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Decomposition of China's Pollutant Emissions of Transport Sector Based on LMDI Method

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Abstract. The transport sector, as one of the principal source of air pollution, has attracted a growing attention in academia in recent years. By employing the LMDI method, this paper focuses on the driving factors of pollution in transport sector based on the pollutant emission data of motor vehicles from 2010-2018. The results show that the production effect is the main driver for the changes of NO_x and PM emissions in the transport sector, while for HC, pollution intensity effect is the largest contributor. The pollution intensity effect reduced NO_x and PM emission by 307% and 381%, respectively, which plays the dominant role in reducing their emissions. Compared to other effects, the structure effect and the vehicle effect make minor contributions to the changes of pollutant emissions.

1. Introduction

Nowadays, the pollution issue in transport industry is becoming increasingly prominent in China. The growing motor vehicles, which emit nitrogen oxides (NO_x), fine particulate matter (PM), hydrocarbons (HC) and so on, have become an important source of air pollution in many big cities and are also a bottleneck that will restrict the sustainable development of the cities. For example, motor vehicles accounted for 10%-27% of total pollutant emissions in 2016 in Hebei. Pollution of transport sector, especially from motor vehicles, is getting more and more attention both in academia and in society. In 2018, the State Council of China proposed to win the tough battle to prevent and control pollution, adjust the transportation structure and reduce pollution for diesel trucks. Later, the Three-Year Action Plan for Winning the Blue Sky Defense Battle also proposed to strengthen the prevention of mobile source pollution. Therefore, it is of great significance to study the influencing factors of pollutant emissions in the transportation industry. In this paper, we investigate the underlying factors that affect the pollution in transport based on Logarithmic Mean Divisia Index (LMDI) method. To the best of our knowledge, we are one of the first papers to explore the pollution of transport sector from the decomposition perspective.

2. Literature Review

There are many decomposition techniques developed to examine the factors affecting the changes in pollution emission or carbon CO₂ emission. Among them, the Logarithmic Mean Divisia Index (LMDI)



is widely used. However, most of the existing researches focus on the regional pollution, wastewater discharges or industrial pollution discharge [1-3], very few studies have explored the transport sector.

With respect to the transport sector, many studies have investigated the influence mechanism of CO₂ emissions based on LMDI and get different findings. Wang et al. [4] found that the transportation intensity effect and transportation services share effect played a main role in the reduction of CO₂ emissions in China. Zheng et al. [5] have estimated seven drivers for changes in CO₂ emissions in China for 2000–2016, including industrial structure, energy and on. Their results showed that regional structure is the main driver in reducing CO₂ emissions.

Besides the large amount of CO₂ emission, transport activities also produce high pollutant emission. Many scholars have investigated the pollution of transport sector. Wang et al. [6] studied the trends of vehicular emissions in big cities of China from 1995 to 2005 and found that the growth rates of vehicular emissions have begun to slow down. Cui et al. [7] studied the PM_{2.5} source based on a hybrid method and found that mobile emission is the major contributor of PM_{2.5} in Guangzhou, which accounts for 20.7%- 37.4% in different seasons. Wu et al. [8] have reviewed vehicle emission control tools and have assessed current status and future trends of vehicle emissions in China. As the pollution data of transport is not available, few studies have explored the pollution of transport sector from the decomposition perspective. As the motor vehicles are the largest emitter of the transport sector, we collect motor vehicles as alternatives of pollution of transportation industry and aims at identifying the main factors affecting the changes in pollution in this paper.

3. Method and Data

In this section, we first elaborate the method for investigating the factors that affect the pollution in transport based on LMDI approach. Then we briefly describe the data used in this study.

3.1. The LMDI Method

The LMDI method was first proposed by Ang et al. [9,10] and has become one of the most popular method for index decomposition analysis (IDA). LMDI disentangles multiple underlying factors that have impacts on the desired objective and analyzes how these factors affect the final objective. It has become popular and been widely applied for various applications [11,12,13]. In this paper, we adopt LMDI to identify the driving forces of changes of pollutant emissions in the transport sector.

The pollutant emissions P (which represents NO_x, HC and PM emission of motor vehicles in this paper) can be decomposed into the following contributing factors:

$$P^t = G_A^t \times G_T^t \times V_{sum}^t = G_A^t \times \frac{G_T^t}{G_A^t} \times \frac{V_{sum}^t}{G_T^t} \times \frac{P^t}{V_{sum}^t}, \quad (1)$$

where G_A^t is the overall Gross Domestic Product(GDP) of China in t^{th} year, G_T^t is the value added that is related to transportation in t^{th} year, and V_{sum}^t is the overall number of vehicles in China in t^{th} year.

According to Eq. (1), the pollutant emissions P is contributed by four underlying factors:

$$P^t = G_A^t \times R^t \times M^t \times S^t, \quad (2)$$

where $R^t = \frac{G_T^t}{G_A^t}$ is the ratio of total GDP for transport, which indicates the economic structure of the transport sector. $M^t = \frac{V_{sum}^t}{G_T^t}$ is the number of vehicles per GPD and $S^t = \frac{P^t}{V_{sum}^t}$ is the pollution of unit vehicle, which indicates the pollution intensity of the vehicle.

Thus, we can decompose the relative changes from P^0 to P^t as four factors, i.e. production effect ΔP_G , structure effect ΔP_R , vehicle effect ΔP_M and pollution intensity effect ΔP_S :

$$\Delta P = P^t - P^0 = \Delta P_G + \Delta P_R + \Delta P_M + \Delta P_S, \quad (3)$$

According to the LMDI approach [9], each factor can be represented as:

$$\Delta P_G = \frac{P^t - P^0}{\ln P^t - \ln P^0} \times \ln \frac{G_A^t}{G_A^0}, \quad (4)$$

$$\Delta P_R = \frac{P^t - P^0}{\ln P^t - \ln P^0} \times \ln \frac{R^t}{R^0}, \quad (5)$$

$$\Delta P_M = \frac{P^t - P^0}{\ln P^t - \ln P^0} \times \ln \frac{M^t}{M^0}, \quad (6)$$

$$\Delta P_S = \frac{P^t - P^0}{\ln P^t - \ln P^0} \times \ln \frac{S^t}{S^0}. \quad (7)$$

Thus we can obtain the impacts of different factors for the pollution emissions. In this paper, we investigate the impacts on several different pollutant emissions, i.e., NOx, HC and PM emission of motor vehicles.

3.2. Data

The paper focuses on the 3 pollutants (carbon monoxide excluded) in the China Vehicle Emission Control Annual Report, which is published by Ministry of Environmental Protection of People's Republic of China. From these reports, we collect data of motor vehicle population and their pollutants from 2010-2018. Total GDP and value added of transport, storage and post industry are from China Statistical Yearbook. In order to eliminate the effect of price, we use year 2010 as the base price year and adjust all the values into 2010 constant price.

4. Results

4.1. Trends of pollutant emissions of motor vehicles

From 2010 to 2018, the pollutant emission of motor vehicles shows a downward trend, as shown in Figure 1. PM emissions have reduced from 598 in 2010 to 442 thousand tons in 2018, with the largest fall of 26.2%. NOx emissions have decreased by 6.1% and the HC emissions have decreased by 24.3% since 2010. At the same time, the number of motor vehicles has increased from 190 million in 2010 to 327 million in 2018.

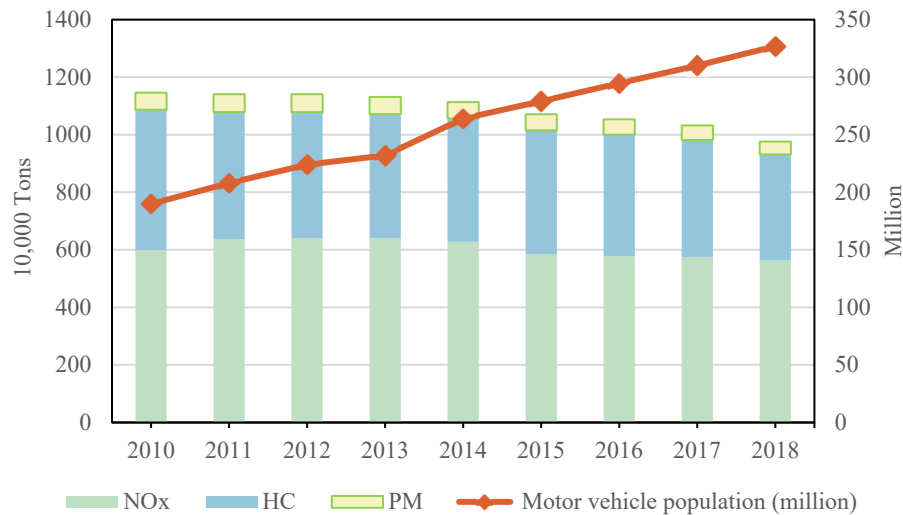


Figure 1. Pollutant emissions of vehicles and motor vehicle population from 2010-2018

4.2. Decomposition of pollutant emissions in transport sector

Based on LMDI, the driving factors of NOx, HC and PM emissions in transport sector are examined from 2010 to 2018. The results are shown in Table 1-3 and Figure 2. Generally, the production effect is the largest contributor for the changes of NOx and PM emissions, while for HC, pollution intensity effect is the largest contributor.

The average production effect ΔP_G over 2010-2018 is positive for NOx and PM, which accounts for 932% and 498%, respectively. However, for HC, the average production effect is negative. The structure effect ΔP_R plays a minor role, which contributes -242%, 75% and -123% to the changes of NOx, HC and PM emission. The vehicle effect ΔP_M is negative for NOx and HC, while positive for PM. The pollution intensity effect ΔP_S reduces NOx and PM emission by 307% and 381%, which plays the dominant role in reducing their emissions. This may be due to the improving vehicle emission standards and cleaner fuel standards in China. Another important factor that leads to the large decreases in emissions of NOx and PM is the development of technologies, such as diesel particulate filters. In addition, China's elimination of yellow-labeled cars and old cars is also increasing. From 2014-2017, 20.6 million yellow-labeled and old cars have been cleaned up off the road, which promoted the pollution intensity a lot.

Table 1. Contribution of different factors to NOx emissions (10,000 tons) (10,000 tons)

Year	2010~2011	2011~2012	2012~2013	2013~2014	2014~2015	2015~2016	2016~2017	2017~2018
ΔP	38.1	2.5	0.6	-12.8	-52.6	-7.1	-3.5	-11.4
ΔP_G	56.4	48.4	47.9	44.7	175.8	37.9	37.7	36.2
ΔP_R	0.6	-10.6	-7.0	-4.8	-37.9	-0.8	14.0	8.4
ΔP_M	-1.1	9.6	-18.4	42.0	41.5	-5.3	-22.4	-14.2
ΔP_S	-17.9	-44.8	-21.9	-94.7	-232.0	-38.9	-32.7	-41.8

Table 2. Contribution of different factors to HC emissions (10,000 tons) (10,000 tons)

Year	2010~2011	2011~2012	2012~2013	2013~2014	2014~2015	2015~2016	2016~2017	2017~2018
ΔP	-46.0	-3.0	-7.0	-2.8	-11.0	-8.2	-14.9	-38.3
ΔP_G	42.3	33.3	32.5	30.3	125.4	27.8	27.1	24.7
ΔP_R	0.5	-7.3	-4.7	-3.2	-27.0	-0.6	10.0	5.7
ΔP_M	-0.8	6.6	-12.5	28.5	29.6	-3.9	-16.1	-9.7
ΔP_S	-88.0	-35.6	-22.3	-58.3	-138.9	-31.5	-35.9	-59.0

Table 3. Contribution of different factors to PM emissions (10,000 tons) (10,000 tons)

Year	2010~2011	2011~2012	2012~2013	2013~2014	2014~2015	2015~2016	2016~2017	2017~2018
ΔP	2.3	0.1	-2.8	-2.0	-6.1	-2.6	-2.5	-6.7
ΔP_G	5.6	4.7	4.5	4.1	17.0	3.6	3.4	3.0
ΔP_R	0.1	-1.0	-0.7	-0.4	-3.7	-0.1	1.3	0.7
ΔP_M	-0.1	0.9	-1.8	3.9	4.0	-0.5	-2.0	-1.2
ΔP_S	-3.2	-4.5	-4.9	-9.5	-23.4	-5.6	-5.1	-9.2

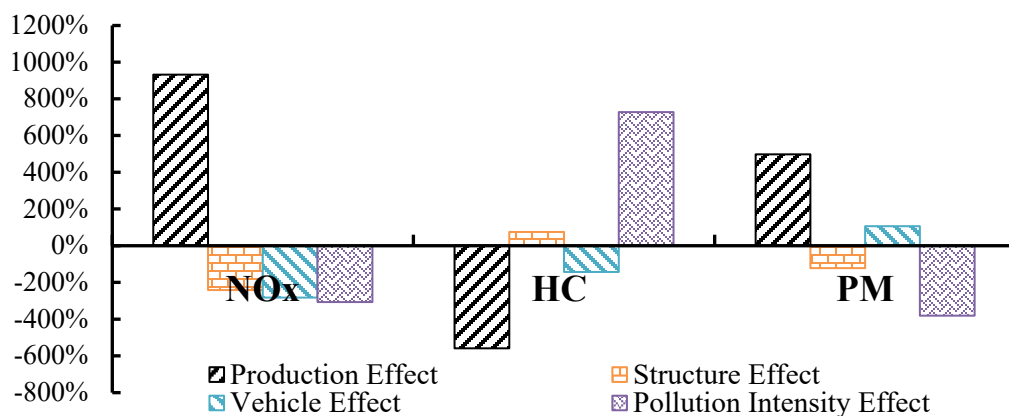


Figure 2. The average contributions of the four factors over 2010-2018

5. Conclusion

In this paper, we focus on the driving factors of pollution changes in transport sector from 2010-2018 based on the LMDI method. The results show that the production effect is the key driver for the changes of NO_x and PM emissions in the transport sector, while for HC, pollution intensity effect played the main role. The pollution intensity effect reduced NO_x and PM emission by 307% and 381%, respectively, mainly due to the improved technologies and stricter emission standards for diesel and gasoline vehicles in China. Compared to other effects, the structure effect and the vehicle effect make minor contributions to the changes of pollutant emissions.

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