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Empirical Analysis of Environmental Kuznets Curve Under Opening Economic Conditions

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Abstract: The research reported in this paper examined whether or not there exists the U-curve relation, as the Environmental Kuznets Curve suggests, between China's economic development and environmental pollution, based on the Zhejiang's time series data (1985-2005) on economy and environment. The study was also interested in the impact of opening-trade and FDI on economic development and the quality of environment. The analysis showed that the simple non-linear relationship between environment and income regardless of the element of 'openness' was changed when the result of pollution control was taken into account. The 'hypothesis of pollution haven' seemed to hold water when used to describe the impact of opening-trade on developing countries.

Keywords: Environmental Kuznets Curve International trade FDI

1.Literature Review

The classical H-O Theory argues that opening-trade and FDI is beneficial to improve the social welfare and increase the economic growth of relevant countries. But the theory seldom takes environmental elements into account. After the World WarⅡ, environmental pollution has pervaded all over the world as the globalization of opening-trade and FDI. At the same time, researchers have attached increasing importance to the impact of opening-trade and FDI on economic development and environmental quality. The theoretical model of Environmental Kuznets Curve and the empirical studies on EKC could be regarded as the milestone of the development of these theories. Grossman-Krueger(1991) firstly uses the elment of 'openness' to study EKC. The result indicates that opening-trade has little impact on the environment, as the research finds that only the density of SO2 is lower in the countries with greater openness while there's no strong evidence revealing the relationship between other elements and opening-trade. Rock(1996) finds that the element of 'openness' and the environmental pollution level is negatively related when he compares two countries with the same proportion of manufacturing industry in income and GDP. Rock holds the opinion that the economic development strategy on the basis of the economic integration advocated by the World Bank is environmentally costly, and the environmental quality of developing countries will be on a trend of continuing deterioration until it reaches the apex of EKC. Suri-Chapman(1999) analyzes the influence of the economic growth, international trade and economic restructuring on the apex of EKC of energy consumption, which suggests that in developing countries of East Asia and Latin America, the sector producing manufactured exports accounts for the largest part of energy consumption. As a result of international trade, developing countries with comparative advantage on environmental resource are intended to have a resource-intensive industrial structure. Therefore, for developing countries in the process of industrialization, the turning-point of EKC is higher. Agras-Chapman(1999) introduces the variable of price to further study the evolution of energy use, which shows little evidence that the variable of trade could explain the phenomenon, in the other hand, the price elasticity in short and long run could better interpret it. Landmark(2002) finds that the oil price fluctuation, technical feedback and changes in industrial structure could explain the trend that Sweden's CO2 emission was inverted U-shaped during 1870 to 1997. Cole(2004) studies the elements of trade openness and industrial structure, and concludes that the improvement of environmental quality benefits from several factors such as demand for environmental monitoring and technical input to environmental protection, trade openness, decrease in the ratio of manufacturing output and changes in the structure of pollutive imports. In order to cross the turning point of environmental quality, it is crucial for developing countries to lower the revenue elasticity of manufacturing products.

In China, Zhang Xiao is the pioneer in this field. In 1997, he analyzes the data of air quality of China from 1985 to 1995 since the reform and opening up, and finds that the relationship between the changes in SO2 and real GDP per capita (1978 as the base year) is inverted U-shaped, with the turning point in the range of real GDP per capita from 1200 to 1500 yuan. His research indicates that air quality of China has been improved since 1978. Ling Kang and Wan Huanchen(2001) takes Nanjin as example to look into the relationship between economic development and environmental pollution. The result turns out that the emission of exhaust gas, SO2 and spent residue is rising instead of inverted U-shaped during 1988 to 1998, hence there's no turning point of the curve. Wu Yuping(2001) uses the economic and environmental data of Beijing, and sets up a model to evaluate the relationship between the two. She finds that some environmental indexes are inverted U-shaped, such as nitrogen oxide, total suspended particles, industrial waste water emissions, COD, industrial production of solid waste, calendar year stock and so on. Yang Haisheng and Jia Jia(2005) adopt random effect model and fixed effect model to examine whether or not the globalization would affect the shape of China's EKC, and how much the effect is. They finally come to the conclusion that the increase in international trade has no obvious effect on China's EKC, though it provides China's environmental protection with economic base and brings in environmental technology. In addition, they find that FDI and environmental pollution are positive related. In other words, FDI has a negative effect on the environmental quality, which throws a wrench into China's crossing over the turning point of EKC.

Based on the recent study on EKC, this paper intends to use the Zhejiang's time series data (1985-2005) on economy and environment to analyze Environmental Kuznets Curve empirically. Besides, two control variables, opening-trade and FDI, are introduced into the model, and the impact of these two variables on the EKC is examined.

2.Empirical data sources and methods

According to the representativeness and availability of the information, we use the original data of Zhejiang in time series of 1985 to 2005, and the pollution falls into 3 categories: gas pollution emissions, liquid pollution emissions and solid waste. Variables of pollution emissions include logit of emission of exhaust gas, industrial solid waste and waste water(see in Table 1), with data from corresponding period of the 'Statistical Year book of Zhejiang'. Changes in income are measured by per capita income, here referring to the real GDP per capita(1985 as the base year) which has eliminated the effect of inflation.

Table 1:Summary Statistics of Pollution Emissions and GDP per capita

year	GDP per capita	Emissions of exhaust gas	industrial solid waste	waste water
1985	1067.00	1860	4.72	11.58
1986	1115.42	2275	4.94	11.60
1987	1205.00	2420	4.25	11.59
1988	1374.65	2359	3.89	11.56
1989	1525.16	2458	3.87	11.53
1990	1563.40	2595	4.06	11.78
1991	1597.37	4676	3.04	11.53
1992	1695.49	3136	3.04	11.67
1993	1944.78	2878	2.94	11.57
1994	2263.84	2996	2.40	11.52
1995	2564.66	3108	2.48	11.54
1996	2679.33	3279	2.48	11.36
1997	2699.30	4884	3.33	11.73
1998	2641.37	5016	3.50	11.64
1999	2585.81	5417	2.40	11.67
2000	2627.46	6509	1.79	11.82
2001	2668.03	8530	1.61	11.97
2002	2748.89	8532	1.61	12.03
2003	2906.12	10432	1.39	12.03
2004	3047.22	11749	1.49	12.02
2005	3117.39	13025	1.73	12.17

According to the study by Grossman-Krueger(1995), an econometric model of the relationship between economic development and environmental pollution is set below:

$$\ln y = \beta_0 + \beta_1 \ln x + \beta_2 \ln^2 x + \beta_3^3 \ln x + \xi$$

Here y represents pollution emission; x represents GDP per capita; β_1、β_2、β_3 are model parameters; ξ is the random parameter. The probable results of regression analysis may suggest : (1) if $\beta_1 > 0$、$\beta_2 < 0$、$\beta_3 > 0$, the curve is N-shaped; if $\beta_1 < 0$、$\beta_2 > 0$、$\beta_3 < 0$, it is inverted N-shaped. (2) if $\beta_1 > 0$、$\beta_2 < 0$、$\beta_3 = 0$, the curve turns out to be EKC, which is inverted U-shaped; otherwise, when $\beta_1 < 0$、$\beta_2 > 0$、$\beta_3 = 0$, the curve is U-shaped. (3) if $\beta_1 \neq 0$、$\beta_2 = 0$、$\beta_3 = 0$, environment and income are linear related.

3.Empirical Analysis of Environmental Kuznets Curve

With the reference to the data from 1985 to 2005 of Zhejiang Province, we respectively analyze the three elements in Table 1 and GDP per capita in retrogressive method. Meanwhile, according to the W.D statistics of the estimates, we can determine whether the regression residuals are self-correlated. Then AR is added into the estimated equation correspondingly in order to eliminate the self-correlation error.

3.1EKC test of industrial waste water and GDP per capita

As the W.D statistics suggest the self-correlation of the regression residuals, the data in Table 2 are estimated after AR(2) is introduced into the model:

$$\ln iwater = -0.88 \ln agdp + 80.30 + \left[AR(1)、AR(2) \right]$$

$$AR(1) = 0.432934 \qquad AR(2) = 0.565160$$

The model above suggests a linear relationship between GDP per capita and industrial waste water: every 1% increase in GDP per capita will make industrial waste water drop 0.88%. As to further examine the probable curvilinear relationship between the two variables, we added a high order of GDP per capita into the model, and in the aspect of Goodness of Fit test, there's strong evidence of the N-shaped relationship between waste water and GDP per capita.

$$\ln iwater = 2.02 \ln agdp - 0.03 \ln agdp^3$$

Table 2: Estimates of water pollution emissions and GDP per capita

Types of Estimation model	The first power	The second power	The third power
β_1	-0.88 (-2.08)	0.97 (2.32)	2.02 (11.35)

β_2	0	-14.38 (-2.26)	0
β_3	0	0	-0.03 (-9.28)
C	80.30	64.44 (2.70)	0
AR	$AR(2)$	$AR(0)$	$AR(0)$
R-squared	0.77	0.45	0.79
$D \cdot W$	2.65	0.84	0.87
F-statistic	16.99	7.23	8.28

The conclusion from the modified equation is basically consistent with the original model. The industrial waste water and GDP per capita are negative related, and the turning points of the N-shaped curve are GDP per capita of 23,000 yuan and 47,000 yuan respectively. When GDP per capita is below 23,000 yuan, the industrial waste water increases with the rise of GDP per capita; when GDP per capita exceeds the critical value of 23,000 yuan, the rise in GDP per capita contributes to the control of industrial waste water; once GDP per capita is in excess of 47,000 yuan, the emission of industrial dust will climb up. The result reminds us that it could be a complex curvilinear relationship between GDP per capita and environmental pollution.

3.2 EKC test of air pollution and GDP per capita

Table 3: Estimates of emissions of exhaust gas and GDP per capita

Types of Estimation model	The first power	The second power	The third power
β_1	0.35 (0.89)	-21.85 (-1.41)	-10.22 (-0.12)
β_2	0	1.46 (1.01)	-0.10 (-0.01)
β_3	0	0	0.07 (0.14)
C	9.98	93.63 (1.58)	69.56 (0.31)

AR	$AR(0)$	$AR(1)$	$AR(0)$
R-squared	0.59	0.63	0.63
$D \cdot W$	2.32	2.29	2.28
F-statistic	12.20	9.22	6.50

Table 3 shows the estimates of emissions of exhaust gas and GDP per capita. Similarly, AR(1) is introduced into the model to eliminate the self-correlation of the regression residuals. With regard to the estimates, the following model is built:

$$\ln fq = -21.85 \ln agdp + 1.46 \ln agdp^2 + 93.63 + AR(1)$$

$$AR(1) = 0.622395$$

This model indicates that the emission of exhaust gas and GDP per capita show a U-shaped relationship, with the turning point at GDP per capita of 3,300 yuan. The U-shaped curve describes the impact of GDP per capita on the emission of exhaust gas: When GDP per capita is below the critical value of 3,300 yuan, the emission of exhaust gas decreases as GDP per capita rises; once GDP per capita exceeds 3,300 yuan, the emission of exhaust gas rises with GDP per capita. Comparing with current GDP per capita of Zhejiang Province, the present stage of Zhejiang is on the right side of the U-shaped curve, which means that the emission of exhaust gas rises with GDP per capita.

In addition, the third power of GDP per capita is also included into the equation, the result shows as follows:

$$\ln fq = -10.22 \ln agdp - 0.10 \ln agdp^2 + 0.07 \ln agdp^3 + 69.56$$

According to the t-statistics of the first, second and third power of GDP per capita, the assumption that the first, second and third power of GDP per capita are joint significant does not hold water. So we can come to the conclusion that it is merely quadratic relationship between the emission of exhaust gas and GDP per capita.

3.3EKC test of industrial solid waste and GDP per capita

Table 4 shows the estimates of industrial solid waste and GDP per capita. Similarly, AR(2) is introduced into the model to eliminate the self-correlation of the regression residuals:

$$\ln fq = 3.25 \ln agdp - 0.38 \ln agdp^2 + \left[AR(1)、AR(2) \right]$$

$$AR(1) = 0.816886 \qquad AR(2) = -0.375065$$

Table 4: the estimates of industrial solid waste and GDP per capita

Types of Estimation model	The first power	The second power	The third power
β_1	-2.45 (-3.64)	3.25 (4.70)	160.80 (0.78)
β_2	0	-0.38 (-4.22)	-20.00 (-0.73)
β_3	0	0	0.81 (0.66)
C	21.58 (4.14)	0	420.15 (0.80)
AR	$AR(2)$	$AR(2)$	$AR(2)$
R-squared	0.82	0.83	0.84
$D \cdot W$	1.91	1.92	1.97
F-statistic	23.47	17.20	13.17

It is conveyed that the relationship of industrial solid waste and GDP per capita is presented as Kuznets Curve, which is inverted U-shaped. The turning point of the curve is 6,700 yuan. When GDP per capita is less than 6,700 yuan, industrial solid waste and GDP per capita will rise simultaneously; when GDP per capita exceeds 6,700 yuan, industrial solid waste falls as GDP per capita rises. In a word, the estimates of Zhejiang suggest solid pollution has a relatively lower critical value of GDP per capita. The possible reason lies in: supervision on solid pollution is easier than on waste water and exhaust gas, therefore, solid pollution could be in efficient control.

In summary, we find that the relationship between environmental pollution and changes in income or economic development is uncertain, because in some degree, the estimates of EKC depend on the selection of measurements, sample data and estimation method. Specifically, industrial waste water and GDP per capita are N-shaped related; emission of exhaust gas and GDP per capita are U-shaped related; the relationship of industrial solid waste and GDP per capita is inverted U-shaped. Thus, the shape of EKC is determined by the selection of the original data and estimation method to a great extent.

4. Further estimation of EKC

On the basis of the analysis above, we further introduce in control variables that affect environmental pollution, and reestimate the EKC in order to: firstly, to examine whether the relationships between the elements of pollution and GDP per capita will change after modifying, especially whether the turning points will move; secondly, to study the impact of control variables on environmental pollution, and try to find out the determinant of environmental pollution.

With regard to the current study in this field and the relationship between China's environment and income, this section will focus on two control variables, the trade openness and FDI, in open economy of Zhejiang Province.

(1) Trade openness. According to the Comparative Advantage Doctrine, the impact of international trade on the environmental quality drives pollution-intensive industry from developed countries to developing countries, or from countries with severe environmental regulations to those with less severe regulations. So EKC shows the difference in division of labor based on specialization: developed countries specialize in products with less pollution, while developing countries produce resource-intensive and energy-intensive products. In other words, there is a 'substitution effect' of international trade on environmental pollution, known as the 'pollution haven hypothesis'. In this section, trade openness(marked as open), that is the proportion of export in GDP, is the measurement of the environmental effect of opening trade.

(2) FDI. FDI contributes a lot to China's economic construction, as it brings in capital and technology, and promotes employment; it also stimulates export and increases regional economic growth ultimately. However, it causes some environmental problems. Since some provinces do not pay enough attention to sustainable development while they eagerly make use of FDI to increase the economic growth, developed countries have the chance to transfer pollution-intensive industry to China. During the past 20 years, pollution-intensive industries or projects are the major foreign investment projects in coastal areas. These industries or projects include chemicals, petrochemicals, leather, printing and dyeing, electroplating, pesticides, paper, mining and metallurgy, rubber, plastics, construction materials, pharmaceuticals and so on. In this section, the proportion of FDI in GDP(marked as fdi) is considered to measure the environmental effect of FDI.

Similarly, we use the data in Table 1 to estimate the modified model in which control variables are included:

$$\ln y = \beta_0 + \beta_1 \ln x + \beta_2 \ln^2 x + \beta_3^3 \ln x + \lambda \frac{open}{GDP} + \xi$$

$$\ln y = \beta_0 + \beta_1 \ln x + \beta_2 \ln^2 x + \beta_3^3 \ln x + \lambda \frac{fdi}{GDP} + \xi$$

We firstly estimate the equation including the square and cube of GDP per capita, and the t-statistics of its estimated coefficient could suggest the shape of the curve, N-shaped or inverted U-shaped. If the cube of GDP per capita is not significant, the equation will be reestimated after the exclusion of the cube of GDP per capita. Table 5, Table 6 and Table 7 represent the estimated relationship between 3 elements of pollution and GDP per capita respectively.

Table 5: Estimates of water pollution emissions and GDP per capita

Estimation model	Trade openness	FDI
β_1	2.72 (19.68)	2.64 (5.55)
β_2	-0.16 (-8.87)	-0.14 (-2.33)
β_3	0	0
C	0	0
λ	6.96 (3.54)	-5.78 (-0.34)
AR	$AR(1)$	$AR(1)$
R-squared	0.72	0.58
$D \cdot W$	2.22	2.28
F-statistic	10.72	4.58

Table 6: Estimates of emission of exhaust gas and GDP per caipa

Estimation model	Trade openness	FDI
β_1	0.99 (23.71)	-30.71 (-1.05)
β_2	0	-1.92 (1.00)
β_3	0	0
C	0	0
λ	11.35 (2.93)	-13.14 (-0.68)
AR	$AR(1)$	$AR(1)$

R-squared	0.91	0.91
$D \cdot W$	2.36	3.09
F-statistic	53.90	39.91

Table 7: Estimates of industrial solid waste and GDP per capita

Estimation model	Trade openness	FDI
β_1	498.37 (1.91)	1.68 (4.43)
β_2	-66.98 (-1.97)	0
β_3	3.10 (2.03)	-3.34
C	-1123.97 (-1.82)	0
λ	-21.95 (-4.17)	-44.34 (-0.72)
AR	$AR(0)$	$AR(2)$
R-squared	0.90	0.83
$D \cdot W$	1.90	1.85
F-statistic	34.95	23.74

According to the estimates showed in Table 5, Table 6 and Table 7, new curvilinear relationships are indicated after considering the element of openness:

(1) Industrial waste water:

$$\ln y = 2.72 \ln x - 0.16 \ln^2 x + 6.96 \frac{open}{GDP} + AR(1) \quad AR(1) = 0.174822$$

$$\ln y = 2.64 \ln x - 0.14 \ln^2 x - 5.78 \frac{fdi}{GDP} + AR(1) \quad AR(1) = 0.719393$$

The new relationship between industrial waste water and GDP per capita is inverted

U-shaped, with the turning point of GDP per capita at 23,000 yuan.

(2) Emission of exhaust gas:

$$\ln y = 0.99\ln x + 11.35\frac{open}{GDP} + AR(1) \quad AR(1) = 0.638580$$

$$\ln y = -30.71\ln x - 1.92\ln^2 x - 13.14\frac{fdi}{GDP} + AR(1) \quad AR(1) = 14.13383$$

The estimates suggest a positive linear relationship between the emission of exhaust gas and GDP per capita after the element of openness is included. When considering the impact of FDI, the curve of the emission of exhaust gas and GDP per capita presents as inverted U-shaped, with its turning point at 18,000 yuan.

(3) Industrial solid waste:

$$\ln y = 498.37\ln x - 66.98\ln^2 x + 3.10\ln^3 x - 21.95\frac{open}{GDP} - 1123.97$$

$$\ln y = 1.68\ln x - 3.34\ln^3 x - 44.34\frac{fdi}{GDP} + AR(1) + AR(2)$$

$$AR(1) = 0.740852, \quad AR(2) = \text{-}0.361756$$

We can judge from the above estimates that the relationship of industrial solid waste and GDP per capita is N-shaped with the impact of the element of openness.

Therefore, the core of this paper is the changes in the shape of the environment-income curve after the element of openness is considered. The table below compares the difference between two types of estimates:

Table 8: Comparison between two types of estimates

Types of pollution	Shapes of the curve		
	First model	Second model	
		Trade openness	FDI
Industrial waste water	Positive linear	Inverted U-shaped	Inverted U-shaped
Emission of exhaust gas	N-shaped	Positive linear	Inverted U-shaped
Industrial solid waste	Inverted N-shaped	Inverted U-shaped	N-shaped

Table 8 indicates the changes in shape of environment-income curve. Comparing the characteristics of the curves, we discover the rule that the consideration of control variables will change the non-linear relationship between environment and income. The reason that environment-income curve are positive linear in the first model lies in that, in the first model, changes in GDP per capita are partly influenced by industrial restructuring, trade liberalization, technical progress and environmental policy. Once these control variables are isolated, environment-income relationship will change accordingly.

Besides, we empirically examine the pollution haven hypothesis of the impact of trade openness on the developing countries' pollution, but the effect of foreign-funded enterprises is not taken into account. According to the pollution haven hypothesis, the impact of trade openness on developed countries and developing countries is different because of the comparative advantages and international division of labor: international trade facilitates developed countries to transfer the pollution-intensive industries to developing countries, which means that the disadvantage in the international division could worsen the environmental quality of developing countries. The estimated coefficient of open are significantly positive except the one of industrial solid waste, the other two being 6.96 and 11.35 respectively. The estimated coefficient of open being significantly positive suggests that the increase of trade openness impels the emission of industrial pollution to rise, which is the same as the pollution haven hypothesis. In addition, the impact of FDI on environmental pollution is not significant yet. As the estimated coefficient of fdi is negative and the t-test is not significant, it is reasonable that FDI benefits to reduce the industrial pollution of Zhejiang Province, although the impact is not apparent. There are two possible reasons: First of all, Zhejiang has gained great economic strength since the reforming and open-up policy was adapted about 20 years ago. Thereby, the negotiation and contracting of foreign investment have attached increasing importance to the environmental effect of the projects. Some projects related to environmental protection contributes directly to the exploration and employment of the new technology of environmental protection. Second, the technology spillover effect of foreign-funded enterprises increases the factor-productivity and technical level of developing counties, and further influences the environmental pollution by technological progress and industrial restructuring.

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