The Relationship Between Environmental Quality and Economic Development Along Yangtze River Belt

Bowen Cai[1,a,*]

[1] *Yunnan Construction and Investment Holding Group Co. Ltd*
KunMing, China
a.15528072673@163.com
**corresponding author*

Keywords: Yangtze River Economic Belt, Environmental Kuznets Curve, fixed effect model

Abstract: The Yangtze River Economic Belt is a very important region for China's economic development. This article aims to explore whether there is an Environmental Kuznets Curve (EKC) between pollutant discharge and economic development in the Yangtze River Economic Belt, and at the same time find the corresponding inflection point. The single fixed effect model is used, and the control variable method is used, and the time trend term is added to establish the regression equation. Through empirical analysis, EKC exists on both pollutant emissions, but the inflection point of sulfide emissions is ten times that of dust emissions; at the same time, the impact on economic development on sulfide emissions is more significant than dust emissions. Among other variables, the proportion of secondary industry also shows a high degree of significance especially for sulfide emissions, but the impact on dust emissions is relatively weak. This provides a theoretical basis of China's low-emission and low-pollution supply-side reform in the future

1. Introduction

The Yangtze River Economic Belt covers 11 provinces and cities including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Guizhou, and Yunnan, with an area of approximately 2,052,300 square kilometers, accounting for 21.4% of the Chinese territory. This economic zone has a population of about 599 million in 2018 and can generate 40.3 trillion yuan of GDP, accounting for 44.1% of China (Network of the development of the Yangtze River belt). The economic development of this economic belt has been rapid since the beginning of the reform and opening up in late 1970s. However, at the same time, serious environmental pollution occurred alongside with fast economic growth. The long-term extensive industrial growth model has put great pressure on Chinese ecological environment.

The core concept of China's development today is sustainable development. For the Yangtze River Economic Belt, China issued and implemented the "Outline of the Yangtze River Economic Belt Development Plan", which established the overall strategy of the Yangtze River Economic Belt for ecological priority and green development. However, China is in a critical period of transformation and upgrading of its economic development. At the same time, it accompanies by increasing pressure on resources and the environment. Industrial pollution has gradually become a major factor hindering the sustainable development of the Yangtze River Economic Belt.

Therefore, coordinated development has become an urgent task for the construction of ecological civilization in the Yangtze River Basin. The contradiction between economic growth and environment is intensifying, which promotes the study of environmental Kuznets curve. EKC began with empirical research, which refers to the inverted U-shaped relationship between economic growth and environmental pollution levels. This paper mainly analyzes the empirical relationship between industrial pollution and economic development in the Yangtze River Economic Belt through Environmental Kuznets Curve (EKC) model, and aims to provide support for the coordinated development of the Yangtze River Economic Belt environment and economy.

In the process of exploring the relationship between economic growth and environmental quality, the Environmental Kuznets Curve (EKC) is helpful to explain the changing law of environmental quality of different economic growth stages [1]. This assumption describes the inverted U-shaped relationship between per capita income and environmental index, which means that the income of the residents increases with the development of the economy, and because the environmental quality will improve when the per capita income reaches a turning point. The EKC hypothesis has been confirmed by most major pollutants such as SOx, NOx, and carbon monoxide (CO), which exhibit inverted U-shaped trajectories [2]. In addition, the EKC curve can be used in other environmental coefficient. For example, Kang & Zhao et.al [3] makes the EKC by using spatial measurement methods between CO_2 emission and economic index to find the EKC curve has an inverted-N trajectory. The EKC curves between the concentration of PM2.5 and economic urbanization also exists, and shows an inverted N-shaped or inverted U-shaped curve [4]. Based on the EKC curve, Yin, Ming & Zheng[5] analyzes how to control carbon emissions through environmental regulation and technological methods Meanwhile, using the EKC curve, it was found that population growth also has an impact on the environment, that is, positive population growth will make the EKC curve steeper and have a higher peak[6]. Therefore, it shows that the scope of application of EKC is very wide, not only limited to several kinds of emissions, but also used to analyze the impact on population growth and other factors of the environment. Based on the current index research, this study will explore the relationship between SO_x, dust emissions, the proportion of secondary industry, and GDP per capital.

EKC's performance is different to different regions; Azam and Khan [7] made a substantial analysis of the four income levels of the country and discovered the variability of the relationship between economic development and the environment. The EKC curve of 28 European countries indications that controlling residential energy consumption is a very important measure to reduce carbon dioxide emissions [8]. EKC analysis was also conducted in Southeast Asia, revealing increasing renewable energy and agriculture decreases CO2 emissions, while nonrenewable energy is positively correlated to emission, and proved that developing sustainable agriculture can promote renewable energy and reduce emissions [9]. Specially, according to Generalized Method of Moments (GMM) estimator and an auto regressive distributed lag (ARDL) model with alternative panel estimators, Li, Wang and Zhao [10] find that the Environmental Kuznets Curve (EKC) hypothesis is well supported for all three major pollutant emissions in China across different model sand estimation methods. This paper selects panel data onto 2000 to 2017 in 11 places along the Yangtze River Economic Belt (China) to analyze the relationship between economic growth and environmental quality. The basic fixed-effects model uses the environmental Kuznets curve model to conduct an empirical analysis of environmental indicators and GDP per capital.

2. Data and Methodology

The dataset of this paper is for the period of 2000-2017, and it consists of panel observations for 11 Yangtze River Economic Belt's provinces namely Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Guizhou, and Yunnan (Chongqing merged into Sichuan). The data include dust emission per capital, the proportion of secondary industry (percentage), the volume of Sulphur Dioxide Emission per Capital, the gross domestic product (GDP) per capita, and the population density. The dust emission is in the unit of tons per capital, which measured by dust emission divided population. The data onto dust emission comes from China's Statistical Yearbook 2016, and the data population comes from China's Statistical Yearbook 2019. Regarding the proportion of secondary industry, data onto 2000 to 2010 came from Peking University CCER Economic and Financial Database, and data from 2011 and 2017 came from China Statistical Yearbook 2019. At the same time, the data onto Volume of Sulphur Dioxide Emission per Capital that Unit of kilogram per person came from China Statistical Yearbook 2019. As for the Real GDP per capital, it is the unit of yuan per person (in 2000 price), which calculate by the ratio of provincial real GDP to provincial population, and the data collection came from China Statistical Yearbook 2019.

Since the data collected this time is panel data from different provinces and at different points in time, the fixed-effect model (FEM) method is used this time. In formula (1), y_{it} is the real GDP per capita, x_{it} is independent variables, γ_t is intercept, and u_{it} is random perturbation. Average the equation (1) over time, get equation (2), then, equation (2)-(1) get equation (3).

$$y_{it} = \lambda_i + \sum_{k=2}^{K} \beta_k x_{kit} + u_{it} \tag{1}$$

$$\bar{y}_i = \beta_1 \bar{x}_i + a_i + \bar{u}_i \tag{2}$$

$$\ddot{y}_{it} = \beta_1 \ddot{x}_{it} + \ddot{u}_{it}, \quad t = 1, 2, \ldots, T \tag{3}$$

Through fixed effect models, such as Equation 3, you can ignore the effects of α_i, even if α_i and X_i are correlated. Therefore, FEM is assumed that all included studies have a common real effect size, or that except for random errors, the observed effect size is the real effect size. This time, by using *EViews 10* software, fixed-effect regression performed on the collected panel data to obtain the required equations and data. At the same time. Draw the corresponding EKC to explore the impact of different environmental indicators on economic development.

3. Empirical Analysis

The data onto sulfide emissions, dust emissions, GDP of the Yangtze River Economic Belt and the total population of the region are collated to obtain relevant per capita data. After that, the collated data is imported from *EViews 10* for single fixed effect regression, and new variables are added in turn according to the control variable method for regression. At the same time, additional time trend items will be added to improve the results.

$$Ln\ SOx = C + \beta_1 Ln\ GDP(per\ capital) + \beta_2 Ln^2\ GDP(per\ capital) + u_i \tag{4}$$

$$Ln\ SOx = C + \beta_1 Ln\ GDP(per\ capital) + \beta_2 Ln^2\ GDP(per\ capital) + T + u_i \tag{5}$$

Based on model (4) and (5), the results obtained using the single fixed effect model are shown in Table 1. According to Table 1, under the fixed-effect model, the basic regression equation (6) & (7) can be obtained. It can be found from equation (6) that the EKC curve exists and its inflection point is equal to *e^ (7.285/ (2*0.398)) = 9433.383.* This is in line with EKC's theory that the relationship between economic development and the environment resembles an inverted U-shape curve. In addition, environmental pollution levels increase as the economic develops, but begin to decrease as rising incomes pass beyond a turning point [11].

Table 1: Results of fix-effected panel data regression (SO_x)

	ln SO_x					
ln GDP	7.285 (9.894)***	3.399 (3.876)***	2.751 (3.005)***	5.944 (8.152)***	3.487 (4.051)***	3.190 (3.386)***
$\ln^2$ GDP	-0.398 (-10.342)***	-0. 199 (-4.382)***	-0.164 (-3.430)***	-0.252 (-5.568)***	-0.160 (-3.436)***	-0.153 (-3.204)***
C	-30.467 (-8.681)	-13.556 (-3.369)	-10.257 (-2.413)	-29.996 (-9.203)	-16.908 (-4.092)	-14.809 (-3.004)
T	———	———	———	-0.157 (-5.284)	-0.087 (-2.746)	-0.069 (-1.790)
THE PROPORTION OF SECONDARY INDUSTRY	———	4.293 (6.677) ***	4.018 (6.205)***	———	3.376 (4.730)***	3.442 (4.784)***
THE POPULATION DENSITY	———	———	- 0.000 (-2.206)**	———	———	- 0.000 (-0.783)
R^2	0.701	0.765	0.771	0.745	0.775	0.776

Note: * Means 10% significance level; ** means 5% significance level; *** means 1% significance level.

$$\text{Ln } SO_x = -30.467 + 7.285\text{Ln GDP} - 0.398\text{Ln}^2\text{ GDP} + u_i \quad (6)$$
$$(9.894) \qquad (10.342)$$

$$\text{Ln } SO_x = -29.996 + 5.944\text{Ln GDP} - 0.252\text{Ln}^2\text{ GDP} - 0.157T + u_i \quad (7)$$
$$(8.152) \qquad (-0.573)$$

In these six regression equations, the correlation is greater than 0.7, showing a good correlation. At the same time, Ln GDP and Ln^2GDP both meet the significance below 1% significance level. From the perspective of control variables, the coefficients of the secondary production ratio are all greater than 0 dozen, indicating that the impact on sulfide emissions is positively correlated, and all show relatively good significance. In Table1, that no matter whether the time trend item is added or not, in addition to the population density, several other variables are satisfied with the 1% significance level, which shows that sulfide emissions have a good correlation with economic development. Such significant results are similar to Ahmad and Hall [1]. As for the population density, it can be seen from Table 1 that the coefficient of population density is relatively small and not significant, which indicates that the population density has a relatively small effect on sulfide emissions. Due to the population rise, it may cause an increase in emissions, but at the same time, as the population is concentrated, it is possible to save energy. The simultaneous use of these two aspects will lead the impact on population density of sulfides to have an outstanding feature.

Similarly, according to the model (8) (9) and using the fixed effect model, the regression is established through *EViews 10* and the Table 2 is obtained

$$\text{Ln Dust} = C + \beta_1 \text{Ln GDP(per capital)} + \beta_2 \text{Ln}^2 \text{ GDP(per capital)} + u_i \quad (8)$$

$$\text{Ln Dust} = C + \beta_1 \text{Ln GDP(per capital)} + \beta_2 \text{Ln}^2 \text{ GDP(per capital)} + T + u_i \quad (9)$$

According to Table 2, under the fixed-effect model, the basic regression equation (10) & (11) can be obtained. It can be found from equation (10) that the EKC curve exists and its inflection point is equal to *e^ (1.394/(2* 0.0.102))= 928.280*. Compared with the EKC inflection point of sulfide, the inflection point of sulfide is 9433.383 (Table 1), but the per capita GDP of the inflection point of dust emissions is only one tenth of the inflection point of sulfide. The reason for this difference is that the per capita GDP index is highly significant for sulfide emissions, but dust emissions are not. Therefore, in the sulfide regression equation, the coefficient of per capita GDP emission is much larger than the coefficient of dust emission, which is also the reason why the inflection point after calculation is quite different.

$$\text{Ln Dust} = -1.726 + \underset{(2.295)}{1.394}\text{Ln GDP} - \underset{(3.224)}{0.102}\text{Ln}^2\text{GDP} + u_i \quad (10)$$

$$\text{Ln Dust} = -1.733 + \underset{(2.175)}{1.414}\text{Ln GDP} - \underset{(2.593)}{0.104}\text{Ln}^2\text{ GDP} + 0.002T + u_i \quad (11)$$

Similar to the regression results of sulfides, the correlations are all greater than 0.7(Table 1), which also means that the correlation is better. Through equations (10) and (11), the basic equations still show good significance. The impact on economic development on sulfides is far greater than its impact on dust emissions[12]. However, through the control variable method, the coefficients of the secondary production ratio are all greater than zero, which also shows that the secondary production ratio is positively correlated with dust emissions. At the same time, the population density coefficient is still very small, and has almost no effect on dust emissions. However, the proportion of secondary production and population density to dust emissions are not obvious. This may be because the proportion of secondary production and population density are not the main factors affecting dust emissions, as well as the similar results from Azam and Khan [7] , Li, Wang and Zhao [10] and Liu Zhang and Bae[13], there is an EKC curve between major pollutants and economic indicators.

The results of dust emissions show that initially only the GDP per capita or the time trend item is added, they all show a good significance level and the square of the logarithm of GDP per capita even reaches the significance level of 1%. However, through the control variable method, the significance level of GDP per capita has been decreasing, and even 10% cannot be satisfied. It can be seen that GDP per capita has a small impact on dust emissions, and it leads to a very small per capita GDP at the inflection point of the EKC curve of dust emissions. This result is similar to Wang and Ye (2017) research and analysis of carbon dioxide.

Table 2: Results of fix-effected panel data regression (Dust)

	Ln Dust					
Ln GDP	1.394 (2.295)*	0.910 (1.120)	0.634 (0.740)	1.414 (2.175)**	0.893 (1.096)	0.309 (0.3489)
Ln^2 GDP	-0.102 (-3.224)***	-0.078 (-1.843)*	-0.062 (-1.398)	-0.104 (-2.593)***	-0.085 (-1.926)*	-0.070 (-1.567)
C	-1.726 (-0.596)	0.382 (0.10)	1.784 (0.448)	-1.732 (-0.595)	1.042 (0.266)	5.160 (1.113)
T	——	——	——	0.002 (0.085)	0.017 (0.571)	0.051 (1.411)
The Proportion Of Secondary Industry	——	0.535 (0.898)	0.418 (0.689)	——	0.716 (1.060)	0.846 (1.250)
The Population Density	——	——	-0.000 (-1.001)	——	——	-0.000 (-1.634)
R^2	0.710	0.711	0.713	0.710	0.712	0.717

Note: * Means 10% significance level; ** means 5% significance level; *** means 1% significance level.

By comparing the inflection points of the EKC curves of the two pollutants, it is found that their EKC inflection points are very different, with a gap of several times. This is due to the nature of the two pollutants. The proportion of sulfide in the secondary industry is larger, which also leads to the greater influence of the proportion of secondary production of the sulfide in the regression equation. As a result, the specific gravity of secondary production shows a highly significant difference in sulfide emissions. Moreover, the impact on GDP per capita on sulfides is far greater than the impact on dust emissions.

4. Conclusion and Suggestion

This paper uses the fixed-effect model for important provinces in the Yangtze River Economic Belt. In the EKC model of pollutant emissions, that is, sulfide dust emissions, the variables of per capita GDP, proportion of secondary production, and population density are introduced, and based on a single fixed effect, a time trend item was added to discuss the relationship between economic development and pollutant emissions. Got the following conclusion.

Through empirical analysis of per capita GDP and comprehensive pollution indicators, it is concluded that there is a Kuznets inverted U-shaped relationship between the overall economic growth and environmental quality of the Yangtze River Economic Belt. With regard to sulfide emissions, the key inflection point is RMB 9433.383 per capita. According to the data obtained, the overall per capita GDP of the Yangtze River Economic Belt has exceeded the inflection point, and the future development will be in the second half of the Kuznets Curve, that is, the environmental quality will improve with economic growth. With regard to dust emissions, the key inflection point is RMB 928.280 per capita. At the initial stage, the entire Yangtze River Economic Belt has exceeded this inflection point. It shows that the environmental quality of dust emissions has begun to improve. Today, China is vigorously carrying out industrial transformation and upgrading, which makes economic development less dependent on traditional industries. It improves that the nature of industry is the key factor to promote the coordinated development of the environment and economy in the Yangtze River Economic Belt. To ensure the sustainable development of the Yangtze River Economic Belt, we must vigorously promote the optimization and upgrading of industries, and improve the construction of a new pattern of common progress of environmental protection and economic growth.

According to the control variable method, with the addition of secondary production proportion, population density and other variables, the correlation coefficient R2 of the regression equation is constantly rising, indicating that these variables are related to pollutant emissions. From the numerical point of view, the coefficients of the secondary production specific gravity are all positive, which means that the secondary production specific gravity is positively correlated with pollutant emissions. From the size point of view, the secondary production specific gravity has a greater impact on sulfide emissions than dust emissions. The nature of the substance is closely related to the secondary industry, which also leads to a significant proportion of secondary production of sulfide emissions. However, the coefficient of population density is close to 0, which has almost no effect on pollutant emissions. For the Yangtze River Economic Belt, once the proportion of the secondary industry was very large, now China's industrial transformation and upgrading of the Yangtze River Economic Belt is completed, and the proportion of secondary industry will change. For example, the proportion of secondary industry in Sichuan is rising, while Shanghai's the proportion of secondary production is declining rapidly. In some places, such as Jiangsu, Hubei, the proportion of secondary production does not fluctuate much, depending on the development characteristics of the Yangtze River Economic Zone. China should carry out low-emission-oriented "supply-side reforms" in the future, gradually phase out backward production capacity and excess production capacity, and vigorously promote clean energy technologies to achieve green manufacturing.

References

[1] Grossman, G. and Krueger, A., 1995. Economic Growth and the Environment. The Quarterly Journal of Economics, 110(2), pp.353-377.

[2] Danesh Miah, M., Farhad Hossain Masum, M., Koike, M., 2010. Global observationof EKC hypothesis for CO2SOx and NOx emission: A policy understanding forclimate change mitigation in Bangladesh. Energy Policy 38, 4643–4651.

[3] Kang, Y. Q., Zhao, T., & Yang, Y. Y. (2016). Environmental Kuznets curve for CO2 emissions in China: A spatial panel data approach. Ecolnical Indicators, 63, 231-239.

[4] Wu, J., Zheng, H., Zhe, F., Xie, W. and Song, J., 2018. Study on the relationship between urbanization and fine particulate matter (PM2.5) concentration and its implication in China. Journal of Cleaner Production, 182, pp.872-882.

[5] Yin, J. H., Zhang, M. Z. &.Chen Z. J. (2015). The effects of environmental regulation and technical progress on CO2 Kuznets curve: An evidence from China, Energy Policy77, 97–108.

[6] Wang, S., Fu, Y. and Zhang, Z., 2015. Population growth and the environmental Kuznets curve. China Economic Review, 36, pp.146-165.

[7] Azam, M. and Khan, A., 2016. Testing the Environmental Kuznets Curve hypothesis: A comparative empirical study for low, lower middle, upper middle and high income countries. Renewable and Sustainable Energy Reviews, 63, pp.556-567.

[8] Pablo-Romero, M. and Sánchez-Braza, A., 2017. Residential energy environmental Kuznets curve in the EU-28. Energy, 125, pp.44-54.

[9] Liu, X., Zhang, S. and Bae, J., 2017. The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production, 164, pp.1239-1247.

[10] Li, T., Wang, Y. and Zhao, D., 2016. Environmental Kuznets Curve in China: New evidence from dynamic panel analysis. Energy Policy, 91, pp.138-147.

[11] Liobikienė, G. and Butkus, M., 2017. Environmental Kuznets Curve of greenhouse gas emissions including technological progress and substitution effects. Energy, 135, pp.237-248.
[12] Ahmad, M. and Hall, S., 2017. Economic growth and convergence: Do institutional proximity and spillovers matter?. Journal of Policy Modeling, 39(6), pp.1065-1085.
[13] Wang, Z. and Ye, X., 2017. Re-examining environmental Kuznets curve for China's city-level carbon dioxide (CO2) emissions. Spatial Statistics, 21, pp.377-389.