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An Empirical Study of the Environmental Kuznets Curve for Environment Quality and Economic Growth --Evidence from China's Panel Data[1]

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ABSTRACT
This paper attempts to examine the determinants of environmental degradation within the framework of Environment Kuznets Curve (EKC) hypothesis using China's city-level panel data from 2003 to 2012. The population agglomeration as well as three types of cities such as municipalities, sub-provincial city and prefecture-level city are considered in our paper. Our empirical results with the whole sample data verified the theory of the EKC hypothesis, which shows a reverse "U" shape between economic growth and environmental pollution. In addition, the effect of population on environmental pollution is quite different among the various types of cities. The results of this study can serve as a useful reference for policy makers in terms of achieving economic and environmental sustainability.

Keywords: *Economic growth, Environment Kuznets Curve, Fixed effects model, Panel data*

I. Introduction

In 2014, China's GDP reached 636462.71 yuan (103601.05 in current USD) which is the second largest economy in the world . Meanwhile, in 2014, China's GDP per capita increased from 381.75 yuan in 1978 to 46652.25 yuan (7593.88 in current USD). According to the World Bank's classification, China has become an upper-middle income economy. Meanwhile, China has been witnessed the fastest pace of urbanization in the world. Currently, China has the largest urban population in the world, with 749 million urban dwellers in 2014, accounting for 54.77 percent of China's total population and 20 percent of the global population. However, this impressively rapid economic growth and population agglomeration process has placed abundant stress on environment, which has experienced a large degradation problem. Environmental pollution issues are often front page news and present enormous challenges for China's sustainable development, bringing concern to the central government. In fact, quite a large number of cities in China have reported intense pollution as an air quality problem. Understanding environmental degradation and its determinants has become increasingly important throughout China.

The nexus between the environment and economic growth has attracted a notably large amount of attention for a long time. A considerable body of literature has examined the relationship between economic growth and environmental degradation. The famous Environment Kuznets Curve (EKC) hypothesis, which was first proposed by Grossman and Krueger (1991), is defined as a U-shape relationship between economic growth and environmental degradation. The EKC hypothesis posits that environmental pollution will increase with economic growth until a certain income level is reached and then decrease as economic growth proceeds. Soon after this hypothesis was introduced, many empirical studies attempted to test the relationship between economic growth and environmental degradation (Shafik, 1994; Torras and Boyce, 1998; Friedl and Getzner,2003; Ang,2007; Saboori et al, 2012;Wang et al., 2015; Apergis and Ozturk, 2015). Most of these empirical studies have verified the EKC hypothesis, although some have not. This discrepancy may because of (1) various research areas, which include global, national, state, provincial, and city levels; (2) different types of data, including time series, panel, and cross-sectional data; and (3) distinct environmental indicators, such as CO_2 emissions (Richmond and Kaufmann,2006; Jaunky,2010; Saboori et al 2012; Robalino-López et al., 2015), which is the most popular, as well as SO_2 emissions, CO emissions, water pollution, energy consumption (Suri and Chapman, 1998;Belloumi,2009;Omri, 2013) and even ecological footprints (Al-mulali, et al., 2015).

To the best of the author's knowledge, based on the literature review, previous studies indicate that little attention has been paid to city-level panel data, particularly the comparison between different types of cities

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such as the municipalities, sub-provincial city and prefecture-level city. Therefore, it is worthwhile to examine the Environmental Kuznets Curve from China's panel data. The rest of the paper is organized as follows. Section 2 describes the model and data adopted in this study. The estimation and results are demonstrated in the third section. Finally, section 4 presents the conclusions and policy implications.

II. Methodology

2.1 Empirical model

Besides the U-shape relationship between economic growth and environmental degradation which is indicated in EKC hypothesis, there are a number of other factors which are also important to the environmental degradation and need to be controlled. Ehrlich and Holdren (1971) describe the impact of economic human activity on the environment in the famous "I= PAT" model which indicate that the population, affluence and technology has impacts on environment. Therefore, our model also include the transition of demographic transition and the industry structure into our research. The population density and the share of industry in total GDP is considered as the proxy as demographic transition and industry structure transition respectively. Our econometric specification in static panel data terms is represented by the following model 1.

$$LnEnv_{it} = \alpha_1 GDPPC_{it}^2 + \alpha_2 GDPPC_{it} + \beta \ln Pop_{it} + \gamma \ln Ind_{it} + a_i + \varepsilon_{it} \quad (1)$$

Where GDP per capita (GDPPC) and its square (GDPPC2) are the measurement of EKC hypothesis. ***Pop*** indicate the population density; The ***Ind*** is used to measure the industry share of GDP. The subscript i denotes the different cities, whereas t indicates the time period. α_1 and α_2 is the coefficient of economic growth where the α_1 is expected with negative sign. β and γ are the coefficient for population density and industry share respectively. ε is the error term, while the a_i is vector of time-invariant variables which is not changed by time by relevant with the dependent variables. Eq. (1) is a panel model that contains fixed region and time effects.

2.2 Measure and Data

This section presents the data sources for our study and introduces details for the explanatory variables as well as the reasons for their inclusion. The panel data used in our study come from provincial and national statistical yearbooks. The final panel data collected in our study include 290 cities from all 31 provinces over the period of 2003-2012, with a total of 2863 observations.

As for the dependent variable, most of the studies use a single indicator, such as CO_2 emission, SO_2 emission, CO emission, or water pollution. Several studies adopt composite indicators (such as Jha and Murthy, 2003; Babuand Datta, 2013; Farhani et al., 2014;Wang et al., 2015). Due to data limitations in terms of city-level environmental pollutants, we use a single indicator for the environment variable. Due to the data available, we adopt the discharged volume of industrial waste water as the dependent variable to measure environmental pollution in our study. The waste water pollution vary from a low of 17 ten thousand tons to a high of 91260 ten thousand tons, with a mean of 7795.25 ten thousand tons and standard deviation of 10377.57 ten thousand tons. Here, we adopt its logarithm form to reduce the possibility of volatility. For the explanatory variable, GDP per capita, which measures economic growth, is another explanatory variable. It varies from a low of 3.31 ten thousand yuan to a high of 45.03 ten thousand yuan, with a mean of 2.73 ten thousand yuan and standard deviation of 3.31 ten thousand yuan. The variable density measures the population density on a per square kilometer basis. It varies from a minimum 4.7 people/km2 to a maximum of 2661.54 people/km2, with a mean of 425.62 and standard deviation of 299.84. Finally, the industrial share of GDP has a mean value of 48.87 percent, varying from 9 percent to 90.97 percent. Descriptive statistics, including the mean, standard deviation and minimum and maximum values of the study variables, are given in table 1.

Table 1. Descriptive statistics of the whole sample

Variable	Definition	Unit	Obs	Mean	Std.Dev.	Min	Max
Environment degradation	discharged volume of industrial waste water	Ten thousand Ton	2846	7795.252	10377.57	17	91260
GDPPC	GDP Per capita	10,000 yuan	2863	2.73	3.31	0.19	45.03
Density	Population density	People/km^2	2862	417.17	318.68	4.70	2661.54
Industrial share	The share of industry to GDP	Percent	2863	48.87	11.48	9.00	90.97

In addition, to quantify the impact of different economic and human activities on environmental pollution among different types of city such as municipalities, sub-provincial city and prefecture-level city, we need additional regression models for these three types cities.

III. Estimation and Results

In this section, we briefly describe our estimation method first and then present our estimation results. There is the possibility of unobserved city-specific effects, which do not change with time, correlated with the dependent variable. F-test reject the inexistence of unobserved city-specific effects and therefore, we adopted both the fixed effects (FE) model and Radom effects (RE) model for our research question. The FE model can control the regional unobserved time-invariant variables via differencing method (Hanisch et al, 2013), while the random-effect (RE) model takes account of the additional information from the time-invariant variable which is more efficiency than FE model (Rabe-Hesketh and Skrondal 2008). However, the RE model's strict assumption that the correlation between the unobservable variable and explainable variable is 0 (correlation (u, Xi)=0) which is difficult to achieve. What's more, the estimators by pooled ordinary least squares (OLS) model is also reported as it would be the most efficient one if the time-invariant variable is not statistic significant. But the city dummy is also included in the OLS models to decrease the individual effects in the city level.

From the results of model 1 shown in table 2, we obtained the following findings: (1) Our empirical results support the EKC hypothesis, showing a reverse "U" shape between economic growth and environmental pollution. The square of GDPPC has the standard negative estimated coefficients with all the OLS model, FE model and RE model but it only statistically significant for in the OLS model. But the variable of GDPPC is standard positive and statistically significant in all the three models. Based on the estimator of OLS model, the Kuznets turning point is 176894.85 yuan which indicates that before the GDP per capita arrives at this point, economic growth and discharged volume of industrial waste water have a positive relationship. After arriving at this point, the relationship turns negative. However, in our sample observation, GDP per capita after the turning point accounts for only 0.844 percent, which means that the square of GDP per capita can be neglected in our study. This indicates that most of the cities in China still on the way of environment degradation in the near future. But different types of cities may have various routes which need to be further discussed in the next section. (2) The variables of population density is statistically significant and standard positive in terms of the environmental pollution of discharged industrial waste water with all the OLS model, FE model and RE model. This result indicates that the more population density the city is, the more environmental pollution that city would have. The economic interpretation of the results of the main specification is that when all control variables are included, if the population density increases by 1 percent, the total discharged volume of industrial waste water increase 0.09 percent to 0.43 percent in different models. (3) Finally, the variable of industrial share is also significant and stand positive in all the three regression models. More details, when all control variables are included, the industry share increases by 1 percent, the total discharged volume of industrial waste water increase 1 percent to 1.5 percent.

Table 2. Estimation results for the whole sample with the fixed effects model

Variables		OLS Model 1	FE Model 2	RE Model 3
GDPPC2		-0.003***	-0.000	-0.000
		(-5.88)	(-0.04)	(-0.50)
GDPPC		0.090***	0.018**	0.022***
		(6.99)	(2.50)	(3.05)
LnPop		0.429***	0.091*	0.298***
		(21.95)	(1.65)	(7.45)
LnInd		0.015***	0.010***	0.010***
		(6.57)	(5.69)	(6.24)
City types. base: municipality	Prefecture-level city	-1.264***	-	-
		(-8.01)	-	-
	Sub-provincial city	-0.609***	-	-
		(-3.80)	-	-
_cons		6.258***	7.357***	6.131***
		(29.45)	(23.04)	(25.57)
N		2843.00	2843.00	2843.00
R2		0.299	0.026	

Note: "*", "**", and "***"denote significance at the 10%, 5% and 1% levels, respectively.

To further explore the variation in environment impact for different types of cities, the city samples of municipalities, sub-provincial city and prefecture-level city are run independently in our research. The estimation results with both FE model and RE model are shown in table 3. What's more, Hausman test shows that the RE model is rejected in prefecture-level city and municipalities but it can't be rejected in sub-provincial city. Therefore, the estimators in model (1), (3) and (6) is more efficient than others. From the estimation results, we find that the effect of population on environmental pollution is quite different among the various types of cities. Mainly, we obtain the following findings: (1) the estimated coefficients for different types of cities have different signs. For the square of GDP per capita is standard negative for prefecture-level city while it is positive for municipalities and sub-provincial city. These results indicate that the EKC hypothesis is verified in prefecture-level city while it is not the case for more developed municipalities and sub-provincial city. (2) The population density is standard positive for all three types of cities but it is not statistic significant for sub-provincial city. These results shows that population agglomeration result in some environmental degradation. (3) The variable of industrial share is positive and statistic significant and for prefecture-level city and municipality while it is insignificant and negative for sub-provincial.

Table 3. Estimation results for the different city types with the fixed effects model

Variables	Prefecture-level city		Municipalities		Sub-provincial city	
	FE(1)	RE(2)	FE(3)	RE(4)	FE(5)	RE(6)
gdpp2	-0.002***	-0.001***	0.007*	0.033***	0.000	0.000
	(-2.97)	(-2.73)	(1.91)	(8.66)	(1.11)	(0.99)
gdpp	0.045***	0.044***	-0.133*	-0.628***	0.003	0.001
	(4.32)	(4.22)	(-1.98)	(-10.08)	(0.20)	(0.09)
lndens	0.08	0.263***	-3.134*	0.938***	0.257	0.321
	(1.34)	(6.42)	(-1.82)	(7.32)	(0.73)	(1.10)
share2	0.008***	0.009***	-0.013	0.020***	-0.004	-0.006
	(4.36)	(5.26)	(-1.65)	(3.61)	(-0.35)	(-0.47)
_cons	7.402***	6.274***	32.450***	5.247***	7.981***	7.649***
	(22.82)	(25.79)	(2.82)	(7.47)	(3.29)	(3.81)
N	2654.00	2654.00	40.00	40.00	149.00	149.00
r2	0.03		0.62		0.08	

Note: "*", "**", and "***"denote significance at the 10%, 5% and 1% levels, respectively.

IV.Discussion and policy implication

This paper tries to examine the determinants of environmental degradation within the framework of Environment Kuznets Curve (EKC) hypothesis using China's city-level panel data from 2003 to 2012..This study also attempts to distinguish the different impacts with different types of cities. The results of this empirical study have several profound implications.

First, our empirical results with the whole sample data verified the theory of the EKC hypothesis, which shows a reverse "U" shape between economic growth and environmental pollution. However, the share of our observations with a GDP per capital exceeding the U-shape turning point is only 0.844 percent, which can be ignored. This result further indicates that economic growth and environmental pollution present a negative relationship based on our panel data. This is because the research period is between 2003 and 2012, during which China's rapid economic growth was accompanied by increasingly severe environmental degradation. We should note that though our result shows a U-shape relationship between economic growth and environmental pollution, the environmental quality will not be improved automatically without any protection. With the rapid rise in household income due to the fast development of China's economy, the public is becoming more concerned about environmental quantity. In addition, the government has the ability to manage environmental issues with increased fiscal revenue from economic growth. Thus, the government should pay more attention to the management and protection of the environment and adjust the economic industry structure with, e.g., the development of service sectors. China still has a long way to go in terms of adjusting its economic structure.

Second, when referring to different types of cities, our research reveals that the relationship between economic growth and environmental degradation is different for various types of cities. Specifically, economic growth and environmental pollution show a U-shape relationship for prefecture-level city while it is opposite for municipalities and sub-provincial city cities. Generally, the municipalities and sub-provincial cites enjoy more resources with better public infrastructure, more developed industries. Therefore, these cities developed much better than others and may have reached at the Environmental Kuznets turning point earlier. China may still have a long way to go in terms of managing environmental issue, and local governments should not sacrifice the environment during economic development.

Third, population density in cities is accompanied by a larger urban population. from the statistical data show that the larger the population density of a city, the more environmental pollution there will be in that city. This result is consistent with some studies that "the process of urbanization is likely to have a negative impact on environment". This indicate that with the development of urbanization, the local government should consider about the population carrying capacity which is related to the environment, resources, the economy.

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References

[1] Al-mulali, U., Weng-Wai C., Sheau-Ting, L., and Mohammed, A. Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecological Indicators 48: 315-323,2015.
[2] Ang, J.B. CO2 emissions, energy consumption, and output in France. Energy Policy 35, 4772–4778, 2007.
[3] Angel, M., Tárraga, O. A conceptual framework to assess sustainability in urban ecological systems. Int. J. Sustain. Dev. World 13 (1), 1–15, 2006.
[4] Apergis, N. and I. Ozturk. Testing Environmental Kuznets Curve hypothesis in Asian countries. Ecological Indicators 52: 16-22,2015.
[5] Barrios, S., Bertinelli, L., Strobl, E. Climatic change and rural–urban migration: The case of sub-Saharan Africa. Journal of Urban Economics 60 (3): 357-371,2006.
[6] Belloumi, M. Energy consumption and GDP in Tunisia: cointegration and causality analysis. Energy Policy 37, 2745–2753 ,2009.
[7] Brennan, E. M. Population, Urbanization, Environment, and Security: A Summary of the Issues. ENVIRONMENTAL CHANGE & SECURITY PROJECT REPORT(ISSUE 5).1999.
[8] Chen, J.. Rapid urbanization in China: A real challenge to soil protection and food security. CATENA 69 (1): 1-15,2007.
[9] Dietz, T., Rosa, E.A.. Effects of population and affluence on CO2 emissions. Proceedings of the National Academy of Sciences of the United States of America 94, 175–179,1997.
[10] Du, B., Zhang, K.M., Song, G.J., Wen, Z.G.Methodology for an urban ecological footprint to evaluate sustainable development in China. Int. J. Sust. Dev. World 13 (4), 245–254,2006.
[11] Ehrlich, P.R., Holdren, J.P.. Impact of population growth. Science 171,1212–1217,1971.
[12] Fan, Y., Liu, L., Wu, G., Wei, Y. Analyzing impact factors of CO2 emissions using the STIRPAT model. Environmental Impact Assessment Review 26,377–395, 2006.
[13] Fan, Y., Liu, L., Wu, G., Wei, Y.Analyzing impact factors of CO2 emissions using the STIRPAT model. Environmental Impact Assessment Review 26,377–395, 2006.
[14] Friedl, B., Getzner, M. Determinants of CO2 emissions in a small open economy. Ecol. Econ. 45, 133–148,2003.
[15] Grossman, G.M., Krueger, A.B. Environmental impacts of a North American Free Trade Agreement. National Bureau of Economic Research Working Paper 3914. NBER, Cambridge, MA. , 1991.
[16] Jaunky, V.C.. The CO2 emissions–income nexus: evidence from rich countries. Energy Policy 39, 1228–1240,2010.
[17] Omri, A. CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. Energy Economics(40): 657–664,2013.
[18] Richmond, A.K., Kaufmann, R.K. Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecol. Econ. 56, 176–189,2006.
[19] Robalino-López, A. and Á. Mena-Nieto, et al. Studying the relationship between economic growth, CO2 emissions, and the environmental Kuznets curve in Venezuela (1980–2025). Renewable and Sustainable Energy Reviews 41: 602-614,2015.
[20] Saboori, B., Sulaiman, J., Mohd, S.Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the Environmental Kuznets Curve. Energy Policy 51, 184–191,2012.
[21] Shafik, N. Economic Development and Environmental Quality: An Econometric Analysis Author(s): Nemat Shafik Source: Oxford Economic Papers, New Series, Vol. 46, Special Issue on Environmental Economics (Oct., 1994), pp. 757-773,1994.
[22] Sharif Hossain, M. Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries.Energy Policy 39 (11): 6991-6999,2011.
[23] Suri, V. and D. Chapman. Economic growth, trade and energy: implications for the environmental Kuznets curve. Ecological Economics 25 (2): 195-208,1998.
[24] Torras, M. and J. K. Boyce. Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve. Ecological Economics 25 (2): 147-160,1998.
[25] Wang, L., Zhou, D., Wang, Y., and D. Zha. An empirical study of the environmental Kuznets curve for environmental quality in Gansu province.Ecological Indicators 56: 96-105,2015.
[26] Wang, M., Che, Y., Yang, K., Wang, M., Xiong, L., Huang, Y. A local-scale lowcarbon plan based on the STIRPAT model and the scenario method: the case of Minhang District, Shanghai, China. Energy Policy 39, 6981–6990,2011.
[27] Yuan, X.L., Zuo, J.. Transition to low carbon energy policies in China– from the Five-Year Plan perspective. Energ. Policy 39 (6), 3855–3859, 2011.
[28] Zha, Donglan Mostafa, M.M. A Bayesian approach to analyzing the ecological footprint of 140 nations. Ecol. Indic. 10, 808–817,2010.
[29] Zhang, C. and Y. Lin. Panel estimation for urbanization, energy consumption and CO_2 emissions: A regional analysis in China. Energy Policy 49: 488-498,2012.