Kuznets Curve based Analysis on the Relationship between Economic Growth and Environmental Quality in Beijing

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Abstract. It is well known that the economic growth of big cities may cause risk on the environment, thus it is essential to study the relationship between economic growth and environmental quality. Particularly, this paper establishes the environmental Kuznets curve measurement models between Beijing's economic growth and environmental pollution levels using 2000-2017 Beijing time series data. Economic development level is measured by GDP per capita. The level of environmental pollution is measured by the discharge of industrial waste water, the discharge of industrial waste gas, the production of industrial solid waste, and the discharge of industrial sulfur dioxide. The empirical results show that the environmental Kuznets curve of Beijing's economic growth and industrial wastewater discharge has an inverted N-type characteristic. Second, the economic Kuznets curve of Beijing's economic growth, whether it is related to the amount of industrial exhaust emissions or the amount of industrial solid waste produced, has an inverted U-shaped curve. In addition, the environmental Kuznets curve of Beijing's economic growth and industrial sulfur dioxide emissions has linear characteristics. Based on the characteristics of these environmental Kuznets curves, this paper finds that there is a relatively good relationship between Beijing's economic development level and the environment relationship after a comprehensive analysis. On this basis, this paper puts forward the suggestions of Beijing's environmental Kuznets curve to Beijing's good environmental level.

1. Introduction

Rapid economic growth in big cities may consume environmental resources, which also brings a series of environmental problems. At present, the relationship between environmental pollution and economic growth has attracted attention from various countries. Judging from the economic development process of each country or region in the world, environmental degradation is an important issue in the process of economic development. After years of research by scholars, the Environmental Kuznets Curve (EKC for short) has proved the correlation between environmental pollution and economic development in a certain sense. It shows that the pollution level of a country will rise with the economic development and the increase of national income. When the economy develops to a certain extent, the pollution level will decrease with the rise of income. The environmental crisis is just a phasic phenomenon. When economic growth reaches a higher stage, it will be resolved automatically. However, the proposal of EKC is based on the industrial development
facts of some developed countries, and for most developing countries, there is still a large difference in whether the relationship between economic growth and the environment conforms to the inverted U-shaped curve.

As the capital of our country, Beijing has always been at the forefront of economic development in our country. At the same time as rapid economic development, environmental problems have been seriously polluted at the beginning of this century. With the increase, Beijing issued a lot of documents and adopted a series of measures. As a result, Beijing's environment has also been improved to a certain extent. However, due to the large amount of pollution emissions, the concentration of emission areas, and the limited overall regional environmental capacity, there is still a large gap between the environmental quality of the capital and national standards and the expectations of the people for a better life. Therefore, this paper attempts to use the data from 2000 to 2017 to examine the true relationship between economic growth and environmental pollution in representative cities with high levels of economic development and increasing attention to environmental pollution, explore whether there is an EKC relationship between environmental pollution and economic growth in Beijing, seek a balance between economic growth and environmental pollution in Beijing, and make suggestions for improving the environmental quality of the capital.

2. Literature review
The relationship between environmental quality and economic development has been a hot topic in economics research. Grossman and Krueger (1992) proposed the concept of the environmental Kuznets curve (EKC) [1] based on the trajectory of deterioration and improvement between economic growth and environmental quality over a long period of time, supported by empirical data from most developed countries. That is, on a two-dimensional plane space, with the per capita income level representing the level of economic development as the horizontal axis, and the amount of pollutant discharge representing the level of environmental degradation as the vertical axis, EKC appears as an inverted "U"-shaped quadratic curve, as shown in Figure 1 below.

![Figure 1. EKC curve](image)

On the relationship between economic growth and environmental pollution, domestic and foreign scholars have done a lot of research, and foreign scholars have studied EKC earlier. Grossman and Krueger (1995) ’s empirical analysis of the EKC hypothesis shows that the inflection point of air and water pollution will appear at about $5,000 per capita income [2]. Jordi and Emilio et al. (2001) used the environmental Kuznets curve to analyze the annual emission flux trends of six air pollutants in Spain. Studies show that only the trend of sulfur dioxide emissions may be consistent with the EKC hypothesis. They believe that the relationship between income levels and various emissions depends on many factors, and that economic growth alone cannot solve environmental problems [3]. Kong and Khan (2019) analyzed core energy consumption among country-specific variables based on panel data from 29 countries (14 developed and 15 developing countries) using the environmental Kuznets curve hypothesis[4].
Domestic scholars began to study the environmental Kuznets curve at the end of the 20th century. Ma and Li (2006) used simplified models to estimate the EKC of industrial wastewater, industrial waste gas, and industrial waste in China. The results show that environmental pollution in China will not automatically improve with economic growth. Li (2016) conducted an empirical study on economic growth and environmental pollution in Gansu Province, and the results showed that the environmental conditions and economic pollution in Gansu Province and even the western region are in a more complex stage [6]; Li and Qiao (2018) conducted a study of Beijing’s economic development and environmental conditions. Two of the "three wastes" indicators they chose to represent pollution levels were in line with EKC characteristics [7]; Song and Yuan (2019) conducted a survey on the environment of Beijing, Tianjin and Hebei. An empirical study on pollution and economic growth has shown that some cities in Beijing, Tianjin, and Hebei are still on the left side of the EKC curve, and further inverted U-shaped green development needs to be achieved [8].

After the above-mentioned literature analysis, especially domestic literature analysis, we can find that the shape of EKC in each region is different, which indicates that the relationship between economic development and environmental pollution varies from region to region, and the shape of EKC varies with different regional characteristics.

3. Construction of the theoretical model
According to the EKC hypothesis proposed by Grossman and Krueger, combined with existing literature in China and abroad, the main forms of the EKC model are the two forms: quadratic and cubic.

The main form of quadratic form is as follows:
\[
Y = \alpha_0 + \alpha_1 X + \alpha_2 X^2 + \mu
\]  

The main form of the cubic type is as follows:
\[
Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \mu
\]

In the two main forms of the EKC model, \( Y \) represents the level of environmental pollution, \( X \) represents the level of economic development, and \( \mu \) represents the random disturbance term. \( \alpha_0, \alpha_1, \alpha_2, \beta_0, \beta_1, \beta_2, \beta_3 \) are the proxy parameters. The shape of the EKC is different when the parameters have different signs, that is, the relationship between environmental pollution and economic growth is different. The meaning of the parameters of the quadratic form is shown in Table 1.

| Estimation parameters | EKC shape        |
|-----------------------|------------------|
| \( \alpha_1 > 0, \alpha_2 = 0 \) | Monotonically increasing |
| \( \alpha_1 < 0, \alpha_2 = 0 \) | Monotonically decreasing |
| \( \alpha_1 > 0, \alpha_2 < 0 \) | Inverted U |
| \( \alpha_1 < 0, \alpha_2 > 0 \) | U |

The meaning of the parameters of the cubic form is shown in Table 2.
Table 2. Relationship between the parameters of the environmental Kuznets cubic model and the shape of EKC

| Estimation parameters | EKC shape                     |
|-----------------------|-------------------------------|
| $\beta_1 \neq 0$, $\beta_2 = \beta_3 = 0$ | Linear relationship           |
| $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 = 0$ | Inverse "U" quadratic curve relationship |
| $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 = 0$ | "U" quadratic curve relationship |
| $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$ | "N" Cubic Curve Relationship  |
| $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$ | Reverse "N" Cubic Curve Relationship |
| $\beta_1 = 0$, $\beta_2 = 0$, $\beta_3 = 0$ | No relationship               |

The construction of the model in this paper will be based on the above theory, and it will be constructed by STATA software. The specific use of the quadratic or cubic type is based on the p-value, F statistics, R2 and so on.

4. An empirical study of Beijing’s economic growth and environmental pollution

4.1. Index selection and data source

The construction of pollution level indicators in this paper selects the representative "industrial three wastes" (industrial wastewater discharge, industrial waste gas discharge, industrial solid waste production), and industrial sulfur dioxide emissions as quantitative indicators of environmental pollution. The per capita GDP is chosen for the construction of economic development level indicators. The selection of time is from 2000 to 2017. The initial time of 2000 was chosen because this paper wanted to examine the relationship between Beijing’s economic growth and environmental pollution since the 21st century. And the end time of 2017 was selected because the lag of data release made it impossible to collect data for some indicators in 2018.

Table 3. Variable definition table

| Variable type          | Symbolic representation | Meaning                                                                 |
|------------------------|-------------------------|------------------------------------------------------------------------|
| Explained variable     | Y1                      | Industrial wastewater discharge (Unit: 10,000 tons)                     |
|                        | Y2                      | Industrial exhaust emissions                                          |
|                        |                         | (Unit: billion standard cubic meters)                                 |
|                        | Y3                      | Production of industrial solid waste (Unit: 10,000 tons)               |
|                        | Y4                      | Industrial sulfur dioxide emissions (unit: ton)                        |
| Explanatory variables  | X                       | GDP per capita (Unit: 10,000 yuan)                                     |
To sum up, this paper selects Beijing’s industrial wastewater discharge Y1 (unit: 10,000 tons), industrial waste gas discharge Y2 (unit: 100 million cubic meters), and industrial solid waste generation Y3 (unit: 10,000) from 2000 to 2017 in Beijing. Industrial sulfur dioxide emissions Y4 (unit: ton) to represent Beijing's pollution emission level. Beijing's per capita GDP (unit: 10,000 yuan) was selected as a measure of economic development level, expressed by X. The data are from the Beijing Municipal Bureau of Statistics and the 2000-2017 "Beijing Environmental Status Bulletin". The variable definition table in this paper is shown in Table 3.

4.2 Empirical analysis

In this paper, STATA is used to operate, and the quadratic curve fitting and cubic curve fitting of EKC are performed, and then the model is judged. Finally, the relationship between Beijing's economic growth and environmental pollution is analyzed. The fitting results of the environmental Kuznets quadratic model are shown in Table 4, and the fitting results of the cubic model are shown in Table 5. Among the brackets is the significance level of the t value in the model.

**Table 4.** Fitting results of the environmental Kuznets quadratic model

| Environmental indicators | $\alpha_0$  | $\alpha_1$  | $\alpha_2$  | $R^2$ | F       | EKC shape |
|--------------------------|-------------|-------------|-------------|-------|---------|------------|
| Y1                       | 30600       | -4976       | 267         | 0.858 | 45.37   | U          |
|                          | (0.00)      | (0.00)      | (0.00)      |       |         |            |
| Y2                       | 489         | 1148        | -87         | 0.739 | 21.24   | Inverted U |
|                          | (0.518)     | (0.000)     | (0.000)     |       |         |            |
| Y3                       | 807         | 160         | -14         | 0.889 | 60.23   | Inverted U |
|                          | (0.000)     | (0.000)     | (0.000)     |       |         |            |
| Y4                       | 174352      | -16184      | 243         | 0.954 | 155.6   | U          |
|                          | (0.000)     | (0.001)     | (0.343)     |       |         |            |

| Y1                       | 30600       | -4976       | 267         | 0.858 | 45.37   | U          |
|                          | (0.00)      | (0.00)      | (0.00)      |       |         |            |
| Y2                       | 489         | 1148        | -87         | 0.739 | 21.24   | Inverted U |
|                          | (0.518)     | (0.000)     | (0.000)     |       |         |            |
| Y3                       | 807         | 160         | -14         | 0.889 | 60.23   | Inverted U |
|                          | (0.000)     | (0.000)     | (0.000)     |       |         |            |
| Y4                       | 174352      | -16184      | 243         | 0.954 | 155.6   | U          |
|                          | (0.000)     | (0.001)     | (0.343)     |       |         |            |

**Table 5.** Fitting results of the environmental Kuznets cubic model

| Environmental indicators | $\beta_0$  | $\beta_1$  | $\beta_2$  | $\beta_3$  | $R^2$ | F       | EKC shape |
|--------------------------|-------------|-------------|-------------|-------------|-------|---------|------------|
| Y1                       | 47158       | -13651      | 1556        | -57         | 0.9631| 121.94  | Inverted N |
|                          | (0.000)     | (0.000)     | (0.000)     | (0.000)     |       |         |            |
| Y2                       | -1556       | 2219        | -246        | 7           | 0.7684| 15.49   | N type     |
|                          | (0.374)     | (0.019)     | (0.060)     | (0.204)     |       |         |            |
| Y3                       | 534         | 303         | -35         | 0.9         | 0.9015| 42.71   | N type     |
|                          | (0.035)     | (0.017)     | (0.047)     | (0.208)     |       |         |            |
| Y4                       | 205533      | -32519      | 2670        | -107        | 0.9584| 107.49  | Inverted N |
|                          | (0.000)     | (0.036)     | (0.207)     | (0.246)     |       |         |            |

From the comparison between Table 4 and Table 5, it can be seen that in the regression model of industrial wastewater discharge and per capita GDP, the parameters of the quadratic model and the cubic model are significant at the level of 5%, but $R^2$ of the cubic model is higher, therefore, the more suitable model for the relationship between industrial wastewater discharge and per capita GDP is the cubic model. And the EKC curve is an inverted N-type. The curve has now passed two extreme points (735.5014 million yuan and 1087.4939 million yuan). The decline stage indicates that the current industrial wastewater discharge has a gradual decline with economic growth. The model shows that the industrial wastewater discharge first shows a positive U-shaped curve followed by an inverted U-shaped curve with economic growth, and the industrial wastewater pollution has undergone an improvement-deterioration-improvement process. There are two turning points in the curve of wastewater discharge and per capita GDP. They are 733.5014 million yuan and 108.74939 million yuan.
yuan respectively, which occurred in 2009-2010 and 2014-2015. When GDP per capita is lower than 733.5014 million yuan, the discharge of industrial wastewater decreases. When the per capita GDP exceeds 73,351.4 million yuan but less than 108,473.9 million yuan, the amount of wastewater discharged increases rapidly with the expansion of the economy. After the per capita GDP exceeded 108,743.9 million yuan, the economy continued to grow, but the amount of wastewater discharge turned into a downward trend year by year. The relationship between wastewater discharge and per capita GDP began to improve. The above shows that in terms of industrial wastewater discharge, the green development model of Beijing's economic growth to promote industrial wastewater pollution has achieved initial results, and the EKC relationship has been established. We call the per capita GDP of 108,874,939 yuan an EKC inflection point.

In the regression model of industrial exhaust emissions and per capita GDP, both $\beta_2$ and $\beta_3$ in the three-dimensional model are not significant at the level of 5%, so the more suitable model for the relationship between industrial exhaust emissions and per capita GDP is quadratic Model, the EKC curve is in the shape of an inverted U. It is calculated that the industrial exhaust emissions reach a maximum when the per capita GDP is 66.24595 million yuan, that is, a turning point occurred in 2008-2009. This shows that when the per capita GDP is less than 66.24595 million yuan, the industrial waste gas emissions increase with the increase of per capita GDP. After the per capita GDP exceeds 66.24595 million yuan, the per capita GDP continues to increase while the industrial waste gas emissions gradually decrease. It can be seen that Beijing's industrial exhaust emissions have improved since 2009. The main reason can be considered that during the 2008 Beijing Olympics, the State Council, the Beijing Municipal Government, and surrounding cities worked together to ensure air quality in Beijing. They spare no effort to comply with Beijing's 2008 "Green Olympics" commitment, and carry out the largest joint regional atmospheric environment improvement, successfully achieving the overall control of air pollution in the Beijing-Tianjin-Hebei city group. During this period, the concentration of air pollutants in the Beijing-Tianjin-Hebei region decreased significantly, and no pollutants exceeded national standards [9]. After the Olympics, the government's control of air pollution was further strengthened, and the "Beijing 2012-2020 Air Pollution Control Measures" was formulated and promulgated, focusing on controlling fine particulate matter (PM2.5) pollution. By 2015, the annual average concentrations of major pollutants such as fine particulate matter (PM2.5), respirable particulate matter (PM10), total suspended particulate matter, industrial sulfur dioxide, and nitrogen dioxide will be reduced by 15 from 2010. However, in view of the actual situation in the past two years, there is still a lot of room for improvement in reducing atmospheric pollutant emissions.

In the regression model of industrial solid waste production and per capita GDP, $\beta_3$ is not significant at the significance level of 5%, so the more suitable model for the relationship between industrial solid waste production and per capita GDP is the quadratic model, and the EKC curve also has an inverted U-shape. Its turning point appeared in 2006-2007, that is, when the per capita GDP reached 564.5328 million yuan/person, earlier than the turning point of industrial exhaust emissions. The actual economic significance of this result is that the early results of the treatment measures and related policies of Beijing's industrial solid waste emissions per capita GDP below the threshold of 564.5328 million people are not obvious, that is, with the economic growth, industrial solid waste emissions continue to increase, causing environmental degradation. After 2007, when the per capita GDP level exceeds the threshold of 564.5328 million yuan/person, industrial solid waste emissions will decrease as Beijing's economic development level increases. That is to the right of the "inverted U-shape" curve, the so-called simultaneous improvement of the level of economic development and environmental quality.

In the regression model of industrial sulfur dioxide emissions and per capita GDP, both $\beta_2$ and $\beta_3$ are not significant at the level of 5%, and in the quadratic model, is not significant at the level of 5%, therefore, a regression model between industrial sulfur dioxide emissions and per capita GDP
may be more suitable for a linear model. So this paper uses STATA software to perform regression again, and the results are shown in Figure 2. The regression results of the model show that the coefficients pass the significance test, and $R^2$, F statistic are also high, indicating that the model is highly credible. Therefore, the model between Beijing's industrial sulfur dioxide emissions and per capita GDP is more suitable for a linear model, and according to the regression result graph, there is a negative correlation between the two, that is, as the per capita GDP increases, the industrial sulfur dioxide emissions decrease. This shows that since the 21st century, Beijing’s regulation of industrial sulfur dioxide emissions has been stricter. As far as industrial sulfur dioxide emissions are concerned, Beijing has not followed the old path of “polluting first and then treating”.

![Figure 2. Linear regression model results of industrial sulfur dioxide emissions and GDP per capita](image)

### 5. Conclusions and suggestions

#### 5.1. Conclusions

In order to explore the relationship between economic growth and environmental quality in Beijing, this paper selects data from 2000 to 2017 in Beijing and conducts an empirical analysis of the relationship between Beijing's economic growth and environmental pollution based on the environmental Kuznets curve theory. The main conclusions are as follows: (1) Among the four indicators selected for measuring pollution levels, two indicators have EKC characteristics. Although the remaining two indicators do not completely show an inverted U shape, the overall pollution level at this stage is also falling. Overall, Beijing's economy and environment are in a "win-win" phase. (2) The EKC curve is not a fixed pattern, but has a variety of morphological characteristics. (3) Environmental pollution is not a result of negative externalities caused by simple economic growth, but a comprehensive problem caused by various factors. After economic development reaches a certain level, economic growth can instead promote pollution reduction.

#### 5.2. Suggestions

Correct understanding of the dialectical relationship between economic development and environmental protection. Regarding the relationship between economic development and environmental protection, we cannot simply think that the two are contradictory. The development of the economy will bring environmental pollution, the deterioration of the ecological environment or the protection of the environment will restrict economic development. It can be seen from the Environmental Kuznets Curve that the economy and the environment are an organic whole that interacts and restricts each other. Economic growth provides protection and economic foundation for environmental protection and pollution control, and at the same time brings more environmental problems due to economic development. Environment Protection provides good conditions for economic development and
restricts economic development to a certain extent. Therefore, we should correctly understand the relationship between the two. We must not blindly pursue economic growth at the expense of the environment. We must pursue environmental protection and economic growth to go hand in hand. Continue to adhere to the road of circular economy.

The circular economy adheres to the "3R" principle of "reduction, reuse, and recycling". From the current environmental Kuznets curve in Beijing, we can see that the overall environmental situation in Beijing is showing a good trend, but making economic growth go hand in hand with environmental protection also requires continuing to maintain or expand more ways to protect the environment. We must dare to eliminate processes and equipment with high energy consumption, heavy pollution, and low economic efficiency, promote polluting enterprises to take the road of circular economy, and actively develop emerging industries with low energy consumption, low pollution, and high scientific and technological content. To promote resource conservation and comprehensive utilization of resources, build a recycling system for renewable resources, and encourage the development of renewable resources industries, government agencies should vigorously publicize the concept of a circular economy and add strength to building a better Beijing together.

References
[1] C. M. Grossman and A. B. Krueger 1992 Enviromental impact of a North American free trade agreement. Princeton University Woodrow Wilson School of Pubic and International Affairs. 401-11
[2] C. M. Grossman and A. B. Krueger 1995 Economic Growth and Enviroment. Quarterly Journal of Economic. 110 353-77
[3] R. Jordi, P. Emilio, F. Mariona and G. Vittorio 2001 Economic growth and atmospheric pollution in Spain: discussing the environmental Kuznets curve hypothesis. Ecological Economics. 39 1-35
[4] Y. S. Kong and R. Khan 2019 To examine environmental pollution by economic growth and their impact in an environmental Kuznets curve (EKC) among developed and developing countries. Plos One. 14
[5] S. C. Ma and G. Z. Li 2006 Kuznets curve of the relationship between China's economic growth and environmental pollution. Statistical Research. 22 37-40
[6] J. E. Li 2016 Kuznets Curve of the Relationship between Economic Growth and Environmental Pollution in Gansu Province. National Commercial Conditions (Economic Research) 31 8-9
[7] Q. Li and T. S Qiao 2018, Empirical Study on the Relationship between Economic Growth and Environmental Pollution in Beijing. China Market. 33 9-13, 28
[8] J. L. Song and G. Yuan, 2019 An empirical study on the relationship between environmental pollution and economic growth in Beijing-Tianjin-Hebei: based on the perspective of EKC test. Northern Economy and Trade. 39 118-20
[9] J. Y. Xin, Y. S. Wang and G. Q. Tang, 2010, Attenuation and reduction of air pollutants in Beijing and surrounding areas during the 2008 Olympics. Chinese Science Bulletin. 55 1512-21