Research on the relationship of economic growth and environmental pollution in Shandong province based on environmental Kuznets curve

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Abstract

The relationship between economic development and environmental pollution of Shandong province is studied. We tested Environmental Kuznets curve hypothesis using data from 1981 to 2008. The results show that there is an inverted U-shaped curve between emission of sulphur dioxide or soot and GDP per capita. It can be explained by ever-cleaner industrial structure, quickly increasing environmental protection investment and stricter environmental policy. The turning points of sulphur dioxide and soot are both apparently less than that of developed countries. It indicates the possibility to exceed the extreme point at the low level of per capita income for developing countries. Waste water and industrial solid waste do not accord with the EKC curve. It relates to quickly ascending discharge of municipal waste water and attributes of solid waste. Our study reveals the importance of adjusting industrial structure, increasing environmental protection expense and strengthening the construction of environmental policy. Moreover, it points to the necessity and urgent need of improving the treatment facilities for polluted water, developing clean production and carrying on recycled use of waste.

Keywords: Economic growth; Environmental pollution; Environmental Kuznets curve; Shandong

1. Introduction

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Mankind has paid a great cost as a result of severe environmental deterioration in pursuit of the development of the economy since the industrial revolution especially the Second World War. The relationship of economic growth and environmental pollution has received growing recognition throughout the world since 1970's. Grossman and Krueger put forward that the level of economic growth and environmental degradation follows an inverted U-shaped relationship based on data analysis from many countries in 1991 \[1\]. Because of its resemblance to the pattern of inequality and income described by Simon Kuznets, this pattern of inverted U-shaped relationship between environmental pollution and economic development level has been labelled the “environmental Kuznets curve” (EKC). Environmental quality will appear first to worsen and later to improve as one country’s income grows according to EKC. It coincides with the fact that the most of poorest and richest countries have the cleaner environments than middle-income countries in the world. The explanations for the inverted U-shaped relationship between environmental pollution and economic development level include: as an economy develops, firstly, people are willing to and have the capability to pay more for environmental quality; secondly, the economic structure will change to a higher portion of services compared with industry; finally, a city will have the perfect and concentrated pollution control measures and an enterprise will possess the higher level of technological eco-efficiency \[2\).

The relationship between economic growth and environmental pollution have been extensively investigated and analyzed in some developed countries. However, there has been relatively few research on the relationship for developing countries. Some conclusions on the inverted U-shaped relationship between the emission of key industrial pollutants and average per capita income from developed countries do not always correspond to the truth of developing countries. China, as the most populous developing country and also one of the highest economic growth rates in the world, is playing a greater role in the global environment. Thus it is significant to study the relationship between economic growth and environmental pollution in China for harmonizing economic development and environmental protection in developing countries and even in the whole world. Shandong is one of the most populous provinces in China with a rapid economic growth. Shandong province makes the strategy policy of developing recycling economy and constructing eco-province in 2003. Here we test the EKC hypothesis using data of primary pollutant discharge and GDP per capita (GDPPC) from Shandong. We try to analyze the causes and give insights into harmonious development of economy and environment in Shandong.

![GDP of total and three industrial sectors in Shandong Province](image)

**Fig. 1. GDP of total and three industrial sectors in Shandong Province**

**2. Economic growth in Shandong**

According to the data of Shandong Statistical Yearbook (1982-2009), the GDP has increased with an average annual growth rate of 18.1% from 1981 to 2008. The total GDP of Shandong was only 34.66 billion yuan in 1981. By the end of 2008, the GDP reached 3107.21 billion (Fig. 1). The tertiary sector of industry grows fast with the average annual growth rates of 21.1%, followed by the secondary and
primary sectors of industry with the growth rates of 19.2% and 12.3% respectively. Fig. 2 shows the development trends of the GDPs of the three industries and their contributions to total GDP in Shandong province from 1981 to 2008. It is obvious that secondary industry made the primary contribution to GDP of Shandong province. Its contribution ratio to total GDP has increased from 44.8% in 1981 to 57% in 2008. The contribution of primary industry kept decreasing from 38.2% in 1981 to 9.6% in 2008. On the contrary, the contribution of tertiary industry showed an overall rapid ascent from 17% in 1981 to 33.4% in 2008.

Fig. 2. Proportion of three industrial sectors in Shandong Province

3. Testing Environmental Kuznets curve hypothesis

In this study, we use the following equation to describe the relationship between economic growth and environmental pollution:

\[ \ln(P_t) = b_0 + b_1 \ln(GDP_t) + b_2[\ln(GDP_t)]^2 \]  

(1)

Where \( P \) represents the concentration of a pollutant; GDPPC represents GDP per capita; \( \ln \) indicates natural logarithm transformation; \( t \) denote time index; \( b_0, b_1 \) and \( b_2 \) are coefficients to be estimated. Here no time effects are estimated as GDPPC kept increasing monotonically during the research period. If the regression coefficient \( b_2 \) is negative, the equation corresponds to the standard EKC model; if the coefficient \( b_2 \) is zero or a positive number, the model does not hold EKC model.

Table 1. Regression analyses between pollutant discharge and GDP per capita in Shandong

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>( R^2 )</th>
<th>( F )</th>
<th>( P )</th>
<th>( b_0 )</th>
<th>( b_1 )</th>
<th>( b_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWW</td>
<td>0.953</td>
<td>254.91</td>
<td>0.000</td>
<td>7.724 1</td>
<td>-0.347 8(0.069)</td>
<td>0.037 7(0.002)</td>
</tr>
<tr>
<td>ESD</td>
<td>0.769</td>
<td>41.55</td>
<td>0.000</td>
<td>0.317</td>
<td>1.71(0.000)</td>
<td>-0.099 2(0.000)</td>
</tr>
<tr>
<td>ES</td>
<td>0.836</td>
<td>63.65</td>
<td>0.000</td>
<td>-1.639 8</td>
<td>2.305 8(0.000)</td>
<td>-0.151 7(0.000)</td>
</tr>
<tr>
<td>EISW</td>
<td>0.975</td>
<td>492.19</td>
<td>0.000</td>
<td>5.645 3</td>
<td>-0.823 4(0.000)</td>
<td>0.071 5(0.000)</td>
</tr>
</tbody>
</table>

Note: \( b_0 - b_2 \) refer to the coefficients of Eq. (1); EWW, ESD, ES and EISW represent emissions of waste water, sulphur dioxide, soot and industrial solid waste respectively; GDPPC means GDP per capita; Data in parentheses are p values; Error df=25 in all regressions.

We study four dependent variables: emissions of waste water (EWW), sulphur dioxide (ESD), soot (ES) and industry solid waste (EISW). For the ESD and ES, the ln-ln plot clearly shows an inverted U-shaped relationship (Fig. 3B and C), and coefficients of the models corresponding to the square term in Eq. (1) are significantly different from 0 (Table 1). EKC thus applies in these variables.

The regression model with ESD as the dependent variable is given by the following equation:

\[ ESD = 0.317 + 1.71 \text{ GDPPC} - 0.0992 \text{ GDPPC}^2 \]  

(2)
From equation (2), we can obtain the turning point at $GDPPC = 5.536$. This reveals that the value of ESD begins to decrease when $GDPPC$ exceeds 5.536 yuan which occurred at the time interval between 1995 and 1996. On the contrary, the value of ESD increases with the rising of $GDPPC$ when $GDPPC$ is less than 5.536 yuan.

The regression model with $ES$ as the dependent variable is given by the following equation:

$$ES = -1.6398 - 2.3058 \cdot GDPPC - 0.1517 \cdot GDPPC^2$$

(3)

From equation (3), we can obtain the turning point at $GDPPC = 1998$ yuan which occurred at the time interval between 1991 and 1992. This reveals that the values of ES begins to increase with the rising of $GDPPC$ when $GDPPC$ is less than 1998 yuan, then to decrease when $GDPPC$ exceeds 1998 yuan.

In the fourth pollutants, however, EWW and EISW have significantly ascended over the study period, and EKC does not hold (Fig. 3A and D).

Fig. 3. The relationship between GDP per capita and environmental pollution in Shandong. The curves show quadratic regression models fitted to the data on ln-ln scale. EWW, ESD, ES and EISW represent emissions of waste water, sulphur dioxide, soot and industrial solid waste respectively. GDPPC means GDP per capita.

4. Discussion

The above analysis indicates that the relationship between economic growth and environmental pollution in Shandong does not totally accord with the traditional EKC. The results reveal two types of relationship, including the inverted U-shaped and upward pattern.

The inverted U-shaped patterns are observed in the study of ESD and ES. The turning points are both apparently less than that of developed countries. It indicates the sulphur dioxide and soot pollution of
Shandong can arrive at the right side of EKC at low GDPPC values. Thus, for developing countries, it is possible to exceed the extreme point at the condition of the low GDPPC. For the sulphur dioxide and soot discharged, Shandong province has passed the turning point of the EKC currently. It means that the pollution of sulphur dioxide and soot will alleviate with the further development of economy. The inverted U-shaped curve is identical with the industry structure development of Shandong province. The economy development of Shandong province changes from a clean agricultural economy to a polluting industrial economy, then to a clean service economy (Fig. 2). In these three industries, the tertiary industry in Shandong grows the quickest with the average annual growth rates of 21.1%. The secondary and primary sectors of industry is second and third. In addition, the inverted U-shaped patterns have a close relation with the environmental policy. In 1996, the government of Shandong province made the annual plan on the province’s environment protection in which the index of control of total pollutant emission brought into the annual national economic and social development program of Shandong province for the first time. Furthermore, Shandong province has a quickly increasing environmental protection investment since 1996 [3]. Thus it is obvious that the optimization of industrial structure, governmental pollution abatement expense and environmental policy have a significant and positive effect on environmental quality at least for the sulphur dioxide and soot pollutants’ emissions examined in this paper.

In our study, EWW and EISW do not support EKC. It is consistent with some earlier researches in which the positive relationship between EISW and GDPPC was found [4]. It reveals the necessity and urgent need for promoting clean production and recycled use of waste in Shandong. Waste water discharged of Shandong province keep increasing over the whole period. The rapid increase in municipal waste water discharged make the dominant contribution to growing tendency of total discharge of waste water. The municipal waste water originates mostly from consumption behaviours including residential emissions and emissions from the service sector. The population and standard of living especially tertiary industry have maintained a sustained and rapid growth in Shandong. However, the treatment facilities for polluted water do not keep pace with that. Thus it is possibly one of the important part of environmental protection of Shandong in future.

Acknowledgements

This work is supported by the Natural Science Foundation of Shandong Province, China (No. ZR2010DQ005 and No. ZR2010DQ025) and Ph.D. fund of University of Jinan (No. XBS0841).

References