Study on Relationship between Economic Development Level and Air Quality

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Abstract. In the paper, by using the relevant data of Jinan from 2003 to 2016, the relationship is studied between GDP per capita and the annual emission concentration of all kinds of atmospheric pollutants. The fitting curve is gained. Compared with EKC, it is found that the character of EKC does not consistent with the type “U” entirely. Combining with the industry structure and the input of environmental protection, some conclusions are obtained. The analysis result can provide some references for the sustainable development of urban economy and environment.

1. Introduction
With the rapid development of urban industrialization, the emission of all kinds of atmospheric pollutants can make urban air quality more or less decrease. But GDP (Gross Domestic Product) per capita, the important indicator of urban economic development level, has close relationship with urban air quality. So, studying the relationship between them is very important, which can analysis the health degree of urban economic development, explore the way of the sustainable development of the urban economic environment.

The paper does some research about the relevant data of Jinan from 2003 to 2016, by using the software SPSS. In order to provide some references for the effective management of the city and the achievement of energy conservation and emissions reduction, the relationship between atmospheric pollutants emission and GDP per capita is carried out in the paper.

2. Description of Study Area
Jinan is the capital of Shandong province, located at north latitude 36°40′ and east longitude 117°00′. It adjoins with mountain Tai and the Yellow River. The terrain of Jinan is expressed as the south-high and the north-low. With the influence of solar radiation, atmospheric circulation and geographical environment, the climate of Jinan is the type of sub-humid warm temperate continental monsoon. It is obviously drought and less rain in spring, warm and rainy in summer, cool and dry in fall, cold and little snow in winter.

Jinan joins with capital economic circle in north and Yangtze River Delta economic circle in south. It connects Shandong Peninsula with central China. It is an important intersection of Bohai economic zone and Beijing-Shanghai economic axis. It is the core city of the provincial capital economy group and the center of political, economic and cultural in Shandong province. In 2017, Jinan is selected national civilized city.
3. Data

The data used in the paper are from:

1. “China Statistical Yearbook” (2004-2016)
2. “Environmental quality bulletin of Jinan” (2016)
3. “Shandong Statistical Yearbook” (2017)

Through these documents, some data are obtained, such as annual mean value of atmospheric pollutant concentration of Jinan and GDP per capita of Jinan from 2003 to 2016. The specific data are shown in table 1.

| Year | GDP per capita | SO₂ | NO₂ | PM₁₀ | Year | GDP per capita | SO₂ | NO₂ | PM₁₀ |
|------|---------------|-----|-----|------|------|---------------|-----|-----|------|
| 2003 | 23590         | 0.064 | 0.046 | 0.149 | 2010 | 57947         | 0.045 | 0.027 | 0.117 |
| 2004 | 27610         | 0.045 | 0.038 | 0.149 | 2011 | 64310         | 0.051 | 0.036 | 0.104 |
| 2005 | 31606         | 0.060 | 0.024 | 0.128 | 2012 | 69444         | 0.055 | 0.041 | 0.104 |
| 2006 | 36394         | 0.040 | 0.021 | 0.114 | 2013 | 74993         | 0.095 | 0.061 | 0.199 |
| 2007 | 42171         | 0.056 | 0.023 | 0.118 | 2014 | 82052         | 0.069 | 0.057 | 0.172 |
| 2008 | 45724         | 0.052 | 0.022 | 0.126 | 2015 | 85919         | 0.047 | 0.053 | 0.163 |
| 2009 | 50376         | 0.050 | 0.025 | 0.123 | 2016 | 90999         | 0.038 | 0.045 | 0.141 |

4. Study Method and Analysis

In 1955, Kuznets, who is Nobel Prize winner and economist, proposed the curve between per capita income level and distributive fairness, namely EKC (Environmental Kuznets Curve). The character of the curve shows “inverted U”. In 1991, Grossman and Theodore proposed that the relation curve of per capital income level and pollutants emission shows “inverted U” similarly. That is to say, with the increase of the per capital income level, the pollutants emission show the phenomenon of ascending first and then descending.

In the paper, using the relevant data of Jinan, adopting mathematical statistics method, the EKC is studied. The atmospheric quality of economic development of Jinan is analyzed.

4.1. Single Indicator Analysis

For a region, GDP per capita reflects the level of economic development. First, the analysis is conducted between GDP per capita and every indicator, such as SO₂, NO₂, PM₁₀, of Jinan from 2003 to 2016. The results of the analysis are as figure 1 and figure 2.
From figure 1, it can be found that GDP per capita of Jinan is sustainable growth from 2003 to 2016.

From figure 2, it can be found that annual mean value of atmospheric pollutant concentration is changed as follows.

(1) SO₂: Concentration annual mean (CAM) of SO₂ of Jinan from 2003 to 2016 is basic stable. In 2013, it increases substantial and reaches the peak of the annual mean concentration. And then, it shows a trend of rapid decline. On the whole, it shows a trend of “stable-rise- decline” in the past 14 years.

(2) NO₂: CAM of NO₂ of Jinan from 2003 to 2006 declines year by year. From 2006 to 2013, it increases year by year slowly. In 2013, it reaches the peak value. And then, it shows a trend of rapid decline. On the whole, it shows a trend of “decline-rise-rapid decline” in the past 14 years.

(3) PM₁₀: CAM of PM₁₀ of Jinan from 2003 to 2006 declines year by year. From 2006 to 2008, it increases slightly. From 2008 to 2011, it declines year by year. But in 2013, it reaches the peak value. And then, it declines rapidly. On the whole, it shows a trend of “decline-rise-rapid decline” in the past 14 years.

4.2. Correlation Analysis
The fitting analysis is conducted by using the data of GDP per capita and the annual mean value of atmospheric pollutant concentration over and over again. It is found that the thrice curve fitting is best. The fitting results are shown in table 2 and figure 3, figure 4, figure 5.

### Table 2. Model Summary and Parameter Estimation the independent variables: GDP per capita

| equation | Model Summary | Parameter Estimation |
|----------|--------------|----------------------|
|          | R square | F | Sig. | constant | b1 | b2 | b3 |
| SO₂      | twice     | 0.017 | 0.093 | 0.912 | 0.044 | 0.373 | -2.672 |
|          | thrice    | 0.357 | 1.852 | 0.202 | 0.209 | -10.132 | 197.738 | -1170.989 |
| NO₂      | twice     | 0.582 | 7.661 | 0.008 | 0.059 | -1.390 | 15.478 |
|          | thrice    | 0.915 | 36.042 | 0.000 | 0.215 | -11.304 | 204.605 | -1105.058 |
| PM₁₀     | twice     | 0.329 | 2.697 | 0.111 | 0.204 | -3.282 | 32.252 |
|          | thrice    | 0.427 | 2.481 | 0.121 | 0.372 | -14.001 | 236.733 | -1194.773 |
From the figure 3 to figure 5, the relationship between GDP per capita and the CAM of SO\textsubscript{2}, NO\textsubscript{2}, PM\textsubscript{10} of Jinan from 2003 to 2016 is not fully agreement, it shows “U+ inverted U”, along with the growth of GDP per capita.

4.3. Comprehensive Indicator Analysis
If the three factors are taken into consideration, GDP per capita fits with the comprehensive results of all kinds of indicator again.

The specific analysis method is as follows. First, the factor analysis is performed of the concentration annual mean of SO\textsubscript{2}, NO\textsubscript{2}, PM\textsubscript{10} by using SPSS, in order to determinate the weight of
these three factors. And then, the comprehensive indicator value of atmospheric pollutant concentration is obtained under the different weights. The calculation results are shown in table 3.

Table 3. The Comprehensive Indicator Value of Jinan Atmospheric Quality

| year  | Comprehensive value | year  | Comprehensive value |
|-------|---------------------|-------|---------------------|
| 2003  | 0.392               | 2010  | -0.462              |
| 2004  | -0.067              | 2011  | -0.288              |
| 2005  | -0.191              | 2012  | -0.134              |
| 2006  | -0.669              | 2013  | 1.494               |
| 2007  | -0.339              | 2014  | 0.813               |
| 2008  | -0.373              | 2015  | 0.315               |
| 2009  | -0.374              | 2016  | -0.116              |

In table 3, the higher comprehensive indicator value shows the higher concentration. That is to say, it shows the worse atmospheric quality. On the contrary, it shows that the atmospheric quality is better. Curve fitting is carried out between GDP per capita and the comprehensive indicator value over and over again. Finally, it is found that the thrice curve fitting is best. The result of the curve fitting is shown as below as table 4 and figure 6.

Table 4. Model Summary and Parameter Estimation the independent variables: GDP per capita

| equation | Model Summary | Parameter Estimation |
|----------|---------------|----------------------|
|          | R square      | F                    | Sig.   | constant | b1   | b2   | b3   |
| twice    | 0.248         | 1.812                | 0.209  | 0.623    | -38.706 | 428.590 |
| thrice   | 0.585         | 4.691                | 0.027  | 7.175    | -455.911 | 8387.405 | -46503.109 |

In figure 6, as the increase of GDP per capita, the concentration of pollutant in air is shown “U+ inverted U”. It is not entirely consistent with EKC characteristics. But in the short term, it is EKC. So EKC does not accord with the actual development of the city in the long term.

Figure 6. The Fitting curve of GDP per Capita and the Comprehensive Value
5. Conclusion  
Through the analysis above, based on the industrial structure of Jinan from 2003 to 2016 (figure 7), the ratio of the second industry shows the trend of first increase and then drop. From 2003 to 2006, it shows steady increase in trend, and after 2007, it reduces year by year. On the contrary, the ratio of the third industry grows rapidly. From 2009, it is more than 50%. The decrease of the second industry reduces the air pollutants emission effectively.

Combined with the cost of energy conservation and environmental protection of Jinan in recent years (figure 8), the overall environmental input trend is increasing year by year. But in 2011 and 2013, there is a little decrease. After 2014, the total cost has increased substantially. It shows that the relevant departments attach more importance to the atmospheric environment quality. This is one of the important reasons for the obvious decrease of air pollutants emission of Jinan and the obvious improvement of air quality from 2014.

![Figure 7. The Industry Structure of Jinan](image-url)
Figure 8. The Cost of Energy Conservation and Environmental Protection

From what has been discussed above, there is a close relationship between GDP per capita and air quality. In order to possess good economic environment, the relevant departments must to raise the input of environment protection and enhance the controlling in strength of atmospheric pollutant to ensure the sustainable development of the urban economic environment. The analysis result can provide a certain reference for the sustainable development of the city.

Acknowledgements
This work was supported by the Natural Science Foundation of Shandong Province of China (Grant No. ZR2014AM001).

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