Research on the Measurement Model of the Relationship between Economic Growth and Environment in Shandong Province

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Abstract. Through the analysis of the measurement model of the environmental and economic data of Shandong Province from 1989 to 2003, it is found that the fitting curve between industrial "three wastes" emissions and economic growth does not completely conform to the characteristics of the typical environmental Kuznets curve. This paper believes thinks that the economic development, changes in industrial structure, upgrading of energy consumption structure, policy and technology are the main factors leading to the non-typical environmental Kuznets Curves in Shandong province.

Keywords: Economic growth, Environmental Kuznets Curves, Shandong province.

1. Introduction

Environmental pollution is an important factor affecting economic development. The economic development level and strength of a region will also objectively affect environmental quality. There is a close relationship between economy and environment, which is usually described by environmental Kuznets curve. In 1995, American economists, Grossman and Kreuger, analyzed the changes of pollutant emissions in different regions of 66 countries around the world for many years. They pointed out that there is an inverted U-shaped relationship between the changing trend of most environmental pollutants and the changing trend of per capita national income, that is, the degree of pollution first increases and then decreases with the growth of per capita income. The peak of the pollution level is approximately at the middle-income level. The more recognized turning point for EKC is that the per capita GNP is around 4000~5000 USD. If the horizontal axis represents economic growth (GDP, GNP, or its per capita amount, etc.), and the vertical axis represents pollution levels (three wastes emissions, etc.), then the relationship curve between pollution level and economic growth is in an inverted U shape. Accordingly, they put forward the hypothesis of Environmental Kuznets Curves (EKC).

Since the Environmental Kuznets curve was proposed by Grossman and Krueger and shafik and Bandyopadhyay based on empirical data, experts and scholars from various countries have conducted empirical research on the relationship between economic growth and environmental pollution from different perspectives. It proves that there is indeed inverted "U" relationship between the two. Our
country's research on EKC is relatively late, mostly empirical research on industrial pollution. However, some research results show that some domestic environmental pollution indicators have reached the turning point of the inverted "U" curve earlier than foreign countries. At the same time, it was found that some indicators did not have a turning point, which is believed to be due to the economic development stage.

With the deepening of research, different scholars have reached different conclusions about the specific form of the environmental Kuznets curve according to different research fields and objects. According to the research of many scholars at home and abroad, the main ones are: inverted "U" type relationship, synchronization relationship, "U" type relationship and "N" type relationship. In addition, the functional models describing the environmental Kuznets curve usually include quadratic regression curves and cubic regression curves. This difference is due to the fact that different regional economies and environments are at different stages of development, levels, coordination and coordination of different regions.

2. Construction of Measurement Model of Economic Growth and Environmental Pollution Evolution in Shandong Province

2.1. Index selection
The selection of typical environmental indicators is the key to constructing the relationship model between economic growth and environmental pollution levels. This paper selects two types of indicators: one is environmental indicators, including flow indicators: industrial waste water emissions, industrial waste gas emissions, and industrial solid waste generation; inventory indicators: COD emissions in industrial wastewater. The other is economic indicators, which is the per capita GDP (current year price) of Shandong Province from 188 to 2005. The analysis data are from Shandong Environmental bulletin and Shandong Statistical Yearbook (1989-2006).

2.2. Construction of econometric model
First, take the environmental indicators such as industrial waste water and industrial waste gas emissions as the Y-axis and per capita GDP as the X-axis, make a scatter diagram of the numerical sequence, and find that they are not linear. Therefore, according to several common models of existing environmental Kuznets curve research, combined with the actual situation of Shandong Province, we select the quadratic curve, quadratic polynomial, cubic polynomial and exponential curve. Several function curve models, such as number function, compound simulation for fitting. From the regression fitting coefficient R2 and F value test effect, the cubic polynomial curve fitting is the best and has the most statistical significance. Therefore, we use the cubic polynomial model to describe the interaction between economic growth and environmental pollution in Shandong Province.

The measurement model is:

$$Y=\beta_0+\beta_1x+\beta_2x^2+\beta_3x^3+\varepsilon$$  (1)

(1) where, Y is industrial pollutant emissions, x is GDP per capita, $\beta_0$, $\beta_1$, $\beta_2$, and $\beta_3$ are model parameters, and $\varepsilon$ is a random error term.
2.3. Curve simulation

2.3.1. Curve simulation of GDP per capita and industrial wastewater discharge.

It can be seen from Figure 1 that the $R^2$ of the fitting curve between economic growth and industrial wastewater discharge is 0.7575, and the regression model has a good goodness of fit, which has full explanatory significance for the environmental Kuznets curve. At present, industrial wastewater is in the rising stage on the left side of the inverted "U" curve. With the increase of GDP per capita, the increasing trend of industrial wastewater discharge is relatively flat, which is closely related to the adjustment of industrial structure and the increase of industrial wastewater treatment in Shandong Province.

2.3.2. Curve simulation of GDP per capita and COD discharge of industrial wastewater.

From this model, it can be seen that with the increase of GDP per capita, COD emissions in industrial wastewater show a clear downward trend. The theoretical inflection point is calculated to be 11,000 yuan, and the curve is similar to the right part of the inverted U-shaped EKC. At present, the
COD discharge of industrial wastewater is controlled at a low level, and the pollution is beginning to develop benign.

2.3.3. Curve simulation of GDP per capita and industrial waste gas emissions.

![Graph of GDP per capita vs. industrial waste gas emissions](image)

Figure 3. Relationship between GDP per capita and industrial exhaust emissions.

From this model, it can be seen that the cubic curve characteristic $R^2 = 0.9796$, and its fitting degree is very high. When the per capita GDP reaches more than 8,000 yuan, exhaust emissions show a clear upward trend. The curve conforms to the typical EKC characteristics and is on the left side of the inverted U-shaped curve. The theoretical turning point is calculated to be 36,300 yuan.

2.3.4. Curve simulation of per capita GDP and industrial solid waste production.

![Graph of GDP per capita vs. industrial solid waste production](image)

Figure 4. Relationship between per capita GDP and industrial solid waste production.

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3. Analysis of simulation results

From the EKC trajectory analysis of industrial "three wastes" in Shandong Province, it can be found that the relationship between economic growth and environmental pollution in Shandong Province does not completely match the typical EKC characteristics. The COD in industrial wastewater has dropped to a low level, but the discharge of other pollutants still fluctuates or even rises. The relationship between pollutant discharge and per capita GDP is in the rising stage of EKC, and there is still some distance from the turning point. It can be said that, so far, the economic growth of Shandong Province has not significantly improved the environment. This is mainly due to the fact that Shandong Province is undergoing a period of industrialization. Industries, especially heavy industries, such as energy, chemicals, machinery, electronics, have been increasing in the economy, which is bound to put a certain pressure on environmental quality. With the growth of per capita GDP, the environmental pollution caused by the "three wastes" of Shandong's industry will show an increasing trend, and it will continue to shoulder the dual responsibility of economic development and environmental protection for a long period of time in the future.

From the measurement results, we can also find that the relationship between economic growth and environmental pollution does not necessarily completely conform to the general EKC characteristics. EKC has different forms, turning points and time span in different countries or regions. Income level is an important factor affecting environmental quality. Shandong's per capita GDP rose from 2556 yuan in 1992 to 9555 yuan in 2002, and its economic growth ranked the top in China. However, with the increase in per capita income, the amount of waste gas and solid waste pollution or per capita pollution did not show the expected trajectory of first rising and then gradual decline. On the contrary, wastewater discharge will fluctuate repeatedly. In other words, the improvement of environmental quality does not happen automatically with the increase of income level. It can be seen that in addition to the income level, other factors such as society and nature also affect the environmental quality, especially the environmental policy of the country or region, the level and scale of economic activities, the economic structure, the technical level, the environmental investment and its effect, and the environmental awareness of the public etc.

4. Conclusion and discussion

The comprehensive decision-making of economic development and environmental protection has an important impact on EKC. Pollution prevention is more cost-effective than pollution first and governance. Environmental degradation has a cumulative and amplifying effect, and certain environmental degradation allowed in the early stages of economic development may become irreversible degradation in the later stages. Therefore, Shandong can neither follow the old road of "pollution first, control later" in developed countries, nor give priority to economic development. Although the level of industrialization in Shandong Province is still relatively low, its economic growth is strong, with a GDP growth rate of 17.96% in recent years. The economic structure has been continuously optimized, and the ratio of the three industries has been adjusted from 29.70: 44.48: 25.82 in 1988 to 10.41: 57.40: 32.19 in 2005. While increasing the level of economic growth, attention should be paid to coordinating the relationship between environment and development. It should take the road of new industrialization, make use of the advantage of late development, avoid the old road taken by advanced countries or newly industrialized countries, and strive to reduce the peak value and curvature of EKC. Make EKC an indicator of the coordinated development of environment and economy.

To achieve the above goals, it is necessary to promote the transformation of the economic structure from high energy consumption and high pollution to an environmentally friendly economic structure in the process of economic development, and vigorously advocate the concepts of cleaner production and circular economy. Fundamentally change the development mode, adhere to the comprehensive decision-making on environment and development, and carry out reasonable policy control. Under the rigid constraints of the current economic level, it is possible to make full use of the flexible range in
which policies play a role, carry out reasonable adjustments, and promote the coordination of economic development and environmental protection. The specific control directions are:

(1) Advocate economic growth, production and consumption methods that are conducive to sustainable development.

Green GDP should be used to guide the transformation of economic growth mode to the direction of high efficiency, low consumption and low pollution. Pollution control should be strengthened in production to reduce the total amount of pollutant discharge. Through clear institutional arrangements with clear property rights and reasonable environmental resource pricing, as well as resource taxes, pollution taxes, etc. We should carry out cleaner production, realize the transformation from end management to process management, and advocate green consumption mode.

(2) Adhere to the comprehensive decision-making of environment and development, and pay equal attention to economic development and environmental protection.

In combination with the strategic adjustment of national economic structure, we should transform traditional industries with high and new technology, eliminate backward technology and process, reduce the amount of pollution through technological innovation and upgrading, adjust the investment structure, and induce the construction of environment-friendly projects and the formation of industrial clusters. We should control the ecological damage from the source of development and construction, adjust the industrial and product structure, and control the source and the whole process of pollution prevention and control.

(3) Continue to increase investment in environmental governance, establish a market-oriented environmental protection investment and financing system, and achieve diversification of investment entities.

At present, Shandong's environmental protection investment accounts for more than 1% of GDP. In 2002, environmental protection investment accounted for 1.37% of GDP in the same period. International experience shows that investment in environmental protection accounts for 1% to 1.5% of GDP, which can control pollution, while accounting for 2 to 3% can gradually improve the environment. To continuously improve the overall environmental quality, especially the quality of industrial waste gas and industrial solid waste, Shandong Province should continue to increase environmental protection investment and establish a market-oriented environmental protection investment and financing system while ensuring economic development. Realize the diversification of investment entities, strive to reduce the peak of environmental quality deterioration accompanying economic development, and ease the curve as much as possible, strive to shorten the span of the curve, so that the turning point for the better environmental quality of waste gas and solid waste will arrive ahead of schedule.

(4) Continuously revise and improve various related environmental regulations, standards and policies.

Market economy is a legal economy. We should constantly improve various environmental regulations, standards and policies, improve market mechanism, strengthen environmental management, and internalize the external cost of environmental pollution.

(5) Further enhance public awareness of environmental protection.

The basic driving force of environmental protection is the public, so it is necessary to strengthen environmental education and publicity, and raise the public's environmental awareness. It is believed that through the improvement and implementation of the above policy measures, it will not be far away to gradually realize the win-win goal of economic growth and environmental improvement in the process of industrialization in Shandong Province.

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