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# Empirical research on relationship between economic development level and environmental pollution-based on panel data of 5 cities in poyang lake ecological economic zone

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## ABSTRACT

Based on panel data from 2001 to 2011, this paper analyzes curve fitting relationship between per capita GDP and contamination output of $SO_2$, Industrial Waste Gas and Industrial Waste Water in Nanchang, Jingdezhen, Jiujiang, Yingtan and Xinyu. Quadratic equation models of relationship between per capita GDP and contamination output of SO2, Industrial Waste Gas could be established, which are "inverted U-type" curve. Both cubic equation models of relationship between per capita GDP and contamination output of $SO_2$, Industrial Waste Gas, and Industrial Waste Water could be established, which are "Positive N-type" curve. Cubic equation is better than quadratic equation in efficiency of modeling and goodness of fitting curve. Furthermore, this paper discusses the relevant policy recommendations.

## KEYWORDS

Panel data; Environmental kuznets curve (EKC); Per capita GDP; Contamination output.



## INTRODUCTION

The coordinated development between economic society and ecology environment has become a hot topic which has got great attention from all over the world. Having experienced 30 years' rapid development in economy, China also pays more attention to environment-friendly society. In the nineties of last century, Panayotou used the "inverted U-type" hypothesis of economic growth and income gap proposed by Kuznets for reference and put it into environmental area, and then put forward the Environmental Kuznets Curve (EKC)[1]. Its basic point is that when the economic development level is comparatively low, the contamination output will increase with the increase of average income; and when a certain turning point is surpassed, the contamination output will decrease with the increase of average income. In 1991, Grossman and Krueger took North America as an example to start empirical researches on this problem as precedents. In 1995, they extended the study to many countries globally. Through the research on the relationship between per capita income and the air as well as watershed pollution index, this viewpoint has been further deepened. It suggests that the occurrence of the turning point of "inverted U-type" curve varies according to different pollutants, but in most cases, the turning point appears before the per capita income reaching $ 8,000[2].

After putting forward the EKC curve, it caused many evaluations and follow-up studies of many researchers. In the aspect of theoretical research, from multiple perspectives such as the transition of economies of scale, technological progress and industrial structure, the environment quality requirements, the formulation and implementation of government regulations on environmental protection, environmental regulation and management, the international transfer of industry, many scholars investigate the above factors may produce the inhibition or promotion on contamination output at the background of economic growth[3]. In terms of empirical study, the model construction has been developed from the simple quadratic equation, to the cubic equation and even logarithmic equation, etc[4]. In fact, the "inverted U-type" curve is not the only curve shape that indicates the relationship between the economic development level and the environmental indicator. According to different models and different parameters, there may form different curve shapes. Take the following formula as an example:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 X_{it}^{\ 2} + \beta_3 X_{it}^{\ 3} + \mu_{it}$$

In the formula, Y refers to environmental index, X refers to per capita GDP, i refers to individual, t refers to time, and μ refers to residual. In the formula : (1) If β2=0 and β3=0, then it is a linear equation. (2) If β3=0, it is a quadratic equation. Meanwhile, if β1>0 and β2<0, the curve is of the "inverted U-type"; if β1<0 and β2>0, the curve is of the "U shape". (3) If β1<0, β2>0 and β3<0, the curve is of the "inverted-N shape"; if β 1>0, β2<0 and β3>0, the curve is of the "N shape"[3]. The development tendency represented by different types of curves and the containing policy implications are significantly different.

In recent years, many Chinese scholars begin to build the model and conduct empirical validation on the relationship between the economic development level and the environmental index. The research conclusions vary significantly with the area of the target being researched and the selection of the indicators. For example, the research by Liu Yaobin etc. (2006) showed that the difference between every environmental pressure factor of Jiangsu Province and the coupling law and characteristic of urbanization is very big, appearing as the regulations of "U"type, inverted "U" or "N"type as well as stage characteristics[5]. Huang Yisui, etc. (2009) carried out researches aiming at the data of Fujian Province from 1988 to 2007. They adopted urbanization rate as the economic indicator, and found that the fitting of industrial waste water emissions and urbanization rate showed the "U" shape, and the fitting of industrial waste gas emissions and urbanization rate showed the right half of the "U" shape, and the fitted equation of industrial waste gas emissions and urbanization rate was an exponential function[6]. Xu Guangyue etc. (2010) carried out the research aiming at the China province data of 1990-2007 and discovered that there was environmental Kuznets curve of per capita carbon emission showing "inverted U-type" in China's eastern and middle areas and "U shape" in western areas[7]. Ding Jihong etc. (2010), based on the annual data of the six contamination index in Jiangsu province from 1985 to 2006, found that the comprehensive pollution index in Jiangsu province and its per capita GDP have the curve feature of "N"[8].

## THE OBJECTS OF THE STUDY

This paper selected five cities named Nanchang, Jingdezhen, Jiujiang, Yingtan and Xinyu, which are located at the south bank of the middle and lower reaches of Yangtze River and the northern part of Jiangxi province, as the objects of the study. Among, all administrative regions in Nanchang, Jingdezhen, Yingtan, and administrative regions in Jiujiang except Xiushui county, as well as administrative regions in Xinyu except Fenyi county all belong to Poyang Lake Ecological Economic Zone. Poyang Lake, located at the center of this region, undertakes many ecological functions such as flood regulation and water storage, adjusting climate, degrading pollution, protecting diversity of creatures, which plays an important role in national ecological layout. To ensure the availability of statistic data, the 5 above mentioned city areas are included into the research. These five cities have stronger overall strength in Poyang Lake Ecological Economic Zone and even in the whole Jiangxi province. In 2010, the total GDP of areas included in the Poyang Lake Ecological Economic Zone in these 5 cities was 447.8 billion, which took 81.3% of that of the whole area and 47.4% of that of the whole province. Since

the new century, the 5 cities' per capita GDP continued rapid growth (Figure 1). According to average exchange rate of RMB against US. dollar, per capita GDP in 5 cities is 919 dollars in 2001, and in 2006, it is 2195 dollars, reaching 3805 dollars in 2009, as well as increasing to 6446 dollars in 2011. From 2001 to 2011, variation of per capita GDP in 5 city is corresponding with important interval of the "environmental Kuznets curve"; research on the relationship between per capita GDP in 5 cities and pollutant emissions has strong practical significance and urgency for the prediction of the trend in contamination output in the future and exploring the path of coordinated development between economic social and environmental protection.

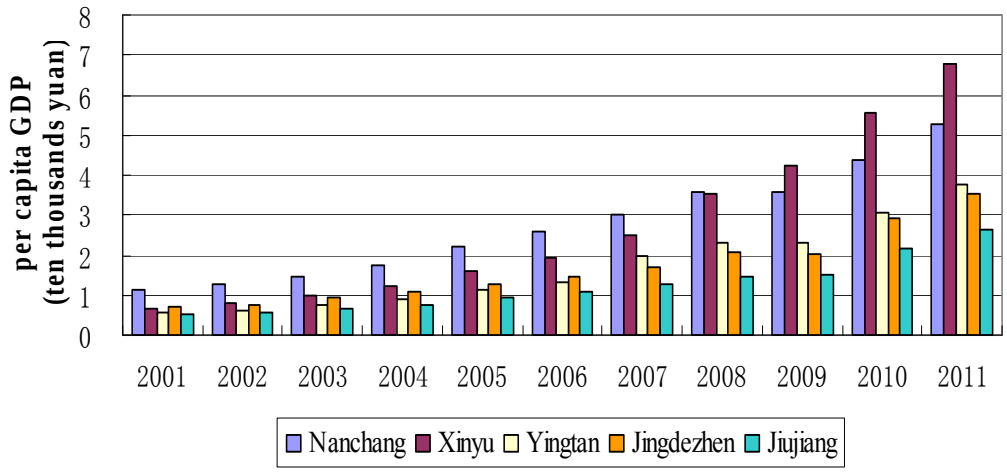


**Figure 1 : Per capita GDP of five cities (2001—2011)**

## ANALYSIS METHOD, CHOICE OF INDICATOR AND DATA SOURCE

Panel data is gained by continuous tracking of individuals in a same group at many stages. Owing to the combination of time sequence data and cross section data, panel data can provide more information, more changes, less multicollinearity, more freedom degree and efficiency; therefore, it becomes an important analysis field in modern econometrics[9]. This paper uses panel data analysis to study the curve fitting relationship between per capita GDP and contamination output of five cities. Adopting statistical material of 5 cities in 2001-2011, this paper conducts analysis by means of Eviews6. The panel data consists of 5 individual sections, 11 time sections, which have 55 group data. Contamination output index includes the $SO_2$ emissions (ten thousands tons), the industrial waste gas emissions (billion standard cubic meters), the industrial waste water emissions (ten thousands tons). The data used in this study comes from "Jiangxi Statistical Yearbook" of 2002 to 2012.

## MODEL BUILDING

To avoid the influences of Cross-section heteroskedasticity and sequence autocorrelation on the result of OLS, this paper sets Cross-section SUR to build panel data model. First, it determines the model type of the quadratic equation for $SO_2$ and per capita GDP. The Cross-section F statistic of F test is 69.5 and the probability of P value is 0.0000; so mixed effect model is refused; Chi-Sq statistic of Hausman test is 7.2, and the probability of P value is 0.027, which rejects null hypothesis at the significance level of 5%, thus the random effect model is refused. Upon examination, select the model of individual fixed effect to simulate the curve. After model establishment, record all the parameters and statistical test indexes.

Using the above method, determine the model type of cubic equations for $SO_2$ and per capita GDP, the model type of quadratic and cubic equations for industrial waste gas emissions and per capita GDP, the model type of quadratic and cubic equations for industrial waste water emissions and per capita GDP, then establish the model and record the parameters and statistical indexes. After inspection, all models are individual fixed effect models, various parameters and important statistical test indexes are summarized and shown in TABLE 1. NC-C, JDZ-C, JJ-C, YT-C, and XY-C in the table present the individual intercepts of Nanchang, Jingdezhen, Jiujiang, Yingtan and Xinyu respectively.

Seen from the regression model of the $SO_2$ emissions and per capita GDP, quadratic equation parameters all pass the null hypothesis test, which are significant at 1% level, and the model's adjusted coefficient of determination is 0.854; All parameters except the constant term of the cubic equation pass the null hypothesis test, and they are significant at 1% level and the adjusted coefficient of determination reaches 0.879, which reflects the model's imitative effect is superior to that of the quadratic equation. But the DW statistical value of the cubic equation model is slightly below that of the quadratic equation model.

The regression model of industrial waste gas emissions and per capita GDP shows that all parameters in quadratic equation can pass the null hypothesis test, and they are significant at 1% level, the adjusted coefficient of determination is

0.903; All parameters except the constant term of the cubic equation pass the null hypothesis test, and they are significant at 1% level and the adjusted coefficient of determination reaches 0.917, which reflects the model's imitative effect is superior to that of the quadratic equation. But the DW statistical value of the cubic equation model is below that of the quadratic equation model, and there is certain self-correlation in the residual sequence.

**TABLE 1 : Parameters and inspection results of panel data model of relationship between per capita GDP and three kinds of contamination outputs**

| | Regression model of $SO_2$ emissions and per capita GDP | | Regression model of industrial waste gas emissions and per capita GDP | | Regression model of industrial waste water emissions and per capita GDP | |
|---|---|---|---|---|---|---|
| | Quadratic equation | Cubic equation | Quadratic equation | Cubic equation | Quadratic equation | Cubic equation |
| C | 3.137* (0.171) | -0.074 (0.384) | 125.890* (35.618) | -47.569 (65.144) | 5425.359* (299.627) | 4536.818* (523.463) |
| RJGDP | 0.977* (0.139) | 5.800* (0.490) | 278.227* (26.348) | 559.983* (80.529) | 455.911** (217.312) | 1705.711* (614.362) |
| SRJGDP | -0.104* (0.021) | -1.879* (0.164) | -12.984* (3.764) | -124.782* (27.311) | -22.370 (28.621) | -464.775** (191.889) |
| CRJGDP | | 0.176* (0.016) | | 11.730* (2.633) | | 42.587** (17.500) |
| NC-C | -1.915 | -1.818 | -170.931 | -156.817 | 2327.863 | 2324.306 |
| JDZ-C | -0.645 | -0.792 | -254.295 | -261.460 | -1331.297 | -1365.619 |
| JJ-C | 3.343 | 3.404 | 544.920 | 544.644 | 914.379 | 950.613 |
| YT-C | -0.412 | -0.339 | -136.974 | -130.946 | -821.815 | -800.594 |
| XY-C | -0.371 | -0.455 | 17.280 | 4.579 | -1089.129 | -1108.706 |
| Adjusted R2 | 0.854 | 0.879 | 0.903 | 0.917 | 0.699 | 0.696 |
| F statistic | 53.728 | 57.297 | 84.776 | 85.778 | 21.891 | 18.673 |
| DW statistic | 1.371 | 1.342 | 1.544 | 1.391 | 1.302 | 1.339 |

**Note: The parameter values in brackets of the table are the standard errors. *, **, ***which separately indicates the significance level of 1%, 5% and 10%.**

The difference between quadratic equation model and cubic equation model is more obvious in the regression model of industrial waste water emissions and per capita GDP. Partial regression coefficent of per capita GDP of quadratic equation passes null hypothesis test at 5% level, and statistical test probability of partial regression coefficent of per capita GDP's square reaches 0.438, which can not pass the null hypothesis test completely, indicating that the regression model of industrial waste gas emissions and per capita GDP can not be established. The constant term and partial regression coefficent of per capita GDP of cubic equation pass null hypothesis test at 1% level. The partial regression coefficent of Per capita GDP square and per capita GDP cubic pass null hypothesis test at 5% level. The adjusted coefficient of determination of this model is 0.696, and the degree of fitting is obviously below that of cubic equation regression model of $SO_2$, industrial waste gas emissions and per capita GDP. The statistical value of DW shows the residual sequence has certain self-correlations.

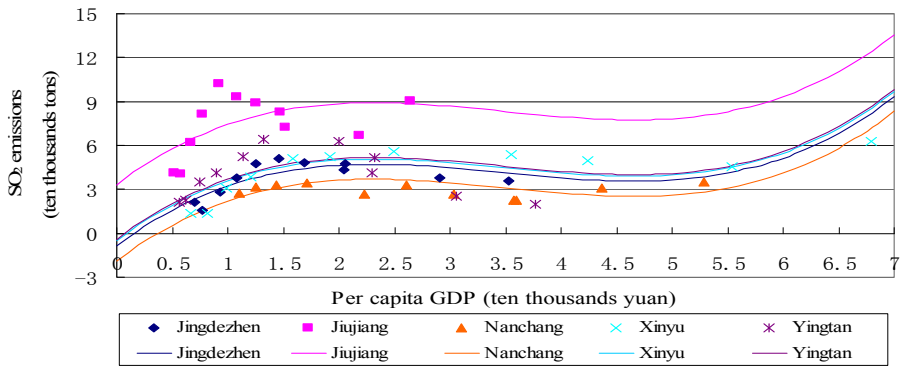


**Figure 2 : Scatter and cubic equation curve fitting of relationship between per capita GDP and output of $SO_2$**

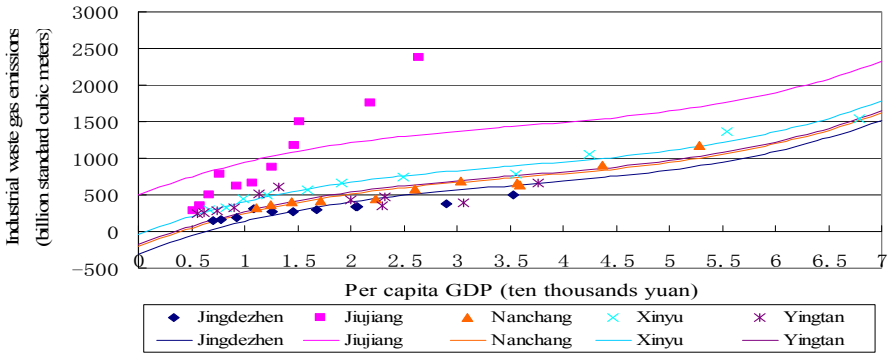


**Figure 3 : Scatter and cubic equation curve fitting of relationship between per capita GDP and output of Industrial Waste Gas**

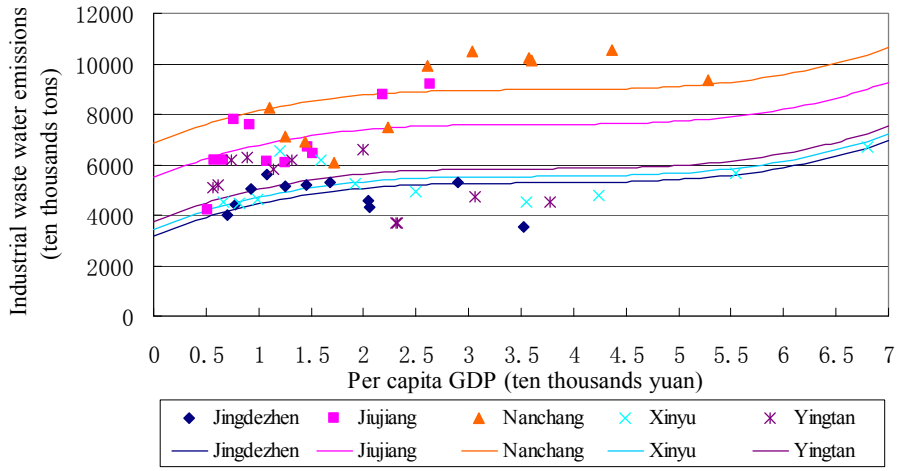


**Figure 4 : Scatter and cubic equation curve fitting of relationship between per capita GDP and output of Industrial Waste Water**

Seen from the overall situations, it is able to establish the cubic equation regression models of the per capita GDP and the emissions of the three pollutants, i.e. $SO_2$, industrial waste gas and industrial waste water, and the overall simulated results of which are better, while it is able to establish only two quadratic equation model. It also shows that the goodness of fitting of the cubic equation models is superior to that of the quadratic equation. We can judge from the model parameters shown in Table 1, the two quadratic equation models are both "inverted U-type" curves, while three cubic equation models are "N shape" curves. Figure 2, Figure 3 and Figure 4 show the matching conditions between fitting curves based on the cubic equation and the plot of per capita GDP and contamination output.

## CONCLUSIONS AND PROPOSALS

According to modeling process based on panel data of 2001 to 2011 in Nanchang, Jingdezhen, Jiujiang, Yingtan and Xinyu, the model constructed according to the thought of "environmental Kuznets curve" can effectively match the relations between per Capital GDP and contamination output of $SO_2$, industrial waste gas, industrial waste water. The quadratic equation models of per capita GDP and $SO_2$, per capita GDP and industrial waste gas can be constructed, which belong to "inverted U-type" curve; the cubic equation models of per capita GDP and $SO_2$, per capita GDP and industrial waste gas, per capita GDP and industrial waste water can be constructed, which belong to "N shape" curve. Cubic equation is superior to quadratic equation in modeling effectiveness and matching goodness. As a regression parabola, the cubic function has essential difference from parabola-type quadratic function in the aspects of nature and development tendency of the curve. Thus, whether the "inverted U-type" hypothesis of environmental pollution and economic development proposed based on the quadratic equation can be established in these five cities or not, we should also conduct a further modeling judgment according to the changes of statistic in future few years. The government should not use "inverted U-type" EKC curve indiscriminately and simply to conclude that the condition of environment pollution will self-improve along with the promotion of the economic development level.

At present, building Poyang Lake ecological economic zone has formally become the national strategy and the responsibility of the five cities for environment protection is more prominent. In 2011, the per capita GDP of Nanchang city and Xinyu city reached 52,800 yuan and 67,900 yuan respectively. The trend of the fitting curves of the cubic equation

indicates that it is in the rising range of three terms of contamination output. The two cities should insist on efficient development, accelerate the development of modern service industry and work hard to construct a resource-saving and environmental-friendly industry system. The per capita GDP of Jiujiang city, Yingtan city and Jingdezhen city respectively are 26,400 yuan, 35,300 yuan and 37,700 yuan. Although they are in the relatively flat interval of the changes of the contamination output, Jiujiang city which is an important industrial base in coastal area of Yangtze River, Yingtan city which is a famous copper world and Jingdezhen which is an important industrial town, are all facing the crises such as the increasingly serious of water pollution of Poyang Lake, the protruding pressure of environmental protection, radical increase of energy demand and resource depletion etc. The three important industrial cities should change its traditional development pattern of "valuing exploitation and neglecting protection" in time, transform and advance traditional industry enthusiastically, promote energy conservation and emissions reduction, and strengthen integrated pollution control. The five cities should attach more importance to their responsibilities of leading the economic development and protecting the ecological environment. They should regard the ecological construction and environmental protection as the top priority so as to provide referential experiences for the comprehensive development of rivers and lakes regions.

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