The difference of industrial NOX emission and the effect of income division reduction in China

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Abstract: In this paper, based on industrial added value and per capita NOX emissions intensity, regional emissions difference of China's 30 provinces from 2008 to 2017 was calculated and analyzed by Theil index and an empirical research on the effect of various factors on NOX emission reduction. The main conclusions were as follows. The regional differences of China NOX emission intensity are evident. The regional difference of industrial added value of NOX emissions intensity was greater than the average per capita NOX emissions intensity and the differences are mainly shown in the western area by two kinds of indexes. On the whole, the impact of GDP per capita on industrial value-added emission intensity and per capita emission intensity is different. Therefore, in order to improve the effectiveness of NOX emission reduction, the government should adopt different strategy based on the income characteristics of different regions.

1. Introduction
Since the 20th century, China's economy has entered a stage of high-speed development. In the process of economic development, the discharge of a large number of pollutants and large-scale air pollution has become an unavoidable and serious problem. It has also become the core problem that restricts the sustainable development and the construction of urban ecological civilization. As an important pollutant which has an important influence on the regional air pollution, NOx is not only the main substance of forming acid rain, but also the important substance of forming photochemical smog in the atmosphere and the important factor of consuming O3, it is harmful to human health and ecological environment.

In order to effectively control environmental pollution, governments have increased efforts to control environmental pollution. However, affected by the level of economic development, population distribution and other factors, there are great differences in resource utilization rate and NOx pollution contribution among regions, any unscientific governance model is bound to lead to inefficient governance and repeated governance, and ultimately reduce the effectiveness of environmental protection. It is also in line with the idea of emphasizing regional differentiated total amount control and refined emission reduction management during the 13th Five Year Plan period.

For the study of NOx emission, the early statistical data are scarce, the study tends to calculate the NOx emission inventory of different industries by the emission factor [1-2]: Calculate the NOx emission from 1995 to 2004, and simulate the NOx emission and spatial distribution from 2006 to 2010[3]; In this paper, the distribution of NOx in eastern China and Yangtze River Delta Economic Zone is studied[4]; The effects of economic development and technological progress on NOx emissions from energy consumption are analyzed by means of subsector and sub energy NOx.
emission inventories[5]. Since then, some researches have applied the space-time analysis method to the study of NOx concentration distribution by remote sensing technique [6]. In 2006, the NOx factor was included in the category of Environmental Statistics: the main driving factors were obtained by LMDI model [7]; the factors were decomposed by LMDI method [8].

The above studies rarely use relevant indicators to quantify the regional differences of NOx, lack the structural decomposition of the differences, and lack the research on NOx emission reduction effect and regional governance strategy from the perspective of income division. This paper takes China's provincial panel data as a sample, and uses Theil index to complete the three-regional decomposition of NOx industrial added value emission intensity and per capita emission intensity. Theil index has the advantages of decomposable regional differences and invariable differences when variables change year-on-year. Based on EKC theory, considering population, energy, industrial structure and policy factors, this paper discusses the influence of various factors on NOx emission intensity at different income levels according to regional income levels.

2. Regional difference description and structure decomposition of NOx emission

2.1. Calculation method of regional difference of NOx emission

Referring to the existing research on the decomposition of Theil index structure difference [9-12], the calculation formula of Theil index used to express NOx emission intensity in this paper is as follows:

\[
T = \sum_{i} \sum_{j} \left( \frac{N_i}{N} \right) \ln \left( \frac{N_i / N}{X_i / X} \right) = T_w + T_b
\]

\[
T_w = \sum_{j} \left( \frac{N_j}{N} \right) T_r = \sum_{j} \sum_{i} \left( \frac{N_j}{N_i} \right) \ln \left( \frac{N_j / N}{X_j / X} \right)
\]

\[
T_b = \sum_{j} \left( \frac{N_j}{N} \right) \ln \left( \frac{N_j / N}{X_j / X} \right)
\]

In formula (1) - (3): \( i \) represents province; \( j \) represents region; \( T \) represents total Theil index of NOx emission; \( T_w \) represents intra group Theil index; \( T_b \) represents inter group Theil index; \( T_r \) representing the provinces in the region; \( N \) is the sum of NOx emission of each province; \( X \) is the industrial added value or population of each province, corresponding to the industrial added value emission intensity or per capita emission intensity respectively.

2.2. Overall difference decomposition and result analysis of NOx emission

Based on the industrial added value and population, this paper calculates the Theil index of China's NOx emission intensity from 2008 to 2017. From the change of index growth rate, the industrial added value and per capita Theil index show the largest negative growth rates in 2011, which are 52.7% and 45.8% respectively, this may be related to the environmental protection work during the "12th Five Year Plan" period, which focuses on the total amount control and emission reduction of NOx. Since 2011, the two kinds of indexes have bottomed out and rebounded, and the difference of NOx emission has rebounded to a certain extent, indicating that with the increasing downward pressure of economy, the contradiction between development and protection has become more prominent. Since 2011, the Theil index of industrial added value is higher than that of per capita, and it shows a trend of increasing year by year, indicating that the matching degree of NOx emission and industrial added value is lower than that of NOx emission and population. Therefore, it is more challenging to implement NOx emission reduction policy with industrial added value as index.

2.3. Three-region decomposition of NOx emission difference

The results are shown in Table 1 (limited to space, with some years listed).
### Table 1. The NOx emission Theil index and its contribution rate in the three regions

| Year | East | Central | West | T_W | T_B | Contribution Rate |
|------|------|---------|------|-----|-----|-------------------|
|      | T    |         |      | T_W | T_B | East | Central | West | T_W | T_B |
| 2008 | 0.041 | 0.126   | 0.093 | 0.081 | 0.045 | 0.153 | 0.379 | 0.110 | 0.643 | 0.356 |
|      | 0.065 | 0.272   | 0.151 | 0.156 | 0.015 | 0.243 | 0.816 | 0.178 | 0.908 | 0.091 |
| 2011 | 0.051 | 0.070   | 0.205 | 0.089 | 0.042 | 0.170 | 0.194 | 0.314 | 0.678 | 0.321 |
|      | 0.048 | 0.164   | 0.178 | 0.116 | 0.001 | 0.162 | 0.454 | 0.273 | 0.985 | 0.014 |
| 2013 | 0.064 | 0.102   | 0.235 | 0.115 | 0.046 | 0.170 | 0.229 | 0.312 | 0.712 | 0.287 |
|      | 0.050 | 0.187   | 0.209 | 0.134 | 0.001 | 0.133 | 0.420 | 0.276 | 0.986 | 0.013 |
| 2015 | 0.082 | 0.128   | 0.229 | 0.130 | 0.046 | 0.195 | 0.265 | 0.275 | 0.736 | 0.263 |
|      | 0.061 | 0.190   | 0.212 | 0.140 | 0.002 | 0.146 | 0.394 | 0.254 | 0.982 | 0.176 |

From the perspective of the Theil index of industrial added value, from 2008 to 2017, the regional Theil index (average 0.1101) is much larger than the inter-regional Theil index (average 0.0503), which indicates that the difference of NOx emission is mainly within the region. After three regional decomposition of the regional Theil index, it is found that the eastern part is the smallest, the central part is the largest, and the western part is the second, and the index of the three regions has an upward trend.

From the per capita Theil index, the difference of NOx emission is mainly within the region. After the three-region decomposition of the regional Theil index, it is found that the eastern part is the smallest, and the central part is the largest. Since 2011, the difference in the western part is the largest, followed by the central part, and the eastern part is the smallest, and the indexes of the three regions have an upward trend. The Theil index of the western region has been higher than that of the central and eastern regions, but the difference contribution rate analysis shows that the contribution rate of the western region to the overall difference is far less than that of the central region, and is equivalent to that of the eastern region, which is mainly related to the emission weight coefficient. The average proportions of industrial NOx emissions in the western, central and eastern regions are 18%, 37% and 45%. We should not only curb the expansion of the difference of pollution emission in the west, but also effectively control the scale of pollution emission in the central and eastern regions.

### 3. Analysis of influencing factors of NOx emission and test of emission reduction effect of income division

#### 3.1. Measurement model setting

Based on the summary of existing studies on potential factors of regional pollution differences [7-8,10-20], this paper sets the econometric model according to EKC theory as follows:

$$
\ln \text{nox}_i = \beta_0 + \beta_1 \text{ps}_i + \beta_2 \text{ei}_i + \beta_3 \text{pgdp}_i + \beta_4 (\text{pgdp}_i) + \beta_5 \text{er}_i + \beta_6 \text{ind}_i + \epsilon_i
$$

(4)

#### 3.2. Variable measurement and data description

On variable selection: NOx emission intensity is divided by industrial added value and population at the end of the year; the level of per capita income (pgdp) is expressed by per capita GDP; industrial structure (ind) is expressed by the proportion of the secondary industry in the GDP of each province; energy intensity (ei), the ratio of energy consumption to GDP, is measured; the policy factor is measured by the ratio of the completed investment in waste gas treatment to the industrial NOx emission; the population size (ps) of a region is measured by the arithmetic mean of the population at the end of last year and that at the end of this year.

#### 3.3. Panel regression results and analysis of income groups

According to Hausman test (all P values are less than 0.000), the fixed effect model was selected. Table 2 shows the estimation results of formula (4).

Considering that the traditional division of East, middle and West is not completely based on the
income level, in order to test the difference of pollution emissions in different income areas, the existing provinces are divided into high-income group and low-income group according to the average ranking of pgdp of each province from 2006 to 2015.

Columns (1) to (3): in the national sample, pgdp is significantly negative at the level of 1%, and the coefficient of \((\text{pgdp})^2\) is negative, which indicates that the growth of per capita GDP is conducive to reducing NOx emissions based on industrial added value. From columns (2) and (3), there are significant differences in the impact of per capita GDP of different development levels on pollution emissions: in the high-income group, pgdp is negative, and the coefficient of \((\text{pgdp})^2\) is significantly negative. In the low-income group, the impact of GDP per capita on emission intensity is a quadratic function, which supports the inverted "U" Environmental Kuznets curve. The emission reduction coefficient of the low-income group is higher than that of the high-income group. With the increase of income, the emission reduction effect will increase first and then decrease, and show a "tailing" feature, which shows that giving priority to increasing the per capita GDP of low-income group will help to improve the overall NOx emission reduction effect. The coefficient symbols and significance of other explanatory variables in the whole country, high-income group and low-income group are basically consistent: The coefficient of energy intensity (ei) is significantly positive at 1% level, and the influence coefficient decreases with the increase of income; The intensity of environmental regulation (er) has significant emission reduction effect in the national and high-income groups, but the coefficient of low emission group is negative, but it is not significant; The industrial structure (ind) and population size (ps) have significant negative effects on pollution emission, and the higher emission reduction effect in low-income group is more obvious.

Table 2. The results of panel estimation of industrial NOX emissions from 2008 to 2017

| Variables | ln(nox) | ln(noxp) |
|-----------|---------|----------|
|           | (1)     | (2)      | (3)     | (4)     | (5)     | (6)     | (7)     |
| pgdp      | -0.1332*** | -0.038   | 0.6138** | 0.4905*** | 0.4319*** | 1.9579*** | 0.7239*** | 0.0030*** |
|           | (-2.93)  | (-0.65)  | (2.47)   | (12.10)  | (7.95)   | (7.67)   | (9.22)   |
| (pgdp)^2  | -0.0046*** | -0.0114** | -0.1865*** | -0.0354*** | -0.0303*** | -0.3484*** | -0.0845*** |
|           | (-1.30)  | (-2.69)  | (-3.71)  | (-11.10)| (-8.09)  | (-6.54)  | (-5.83)  |
| (pgdp)^3  | 0.0030*** |          |          |         |         |         |         |
|           |          |          |          |         |         |         | (3.36)   |
| ei        | 0.5521*** | 0.7156*** | 0.7638*** | 0.2335** | 0.4478*** | 0.7188*** | 0.3704*** |
|           | (4.94)   | (5.58)   | (4.01)   | (2.23)  | (3.22)   | (4.27)   | (3.29)   |
| er        | -0.3268*** | -0.3313*** | -0.0449  | -0.4176*** | -0.4260*** | -0.1486  | -0.3938*** |
|           | (-6.79)  | (-6.18)  | (-0.42)  | (-8.97) | (-8.29)  | (-1.35)  | (-7.72)  |
| ind       | -1.5711*** | -1.8441*** | -2.0372*** | 1.7063*** | 0.9979*** | 0.3724   | 1.5733*** |
|           | (-4.71)  | (-4.58)  | (-2.40)  | (5.81)  | (2.59)   | (0.43)   | (5.20)   |
| ps        | -0.3058*** | -0.3516*** | -0.6973*** | -0.4085*** | -0.3439*** | -0.6111*** | -0.3737*** |
|           | (-4.22)  | (-4.34)  | (-1.98)  | (-5.55) | (-3.99)  | (-1.66)  | (-5.50)  |
| Constant  | 6.3424*** | 6.4556*** | 6.9323*** | 4.3419*** | 4.3452*** | 3.4664*** | 3.8046*** |
|           | (16.81)  | (14.90)  | (4.60)   | (12.10) | (9.96)   | (2.24)   | (10.08)  |
| F value   | 118.99   | 130.39   | 42.63    | 93.56   | 113.592  | 58.75    | 109.74   |
| AdjustedR^2 | 0.93     | 0.94     | 0.84     | 0.91    | 0.93     | 0.88     | 0.92     |
| Hausman   | 29.34*** | 18.83*** | 24.50*** | 37.04*** | 18.65*** | 20.05*** | 41.04*** |

Note: t values in brackets, ** *, * *, * indicate that the variables are significant at 1%, 5%, and 10% significance levels respectively.

Columns (4) to (7): in high-income and low-income groups, the impact of per capita GDP on emission intensity supports the inverted "U" Environmental Kuznets curve. Comparing the coefficients of pgdp and \((\text{pgdp})^2\) in columns (5) and (6), the absolute value of the impact coefficient of low-income group is greater than that of high-income group. After the first turning point, the per capita NOx emission intensity first decreases and then increases slightly, and then decreases again after the second turning point, but the emission reduction effect is weakened. Therefore, on the basis of column (4) of the national sample, this paper adds the cubic term \((\text{pgdp})^3\), and obtains the estimation in column (7): the impact of per capita GDP on per capita NOx emission intensity is a cubic function relationship, that is, environmental pollution and economic development show a "N" type, indicating the existence of "restructuring" phenomenon [14,21]. The coefficient sign of other explanatory variables in
4. Conclusions
From 2008 to 2017, the regional differences of NOx emission intensity of industrial added value and per capita NOx emission intensity are obvious: the matching degree of NOx emission and industrial added value is lower than that of NOx emission and population, so it is more challenging to implement NOx emission reduction policy based on industrial added value.

The impact of per capita GDP on the emission intensity of industrial added value and per capita emission intensity is different. The impact on the emission intensity of industrial added value: Considering the characteristics of low-income group (inverted "U" trend) and high-income group (decreasing trend), as a whole, with the increase of income, the emission reduction effect will appear the inverted "U" mode of first rising and then decreasing, and show the "tailing" characteristics of gradually decreasing emission reduction effect; The impact on per capita emission intensity: Based on the characteristics of low-income group (inverted "U" trend) and high-income group (inverted "U" trend), the per capita emission intensity first decreases and then increases slightly after the first turning point, and then decreases after the second turning point. However, the effect of emission reduction is weakened. The national samples show that the impact of per capita GDP on per capita NOx emission intensity is a cubic function, that is, environmental pollution and economic development are "N" type, indicating the existence of "restructuring" phenomenon.

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