The Empirical Study Between Economic Growth and Environmental Pollution in China’s Municipalities

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Abstract

In order to explore the quantitative relationship between economic growth and environmental pollution, the paper takes China’s 4 municipalities, namely, Beijing, Tianjin, Shanghai and Chongqing, as the target for research. In terms of indexes selection, we choose GDP per capita from 1997 to 2012 as the economic development indicator. On the other hand, we select discharge of industrial waste water, emission of industrial waste gas, emission of industrial sulfur dioxide and discharge of industrial solid waste as the environmental pollution indicators. And by means of the typical Environmental Kuznets Curve, we build the cubic polynomial function model between GDP per Capita and the four environmental pollution indicators. Furthermore, the empirical results turn out that the relationship between economic growth and environmental pollution is abundant in N and inverted N shape, which means that inverted U shape (the typical EKC) is just one form of them. Finally, in view of the harmonious development between economy and environment, we put forward some effective suggestions.

Key words: The EKC; Economic growth; Environmental pollution

INTRODUCTION

In order to further promote the development of Chinese characteristic socialism, in 2012, the 18th report of the Communist Party of China1 made the overall layout of construction in five aspects. For the first time, Chinese government put ecological civilization construction on an equally important position with economic construction, political construction, cultural construction and social construction, aiming at building a prosperous society in an all-round way, realizing socialist modernization and rejuvenating the great Chinese nation. With the rapid development of social economy, the attendant environmental pollution is becoming more and more serious, and it has aroused great concern from all sectors of society.2 Against such background, studying the quantitative relationship between economic growth and environmental pollution is of great importance.

1. LITERATURE REVIEW ON THE EKC

The Environmental Kuznets Curve (EKC) was initially a doctrine, with which the American economist Kuznets analyzed the relationship between the level of income per capita and the degree of distribution justice in the 1950s. His research suggested that income inequality firstly expanded and then narrowed with the economic development, presenting an inverted U shape (the typical EKC) is just one form of them. Finally, in view of the harmonious development between economy and environment, we put forward some effective suggestions.

1. The 18th national congress of the communist party of China was held on November 8th in 2012.

2. The economic analysis on the environmental pollution can trace back to 1932, aiming at the environmental pollution in London, Pigou thought that it was the external problems that caused the environmental pollution. However, it is until 1960s that sociologists and economists generally realize that environmental pollution is a big threat to humans. (Fisher & Peterson, 1976, p.3)
environmental quality will deteriorate with the development of economy; when the economic level reaches certain degree, the environment will gradually improve, i.e. the typical EKC (Grossman & Krueger, 1991). As shown in Figure 2.

Since the EKC (Environmental Kuznets Curve) was proposed by Grossman and Krueger in 1991, it has attracted much attention of numerous scholars from all over the world. Some scholars confirmed the existence of the EKC. Shafik & Bandyopadhyay (1992) found that emissions of sulfur dioxide (SO₂) and suspended particulate matter (SPM) originally raised and then reduced with the increase of income per capita. Panayotou (1993) found that the relationship between the degree of forest deforestation and income per capita was shown in an inverted U shape curve. Selden & Song (1994) conducted the study on four air indexes, i.e. SO₂, Nitric oxide (NOₓ), Cobalt (CO) and SPM and confirmed the existence of EKC. Panayotou (2003) discovered that there was an inverted U shape relationship between carbon dioxide (CO₂) and economic growth. Chinese academic Wu Yuping (2002) found that there was an inverted U shape relationship between economic growth and environmental pollution in Beijing. The study on Wenzhou, Zhejiang province indicated that except emission of industrial waste gas, other industrial environmental pollutants and GDP per capita were obviously in line with the typical EKC (Wang, & Li, 2005). Guo and Li (2010) found that discharge of industrial solid waste and GDP per capita met with the EKC, using 29 provinces’ panel data from 1991 to 2007 in China.

However, some others did not support the EKC hypothesis. Kaufmann et al. (1998) found that the trend of income per capita and sulfur dioxide (SO₂) were U shape, other than inverted U shape. Chinese Liu (2007) did research on Yantai, Shandong province, using three environmental pollution indexes and GDP per capita, and the results reflected that the inverted U shape was not the general rule. Zhou, Yuan, Xue and Zhou (2009) made the study on Shanxi Province, finding that there was a long-run equilibrium relationship between economic growth and discharge of industrial waste water, showing the N shape curve. Ding (2012) conducted the study on Guangxi province and came to the results that there was a statistically significant N shape instead of an inverted U shape relationship between environmental pollution and economic growth. Wang (2013) conducted the research and found that the trend between coastal area economy and marine environmental pollution was presented as a N shape curve.

Above all, it can be seen that there does exist certain EKC relationship between environmental pollution and economic growth, but it may be inverted U shape, i.e. the typical EKC, be N shape, inverted N shape or other similar shapes. In the paper, we attempt to explore the evolution rules between economic growth and environmental pollution in China’s four municipalities. In the end, we will provide some helpful suggestions for promoting common development of environment and economy.

2. EMPIRICAL STUDY BASED ON THE EKC

On the basis of the typical EKC model, we conduct the empirical study between economic growth and environmental pollution in Beijing, Tianjin, Shanghai and Chongqing.

2.1 Index Selection

In 1997 Chongqing was carved out of Sichuan province into a municipality that reports directly to Beijing. In order to fully study the succession rule between economic growth and environmental pollution, the time for research ranges from 1997 to 2012. In addition, the main inducement that evokes environmental quality deterioration is discharges of industrial “three wastes”. So we choose discharge of industrial waste water, emissions of industrial waste gas and industrial sulfur dioxide (SO₂) and discharge of industrial solid waste as environmental pollution indicators. On the other hand, we choose GDP
per capita\(^3\) as economic development indicator. The basic data are shown in Appendix A to Appendix D. Furthermore, we draw figures with Origin software, as shown in Figure 3 to Figure 7.

**Figure 3**  
The Trend of GDP Per Capita

Figure 3 vividly depicts the trend of GDP per capita from 1997 to 2012 in Beijing, Tianjin, Shanghai and Chongqing. Although the change of GDP per capita in China’s four municipalities is different, the overall trend is all upward. Averagely speaking, GDP per capita of China’s four municipalities, adjusted for inflation, has almost sextupled since 1997.

Moreover, from the total economy point of view, Shanghai has occupied the first place unchallenged since 1997; Beijing and Tianjin followed after Shanghai, respectively ranking the second and the third. However, from the perspective of GDP per capita, Tianjin exceeded Shanghai and Beijing in 2011 and has been in the first place till now. On the whole, Shanghai and Beijing’s economy performed better than that of Tianjin in the past 16 years.

In addition, economic development level varies greatly among the four municipalities. Chongqing’s economy has expanded greatly since she became the municipality city. But compared with the other three municipalities, Chongqing still lags behind and the absolute amount of gap is likely to widen, just as shown in Figure 3. The evidence that GDP per capita of Shanghai was 4 times that of Chongqing in 1997, which became 2.18 times in 2012, shows that those stubborn gaps have begun to close.

Based on the panel data of China’s four municipalities, we draw figures below to present the tendency of the four environmental pollution indicators from 1997 to 2012, as shown in Figure 4 to Figure 7.

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\(^3\) GDP Per Capita of China’s four municipalities is calculated by resident population of Beijing, Tianjin, Shanghai and Chongqing.
Figure 7 
The Trend of Industrial Solid Waste

Table 1
The Mean Value and the Ranking for Various Indicators

<table>
<thead>
<tr>
<th>Municipality</th>
<th>GDP per capita (CNY)</th>
<th>Industrial waste water (10,000 tons)</th>
<th>Industrial waste gas (100 million standard m³)</th>
<th>Industrial SO₂ (10000 tons)</th>
<th>Industrial solid waste (10000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJ</td>
<td>45871.366</td>
<td>16467.81</td>
<td>3867.94</td>
<td>11.2175</td>
<td>1199.7531</td>
</tr>
<tr>
<td>TJ</td>
<td>40424.985</td>
<td>21125.50</td>
<td>4680.6875</td>
<td>21.0369</td>
<td>1035.3500</td>
</tr>
<tr>
<td>SH</td>
<td>49306.489</td>
<td>59608.81</td>
<td>8714.00</td>
<td>31.6119</td>
<td>1857.5194</td>
</tr>
<tr>
<td>CQ</td>
<td>15282.150</td>
<td>73675.69</td>
<td>5100.3987</td>
<td>63.4640</td>
<td>1928.5994</td>
</tr>
</tbody>
</table>

Ranking
SH > BJ > TJ > CQ

2.2 Model Building

In general, the inverted U shape EKC usually has three kinds of basic functions: quadratic function, cubic function and mixed function. Since cubic polynomial function has the advantages of high goodness of fit and high precision of F test, we build cubic function as Equation (1)\(^4\):

\[
Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \epsilon
\]

\(X\) on behalf of GDP per capita, the unit is CNY. 
\(Y\) on behalf of various environmental pollution indicators, including discharge of industrial waste water, emission of industrial waste gas, emission of industrial sulfur dioxide (SO₂) and discharge of industrial solid waste, the units respectively are 10,000 tons, 100 million standard cubic meters, 10,000 tons and 10,000 tons.

\(\epsilon\) on behalf of random error. 
\(\beta_0, \beta_1, \beta_2, \beta_3\) on behalf of the regression coefficients.

When they are taken different values, the relationship between economic growth and environmental pollution is as follows:

1) \(\beta_1 = \beta_2 = \beta_3 = 0\), a straight line, i.e. economic growth has no effect on environment.
2) \(\beta_1 > 0, \beta_2 = \beta_3 = 0\), monotone increasing, i.e. environment deteriorates with economic growth.
3) \(\beta_1 < 0, \beta_2 = \beta_3 = 0\), monotone decreasing, i.e. environment improves with economic growth.
4) \(\beta_1 > 0, \beta_2 < 0, \beta_3 = 0\), inverted U shape, i.e. the typical EKC, environment deteriorates before improves with economic growth.
5) \(\beta_1 < 0, \beta_2 < 0, \beta_3 = 0\), U shape relationship, i.e. environment improves before deteriorates with economic growth.

\(^4\) The relationship between economic growth and environmental pollution varies with the different beta coefficients. Many scholars have found that the scope of application of the typical inverted U is limited. The paper chooses the cubic polynomial function model so that we can fully study the relationship between economy and environment.

Figure 4 and Figure 6 have the same trend: in the last 16 years, discharge of industrial waste water and emission of industrial sulfur dioxide (SO₂) were decreased on the whole. The absolute volume ranking followed by Chongqing, Shanghai, Tianjin and Beijing.

The tendency of emission of industrial waste gas (as shown in Figure 5) was on the rise as a whole from 1997 to 2012. Chongqing had the largest increase in it, followed by Shanghai, Tianjin and Beijing. But the absolute volume ranking followed by Shanghai, Chongqing, Tianjin and Beijing.

Figure 7 has a similar tendency with Figure 5, the difference is that: discharge of Industrial solid waste in Chongqing, Shanghai and Beijing started at a similar point in 1997, but they moved into different directions after 16 years’ development. Beijing showed a downward trend in the fluctuation, while Shanghai and Chongqing just the opposite. Tianjin presented a trend of increasing between 1997 and 2012.

In conclusion, we calculate the mean value for various indicators in China’s four municipalities and draw a table (as shown in Table 1) combining with the analysis above.
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6) $a_1 > 0, a_2 > 0, a_3 > 0$, N shape relationship, i.e. environment deteriorates, then gradually improves and finally deteriorates with economic growth.

7) $a_1 < 0, a_2 > 0, a_3 < 0$, inverted N shape relationship, i.e. environment first improves, then gradually deteriorates and finally improves with economic growth.

3. THE ANALYSIS FOR EMPIRICAL RESULTS

3.1 Preliminary Judgment by Graphics

We first draw the double Y figures for each municipality using Origin software, making a preliminary judgment about the EKC shape, as shown in Figure 8 to Figure 11.

- Figure 8: The Double Y Figure of Beijing
- Figure 9: The Double Y Figure of Tianjin
- Figure 10: The Double Y Figure of Shanghai
- Figure 11: The Double Y Figure of Chongqing

From the diagrams above, it is easy to distinguish that discharge of industrial waste water and GDP per capita, emission of industrial waste gas and GDP per capita do have certain functional relations. Specifically, there is a decreasing relationship between industrial waste water and GDP per capita in Beijing, Shanghai and Chongqing. And an rising trend exists between industrial waste gas and GDP per capita in Beijing, Tianjin and Shanghai.

However, due to smaller orders of magnitude, it is hard for us to distinguish whether emission of industrial sulfur (SO$_2$) and GDP per capita, discharge of industrial solid waste and GDP per capita have certain functional relations. So we draw the double Y figures between the two pollutants and GDP per capita, as shown in Figure 12 to Figure 15.
From the figures above, we can easily find that emission of industrial sulfur dioxide (SO₂) and GDP per capita, discharge of industrial solid waste and GDP per capita do have one or another relationship.

3.2 The Empirical Test

According to Equation (1), we conduct the empirical study with SPSS software. Here are summary of the regression results between discharge of industrial waste water and GDP per capita, as shown in Table 2.

Table 2 tells us the following information: the goodness of fit (namely $R^2$) in Beijing, Shanghai and Chongqing separately is 0.978, 0.967 and 0.930, which proves that the cubic equation is adopted to fit the experiment data in good effect. However, as a result of unremarkable t value in Chongqing, so only Beijing and Shanghai’s fitted curves are acceptable. Besides, both Beijing and Shanghai’s coefficients are $\hat{a}_1 < 0$, $\hat{a}_2 > 0$, $\hat{a}_3 < 0$, so the curves are inverted N shape.

By further calculation, we find that Beijing has two extreme points: when Beijing’s GDP per capita was 55911.783 CNY, discharge of industrial waste water reached the minimum value; when GDP per capita reached 74192.474 CNY, the maximum value would appear. In 2011, Beijing’s GDP per capita had amounted to 80510.75 CNY, so discharge of industrial waste water at present is in the stage of declining, as shown in Figure 16. This phenomenon is partly attributable to Beijing Green Olympics in 2008, along with widely cleaning up the environment and carrying out environmental education.

Similarly, Shanghai also has two extreme points: when Shanghai’s GDP per capita was separately 67660.343 CNY and 90784.620 CNY, discharge of industrial waste water accordingly reached the minimum and the maximum value. In 2012, GDP per capita in Shanghai was 84459.33 CNY, discharge of industrial waste water had not reached the maximum value, as shown in Figure 17. So before the environment gets much worse, Shanghai should strengthen environmental protection.
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Table 2
The Regression Results Between Discharge of Industrial Waste Water and GDP Per Capita

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Regression function</th>
<th>Statistical indexes</th>
<th>Significant or not</th>
<th>Curve shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>$Y=77353.422-3.263x+5.117E-5x^2-2.622E-10x^3$</td>
<td>$R^2=0.978$</td>
<td>Yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>$t$ value =15.105 -8.722 6.426 -5.104</td>
<td>$DW=1.50$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tianjin</td>
<td>$Y=9770.363+0.918x-1.862E-5x^2+1.067E-10x^3$</td>
<td>$R^2=0.280$</td>
<td>No</td>
<td>N-shape</td>
</tr>
<tr>
<td></td>
<td>$t$ value =1.508 1.733 -1.575 1.391</td>
<td>$DW=1.54$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td>$Y=192756.458-5.895x+7.603E-5x^2-3.199E-10x^3$</td>
<td>$R^2=0.967$</td>
<td>Yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>$t$ value =8.536 -4.009 2.608 -1.779</td>
<td>$DW=1.04$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>$Y=92156.470+0.085x-9.412E-5x^2+1.282E-9x^3$</td>
<td>$R^2=0.930$</td>
<td>No</td>
<td>N-shape</td>
</tr>
<tr>
<td></td>
<td>$t$ value =8.156 0.037 -0.751 0.652</td>
<td>$DW=1.08$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition, the curves of Tianjin and Chongqing are shown in N shape with two extreme points. In 2011, GDP per capita in Tianjin exceeded 80880.91 CNY that corresponded to the minimum value of discharge of industrial waste water. So with further growth of economy, the environment in Tianjin will deteriorate, as shown in Figure 18. Although the results are not statistically significant, the government should also pay close attention to it.

In 2012, Chongqing’s GDP per capita was 8742.28 CNY, less than 48488.562 CNY, so discharge of industrial waste water did not reach the minimum value. Up till now, this environmental indicator is still falling, as shown in Figure 19, and we must be alert to the arrival of its future rise.
Likewise, we do the empirical research between the other three environmental pollution indicators and GDP per capita under Eq (1), the results are shown in Table 3-5.  

### 3.3 Summary of Empirical Study

By summarizing the empirical results, we draw Table 6 as follows.

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**Table 3**
The Regression Results Between Emission of Industrial Waste Gas and GDP Per Capita

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Regression function</th>
<th>Statistical indexes</th>
<th>Significant or not</th>
<th>Curve shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>[ Y = 5042.943 - 0.171t + 4.3964E^{-6}t^2 - 2.839E^{-11}t^3 ]</td>
<td>R²=0.864</td>
<td>yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 4.500 - 2.084 2.524 - 2.526</td>
<td>DW=1.397</td>
<td>F=25.336</td>
<td></td>
</tr>
<tr>
<td>Tianjin</td>
<td>[ Y = -1863.34 + 0.307t - 2.828E^{-6}t^2 + 2.484E^{-11}t^3 ]</td>
<td>R²=0.941</td>
<td>yes</td>
<td>N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = -1.295 2.613 -1.632 1.458</td>
<td>DW=2.074</td>
<td>F=64.248</td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td>[ Y = -7159.749 + 0.746t - 1.219E^{-5}t^2 + 7.492E^{-11}t^3 ]</td>
<td>R²=0.968</td>
<td>yes</td>
<td>N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = -2.203 3.242 -2.671 2.662</td>
<td>DW=2.084</td>
<td>F=122.22</td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>[ Y = 1140.789 - 0.154t + 4.564E^{-6}t^2 - 9.651E^{-10}t^3 ]</td>
<td>R²=0.931</td>
<td>yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 0.572 -0.381 2.063 -2.783</td>
<td>DW=2.846</td>
<td>F=53.773</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4**
The Regression Results Between Emission of Industrial Sulfur Dioxide and GDP Per Capita

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Regression function</th>
<th>Statistical indexes</th>
<th>Significant or not</th>
<th>Curve shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>[ Y = 33.764 - 0.001t + 1.466E^{-8}t^2 - 7.181E^{-14}t^3 ]</td>
<td>R²=0.929</td>
<td>yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 6.988 -2.998 1.952 -1.482</td>
<td>DW=0.972</td>
<td>F=52.263</td>
<td></td>
</tr>
<tr>
<td>Tianjin</td>
<td>[ Y = 14.575E^{-10} - 1.038E^{-8}t^2 + 6.388E^{-14}t^3 ]</td>
<td>R²=0.129</td>
<td>no</td>
<td>N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 2.869 -1.12 1.062</td>
<td>DW=2.134</td>
<td>F=0.591</td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td>[ Y = 72.666 - 0.003t + 5.348E^{-8}t^2 + 3.685E^{-13}t^3 ]</td>
<td>R²=0.688</td>
<td>yes</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 2.892 -1.56 1.648 -1.841</td>
<td>DW=1.040</td>
<td>F=8.827</td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>[ Y = 70.538 + 1.805E^{-8}t^2 - 4.209E^{-13}t^3 ]</td>
<td>R²=0.465</td>
<td>no</td>
<td>Inverted N-shape</td>
</tr>
<tr>
<td></td>
<td>t value = 6.141 0.142 -0.211</td>
<td>DW=0.659</td>
<td>F=3.479</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5**
The Regression Results Between Discharge of Industrial Solid Waste and GDP Per Capita

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Regression function</th>
<th>Statistical indexes</th>
<th>Significant or not</th>
<th>Curve shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>[ Y = 1127.677 - 0.001t + 1.768E^{-7}t^2 - 1.930E^{-12}t^3 ]</td>
<td>R²=0.505</td>
<td>no</td>
<td>Inverted N</td>
</tr>
<tr>
<td></td>
<td>t value = 5.793 -0.097 0.584 -0.988</td>
<td>DW=2.030</td>
<td>F=4.080</td>
<td></td>
</tr>
<tr>
<td>Tianjin</td>
<td>[ Y = 164.506 - 0.013t + 4.332E^{-7}t^2 - 4.199E^{-12}t^3 ]</td>
<td>R²=0.974</td>
<td>yes</td>
<td>Inverted U</td>
</tr>
<tr>
<td></td>
<td>t value = 0.794 0.775 1.146 -1.710</td>
<td>DW=1.686</td>
<td>F=149.97</td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td>[ Y = 993.932 - 0.004t + 8.248E^{-7}t^2 - 7.069E^{-12}t^3 ]</td>
<td>R²=0.966</td>
<td>yes</td>
<td>Inverted N</td>
</tr>
<tr>
<td></td>
<td>t value = 1.831 -0.106 1.176 -1.630</td>
<td>DW=1.843</td>
<td>F=112.88</td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>[ Y = 1417.209 - 0.053t + 7.370E^{-6}t^2 - 1.243E^{-10}t^3 ]</td>
<td>R²=0.987</td>
<td>yes</td>
<td>Inverted N</td>
</tr>
<tr>
<td></td>
<td>t value = 8.354 -1.537 3.916 -4.214</td>
<td>DW=1.830</td>
<td>F=292.42</td>
<td></td>
</tr>
</tbody>
</table>
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Table 6
Summary of the EKC Shape

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Industrial waste water (10,000 tons)</th>
<th>Industrial waste gas (100 million standard m³)</th>
<th>Industrial SO₂ (10,000 tons)</th>
<th>Industrial solid waste (10,000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Significance</td>
<td>Shape</td>
<td>Significance</td>
<td>Shape</td>
</tr>
<tr>
<td>Beijing</td>
<td>Yes</td>
<td>Inverted N</td>
<td>Yes</td>
<td>Inverted N</td>
</tr>
<tr>
<td>Tianjin</td>
<td>No</td>
<td>N shape</td>
<td>Yes</td>
<td>N shape</td>
</tr>
<tr>
<td>Shanghai</td>
<td>Yes</td>
<td>Inverted N</td>
<td>Yes</td>
<td>N shape</td>
</tr>
<tr>
<td>Chongqing</td>
<td>No</td>
<td>N shape</td>
<td>Yes</td>
<td>Inverted N</td>
</tr>
</tbody>
</table>

From Table 6 we can learn that Beijing’s EKC curves are all inverted N shape and most of them are statistically significant. Moreover, emissions of the pollutants basically have a downward tendency, which means that Beijing’s environment is gradually improving.

Speaking of Tianjin, since the regression results between industrial solid waste and GDP per capita are $a_1 > 0, a_2 > 0, a_3 > 0$, so it does not meet any situation of the seven above. By combining with the equation, we can determine that the curve is inverted U shape, while the shapes between the other three indicators and GDP per capita are all N curves.

Shanghai and Chongqing’s EKC curves are mainly inverted N shape, accompanying with N shape at the same time. The different point is that Shanghai’s statistical indicators are all statistically significant while Chongqing’s not. For one thing, Chongqing should further accelerate economic development under the premise of protecting environment so as to narrow the economic gap with the other three municipalities. For another thing, Shanghai should balance the relationship between environmental protection and economic development, so that turn Shanghai into the apple of the whole world’s eye.

CONCLUSION

By conducting the empirical study between environmental pollution and economic growth in China’s four municipalities, we can draw the following conclusions:

1. Further increase the investment in environmental protection.
2. Optimize the industrial structure and transform the mode of economic growth.
3. Develop new clean energy and promote the market operation of environmental protection.
4. Carry out environmental education and propaganda activities so as to strengthen the public’s environmental protection consciousness.
5. Perfect the relevant legal policy, such as implementation of green tax.
6. Attach great importance to science and promote technology innovation.

ACKNOWLEDGMENTS

I would like to thank all those who have given me their generous help, commitment and enthusiasm, which have been the major driving force for me to finish the current paper.

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Special thanks should go to editors who will spend their considerate time and effort into their comments on my paper. I am deeply indebted to my beloved family for their continuous support and encouragement in me all through these years.

REFERENCES


Wang, G. S. (2013). The empirical research on the relationship between economic growth and environmental pollution along the costal area of China. Ocean University of China, Qingdao.


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**APPENDIX**

**A. The Indicators of Beijing**

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP Per Capita (CNY)</th>
<th>Industrial waste water (10,000 tons)</th>
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*Note: Sources of data: Beijing statistical yearbook and China environmental statistics.*
### B. The Indicators of Tianjin

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*Note: Sources of data: Tianjin statistical yearbook and China environmental statistics.*

### C. The Indicators of Shanghai

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*Note: Sources of data: Shanghai statistical yearbook and China environmental statistics.*
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*Note. Sources of data: Chongqing statistical yearbook and China environmental statistics*

### E. The Fitting Curve Between Industrial Waster Gas and GDP Per Capita

![Cubic Polynomial R$^2=0.864$](image)

Beijing
The Empirical Study Between Economic Growth and Environmental Pollution in China’s Municipalities

Tianjin

Shanghai
Chongqing

F. The Fitting Curve Between Industrial SO₂ and GDP Per Capita

Beijing
The Empirical Study Between Economic Growth and Environmental Pollution in China’s Municipalities

Tianjin

Shanghai
Chongqing

G. The Fitting Curve Between Industrial Solid Waste and GDP Per Capita

Beijing
The Empirical Study Between Economic Growth and Environmental Pollution in China’s Municipalities

Tianjin

Shanghai
Chongqing