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Research on the Relationship Between Economic Development and Water Environment Quality in Fujian Province Based on EKC Model

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Abstract. At present, the main trend of China's economic development is the "green new normal", which is to sustainably grasp the relationship between development and environmental protection. As the first national ecological civilization Experimental Zone in China, Fujian Province plays an exemplary role in improving environmental quality. Based on the panel data of Fujian Province from 2001 to 2018, this paper makes an empirical analysis of the existence of the Environmental Kuznets Curve (EKC). The results show that the regression curves of industrial wastewater and industrial COD are not completely consistent with the EKC model, the curve of industrial wastewater is N-type, and it is in the rising stage of n-type, showing a linear increase; The curve of industrial COD is U-shaped and weak inverted U-shaped. At the present stage, we are on the right side of the inverted U-shaped. According to the research results, policies should be made to break the bad interaction between economic development and environmental quality.

Keywords. Economic development, water environment quality, environmental Kuznets curve, pollution control

1. Introduction

At present, the main trend of China's economic development is the "green new normal", which is to harmonize the relationship between development and environmental protection. Developing the economy at the cost of the environment is no longer suitable. It is a task that must be faced directly under the new situation to give consideration to both economic development and environmental protection.

A large number of scholars have shown that the economy and environment can achieve positive interaction. For example, Li et al. (2007) put forward the concept of "green GDP": that is, considering environmental factors on the basis of current GDP, and deducting its resource and environmental costs, which essentially represents the net positive effect of national economic growth [1]. The concept of "green GDP" is beneficial for the government to control high-polluting enterprises. If the government introduces some relevant policies to control pollution emissions and urges enterprises

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to consider their environmental costs, then enterprises are likely to take various measures to reduce their environmental costs, such as controlling their pollution emissions, in order to pursue "profit maximization". In the long run, if enterprises can consciously control their pollution emissions and pay attention to environmental problems, it will reduce the cost of supervision and greatly save the operation cost of the whole society.

As the first National Ecological Civilization Experimental Zone in China, Fujian Province plays an exemplary role in improving environmental quality. Therefore, this paper takes the data of Fujian Province from 2001 to 2018 as samples and refers to the Environmental Kuznets curve (EKC) to build a regression model to explore the win-win situation between economic growth and environmental improvement.

2. Literature Review

Grossman and Krueger (1991) first used the "Kuznets Curve" to empirically test the existence of an inverted U-shaped relationship between environment and income [2]. After that, many scholars extended Grossman & Krueger's model and began to test the model from different perspectives. Most scholars focus on the research of atmospheric environmental indicators because the monitoring history of atmospheric environment indicators in the world is earlier and the data is relatively complete, which is conducive to the construction of the model [3].

Dijkgraaf et al. (2005) found that the relationship between carbon dioxide emissions and per capita GDP is "N" type or inverted "W" type by using the new data set of carbon dioxide emissions and per capita GDP data of OECD countries [4]. Mazzanti (2012) recorded the structural differences in the long-term carbon income relationship of developed countries. Based on the first application of intervention analysis to the Environmental Kuznets curve, it was found that the long-term performance of different developed countries was heterogeneous [5]. Dogan et al. (2016) explored the relationship between carbon dioxide (CO_2) emissions, energy consumption, real output (GDP), the square of real output (GDP^2), trade openness, urbanization and financial development in the United States from 1960 to 2010. The results did not fully support the validity of the EKC hypothesis [6]. The research results of Farhani et al. (2015) show that there is a positive monotonic relationship between real GDP and carbon dioxide emissions, rather than an "inverted U-shape" [7].

The following characteristics can be drawn from these research results:

(1) The data is mainly panel data, and the research objects are concentrated in different countries [8]. Most of the research methods are to build regression models and do statistical analysis, which the research on SO2 is the most.

(2) The income level corresponding to the EKC inflection point is quite different, and its inflection point position depends on the developed degree of the country.

(3) Among many econometric models, the logarithmic square model is considered the standard EKC regression model [9].

To sum up, the research on the relationship between economic growth and environmental quality mainly focuses on the verification of the Environmental Kuznets curve, and most of them use the regression method for statistical analysis of data.

3. Research Model and Data

3.1. Model Setting

The "Environmental Kuznets Curve" originates from the "Kuznets Curve". The Kuznets curve studies the relationship between income and the degree of distribution equity—"inverted U" type relationship, that is, the degree of uneven distribution rises first and then decreases with the increase of income. The traditional model expression is as follows:

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon \tag{1}$$

In 1991, Grossman and Krueger extended the Kuznets curve and found the empirical relationship between environmental pollution and economic growth: the model curve also showed an "inverted U" shape, that is, pollution increased with the rise of per capita GDP in the low-income level, while decreases with the rise of per capita GDP at the high-income level [2].

In this study, the economic indicators of Fujian Province were taken as the independent variable X, and three environmental indicators were taken as the dependent variable Y to establish three regression equations. In addition, on the basis of the traditional model, this paper adopts the logarithmic model, that is, taking the natural logarithm of the pollutant index and the economic index respectively, so as to eliminate the difference and heteroscedasticity of the order of magnitude between the data. The model is as follows:

$$LnY = \beta_0 + \beta_1 Ln(X) + \beta_2 \left(Ln(X)\right)^2 + \varepsilon \tag{2}$$

$$LnY = \beta_0 + \beta_1 Ln(X) + \beta_2 \left(Ln(X)\right)^2 + \beta_3 \left(Ln(X)\right)^3 + \varepsilon \tag{3}$$

In the model, Y is the environmental pollution index, X is the economic growth index, and β_0, β_1, β_2 and β_3 are the model parameters, ε is the random error term. In this paper, we will analyze the model twice and thrice respectively, and compare R^2 and p-values in turn. Through the comparison of the goodness of fit and significance, the optimal EKC model of the environmental pollution index and economic growth index is determined. As far as the fitting degree of the regression model is concerned, R^2 is generally greater than 0.4. If R^2 is larger, it means that the fitting degree of the model is better, that is, the fitting degree of the regression curve to the observed value is better. Generally speaking, the p-value is less than 0.05. The smaller the p-value is, the more significant the result is.

3.2. Indicator Description

This paper takes the relationship between economic growth and environmental pollution in Fujian Province as the object of empirical research and selects six indicators: industrial wastewater discharge, industrial COD discharge, industrial ammonia nitrogen discharge, per capita GDP, fixed asset investment of the whole society and total income of general public budget. These indicators are relatively common indicators, which have been widely used in a large number of scholars' articles, so they can comprehensively reflect the economic growth and environmental pollution in Fujian Province. The data collected from China Environmental Yearbook and Fujian statistical yearbook are as follows (Tables 1 and 2):

Table 1. Original data of economic indicators of Fujian Province.

Year	Per GDP (Yuan)	Fixed assets investment of the whole society (100 million yuan)	Total revenue of general public budget (100 million yuan)
2000	11194	995.38	369.67
2001	11883	1053.84	428.33
2002	12910	1148.76	476.20
2003	14330	1411.45	551.00
2004	16248	1798.38	622.57
2005	18107	2241.70	788.11
2006	20915	2998.45	1012.77
2007	25915	4186.67	1282.84
2008	30153	5148.31	1516.51
2009	33999	6180.94	1694.63
2010	40773	8067.33	2056.01
2011	48341	9885.67	2597.01
2012	54073	12452.24	3008.88
2013	59835	15245.24	3430.35
2014	65810	18141.37	3828.40
2015	70162	21300.91	4144.03
2016	76778	23107.49	4295.36
2017	86943	26226.60	4604.69
2018	98542	29400.02	5045.49

Table 2. Original data of environmental quality indicators in Fujian Province.

Year	Industrial wastewater discharge (10000 tons)	Industrial COD emission (10000 tons)	Industrial ammonia nitrogen emission (10000 tons)
2001	69724.00	10.58	0.87
2002	78510.59	8.44	0.92
2003	98388.20	7.86	0.86
2004	115227.50	8.70	0.90
2005	130939.50	9.94	1.02
2006	127583.41	9.45	0.82
2007	136407.77	9.11	0.59
2008	139996.92	8.44	0.69
2009	142746.99	7.54	0.62
2010	124168.21	8.29	0.66
2011	177185.62	9.59	0.77
2012	106319.29	9.06	0.68
2013	104657.99	8.12	0.61
2014	102051.74	7.76	0.55
2015	90741.41	7.26	0.41
2016	68872.15	3.23	0.21
2017	69860.45	2.38	0.15
2018	147005.37	2.36	0.16

It can be seen from Table 1 that the per capita GDP of Fujian Province grew slowly from 2000 to 2006, and rapidly since 2006. In terms of fixed asset investment, its growth is similar to that of per capita GDP, and 2006 is a dividing point; In addition, compared with per capita GDP and total public budget income, fixed asset investment has always been relatively large.

It can be seen from Table 2 that in terms of industrial wastewater discharge, there are two turning points: 2011 and 2018, and the changes before and after these two turning points are relatively large. However, there was no significant turning point in the industrial COD and ammonia nitrogen emissions, which mainly showed a downward trend.

After reading a large number of relevant references, it is found that most of the research is to get a series of relations through regression of economic growth through different pollution emission indicators. This paper uses principal component analysis to screen different economic indicators and finally selects a comprehensive index that can reflect the degree of economic development.

First of all, it is usually needed to do KMO and Bartlett sphericity test first, then the judgment basis is that the KMO value is greater than 0.6 and Bartlett's p-value is less than 0.05. Based on the original economic data in Table 1, principal component analysis was conducted by SPSSAU, and the results are as follows (Tables 3 and 4):

Table 3. Tests of KMO and Bartlett.

KMO test	**KMO-value**	**0.741**
Bartlett sphericity test	Approximate chi-square	142.21
	DF	3
	P-value	0^{***}

Note: *** indicates significance at 1% level

Table 4. Principal component analysis of economic indicators.

Item	**Characteristic root**	**Variance explanation rate (%)**	**Cumulative (%)**
GDP per capital	2.98	99.43	99.43
Investment in the fixed asset of the whole society	0.01	0.44	99.87
Total revenue of the general public budget	0.01	0.13	100

The extraction of principal components needs to meet two conditions at the same time: first, the feature root should be greater than 1; Second, the cumulative contribution rate is more than 85%. Therefore, this paper extracts per capita GDP as a comprehensive economic index, which can represent 99.433% of the economic development level of Fujian Province.

4. Empirical Analysis

In this paper, Excel software was used to regress the data. The modeling results showed that except for the regression results of industrial ammonia nitrogen, the *P* values of the regression models of other environmental indicators were less than 0.05, and the regression coefficients were statistically significant. The results are shown in Tables 5 and 6:

Table 5. Secondary regression results of per capita GDP and environmental indicators.

Typical environment indicators	Industrial wastewater discharge	Industrial COD emission
Constant term	-39.75	-66.22
Ln (per GDP)	9.89	13.59
[ln (per GDP)]^2	-0.47	-0.67
R^2	0.40	0.72
Time for the turning point	2009	2007
GDP at the turning point (yuan)	33999	25915

Table 6. Third regression results of per capita GDP and environmental indicators.

Typical environment indicators	Industrial wastewater discharge	Industrial COD emission
Constant term	-662.69	851.80
Ln(per GDP)	189.74	-251.45
[ln(per GDP)]^2	-17.74	24.77
[ln(per GDP)]^3	0.55	-0.81
R^2	0.60	0.86
Time for the turning point	2007/2016	2005/2010
GDP at the turning point (yuan)	25915/76778	18107/40773

According to the principle that the closer R^2 is to 1, the better the fitting degree is, the cubic fitting diagram of industrial wastewater and industrial COD is selected as follows:

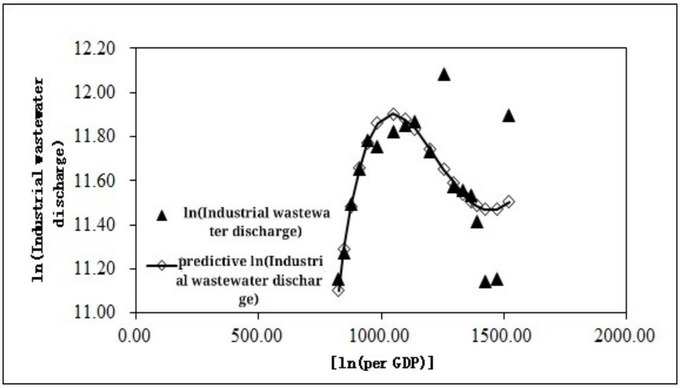

Figure 1. Cubic fitting diagram of industrial wastewater and per capita GDP.

It can be seen from Figure 1 that the fitting EKC curve is not the traditional inverted U-shape, but the N-shape. There are two turning points in the curve, the first turning point is a positive turning point, that is, after the turning point, the pollution degree will be improved with economic growth; The second inflection point is negative, that is, after the inflection point, the degree of pollution will worsen with economic growth.

It is worth noting that the interannual fluctuation of the observed data will cause the existence of individual outliers in the fitting curve. In the cubic fitting graph of industrial wastewater and per capita GDP, outliers appeared in 2011, 2016, 2017 and 2018. It can be seen from Table 1 that the interannual variation of per capita GDP is relatively uniform. Therefore, the outliers above the EKC curve are mainly caused by the sudden increase in environmental indicators. Therefore, we will analyze the causes of the outliers from the aspect of industrial wastewater.

Taking the specific value of 2011 as an example, the vigorous development of the manufacturing industry in Fujian Province is one of the reasons for the sudden increase of industrial wastewater, and the increase of manufacturing enterprises eventually leads to the sudden increase of total industrial wastewater discharge. In addition, before 2011, the relevant laws and regulations of industrial wastewater discharge in Fujian Province were not perfect. In order to save product costs, many manufacturing enterprises directly discharged untreated industrial wastewater into rivers or oceans, which eventually led to the emergence of outliers.

It can be seen from Figure 2 that the relationship between industrial COD and per capita GDP presents a weak inverted U+U-shaped wavy curve, and the curve also has two turning points. The first inflection point is the negative inflection point, that is, after the inflection point, the degree of pollution will worsen with economic growth. The second inflection point is positive, that is, after the inflection point, the degree of pollution will be improved with economic growth.

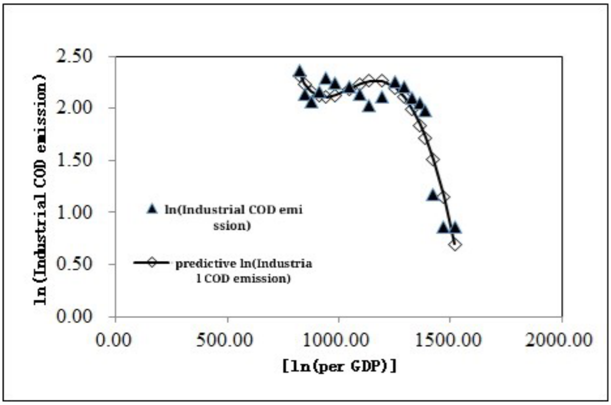

Figure 2. Cubic fitting diagram of industrial COD and per capita GDP.

After 2011, the industrial COD emission showed a downward trend, mainly because of the fewer pollution emissions of paper enterprises, and the industrial COD mainly came from paper enterprises. In 2011, the state promulgated the "discharge standard of water pollutants for pulp and paper industry", which stipulates that the paper industry will implement stricter discharge standards from July 1, 2011, and urge enterprises to make technological innovations to reduce the discharge of pollutants.

5. Conclusion and Relevant Policy Suggestions

The results show that the relationship between environmental pollution and economic growth in Fujian Province is not completely in line with the general Kuznets curve. The curve of industrial wastewater is N-type, and it is in the rising stage of N-type, which is increasing linearly. Therefore, relevant departments should control and regularly monitor the discharge of industrial wastewater and take some measures, for example, the use of scientific and technological progress to promote the upgrading of high-pollution enterprises; The wave type of weak inverted U+U type is presented between industrial COD and GDP per capital, and is on the right side of inverted U-shaped at present. Therefore, relevant departments can make effective policies at this stage to break the adverse interaction between economic development and water environmental pollution. In addition, compared with the GDP per capital at the turning point of industrial wastewater and industrial cod, the per capital GDP at the turning point of industrial COD is smaller, indicating that it is more sensitive to the change of economic growth, so it is more important to strengthen the monitoring of industrial COD.

As far as enterprises are concerned, it is their unshakable social responsibility to pay attention to the environmental problems in their development. The content of an enterprise brand includes not only quality and service but also “enterprise image”. Building a good “enterprise image” requires enterprises to broaden their horizons and actively fulfill their social responsibilities.

In the long run, if the enterprise can not control the pollution effectively, it will lead to the window breaking effect-enterprises no longer pay attention to environmental problems, and the pollution emission problems will become more and more serious. If “environmental protection” can not bring expected profits to enterprises and can not produce positive effects in competition, then the enterprises pursuing profit will lose their interest and belief in it, which is the reason why the environmental pollution management of enterprises often appears as a problem.

Based on the above situation, this paper puts forward some feasible policy suggestions. On the one hand, optimizing the industrial structure is the key to building a two-oriented society. Fujian provincial government needs to reduce the proportion of secondary industry and increase the proportion of tertiary industry; On the other hand, enterprises in Fujian Province need to enhance their ability to sustainable development and improve their environmental governance through the development of science and technology.

In addition, the government must formulate a reasonable reward and punishment system” “Low pollution” enterprises should be rewarded by the market, and can not let bad money drive out good money; The “high pollution” enterprises should be punished accordingly, and bad money can not have a second chance to survive. Specifically, the relevant departments can improve the environmental protection law and adjust the tax system, strengthening the institutional constraints, such as adopting the pollution emission permit system and adjusting and improving the tax structure. These policy constraints, on the one hand, increase the cost of pollution emissions, on the other hand, give enterprises preferential policies to reduce pollution, and let enterprises take the initiative to reduce pollution emissions. In a word, if the government allows enterprises to destroy the environment, it is likely to lead to reverse elimination: in order to increase competitiveness and make huge profits, enterprises that originally focused on environmental protection will catch up with high-polluting enterprises, otherwise, they will be expelled from the market.

To sum up, the shape of the Environmental Kuznets curve is not necessarily “inverted U”, and the model curve will be affected by the region or selected indicators [10]; In addition, the model will also be affected by the policy and its implementation effect [11]. Finally, it should be pointed out that there is still room for improvement in this study, such as expanding the time span of statistical data and the range of indicators. If the more data is selected, the more representative the research results may be, which needs to be strengthened in the future.

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