Analysis of Air Quality Influencing Factors in Eastern Cities of China

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Abstract--Atmospheric pollution is the primary factor affecting air quality, and the management of air pollution is the key to improve air quality. So in this paper, we analyze the extent to which air quality pollution indicators (NO^2), economic growth (GDP per capita), and public transportation (number of actual public buses operating at the end of the year) affect air quality in China based on mixed linear model to evaluate and analyze the air quality of the capital cities of 11 eastern provinces in China in the last five years. Finally,we present conclusions and recommendations. The annual average concentration of NO^2 is negatively correlated with air quality. The number of gdp per capita public bus and tram operations is positively correlated with air quality. Based on the above, we advise that we should strengthen environmental protection, strengthen the management of the factory and improve systems related to environmental pollution.

Keywords- air quality, influencing factor,linear mixed-effects model

1. Introduction

1.1. Background

The development of economic society is based on the usage and transformation of natural resource, so, it is bound to have a certain impact on the nature. Whatever the developed countries or developing countries, most development modes are first "economic development-oriented", and then transformed into "environmental and resource-friendly". And a good economic development mode must be the latter one. It will fully consider the impact of human activities on resources, environment and ecology, instead of blindly pursuing the speed of economic development, and then achieve harmonious coexistence between human and nature[1].

Since the reform and opening up, in the process of China's continuous scientific and technological progress, rapid economic development and the continuous improvement of comprehensive national power, the national happiness index is also increasing, but the environmental pollution problem is also becoming more and more serious, especially the air pollution problem.Hence, it is imperative to improve our country’s air quality, and analyzing the influencing factors of air quality is also very important. For now, we mainly study the influencing factors of our country’s air quality from two aspects, pollution and governance, the atmospheric pollution is the primary factor of influencing air quality, and the governing of air pollution is the key of improving air quality[2]. Therefore, combining the governance indicators of atmospheric pollution and air pollution to analyze, improving our country’s air through introducing secondary pollutants, establishing new evaluation mode of air quality, and evaluating and analyzing the air quality in the capital cities of 11 eastern provinces in our

country in the past five years.

1.2. Objective

The days of air quality reaches and better than Grade II could directly indicate the situation of environment, the annual average concentration of NO_2 can represent air quality, the GDP per capita (Yuan) can represent economic growth, the number of buses and trams operating at the end of the year represents public transportation, and we could mainly study from these three factors.

The purposes of research are as below:

(1)By researching the difference of days that the air quality in the capital cities of the 11 eastern provinces reaches and better than Grade II in 2015-2019, we found the main factors of influencing air quality of capital cities of 11 eastern provinces, and get the conclusions;

(2)Proposing the targeted suggestions and measures for improving air quality.

2. Data Description

2.1. Data Sources

The selected research interval is from 2015 to 2019 year, and the capital cities of 11 eastern provinces are our research objects. Among them, the days of air quality reaches and better than Grade II, the annual average concentration of NO_2, and the number of buses and trams operating at the end of the year represents public transportation are all from the "China Statistical Yearbook" over the years, GDP per capita (Yuan) is from the Provincial Statistics Bureau.

2.2. Data Summary

Our team processed the original data and sorted out the explained variable - DAY and four explanatory variables - YEAR/CON/PGDP/CAR. The corresponding relationship between the final indicator and the original data is shown in the following table:

Table.1 Information about explained variable and explanatory variable

Index type	Full name of index	Index pronoun
Explained variable	The days of air quality reaches and better than Grade II	DAY
Explanatory variable	Year	YEAR
	The annual average concentration of NO^2	CON
	GDP per capita	PGDP
	The number of buses and trams operating at the end of the year	CAR

3. Exploratory Data Analysis

3.1. Trend analysis of air quality reaches and better than Grade II in eleven provinces in the east

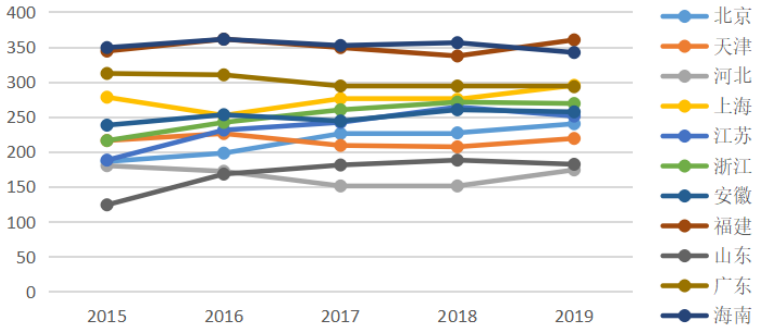

Fig.1 The trend chart of air quality reaches and better than Grade II

The trend of the days with air quality reaches and better than Grade II in 11 provincial capitals is different. It is observed that Beijing, Shanghai, Zhejiang, Jiangsu and Shandong have an annual upward trend; Tianjin, Fujian, Hebei and Guangdong have a downward trend followed by an upward trend; and Hainan and Anhui are in an upward and downward fluctuation.

3.2. Analysis of the variability of indicators between years

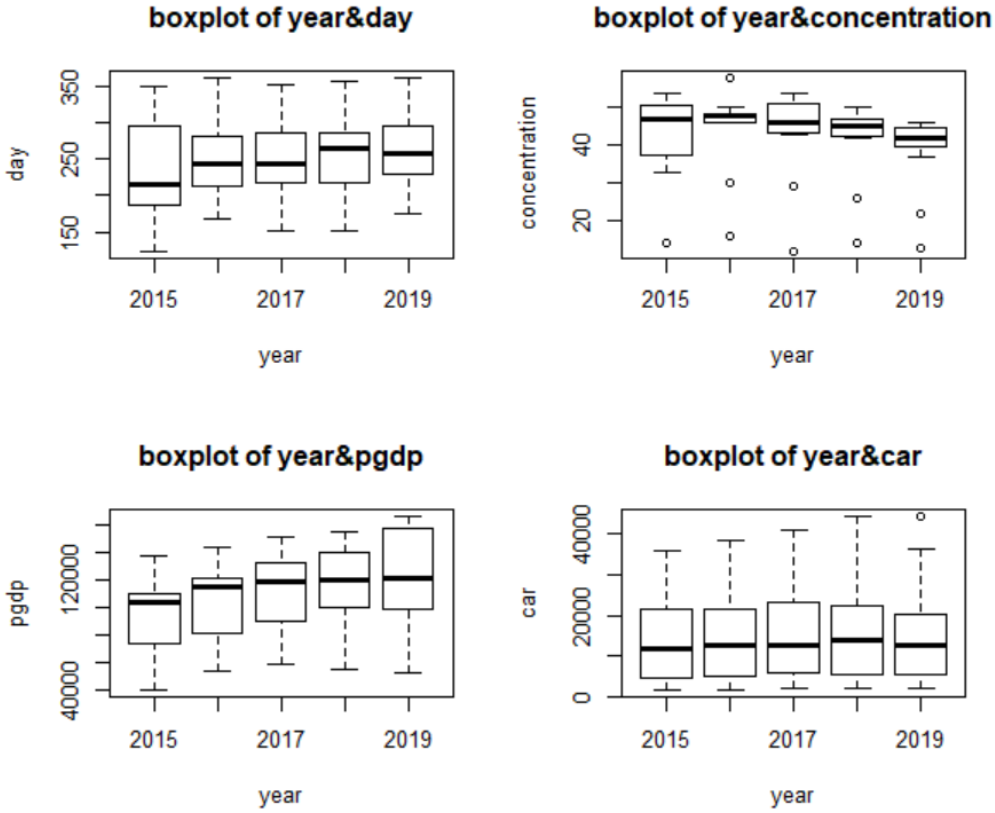

Fig.2 Boxplot of four indicators

From the Fig2, we can draw the following conclusions: As time goes by, the days for air quality to reaches and better than Grade II and GDP per capita gradually were increasing, the average concentration and volatility of nitrogen dioxide were both decreasing, and there was no obvious change in the number of buses and trams.

3.3. Correlation analysis of five indicators

Table.2 Correlation coefficient table of six indicators

	day	year	con	pgdp	car
day	1.00	0.12	-0.76	0.09	-0.14
year	0.12	1.00	-0.15	0.33	0.07
con	-0.76	-0.15	1.00	0.32	0.39
pgdp	0.09	0.33	0.32	1.00	0.72
car	-0.14	0.07	0.39	0.72	1.00

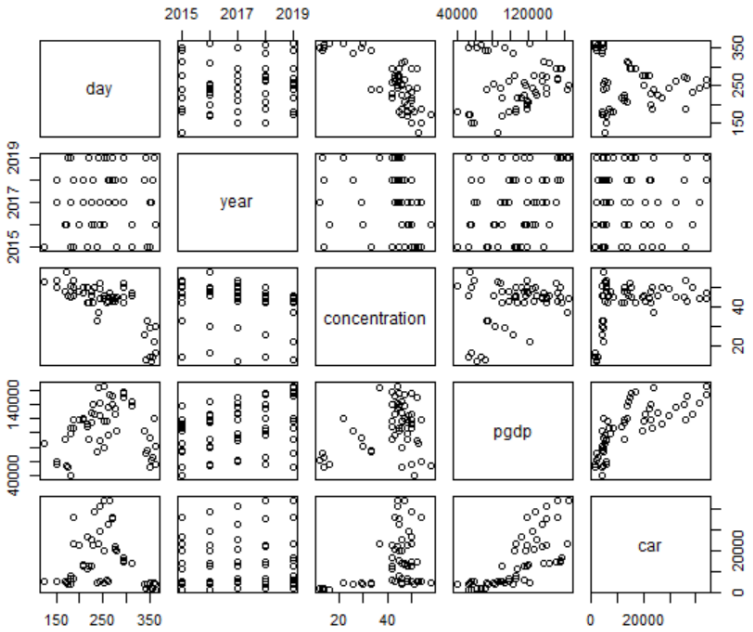

Fig.3 Scatter plot of five indicators

It can be found from the correlation coefficient table and scatter plot that the explained variable DAY has a strong correlation with the explanatory variables Con, PGDP and CAR; Among them, the explanatory variables CON and CAR have a negatively correlated with the explained variable DAY. The explanatory variables PGDP and CAR have a strongly and positively correlation, which the correlation coefficient between CON and CAR is larger, and the correlation coefficient between other variables is smaller.

4. Model

4.1. Model construction

The model built as below:

$$T_{i,t} = \beta_0 + \beta_1 N_{i,t} + \beta_2 \ln Q_{i,t} + \beta_3 \ln G_{i,t}$$

（i =1,2,...,11）（t =1,2,..NO^2.,5）

In this model, Ti,t represents the number of days in the t year when the air quality of the i city reaches and better than Grade II. Because the greater the value of T is, the better the air quality, it is treated as a dependent variable i,t represents the concentration value of NO^2 in the i city in the t year; ln(pgdp)i,t and ln(car)i,t respectively represent the actual per capita GDP and the number of buses and tram cars in the i city at the end of the t year, which these three variables are independent variables.

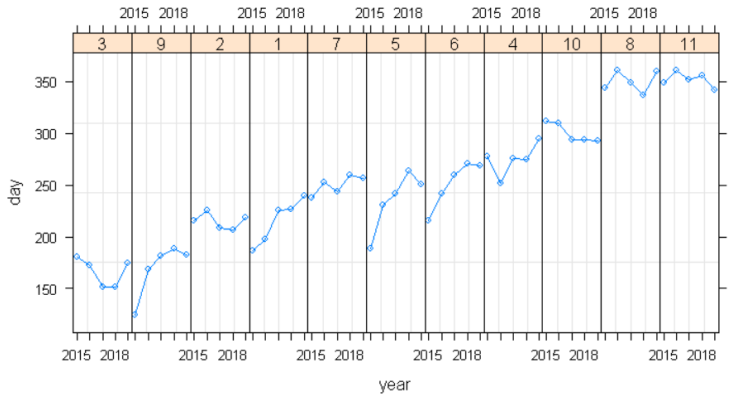

Fig.4 The trend of air quality in different provinces over time

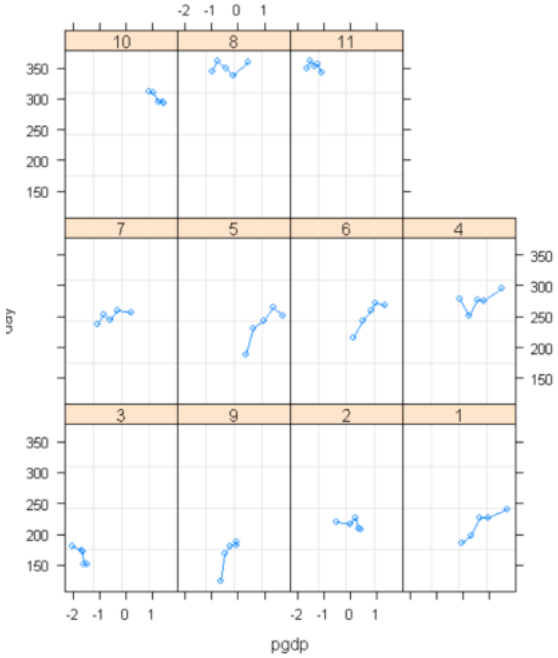

Fig.5 Variation trend of air quality with GDP per capita as independent variable

From the results in Fig4, the intercepts of air quality in 11 provinces are different, and there is also a big difference in slope. Among them, the intercept items of "1", "2", "3"and "9" of provinces are lower, and the air quality of most of the provinces and cities has a positive effect on time. However, the slope of "8"and "11" of provinces is almost constant, and the intercept is also very high.

As an example of standardized GDP per capita, we can see in Fig5 that the effect of independent variables on the interpretation of different provinces is quite different, and the interpretation results due to slope and intercept are also different, combined with the independence assumption that the linear model needs to satisfy, each data point must come from a different population according to the independence requirement. Since repeated measurements, block data, and spatially correlated data do not satisfy the independence assumption, it is assumed that General linear model cannot extract all the information in the sequence. Considering the correlation among intercept term, slope, sample and time, linear mixed-effects model was established to analyze the influence factors of air quality in China.

4.2. Analysis based on linear mixed-effects model

A linear model with random intercept, a linear model with random intercept with random slope and a linear model with random slope are fitted at the same time, and the variance analysis of these three

models is carried out.The results are shown in Table3.

Table.3 Results of the ANOVA test

	AIC	BIC	contrast	p-value
A linear model with random intercept	481.51	493.10	/	/
A linear model with random intercept with random slope	485.51	500.96	1 vs 2	1.0000
A linear model with random slope	481.57	493.16	2 vs 3	0.9686

We found that in the variance analysis from Table3, a linear model with intercept is the best model when considering their errors and significance. Finally, a linear model with mixed intercept is fitted, and the fitting results are given in Table4 below.

Table.4 Results of linear model with mixed intercept

Explanatory variables	Coefficient estimates	Standard error	t statistic	p-value
Intercept	-31.38	23.51	-1.33	0.0351**
NO^2	-2.20	0.57	-3.86	0.0004***
ln(pgdp)	36.25	19.63	1.85	0.0484**
ln(car)	4.51	4.83	0.93	0.7259

Note: * * *, * * and * are significant at 1%, 5% and 10%, respectively.

5. Conclusions and Suggestions

We can draw the following conclusions :

Firstly, in analyzing the three explanatory variables that affect air quality in China, we can see from the significance of the parameters: The p-value of NO2(Nitrogen Dioxide) is less than 0.01, and the p-value of GDP per capita is less than 0.05, so both are statistically significant, while the number of buses operating at the end of the year is not statistically significant.

Secondly, in terms of coefficients, the annual average concentration of NO2 is negatively correlated with air quality, so the days that represents good air quality(T) will decrease by 2.2 days when concentration of NO2 goes up by 1 μg/m3 which might be closely related to industrial pollution and vehicle emissions, and the increasing number of private cars and online car-hailing has led to serious air pollution caused by traffic exhaust emissions in major cities. The number of bus and tram operating is positively correlated with air quality, so the days that represents good air quality will increase by 4.5 days when increase per 1% of the operating number, however, its effect on improving air quality is not significant, because buses and trams cannot fully represent public transport to a certain extent, and other public transportation, such as subways and ships, also pay an irreplaceable role. GDP per capita is positively correlated with air quality. The days that represents good air quality will increase by 36.25 days when GDP per capita increase per 1%, which means, on the one hand, rapid economic growth will promote the technological development of environmental governance, and worsen the environment on the other hand. In contrast, the advantages are stronger than disadvantages.

According to the results, here are some suggestions as below:

Strengthen environmental protection. Advocate public transportation when people travelling, and reduce the use of private cars and online car-hailing, thereby reducing the vehicle exhaust emissions. Encourage everyone to take the energy-saving means of transport, and promote the use of new energy.

Strengthen the management of the factory. There are defined property rights through certain policies and incentives to reduce the intensity of pollution per unit of output of enterprises or industrial transformation from heavy polluting to light polluting or non-polluting industries and supplemented by strict law enforcement to stop further deterioration of the environment so that China's environmental problems can be fundamentally solved.

Improve systems related to environmental pollution. Establishing a circular economy system in the country and building a frugal and harmonious society. according to the relevant policies on air pollution, impose penalties on those companies that overly pollute environment.

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