View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Apollo

The Relationships between Economic Growth and Environmental Pollution Based on Time Series Data: An Empirical Study of Zhejiang Province

Lixia YANG[1] Shaofeng YUAN[2]* Le SUN[2]

[1]Department of Resource Environment & Urban and Rural Planning Management, Zhejiang University of Finance & Economics, Hangzhou 310018, China, Email:yanglixia2001@63.com

[2]Department of land resources management, Zhejiang Gongshang University, Hangzhou 310018, China, Email:shaofengyuan1975@163.com, 181786379@qq.com

Abstract:

By employing the methods of Johansen cointegration test and granger causality test, the paper aimed at investigating the interactions of environmental pollution and economic growth in the process of Zhejiang's industrialization according to the time series data of three kinds of pollution indices from 1981 to 2006. The results showed that three kinds of pollution indices all had a negative long-term cointegration relationship with GDP per capita, which mean that the economic growth is not necessary result in environmental degradation. The results also indicated that the GDP per capita granger caused pollution emission of industrial wastewater and industrial waste gas except for industrial solid waste discharge, while it was not true in versa. This reason was mainly that there was no distinct definition of the negatively external effect of the effective property protection system and market dealing mechanism on environmental pollution.

Key Words: Environmental Kuznets Curve (EKC), Economic growth, Environmental pollution, Cointegration test, Granger causality test

---

*Corresponding author: Shaofeng YUAN, 1975~, Visiting Scholar to Cambridge University, Associate Professor.
Foundation item: National Natural Science Foundation of China (411711151), State Education Commission Foundation (11JCGL12YB), (10YJA630197), Peking University-Lincoln Institute Foundation (20110901), and Zhejiang Province Philosophy & Social Sciences Study Foundation (11JCGL12YB).

1. INTRODUCTION

Along with industrialization and urbanization, the social economy develops in an unparalleled speed, while it inevitably increases the consumption of natural resources and the pressure to protect ecological environment. That is the exploitation of natural resources makes emissions of industrial pollutants increases. The industrial growth finally leads to environmental quality degradation (Peng, 2006). However, there are also studies indicate that economic growth is beneficial to the environment and the two parts mutually promote each other (Beckerman, 1992). The relationships between economic growth and environment quality have not yet drawn definite conclusion and it is still needs to be studied further. As an economic powerful province, Zhejiang Province has certain representative meaning in the area of economic development and environment protection. Based on the empirical research of dynamic relations between economic growth and environment pollution, this paper studies the evolution law of economic growth and environment quality and finally provides significant reference and guidance to the developed provinces in the coordinated development of economy and environment.

2. REVIEW OF ECONOMIC GROWTH IMPACT ON ENVIRONMENT

In the early 1960s, some scholars analyzed the significance of economic growth for the environment based on the principle of mass conservation: output growth will inevitably lead to the increase of the environmental resources extraction in the economic system, and the stock of waste discharged to environment is increasing too (Boulding, 1996). However, natural environment is limited in absorbing waste produced from the economic system, which makes the world economic growth unsustainable. Then continued economic growth will ultimately do more damage to a region, a country, and even the global environment or will help to improve the environmental quality (Zhang, 2008)? In order to better describe the relationship may exist between them, scholars have conducted a lot of researches, and are mainly about the impact of economic growth on the environmental pollution, in which the most important one is the proposition of Environmental Kuznets Curve (EKC) and the related empirical research. Researchers believe that reverse U relation presents between economic growth and environmental pollution. That is the lower stage of economic development, the lower environmental pollution. Environmental pollution is increasing along with industrialization. In the higher stage of economic development, the high-polluting industrial economy turns into service economy or technology-based economy with the changes in the economic structure of the country, and the environmental pollution degree is declining (Grossman, 1992; Grossman, 1995).

Most literatures about EKC first assume that EKC is exist, which will be validated later by different data and research methods. Westen scholars mainly use national cross-sectional data and panel data to validate EKC by fitting the quadratic or cubic polynomial model, such as

(Stern, 1996; Coondoo, 2002; Cole, 2004), while research analyzed by using single country time series data is few. Most studies in China directly use time series data to fit quadratic or cubic polynomial model, and then find the inflection point for authentication, such as (Wu, 2002; Yang, 2003; Liu, 2005; Wang, 2006; Wang, 2007; Peng, 2008).

Throughout these empirical studies, researchers always use classical regression hypothesis model indiscriminately either in cross-sectional data, panel data or time series data, and ignore the preconditions required by the model-the variables involved are stationary, which may make the conclusion a "spurious regression". At the same time, these studies only focus on the impact of economic growth towards environmental pollution, while ignore the mutual influence mechanism and dynamic relationships of the two parts.

3. VARIABLE SELECTION AND DATA PROCESSING

The choice of the typical environment pollution index is the key when studying the interaction between economic growth and environmental pollution. In most empirical study, environmental pollution index mainly use the following two variables: pollutant concentration and emission. Given the availability of data, this paper uses pollutant emission to measure environmental pollution status. Taking into account that industry is the main source of environmental pollution in Zhejiang province, this paper selects these three indices: discharged amount of industrial wastewater (unit: 10^8t), discharged amount of industrial waste gas (unit: 10^4m^3) and the products of industrial solid waste material (unit: 10^4t). Economic growth index uses GDP per capita (unit: RMB, current prices). Compared with the total income, GDP per capita can reflect the influence of income level changes on environmental pollution better. The time series length of economic growth indices and various environmental variables both are 1981-2006. Data resources are the “Statistical Yearbook of Zhejiang Province” and “National Environmental Statistical Bulletin” in the corresponding period.

To avoid violent fluctuations in the data, and to eliminate the problems of possible heteroscedastic and multiple linear, and considering that the time series data is easily to get stationary series after logarithmtics processing and the characteristics of time series data doesn’t change, thus this paper do logarithmtics processing respectively to discharged amount of industrial waste water, discharged amount of industrial waste gas, industrial solid waste material, and GDP per capita. New sequence logarithm respectively named LNindwater, LNindgas, LNsolid and LNagdp, and all the data analysis is completed by using software Eviews5.0.

Table I. The economic growth and environmental pollution data (1981-2006)

Year	*Industrial wastewater (10^8t)*	*Industrial solid waste (10^4t)*	*Waste gas (10^4m^3)*	*GDP per capita (RMB)*
1981	86863	474	761	528
1982	91154	535	1147	595
1983	96853	605	1303	647
1984	109018	631	1557	807
1985	107360	679	1860	1061
1986	108790	845	2275	1229
1987	108318	754	2420	1465
1988	104555	788	2359	1818
1989	101603	810	2458	2005
1990	130229	847	2595	2120
1991	102049	888	4676	2539
1992	116626	945	3136	3185
1993	105734	949	2878	4427
1994	100703	953	2996	6143
1995	102807	1018	3108	8066
1996	85481	1027	3279	9423
1997	124813	1326	4844	10489
1998	113018	1390	5016	11217
1999	117132	1361	5417	12009
2000	136433	1386	6509	13410
2001	158113	1603	8530	14930
2002	168048	1778	8532	17187
2003	168088	1976	10432	20641
2004	165274	2318	11749	24563
2005	192426	2514	13025	29200
2006	199593	3096	14702	34006

4. COINTEGRATION TEST OF ECONOMIC GROWTH AND ENVIRONMENTAL POLLUTION

4.1 Unit Roots Test

Stability test of the time series data of the variables is the precondition for cointegration test of economic growth and environmental pollution. Only when variables are in 1st order can the cointegration analysis be carried out. ADF (Augmented Dickey Fuller) unit roots test is introduced to this paper to test the stability of the time series data of the variables.

According to the tests in Table I, during the sample periods, three kinds of variables of the environmental pollution of LNindwater, LNindgas and LNsolid, and the variable of economic growth of LNagdp are selected. All series at the plain level can not reject the original hypothesis, which means that all series are non-stable series. After first order difference, all series reject the null hypothesis at the level of 5%, which means that all series become stable after the 1st order difference. Based on that, the four series are all non-stable series of first order single integration or I (1). They are all available for cointegration test.

Table II. The results of ADF unit root test

Variables	*ADF test data*	*Test type(ctp)*	*5% Critical value*	*Conclusions*
LNindwater	**0.220732**	**c01**	**-2.991878**	**Non-stable**
DLNindwater	**-7.377185**	**c00**	**-1.955681**	**Stable**
LNingas	**-2.896616**	**ct1**	**-3.603202**	**Non-stable**
DLNingas	**-6.140879**	**c02**	**-2.991878**	**Stable**
LNsolid	**-0.793331**	**ct2**	**-3.603202**	**Non-stable**
DLNsolid	**-5.011847**	**co2**	**-2.991878**	**Stable**
LNagdp	**-2.816174**	**ct2**	**-3.612199**	**Non-stable**
DLNagdp	**-3.180273**	**c01**	**-2.998064**	**Stable**

Notes: Whether the test type keeps intercept and trend term depends on the diagram of the series. In which, c means intercept, t means trend term, and p means hysteresis orders. Hysteresis order is determined by AIC information principles; D means 1st order difference.

4.2 Cointegration Relationship Test

ADF Unit Roots Test shows that LNindwater, LNindgas, LNsolid and LNagdp are all 1st order single integration I (1) series. To further the analysis of the long-term stable relationship between economic growth and all environmental pollution variables, cointegration relationship test of the time series data of the variables is necessary. The basic test concept is that although two or more variables are non-stable series, but some linear combination among them would feature stability. Based on that, there is cointegration relationship among these variables, namely long-term and stable relationship. The cointegration relationship of many variables will be tested in this paper. The multiple cointegration test based on the vector autoregression model is used, which is known as Johansen test. In 1990, Johansen and Juselius proposed the multiple cointegration test based on the vector autoregression (VAR) model. The method overcomes the E-G Test's defect, which usually can only tested two variables. Additionally, the in advance determination of explanatory variable and dependent variable is not necessary. The critical thing is to calculate the two statistics: trace statistic and the statistic of the maximum eigenvalues, and then carry out the analysis of the cointegration relationship.

The key to Johansen Cointegration Test is to select hysteresis orders. The paper starts from higher hysteresis order, adjusts the hysteresis order by t-value test, and then determines the optimal hysteresis order by AIC and SC information principle, which means that the selected hysteresis order should make AIC and SC values as small as possible. Through several adjustments, hysteresis orders of the three systems composed by LNinwater and LNagdp, LNindgas and LNagdp, and LNsolid and LNagdp are all 6. Cointegration relationship tests for various environmental pollution variables and LNagdp are carried out. See the results in Table III below:

Table III. Results of Johansen cointegration test between 3 variables and LNagdp

Variables concluded	*Trace statistics*	*5% Critical value*	*Maximum eigenvalues*	*5% Critical value*	*Cointegration relations*
LNindwate & LNagdp	**25.72366**	**15.49471**	**24.59145**	**14.26460**	-
	1.132214	**3.841466**	**1.132214**	**3.841466**	
LNingas & LNagdp	**24.28995**	**15.49471**	**20.30511**	**14.26460**	-
	3.984839	**3.841466**	**3.984839**	**3.841466**	
LNsolid & LNagdp	**16.83677**	**15.49471**	**14.44887**	**14.26460**	-
	2.387895	3.841466	2.387895	3.841466	

According to Table III, there is long-term and stable cointegration relationship between the selected three kinds of environmental pollution variables and LNagdp. It is negative cointegration relationship, which means that the growth of per capita income, says economic growth is helpful to decrease the industrial emission of wastewater, exhaust gas, and solid waste. Economic growth will not improve the environmental pollution automatically, except for actively adjusting the industrial structure, investing more on environmental protection, and issuing stricter environmental policies and regulations. These measures are being taken by Zhejiang to protect the environment during the quick economic growth. Based on the experience in developed countries, during quick economic growth, only when the investment on environmental protection accounts for 1%-1.5% of GDP can environmental pollution be controlled effectively, and environmental quality can be improved obviously if the ratio reaches 3% (Shen, 2000). During the period of 1999-2006, Zhejiang's environmental investment on environmental protection accounted for 1.63%-2.56% of GDP, which means a leading position throughout the nation. Thus, it should be at the level between effective environmental control and obvious improvement of the environmental quality in Zhejiang Province.

However, there is certain difference between this study's result and overseas research results. According to overseas EKC research literatures, the turning point of inverted EKC U curve is from USD5000 to USD15000 per capita, where economic growth and environmental protection coordinates with each other harmoniously. Economic growth in Zhejiang still has not reached that level, which means that Zhejiang reaches the harmonious coordinated level of the environmental protection at earlier stage of economic growth. The reliability of the conclusion totally depends on the reliability of the environmental pollution and economic growth data.

5. GRANGER CAUSALITY TEST OF ECONOMIC GROWTH AND ENVIRONMENTAL POLLUTION

According to cointegration test, there is long-term and stable cointegration relationship between the selected three kinds of environmental pollution variables of LNindwater, LNindgas and LNsolid and LNagdp. Whether the stable relationship can compose the causality still needs further test, namely whether income changes result in the changes of environmental quality, or whether the changes of environmental quality results in income changes. The causality test method proposed by Granger and Sims is used to solve the problem.

Table. IV Results of granger causality test

Null Hypothesis	*F-Statistic*	*Probability*	*Conclusion*
Granger cause of LNindwater or LNagdp	**0.52455**	**0.77520**	**Accept**
Granger cause of LNagdp or LNindwater	**3.80862**	**0.05179**	**Reject**
Granger cause of LNindgas or LNagdp	**2.13172**	**0.17242**	**Accept**
Granger cause of LNagdp or LNindgas	**6.12439**	**0.01556**	**Reject**
Granger cause of LNsolid or LNagdp	**0.97968**	**0.50182**	**Accept**
Granger cause of LNagdp or LNsolid	**1.05920**	**0.46377**	**Accept**

According to Granger Causality Test in Table IV, among the selected three kinds of environmental pollution variables of LNindwater, LNindgas, and LNsolid, the unidirectional Granger causality only exists between LNindgas and LNagdp, and between LNindwater and LNagdp, while there is no Granger causality between LNsolid and LNagdp. Per capita GDP is the main contributor to the changes in the emission of industrial exhaust gas and wastewater, but changes in environmental quality is not the reason behind the changes in per capita GDP. The conclusion is consistent with several researches: Omisakin (2009) used the timing data from 1970 to 2005 to test the causality between CO2 and income in Nigeria, and it showed that there is no causality between environmental pollution and income changes; Liu (2006) used the timing data from 1973 to 2003 to test the causality between environmental variables (CO2, CO, SO2, NOX) and income in Norway, and it showed that the unidirectional causality from income changes to environmental pollution only exists between CO2 and CO, and the income. However, some researchers get opposite conclusions: Liang et al. (2002) used the time series data from 1973 to 1997 for the empirical analysis in Toronto, and it showed that there is causality between environmental quality and income changes; Day et al. (2003) made the Granger Causality between environmental quality and income in Canada, and it turned out that there is bidirectional causality between them. The two opposite conclusions maybe result from the reason that some researched regions or countries have relatively improved equity transaction market for outside pollution effects, and the residents have higher requirements for environmental quality, so there is the causality between pollution and income changes. On the contrary, some countries or regions lack effective equity transaction system or market transaction mechanism to clearly determine the outside effect of environment pollution, so feedback mechanism of environmental pollution to income changes is relatively weak.

6. CONCLUSION

Johansen cointegration test and Granger causality test are used to research the relationship between economic growth and environmental pollution from 1981 to 2006 in Zhejiang. The conclusions include:

(1) The time series data of the three kinds of environmental pollution variables of the industrial emissions of wastewater, exhaust gas and solid waste, and per capita GDP are all 1st order single integration. There are long-term stable negative cointegration relationships between them. It means that Zhejiang reaches the harmonious coordinated level of the environmental protection at the earlier stage of economic growth.

(2) Except for industrial solid waste, per capita GDP is the major reason for the changes in industrial exhaust gas and wastewater, but environmental pollution is the reason for the changes in per capita GDP. The conclusion is consistent with the situation that Zhejiang is at the later stage of industrialization. During the later industrialization, although it is recognized that the growth in the value of industrial output does not mean the growth of the resources investment, there are still no effective equity transaction system and market transaction mechanism to clearly determine the outside effect of environmental pollution.

(3) The application of Johansen cointegration test and Granger Causality Test in the study of relationship between economic growth and environmental quality has positive meanings in theory and practice.

(4) According empirical researches, economic growth and environmental protection can be coordinated, as larger environment investment and stricter environmental policies regulations get down to play more important roles. It has reference meaning for other regions.

ACKNOWLEDGMENT

The authors gratefully acknowledge to the professors, friends, and colleagues in University of Cambridge and Peking University for the discussions and commitments. We would also like to recognize the National Natural Science Foundation of China (411711151), State Education Commission Foundation (11JCGL12YB), (10YJA630197), Peking University-Lincoln Institute Foundation (20110901) State Education Commission Foundation (10YJA630197), Peking University- Lincoln Institute Foundation (2011) , and Zhejiang Province Philosophy & Social Sciences Study Foundation (11JCGL12YB).

REFERENCES

[1] Beckerman W., 1992, Economic growth and the environment: whose growth? Whose environment, *World Development*, (20):481-496.

[2] Boulding K. E., 1966, The Economics of the Coming Spaceship Earth, *Environmental Quality in a Growing Economy*, ed., H. Jarrett, Baltimore, MD: John Hopkins Press.

[3] Cole M. A., 2004, The pollution haven hypothesis and the environmental Kuznets Curve: Examining the linkages, *Ecological Economics*, 48(3), 71-81.

[4] Coondoo D. and Dinda S., 2002, Causality between income and emissions: a country group-specific econometric analysis, *Ecological Economics*, 40(3), 351-367.

[5] Day K. M. and Graften R. Q., 2003, Growth and the environment in Canada: An empirical analysis, *Canadian Journal of Agricultural Economics*, 51(3), 197-216.

[6] Grossman G. and Krueger A., 1992, Environmental impacts of a North American free trade agreement, Garber P., *The Mexico-US Free Trade Agreement*, Cambridge, MA: M Ⅱ Press.

[7] Grossman G. and Krueger A., 1995, Economic Growth and the Environment, *Quarterly Journal of Economic*, 110(2), 353-372.

[8] Liang J. and McKitrick R., 2002, *Income growth and air quality in Toronto: 1973-1997*, Mimeo, University of Guelph, Economics Department.

[9] Liu G., 2006, *A causality analysis on GDP and air emissions in Norway*, Discussion Papers, Statistics Norway, No.447.

[10] Liu L., 2005, The Environmental Kuznets Curve of Guangdong Province, *Research of Environmental Sciences*, 18(6), 6-11.

[11] Omisakin A. O., 2009, Economic growth and environmental quality in Nigeria: Does environmental Kuznets Curve hypothesis hold?, *Environmental Research Journal*, 3(1),14-18.

[12] Peng L., Tong X. and Shen Y., 2008, Quantitative process of environment and economic progress in Shanghai, *China Population Resources And Environment*, 18(3),186-194.

[13] Peng S. and Bao Q., 2006, Economic growth and environmental pollution: an empirical test for the environmental Kuznets Curve hypothesis in china, *Research On Financial And Economic Issues*, (8):3-17.

[14] Shen M. and Xv Y., 2000, A new type of Kuznets Curve: the relationship between economic growth and environment change, *Zhejiang Social Sciences*, (7),53-57.

[15] Stern D. I., Michael S. C. and Edward B. B, 1996, Economic growth and environmental degradation: The environmental Kuznets Curve and sustainable development, *World Development*, 24(7):1151-1160.

[16] Wang Y., Cui X., and Chen W., 2006, Empirical research on the relationship between economic growth and environmental degradation in Nanjing city [J]. *Resources and Environment in the Yangtze Basin*, 15(2), 142-146.

[17] Wang Z., Wen Z.,Yan F., et al., 2007, Verifying the environmental Kuznets Curve hypothesis and its conditions in Beijing, *China Population Resources And Environment*, 17 (2), 40-47.

[18] Wu Y. and Dong S., 2002, Evaluating environmental policy of Beijing, *Urban Environment & Urban Ecology*, 15(2), 4-6.

[19] Yang K., Ye M. and Xv Q., 2003, Environmental Kuznets characteristics of municipal solid waste growth in Shanghai city, *Geographical Research*, 22(1), 60-66.

[20] Zhang B., Bi J., Ge J., et al., 2008, Empirical study of environmental Kuznets curve in south Jiangsu, *Economic Geography*, 28(3), 376-379, 424.