Regional differences of NO_X emission and its causes in China[*]

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There is a significant regional difference of NO_X emission in China; the total emission amount of economic developed areas is larger while the economic developing regions are relative smaller. From the point of view of the changes, the total emission declining rate of developed areas is larger, which means that these areas still have emission reduction potentials, while the developing regions make pressures to China's NO_X emission reduction on the contrary. In the various factors affecting NO_X emission change, the energy conversion factor and energy efficiency factor are emission reduction factors in vast majority regions, and economic scale factor is emission increasing factor. Therefore, it is necessary to take immediate practical and strong corresponding measures, and should take corresponding countermeasures according to the conditions of different regions; energy structure converting and energy efficiency improving should still be as two important means for NO_X total emission reduction in the future, and it also needs to reduce the effects of economic scale factor through the transformation of industrial structure, what is more, it also needs people to change ways of life.

Keywords: China; NO_X Emission; Factor Decomposition.

1. Introduction

Among the numerous atmospheric pollutants, the effects of carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NO_X) on the environment are particularly prominent. In China, the control has always been focus on SO_2, but NO_X and CO_2 have not got enough attention. During the "11th Five-Year" period, China has achieved the goal of reducing the total emission amount of SO_2 and its declining range up to 14.29%, while the NO_X and CO_2 emissions have shown a rapid increasing trend. As far as NO_X is concerned, up till to 2006 year has been included in China's statistics, and according to the Annual Statistic Report on Environmental in China, the emission of NO_X is 1523.8 million tons in year 2006, as well as according to the data of China People's Government of the Net, in 2010 year China's NO_X emission is 2273.6 million

tons. Due to the high NO$_X$ emission, it become the significant causes of acid atmospheric deposition, ozone, haze and other environmental problems, and lead to a variety of compound pollution problems, which offset the effect brought by the reduction of SO$_2$ emission. Therefore, this paper intends to explore the regional differences and the reasons for the change of NO$_X$ emission in China, and hope to provide some reference for the realization of NO$_X$ emission reduction targets in China.

2. Regional Difference of Nitrogen Oxides Emission and its Change in China

Since the mainland of China has too many provincial units, this paper combines some provinces into regions in order to describe simplicity according to geographical position, economic characteristics, relations and functions. In this paper, there are 7 regions, Northeast (including Liaoning, Jilin and Heilongjiang), North China (including Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia), Northwest (including Shaanxi, Gansu, Ningxia, Qinghai and Xinjiang), East China (including Shanghai, Jiangsu, Zhejiang, Anhui and Shandong), Central China (including Henan, Hubei, Hunan and Jiangxi), Southern China (including Guangdong, Fujian and Hainan) and Southwest (including Chongqing, Sichuan, Yunnan, Guizhou and Guangxi).Tibet Autonomous Region it is not included due to incomplete data.
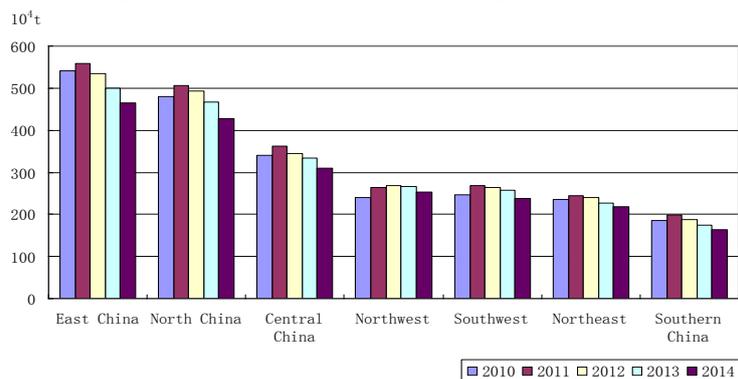

Fig. 1. Regional Comparison of NO$_X$ Emission.

As can be seen from Figure 1, the most emission regions of NO$_X$ are Eastern China and Northern China regions with up to 400 million tons emission; which is followed by the Central China region with 300 million tons emission; Northwest, Southwest and Northeast discharge more than 200 million tons respectively; Southern China at least, emission less than 200 million tons. From the ratio of total emission of every area in 2014 year we can see that Eastern

China and Northern China regions account for 22.4% and 20.6% respectively, Central China accounts for 14.9%, Southern China accounts for 7.9%, the other three regions account between 10.0%-12.0%.

In addition, from the provinces view, the NO_X emission more than 100 million tons in order are Shandong, Hebei, Henan, Inner Mongolia, Jiangsu, Guangdong and Shanxi provinces, the total amount of the seven provinces account for 46.6% of the country's total emission. These provinces are economic scale and population scale large areas, or developed areas of energy industry and heavy industry; whereas small emission provinces (less than 50 million tons) including Hainan, Qinghai, Beijing, Tianjin, Shanghai Chongqing, Ningxia, Fujian, Gansu, Guangxi, Guizhou and Yunnan provinces, excepting the three eastern municipalities these provinces mostly in western region and with smaller population and economic scale areas.

From the point of view of the various provinces and autonomous regions, only in Beijing and Shanghai the two municipalities, the total emission reduce consecutively for four years, and their reduction rate are 24.9% and 23.7% respectively. The remaining provinces in 2010-2011 year experience varying degrees of growth and in 2011-2012 the rest of the provinces began to decrease, except Xinjiang, Hainan, Guizhou, Qinghai and Guangxi provinces still in increase. Generally speaking, in 2014 the vast majority have achieved a reduction in total emission than in 2010 except a small number of provinces. In the higher rate of decline provinces, in addition to Beijing and Shanghai, there also 9 provinces' decline rate exceed the average number, namely Zhejiang, Tianjin, Jiangsu, Guangdong, Shanxi, Hebei, Liaoning, Anhui and Henan (decline rate more than 10%), while other provinces' and regions' decline rate under the average value.

3. Reasons for the Formation of the Regional Differences in the Total Amount of Nitrogen Oxides Emission Changes in China

3.1. *Factor decomposition method and its application*

Kaya identity is one of the most widely used in the influence factors of CO_2 emission model. It relates population, energy, economy and other factors with CO_2 produced by human activities through a simple mathematical formula. Therefore, this study intends to use the Kaya identity to decompose the driving factors of NO_X emission and emission intensity in various provinces of China, and try to clarify the driving direction and driving degree of the various provinces.

3.2. *Analysis model*

Kaya identity is the most common factor decomposition method. Here we use E to represent energy consumption, use G to represent the gross domestic product (GDP), use P to represent population, so we can get the next equation:

$$N = \frac{N}{E} \times \frac{E}{G} \times \frac{G}{P} \times P \qquad (1)$$

Here, N/E means NO_X emission per unit of energy consumption, E/G means energy consumption per unit of GDP, and G/P means per capita GDP.

This equation means that the amount of NO_X emission from a country or region is affected by energy consumption, energy use efficiency, living standards, and population.

If we take changing rate (increment) of the factors mentioned above, we can have the next formula:

$$\Delta N = \Delta\left(\frac{N}{E}\right) + \Delta\left(\frac{E}{G}\right) + \Delta\left(\frac{G}{P}\right) + \Delta P \qquad (2)$$

From the above formula, we can decompose the influence factors of NO_X emission changes in a certain area into energy conversion factor, energy efficiency factor, economic scale factor and population scale factor. That is to say, in order to achieve NO_X reduction, measures in any one form or combination can be taken, including improving the NO_X emission intensity (low energy nitrogen), reducing the energy consumption per unit of production(saving energy), reducing the per capita gross national product (4

slowing economic growth), reducing the population etc.

In this way, the driving factor of the first item energy conversion factor can be calculated as follow:

$$
\begin{aligned}
\Delta\left(\frac{N}{E}\right) = {} & \Delta\left(\frac{N}{E}\right) \times \frac{E}{G} \times \frac{G}{P} \times P + \Delta\left(\frac{N}{E}\right) \times \Delta\left(\frac{E}{G}\right) \times \frac{G}{P} \times P \div 2 \\
& + \Delta\left(\frac{N}{E}\right) \times \frac{E}{G} \times \Delta\left(\frac{G}{P}\right) \times P \div 2 + \Delta\left(\frac{N}{E}\right) \times \frac{E}{G} \times \frac{G}{P} \times \Delta P \div 2 \\
& + \Delta\left(\frac{N}{E}\right) \times \Delta\left(\frac{E}{G}\right) \times \left(\frac{G}{P}\right) \times P \div 3 + \Delta\left(\frac{N}{E}\right) \times \Delta\left(\frac{E}{G}\right) \times \frac{G}{P} \times \Delta P \div 3 \\
& + \Delta\left(\frac{N}{E}\right) \times \frac{E}{G} \times \Delta\left(\frac{G}{P}\right) \times \Delta P \div 3 + \Delta\left(\frac{N}{E}\right) \times \Delta\left(\frac{E}{G}\right) \times \Delta\left(\frac{G}{P}\right) \times \Delta P \div 4
\end{aligned} \qquad (3)
$$

In this way, calculation formula of the second item of energy efficiency factors, the third item of economic scale factors and the fourth item of population factors can be calculated by the form of energy conversion factors respectively. Due to the length of paper, here is not going to expand.

3.3. *Decomposition results*

By using the above model, the driving factors of the changes of NO_X emission in various regions of China during 2010-2013 are shown in Figure 2. It can be seen from the above figure:
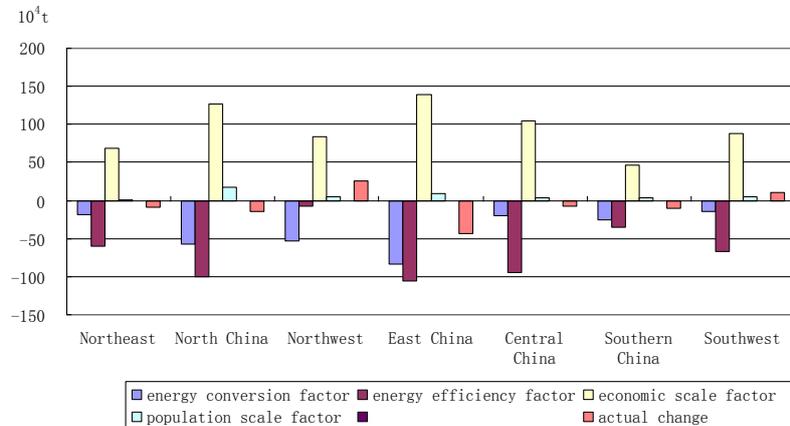

Fig. 2. Factors decomposition of NO_X emission changes of China's different areas.

First, from the view of driving direction of various factors, the driving direction of various factors influencing regional NO_X emission is similar. In every area, the energy conversion factors and energy efficiency factors are the reduction driven, while the economy scale factors and the population scale factors are increasing driven.

Secondly, from the view of the factors' driving force, in the two factors of forward drive force (increasing emission driven), the economy scale factor is the biggest factor in every area, which shows that in China increasing momentum of NO_X emission brought by the expansion of economy scales is still very strong, and there is still big gap in achieving decoupling with economic growth. In which, the most increasing driven region are the East China, North China and Central China area, increasing emission more than 100 million tons; while the driven force of population scale factor is generally small, except for the North China area, where is higher for reaching 17.4 million tons. In the two factors of negative direction driven, the energy efficiency factor is greater than the energy structure factor in all regions besides the Northwest region. This shows that the improvement of energy efficiency is the main reason for the most area of NO_X emission reduction, in which the energy efficiency factor's emission reduction amount is larger in the East China, North China and Central China areas at about 100 million tons, while in the Northwest only 8 million tons. The difference produced by the driving force belonging to energy conversion factors is more

moderate, East China is about 84 million tons where the driving force is the largest, North China and Northwest regions are at about 50 million tons, and other areas range from 14 to 26 million tons, this indicates that the NO_X emission reduction has also made great progress due to the energy structure conversion.

From the view of actual number of changes of NO_X emission factor decomposition, among 2010-2013 years, China's overall NO_X emission reduction is 469 thousand tons, in which the emission reduction due to the energy structure transformation is 2597 thousand tons, emission reduction due to improved energy efficiency is 4685 thousand tons, but the emission increasing due to the economic scale expansion is 6454 thousand tons, and emission increasing due to the changes of population scale is 403 thousand tons. Because the positive number and negative number can offset with each other in these four items, so the final result is equal to the number of actual emission. Among the various regions, only the Northwest did not achieve emission reduction due to the comprehensive result of all factors but increase 262 thousand tons, while other regions have achieved the total emission reduction. In which, the emission reduction in East China is the most at 431 thousand tons, and other areas emission reduction varies from tens of thousands to hundreds of thousands of tons. This shows that even China's NO_X emission has got the peak point and finally began to realize the total emission reduction historically, but the emission reduction effort is still relatively small.

4. Conclusions

From the analysis of this paper, we can at least get the following implications:

(1) From the view of factor decomposition results, the emission reduction strategy at least including the following single or multiple combinations: conversion of energy structure, improving energy efficiency, controlling the economic and population scale.

(2) Energy structure conversion and energy efficiency improvement will still be as two important means for NO_X total emissions reduction; especially it should pay attention to the energy structure conversion. In the near future, it needs to reduce coal consumption and increase natural gas; and in the long-term, it needs to make unremitting efforts to promote renewable energy proportion.

(3) In the future for a long period of time, economic scale will continue to be an increasing factor for the NO_X emission, we can reduce emissions intensity through the industrial structure upgrading, especially through the transformation from heavy and chemical industrial to light industry and service industry.

(4) Although the NO_X emission increasing role of population scale in current time is not great, but with the deepening of urbanization and the

improvement of people's living standards, the role of this factor will increase. The measures taken in this regard need people to work hard in the way of life.

(5) In the future, the east region and southeast coastal areas should take the lead in the total emission reduction to make a greater contribution to the total emission reduction, in which the energy structure conversion should be one of the most important strategies; while in the central and western regions, especially in Northwest China under the precondition of achieving the total reduction, it should take improving the energy using efficiency as an important strategy for NO_X emission reduction.

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