length of time to reach this critical point, so that a reasonable policy framework can be formed in a timely manner.

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