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Study on the Relationship between Economic Growth and Air Pollution in the Pearl River Delta Region

Jiaqi Chen** and Zhoulin Lan*

Guangzhou Xinhua University, No.7, Yanjiang West 1st Road, Machong Town, Dongguan, China

Abstract. To solve the problem of balancing the relationship between economic growth and air quality in the pearl river delta (PRD) region, based on selecting the indicators characterizing the environmental quality of the PRD region (i.e., the concentrations of four pollutants such as O_3, SO_2, NO_2, and PM_{10}) and the GDP of its three major industries during 2006-2021, this paper established a multiple linear regression model of the relationship between economic growth and air pollution in the PRD region, using E-Views and SPSS software. The results show that: the growth of the GDP in primary and tertiary industries in the PRD region will lead to the reduction of the concentration of air pollution; the growth of the GDP in secondary industries will lead to an increase in the concentration of air pollution. The suggestions based on the results are as follow: shifting the focus of industrial development, paying attention to the prospect of tertiary industry development, and continuously promoting the prevention and treatment of air pollution.

1. Preface

Economic development is one of the major factors affecting air pollution emissions, and how to balance economic development and reduce air pollution emissions is one of the major concerns of domestic and international scholars [1-4]. As one of the bases of China's reform and opening up, the Pearl River Delta region plays an important part to drive the economic development of Guangdong in the new century and also plays a non-negligible role in the process of national economic construction. However, the increase in regional GDP cannot avoid the increase in air pollution at the same time. According to the data from the Department of Ecology and Environment of Guangdong Province, there is a downward trend in the annual average concentration of $PM_{2.5}$ and PM_{10}, etc. in the region [5]. But ozone pollution is still very prominent, and the annual average concentration of ozone shows a rising trend, about 0.8 microgram/m^3 per year, showing that air pollution still needs to be improved. Therefore, it will be of practical significance to study the relationship between economic development and air pollution in the PRD region to promote its sustainable development.

2. Research Object and Method

The purpose of this study is to examine the relationship between economic growth and air quality in the PRD region, and to propose suggestions to promote the coordinated and sustainable development of economic growth and air quality in the PRD region through the conclusions of the analysis and to provide a reference for the sustainable development of other regions in China.

To achieve the purpose above, the indicators characterizing the air quality of the PRD region (i.e., the concentrations of four types of pollutants such as O_3, SO_2, NO_2, and PM_{10}) and the regional GDP of its three major industries during the period 2006-2021 were selected. Using E-Views and SPSS software, a multiple linear regression model was established to analyze the relationship between economic growth and air pollution in the PRD region, based on the new data set formed after the construction of the total score of annual average air pollutant concentration using factor analysis.

3. Results and discussion

3.1. Indicator setting and data sources

Based on the primary air pollutants in the PRD region in recent years and the availability of data, the data of economic indicators (i.e., GDP of three major industries) as well as environmental indicators (i.e., four air pollution indicators) for nine cities in the PRD region (i.e., Guangzhou, Shenzhen, Dongguan, Foshan, Zhongshan, Zhuhai, Huizhou, Jiangmen, and Zhaoqing) from 2006 to 2021 were selected, as shown in Table 1. All data come from the statistical yearbook of each city in the PRD region.

*Corresponding author: zhoulinlan@126.com
**2947619052@qq.com

Table 1. Selected economic indicators as well as air pollutant indicators.

Name of economic indicators	Symbols	Name of air pollution indicators	Symbols
GDP of the primary industry	X_1	The annual average concentration of O_3	Y_1
GDP of the secondary industry	X_2	The annual average concentration of SO_2	Y_2
GDP of the tertiary industry	X_3	The annual average concentration of NO_2	Y_3
		The annual average concentration of PM_{10}	Y_4

3.2. Construction of total score of annual average air pollutant concentration

The four environmental indicators selected above were downscaled by factor analysis to calculate the factor score of annual average air pollutant concentration. Finally, the total variance explained by each common factor was used as the weight to constitute the total score (Y).

To confirm the suitability of enrichment on the four original variables of air pollutants, the KMO test and Bartlett's sphericity test were used for validation. The KMO value is 0.763, which is close to 1. The p-value of Bartlett's sphericity test is 0, which is less than the given significance level of 0.05; thus, the original variables are suitable for factor analysis. Factors were extracted using principal component analysis, and the results are shown in Table 2.

Table 2. Total variance explained.

Factors	Initial Eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.486	87.155	87.155	3.486	87.155	87.155	2.264	56.602	56.602
2	0.311	7.776	94.931	0.311	7.776	94.931	1.533	38.329	94.931
3	0.151	3.779	98.710						
4	0.052	1.290	100.000						

Table 3. Comparison of initial solutions for factor analysis.

Common factor variance (1 factor extracted)		Common factor variance (2 factors extracted)	
Initial	Extraction	Initial	Extraction
1.000	0.779	1.000	0.985
1.000	0.889	1.000	0.900
1.000	0.893	1.000	0.941
1.000	0.915	1.000	0.971

From Table 3, it can be concluded that the characteristic root factor with a characteristic root greater than 1 appears in the first factor. However, by comparing the results of the common factor variance of extracting one factor with those of extracting two factors. It is found that extracting two factors is more rigorous, and the cumulative variance contribution of the factors can be close to 95%, so two factors were finally chosen to be extracted.

Table 4. Factor score coefficient matrix.

Indicator	Factor	
	1	2
The annual average concentration of PM_{10}	0.897	0.408
The annual average concentration of NO_2	0.877	0.415
The annual average concentration of SO_2	0.723	0.615
The annual average concentration of O_3	-0.410	-0.904

The orthogonal rotation method with Kaiser standardization was used to implement an orthogonal rotation on the factor loading matrix, and from Table 4, the following two naming interpretations are derived: the annual average concentration of PM_{10}, NO_2, and SO_2 have high loading on the first factor, which mainly explain the three variables mentioned above, and were named F_1 (directly generated pollutants). The annual average concentration of O_3 has high loading on the second factor, so it mainly explains this one variable, which is named F_2 (indirectly generated pollutants), considering the formation of O_3.

The factor score coefficients were estimated and calculated using the regression method, and the resulting component score coefficient matrix (Table 5) and factor score functions (Eq.1, Eq.2, and Eq.3) are shown below:

Table5. Component score coefficient matrix

Indicator	Component	
	1	2
The annual average concentration of O_3	0.707	-1.302
The annual average concentration of SO_2	0.146	0.254
The annual average concentration of NO_2	0.648	-0.382
The annual average concentration of PM_{10}	0.688	-0.427

$$F_1=0.707Y_1+0.146Y_2+0.648Y_3+0.688Y_4 \quad (1)$$

$$F_2=-1.302Y_1+0.254Y_2-0.382Y_3-0.427Y_4 \quad (2)$$

From Eq. (1) and Eq. (2), the formula for the total score of annual average air pollutant concentration can be obtained:

$$Y=(0.566F_1+0.3833F_2)/0.9493 \quad (3)$$

3.3. Regression analysis of the relationship between economic growth and air pollution in the PRD region

Model construction. Using the above-mentioned total score of annual average air pollutant concentration (Y) and the logged GDP of the three major industries as sample data, the multiple linear regression equation of the relationship between economic growth and air pollution in the PRD region was constructed in E-Views software:

$$Y=\beta_0+\beta_1 LNX_1+\beta_2 LNX_2+\beta_3 LNX_3+\mu \quad (4)$$

ADF test. The correlation coefficient matrix shows that the correlation coefficients of LNX_1, LNX_2, LNX_3, and Y are -0.98, -0.96, and -0.97, respectively, with absolute values close to 1, indicating the existence of a strong linear correlation. The ADF test on Y yields rejection of the original hypothesis at model 1, indicating that the original series does not have a unit root and is a smooth series.

Sequential correlation test. The LM test shows that the p-value of the 1st-order residual term is 0.1083, which is greater than the given significance level of 0.05 and does not reject the original hypothesis of serial uncorrelated, indicating that the model is serially uncorrelated and has good multiple linear regression properties.

Statistical tests. Ordinary least squares estimation was used to estimate the parameters of the model, where the R-squared is 0.943 and the adjusted R-squared is 0.934. The adjusted R-squared indicates that 93.39% of the change in air pollution is explained by the change in the GDP of the primary, secondary, and tertiary industries.

Table 6. OLS regression results

Variable	Coefficient	Std.Error	t-Statistic	Prob.
LNX_1	-22.41204	8.101804	-2.766303	0.0160
LNX_2	52.0968	4.211932	12.36886	0.0000
LNX_3	-34.21014	3.277976	-10.43636	0.0000

This estimated model is obtained from the OLS regression results as the following equation:

$$Y=-22.42LNX_1+52.1LNX_2-34.21LNX_3 \quad (5)$$

(8.101804) (4.211932) (3.277976)

The above Eq. (5) shows that for every 1% increase in the GDP of primary industry, air pollution is reduced by 22.42% on average; for every 1% increase in the GDP of secondary industry, air pollution is increased by 52.1% on average; for every 1% increase in the GDP of tertiary industry, air pollution is reduced by 34.21% on average.

Basic assumption test. The integrated statistical test method reveals that this model has a good fit under the ordinary least squares method. The F-value is small and all the t-test values pass the test, thus indicating the absence of multicollinearity in the model. On the other hand, the heteroskedasticity test using the Brosch-Pagan test (B-P test) yields F=2.678777, corresponding to a p-value of 0.0942, which is greater than the given 5% significance level and does not reject the original hypothesis, indicating the existence of homoskedasticity in the model.

4. Conclusions

Through the above analysis, it is found that the growth of GDP in the primary and tertiary industry in the PRD region has a small impact on the changes in the concentrations of selected air pollutants, which is negatively correlated. On one hand, the PRD region has a high urbanization rate, and its air pollutants mainly originate from industrial sources and emissions from urban domestic sources; coupled with the fact that the PRD region is actively promoting rural revitalization and modernization of agriculture and rural areas in recent years, the rural environmental quality has been significantly improved, and thus the concentration of its air pollutants shows a decreasing trend with the development of the primary industry. On the other hand, under the policy guidance of Guangdong Province, the PRD region focuses on the development of the modern service industry in the direction of information, intelligence, and greening, thus the tertiary industry also plays a negative influence on the concentration of air pollutants. Meanwhile, the growth of GDP in the secondary industry has a greater impact on the changes in selected air pollutant concentrations and is positively correlated. Although the PRD region actively develops modern manufacturing industries and attaches importance to clean production, energy conservation, and emission reduction in the production process, it may because the secondary industry itself produces more pollutants in the production process compared with the other two industries, thus also brings more environmental pollution in the process of industrial development. It also reflects from another side that it is still necessary to optimize and upgrade the secondary industry in the PRD region and to reduce the intensity of air pollutant emissions per unit of the product while promoting high-quality economic development, to achieve coordinated and sustainable development of the economy and the air environment[5,6,7,8].

Further, since the primary industry itself accounts for a small percentage, the benefits of reducing air pollution brought by the development of the primary industry will be relatively small, and the focus on the development of the primary industry is not in line with the current socio-economic development trend. The development of the tertiary industry will bring more benefits, after all, the current PRD region has the largest proportion of GDP in the tertiary industry; transformation and optimization of the development of the secondary industry or reduce the intensity of pollutant emissions per unit of product in the secondary industry can help reduce air pollution and improve the atmospheric environment, in line with the current new development pattern.

5. Recommendations

First, further optimization of industrial structure. Transforming and upgrading the traditional secondary industry, improving the quality of development, to lead the traditional industry to high-end, green, and intelligent development. Chenghao Liao and others also proposed to target the air pollution problem from the industrial structure adjustment and other aspects [6].

Second, the development prospects of the tertiary industry should be emphasized. According to local conditions, formulate relevant policies and guidelines to guide the development of tertiary industry and increase support for municipalities in the PRD region, encourage enterprises to innovate and develop new tertiary industry, and attract investment in tertiary industry (including foreign investment). At the same time, promote the upgrading and optimization of the traditional service industry by the tertiary industry.

Third, the prevention and control of air pollution. Eliminate high-pollution, high-emission, high-energy-consuming industrial equipment, rectify scattered dirty and polluting enterprises, conduct "one-to-one" comprehensive treatment of some key enterprises, improve the environmental protection management system and air pollution-related standards and regulations, improve the market emission trading system for air pollution, and promote and implement new energy electric vehicles.

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