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Examination of Chinese environmental Kuznets Curve using provincial panel data of industrial waste gas

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Abstract. Considering the new normal of the economy and urbanization, the Environmental Kuznets Curve in China was analyzed and reconsidered, based on the provincial industrial waste gas and economic data from 1986 to 2016. The results show that a long-term cointegrated relationship exists between the industrial exhaust gases and the income variables. The turning point of Environmental Kuznets Curve has not begun, or is still prerequisite to get income levels comparable to those at which the point of some developed countries occurred to reach the growth level in this inverted U-shaped EKC. Currently, the environmental situation in China requires further improvement, and environmental input is far from sufficient to achieve the intended effect on the atmosphere environment. China is facing a significant environmental pressure and an ecological economic transformation is urgent.

1. Introduction

Since the inception of economic reform, China's economy has been growing rapidly. GDP has reached RMB 68.55 trillion and is ranked the second highest in the world. The average GDP per capita is almost RMB 50,000 (current values), and GDP has grown at an average annual rate of 9.5%. Within a period of over thirty years, the size of China's economy has grown by a multiple of over 127, an achievement that has garnered worldwide attention. Urbanization in China has correspondingly developed rapidly, increasing from an urbanization rate of 17.92% in 1978 to 56.1% in 2016. However, the environmental advantage of a "low cost of resource and energy, infinite value of ecosystem" and the population advantage of "cheap labor" have been the two major pillars supporting China's rapid growth. Environmental pollution discharge has grown rapidly over the years. This has gradually become more obvious in recent years with the coexistence of excessive investment in public infrastructure, a capital surplus, a trade surplus, resource liabilities and an environmental deficit and of the long-term accumulation of multiple-phase, multiple-domain and multiple-type environmental issues. Environmental quality has severely declined, and environment issues have occurred frequently. The severe atmospheric pollution is mainly caused by the "the wastes" of industrial pollution. Atmospheric pollution caused by industrial waste gas, particularly the outbreak of smog in many places in recent years, seriously affects production and living conditions and human health. China already releases the world's highest levels of industrial pollution discharge. The traditional growth model of investment and export, which are the twin engines of China's economic growth, has also been severely affected, and urbanization, which provides the intrinsic momentum for China's economic growth, is also hindered, facing double pressure from inflation and the economic downturn.



The “new normal” of the economy was proposed against this background. Currently, China has entered an advanced stage of industrialization and urbanization. It faces the dual tasks of realizing an industrialization and urbanization rate of 60% by 2020. In the future, the course of urbanization will continue to advance. The next decade will be an important stage, during which industrialization will be achieved with the support of resource and energy and urbanization will progress rapidly, causing further pressure on pollution discharge, which will remain at a high level. In the future, the conflicts between China’s economy and environment may become increasingly acute and complex. There is an urgent need to deeply investigate the consolidation of new relationships, new features and new trends in China’s economic growth and environmental protection, which is of global significance.

Since the start of the 1960s, against a background of continuous global economic and population growth, the environment for humans has continued to deteriorate. With the occurrence of consecutive environmental incidents that affected the world, the relationship between economic growth and environmental degradation has gained increasing attention. Based on the “Limits-to-Growth Theory” [1-3] proposed by such researchers as the Club of Rome, some scholars started to recognize a form of mutually fostering and coordinating development relationship between the economy and the environment at the end of the 1970s [4-7]. Differences in the aforementioned view point regarding the correlation between the economy and the environment have resulted in a wide range of empirical studies. Grossman and Krueger [8] conducted the empirical study on the inverted U-shaped curve relationship between the three types of environmental pollution indicators and economic growth in the NAFTA a quarter of one century ago. Then, Panayotou [7] and Beckerman [9] proposed the Environmental Kuznets Curve (EKC) hypothesis, noting the possible inverted U-shaped Kuznets Curve relationship between economic growth and environmental quality, which has become the most classic expression of the correlation between economic growth and environmental pollution.

First and foremost, the studies are mostly based on empirical studies of developed country cases [8-10]. The EKC of developing countries and emerging countries started to become extensively investigated at the beginning of this century and presently continues to be the focus and emphasis of relevant studies [11-15]. As EKC research has developed, several review articles have also significantly responded with comments and outlook on the EKC, yet debate continues in the academic literature [16-23]. Different pollutants, based on their discharge features and related industry/policy, can have different impacts on EKC performance [15, 24]. The environment-economy relationship is characterized not only by temporal but also by sectional dimensions. At present, many studies in China neglect cross-sectional information and cointegration relationships [25-31] with regard to directly verifying the EKC relationship. Furthermore, many studies neglect China’s urbanization factors given the special transitional backdrop, and, there is not yet enough research on environmental impact taking into account environmental inputs. Against the new backdrop, what does the environment-economy relationship look like? This study uses the volume of industrial waste gas emissions as environmental indicators, combined with complex factors including per capita income, urbanization rate, industry structure, energy use, environmental inputs that affect the environment as mentioned in the EKC literature. This is the essence of the environment-economy relationship on which the world should focus in the future, for this country with the world’s largest discharge of industrial pollution.

2. Methods

Based on the environmental and economic data from 31 provincial economies in China from 1986 to 2016, coming from the China statistical yearbooks, and China environment statistical yearbook of the corresponding years, using panel cointegration method, the EKC in China was analyzed.

2.1. Panel cointegration test

Taking into consideration data instability, all respective variables first undergo panel unit root testing prior to the cointegration test. To guarantee test stability, the four types of panel unit root test methods, namely Levin-Lin-Chu (LLC) [32], Im-Pesaran-Shin (IPS) [33], Fisher-ADF and Fisher-PP [34,35],

were used to comprehensively conduct a unit root test on the economic indicators and environment indicators as well as the first order differences. Whether the regression equation used in the panel unit root test includes constant terms or includes constant terms and trend terms concurrently, when the original value of each respective variable undergoes testing, the results suggest that the null hypothesis of the “the presence of unit root” cannot be rejected. The four types of test are consistent in showing that first order differences do not have a unit root and that each respective time series is a first-order single process.

A panel cointegration test is subsequently performed to analyze whether any cointegration relationship exists among the unstable time series. The cointegration test methodology proposed first by Engle and Granger [36] was used with regard to the cointegration equation residual. The null hypothesis is that the residual is a unit-root process, i.e., there is no cointegration relationship among the variables. Based on the residual regression, 7 statistics proposed firstly by Pedroni [37-39] are constructed to perform the panel cointegration test. Given the small sample, the main consideration is the four statistics of Panel ADF-Statistic, Group ADF-Statistic, Panel PP-Statistic and Group PP-Statistic, with better small sample properties than the others, based on the findings in the Monte Carlo simulation experiments [39-41]. To enhance test stability, Kao's ADF test method [39] is further adopted. All original test hypotheses are set as “no existence of cointegration relationship”. The test results show that Panel ADF-Statistic, Group ADF-Statistic, Panel PP-Statistic and Group PP-Statistic have essentially rejected the original hypothesis among the variables of the EKC at the 1% level of significance. Thus, it can be seen that the EKC is the panel cointegration model for the environmental-economic relationship in China, depicting the characteristics of China's environmental pollution and its long-term equilibrium relationship with the variables of economic growth.

This study can further proceed with an EKC estimation of the cointegration equation by several methods, e.g. the ordinary least squares (OLS) estimator, the fully modified ordinary least squares (FMOLS) estimator proposed first by McCoskey and Kao [40, 41], Phillips and Moon [42] and the dynamic ordinary least squares (DOLS) estimator developed first by McCoskey and Kao [40-42] and Mark and Sul [43]. The similar leads and lags are first selected and determined according to the Schwarz Information Criterion (SIC). The estimation results in Table 1 are derived through OLS and DOLS, by adopting the model with both time and individual fixed effects. The difference in estimation results between the OLS and DOLS methods is relatively large, and the standard pooled OLS estimation could have an underlying problem for serial correlation and for endogeneity of regressors, causing bias to appear in the estimation model, which can be corrected by the DOLS estimator. The Monte Carlo simulation simulations stated that the bias is relatively more for an OLS and FMOLS estimator with a small sample, than the panel DOLS procedure, and the performance of the DOLS estimator in panel cointegration estimation is often better than that of other estimators [39, 41]. Hence, given only a small sample size of China's environmental data is available (environmental statistics work implemented after the start of reform), the DOLS panel cointegration estimator exhibits less deviation compared with OLS or FMOLS.

2.2. EKC Model

Taking into consideration findings on environmental effects, such as the STRIPAT model [3, 41-45], the variables that affect environmental quality in a transitional China, include income, urbanization, industry and energy structure, and environmental inputs [40-45]. The EKC is defined as follows:

$$E_{it} = a + b_1 Y_{it} + b_2 Y_{it}^2 + b_3 O_{it} + e_{it}$$

where E_{it} represents the state of gas pollutants of the economy i in year t , volume of waste gas emissions; Y_{it} represents per capita income of provincial economy i in year t ; and O_{it} represents the other variables that generate an impact on the environment. Other main influencing indicators are also taken into consideration during the actual operation; e_{it} is the stochastic error.

3. Results

Table 1. Panel cointegration estimation of EKC.

income	income ²	Energy Intensity	Industrial Structure	Urbanization	Environmental Input
1.02***	-0.023	0.72***	0.5***	0.04	
4.01***	-0.19***	0.76***			0.08*
-0.56**	0.09***	0.77***	0.26**	0.5***	
5.03***	-0.19**	0.04			0.07

Note: ***, ** and * denotes the estimator of a parameter is significant at 1%, 5% and 10% level, respectively.

By the dynamic ordinary least squares (DOLS) estimator with fixed time and region effects, EKC estimation results are indicated in Table 1. China is still facing a high level of environmental pressure and that the relationship between the volume of industrial waste gas emissions and economic growth does satisfy the the cointegrating inverted EKC. The waste gas pollution variable essentially displays an incremental correlation with economic growth, waste gas discharge shows an upward trend along with economic growth. With regard to the current form of economic growth and the economic system as a whole in China, the path to economic development in harmony with the environment still requires further exploration. Energy conservation and discharge reduction in China still face considerable difficulties. This study indicates that the elasticity coefficient of the volume of industrial waste gas emissions with the industry structure variable is negative. The risk of environmental challenges and difficulties in addressing the course of industrialization and urbanization in the future are still very large, and new forms of urbanization are imminent. After adding the environmental governance factor, Waste gas pollution and economic growth essentially showed an inverted U-shaped EKC relationship. However, the EKC turning point did not appear at an overly low level like several relevant existing studies [46-48], but is positioned above per capita GDP of RMB 100,000 (2016 price level) (approximately USD 15,000). The differences in regional economic development and in concomitant environmental pressure are prominent. The level of economic development of the three directly controlled municipalities in the eastern region is approaching or has already exceeded the critical value of inverted U curve, whereas the level of economic development in provinces in the vast midwestern regions is still relatively far from reaching that value. China still faces immense environmental pressure, and the level of economic development in most regions has not exceeded or is even rather far from the EKC turning point in terms of pollution from the wastes. . Understanding the technological options in discharge reduction, achieving further technological innovation in discharge reduction and implementing such upgrades will generate substantial additional costs for China. This may better indicate China's environmental-economic situation to the world.

4. Conclusions

China's EKC research has important implications for both regional environment quality and global environment change. Currently, it is still complex and difficult to achieve environmental improvement in China. The government's continually increasing financial capabilities have not been aimed at the environmental protection domain. If management is not reinforced and investment intensity is not increased, accumulated effects would be vigorously enhanced, ultimately creating major approaching pollution events and severe consequences. The lack of adequate capital investment will affect the establishment of a circulatory economy system, the renewal, maintenance and upgrade of pollution discharge reduction facilities, and the implementation of environmental projects.

The turning point of Environmental Kuznets Curve has not occurred, or is still needed to reach development levels comparable to those at which the point of developed countries occurred to reach the economic level in the inverted U-shaped curve. Currently, the environmental situation in China requires further improvement, and environmental input is far from sufficient to achieve the intended effect on the environment. China is facing a significant environmental pressure and an ecological economic transformation is urgent. Environmental economic policies should differ over time and

region. Some environmental economic policies how to decrease environmental impact at the reaching turnaround regional economic development should be on the regional level at the first not at the national one. And then this experiences and approaches can be transferred as good praxis on the national level. A special ecological industrialization and sustainability mode can be carried out at the preliminary development stage, in the west undeveloped provinces. While more economic incentives might be implemented in the east China. Certainly, more emissions of waste gas do not equal heavier air pollution. Air quality depends more on emissions of main pollutants than on emissions of waste gas. In fact, since the 12th Five-Year Plan, all provinces in China have achieved reductions of SO₂ and NO_x emissions. Therefore, EKC study may be more meaningful on air pollutant emissions than on waste gas emissions. In addition, air pollution is not caused by industrial waste gas alone. In big cities such as Beijing, motor vehicles contribute to air pollution more than industry. Although further theoretical and empirical investigation on more types of pollutant emissions and regions is clearly needed before any unquestionable conclusion can be drawn, for the EKC on industrial waste gas - related environmental issues, deriving the quantitative estimates of the likely environmental impacts of growth is helpful to advance decision debate.

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