Analysis on Temporal Change and Grey Relation of Transportation Carbon Emissions in Jilin Province

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Abstract. Based on basic datum of transportation energy consumption, this paper measured transportation carbon emissions from 1999 to 2015 in Jilin Province by using measurement model of carbon emissions, and analysed its temporal change. On this basis, grey relational analysis model was used to investigate evolution relationship of transportation carbon emissions and relevant factors in Jilin Province. The results indicated that temporal change of transportation carbon emissions was divided into three phases: smooth progression and slight elevation phase, rapid-growth phase, slow-growth phase, the quantities of transportation carbon emissions increased from 993750t to 3592514t. Diesel, raw coal, electricity power and gasoline were the main factors that affecting total carbon emissions because they had a larger proportion of carbon emissions, in the above factors, temporal change tendency of diesel carbon emissions was basically the same as the total carbon emissions. There was a close relationship between transportation carbon emissions and all relevant factors in Jilin Province, their order of grey relational value was GDP > urbanization rate > population number > unit GDP energy consumption > transportation investment > private cars quantity. On the basis of prediction model, according to the situation of existing economic development, transportation carbon emissions will show a low growth tendency in next five years in Jilin Province.

1. Introduction
In recent years, greenhouse effect caused by excessive energy consumption of the human has become a focus of academic circles. Therefore, the issue of carbon emissions in different areas of production of human life has become a hot research topic. Some studies show that Chinese transportation industry has become the fastest growing sector of China's carbon emissions [1]. Transportation carbon emissions have accounted for about 22% of total carbon in China, and restricted seriously rapid development of low-carboneconomy and construction of ecological civilization in our economic and social [2]. Jilin Province is an important part of the northeast old industrial base, its construction level of ecological civilization is low, and constraints of resources and environment is becoming more and more obvious. Therefore, in Jilin Province, there is important significance that researching transportation carbon emission in the background of development of low carbon economy and accelerating construction of ecological civilization. Based on the above, this research measures transportation carbon emissions from 1999 to 2015, and analyses its temporal change. On this
basis, grey relational analysis model is used to investigate evolution relationship of transportation carbon emissions and relevant factors. Prediction model of transportation carbon emissions is constructed, and is used to predict transportation carbon emissions from 2016 to 2020. This study can provide reference for other areas to develop related study of carbon emissions and provide scientific basis for carbon emission reduction policies made by government or relevant organizations.

2. Temporal change of transportation carbon emissions

2.1. Calculation model

Transportation carbon emissions were due to greenhouse gas emissions caused by energy consumption in transportation process[3]. In this study, basic datum of energy consumption of transportation industry in Jilin Province were collected in the statistical yearbook of Jilin Province (2000-2016), energy types were raw coal, crude oil, gasoline, kerosene, diesel, natural gas, and electricity power, the specific datum are shown in figure 1. According to the guidelines on greenhouse gas inventories of IPCC, calculation model of transportation carbon emission was selected based on previous studies [4, 5], the formula is shown in formula (1).

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C = \sum N_i \times F_i
\]  

(1)

Type of: \(C\) was transportation carbon emissions, \(t\). \(N_i\) was energy consumption of \(i\) sort, \(t/\text{tec}\). \(F_i\) was carbon emission coefficient of \(i\) sort energy, \(\text{t/\text{t}}\), raw coal: 0.7559, crude oil: 0.5857, gasoline: 0.5538, kerosene: 0.5714, diesel: 0.5921, natural gas: 0.4483, electricity power: 2.2132.

2.2. Calculation results and temporal changes

Formula (1) was used to calculate transportation carbon emission in Jilin Province from 1999 to 2015 based on the basic datum of energy consumption in figure 1. The specific results are shown in figure 2.

Temporal change of total carbon emissions is shown in figure 2. Transportation carbon emissions present a growth state in 1999-2015. Total carbon emissions increased from 993750t to 3592514t, total growth rate was 262.51% and annual growth rate was 16.34%. The overall evolution process could be divided into three phases which included smooth progression and slight elevation phase, rapid-growth phase and slow-growth phase. In 1999-2003, temporal change of total carbon emissions changed smoothly, and showed a steady increase in status. Carbon emissions increased from 993750t to 1133526t, during this period, net increment was 139776t, annual growth rate was 3.52%, and the minimum value was 957286t that appeared in 2001. In 2003-2009, temporal change of total carbon emissions showed the status of rapid-growth, withincreased from 1133526t to 3054279t, net increment...
was 1920753t, and annual growth rate was 28.24%. After 2009, growth rate of total carbon emission became smaller, showed a low-growth rate that increased from 3054279t in 2009 to 3592514t in 2015, net increment was 538235t, and annual growth rate was 2.94%, during this period, the range of change was small in 2013-2015, which appeared first drop and then rise.

Composition structure of transportation carbon emissions was analysed according to consumed energy categories. In figure 1 and figure 2, the application time of crude oil and natural gas was short, and their carbon emissions were small. In addition, the amount of kerosene had continued to decline and its carbon emissions were maintained at around 2000t because of energy structure optimization of transportation industry in Jilin Province, accounted for a small proportion of total carbon emissions. Therefore, the temporal changes of the above three types of energy were not analysed in detail.

In figure 2, diesel, raw coal, electricity power and gasoline were the main factor that affecting total carbon emissions. Among them, in 1999-2013, carbon emissions of raw coal showed a fluctuation state, but the overall amplitude was not large, increased rapidly after 2013, and reached 1044200t in 2015; in 1999-2006, carbon emissions of electricity power showed an increasing tendency, which increased from 138768t to 351899t, then dropped to 303208t in 2007. After 2008, carbon emissions of electricity power showed continuous growth, and reached 522758t in 2015; carbon emissions of gasoline fluctuated in study time, and the maximum value was 354543t in 2012, and then gradually decreased to 3306251t in 2015; dynamic change of diesel carbon emissions corresponded to total carbon emissions that explained the main cause of carbon emissions growth of transportation was a lot of diesel energy consumption in Jilin Province. In 2007-2013, due to diesel consumption growth rate decreased, total carbon emissions showed slow growth state. After 2013, total carbon emissions fluctuated because diesel consumption reduced greatly and coal consumption increased.

3. Grey relational analysis of transportation carbon emissions

3.1. Model of grey relational analysis

Grey relational analysis was a method of measuring development tendency of factors according to similarity or dissimilarity between dynamic processes of factors [6]. The analytic model is shown in formula (2).

$$R_{0i} = \frac{1}{N} \sum_{k=1}^{N} L_{0i}(k) = \frac{1}{N} \sum_{k=1}^{N} \frac{\Delta_{0i}(k) + \rho \Delta_{\text{max}}}{\Delta_{\text{max}}}$$

Type of: $R_{0i}$ was grey relational value. $N$ was data number of relevant factor sequence. $L_{0i}(k)$ was relational coefficient of $k$ moment in relevant factor sequence. $\Delta_{0i}(k)$ was absolute difference of $k$ moment in relevant factor sequence. $\Delta_{\text{max}}, \Delta_{\text{min}}$ were maximum and minimum of absolute difference at every moment in relevant factor sequence. $\rho$ was resolution ratio, $\rho = 0.5$ in this study.

3.2. Results of grey relational analysis

According to relativity analysis, this study selected population number, GDP, unit GDP energy consumption, transportation investment, urbanization rate, and private cars quantity as relevant factors of transportation carbon emissions in Jilin Province, the detailed data are shown in table 1. Formula (2) was used to calculate grey relation between transportation carbon emissions and relevant factors. The specific results are shown in table 2.

Table 1. Relevant factor of transportation carbon emissions in Jilin Province from 1999 to 2015

| Year | Population number / ten thousand people | GDP / hundred million Yuan | Unit GDP energy consumption (t standard coal/10000 Yuan) | Transportation investment / hundred million Yuan | Urbanization rate / % | Private cars quantity / 10^5 sets |
|------|----------------------------------------|----------------------------|----------------------------------------------------------|-----------------------------------------------|-----------------------|-------------------------------|
| 1999 | 2616.1                                 | 1682.07                    | 2.1956                                                   | 72.8169                                      | 48.41                 | 13.5194                       |
Grey relational values between transportation carbon emissions and relevant factors are shown in Table 2. There was a close relationship between transportation carbon emissions and all relevant factors in Jilin Province, their order of grey relational value was GDP > urbanization rate > population number > unit GDP energy consumption > transportation investment > private cars quantity. Among them, grey relational value between transportation carbon emissions and GDP was the largest, and its value was 0.9239, which explained economic development level was the primary factor influencing total carbon emissions of transportation, the raising of economic development level would inevitably lead to an increase of carbon emissions. The second factor was urbanization rate, and its value was 0.8803, with the pace of urbanization had been accelerating in recent years, the level of social production and service industry had been developing rapidly, such as railway, highway, waterway, and aviation industry, thereby increased carbon emissions caused by energy consumption. The third factor was population number, and its value was 0.8757, which explained the expansion of population scale would lead to direct and indirect energy consumption of transportation industry, and then had an important impact on transportation carbon emissions. The fourth factor was unit GDP energy consumption, and its value was 0.8273, which explained the upgrading of energy utilization technology could play an important role in reducing transportation carbon emissions. The fifth factor was transportation investment, and its value was 0.8273, which explained capital investment would
promote the increase of transportation industry that had an important effect on transportation carbon emissions. The sixth factor was private cars quantity, and its value was 0.7149. In recent years, carbon emissions of private cars had been widespread concerned. Private cars quantity increased substantially, which driven by the improvement of people's living standards, but also produced a large number of greenhouse gas emissions and strengthened greenhouse effect. With the implementation of private cars control policy and the increasing use of small carbon car, electrical cars and other clean energy cars, the carbon emission effects of private cars will be further controlled.

4. Prediction of transportation carbon emissions based on economic growth

Based on the above analysis, SPSS software was used, this study built a prediction model, which total GDP of 1999-2015 in Jilin Province (comparable price, using 1999 as a baseline) were independent variables ($x$), and transportation carbon emissions were dependent variable ($y$), because GDP was the first relational factor of transportation carbon emissions, and in response to relevant national policies. The decision coefficient and test parameters were used to optimize the model, the prediction model is shown in formula (3).

$$y = 168.3026 \ln x - 1184.1570 \quad R^2 = 0.9762 \quad F = 615.7454 \quad P(Sig.) < 0.0001$$ (3)

In order to respond to national macroeconomic development policy and ensure GDP and per capita income of urban and rural residents will be doubled from 2010 to 2020, the bottom line of economic growth should be above 6.5% in 2016-2020. Therefore, in this study, GDP growth rate was calculated by 6.5% in next five years, and then formula (3) was used to predict transportation carbon emissions of Jilin Province in 2016-2020. The specific predicted results are shown in table 3 and figure 3.

| Year | Predicted value of GDP / hundred million Yuan | Predicted value of transportation carbon emissions / $10^4$ t |
|------|---------------------------------------------|----------------------------------------------------------|
| 2016 | 10561.70                                    | 375.1469                                                 |
| 2017 | 11248.21                                    | 385.7457                                                 |
| 2018 | 11979.35                                    | 396.3445                                                 |
| 2019 | 12758.01                                    | 406.9434                                                 |
| 2020 | 13587.28                                    | 417.5422                                                 |

Figure 3. Transportation carbon emissions in 1999-2020
According to predicted results, in 2015-2020, GDP will increase from 9917.09 hundred million Yuan to 13587.28 hundred million Yuan, and total carbon emissions of transportation will increase from 3592514t to 4175422t in Jilin Province. During this period, net increment of carbon emissions will be 582908 t, total growth rate will be 16.23% and annual growth rate will be 3.25%.

5. Conclusions
This study measured transportation carbon emissions of Jilin Province and analysed its temporal change in 1999-2015. It applied grey relational analysis model to investigate evolution relationship between transportation carbon emissions and relevant factors. Then, prediction model of transportation carbon emissions was constructed, and was used to predict transportation carbon emissions from 2016 to 2020.

According to the results, in 1999-2015, total carbon emissions increased from 993750t to 3592514t, total growth rate was 262.51% and annual growth rate was 16.34%. The overall evolution process could be divided into three phases which included smooth progression and slight elevation phase, rapid-growth phase and slow-growth phase. Carbon emissions caused by a lot of diesel consumption was the first factor of continued growth of transportation carbon emissions, which mainly because agricultural transportation, logistics, transportation, rail transport, urban passenger transport and others had large demand on diesel fuel.

In transportation industry, increasing the usage of electricity and natural gas could cut the usage of diesel, gasoline, and reduce carbon emissions.

Government had introduced a series of laws and regulations on energy saving and emission reduction, as well as new transportation regulations, which effectively limited consumption of diesel and gasoline, and slowed down rapid growth of carbon emissions.

There was a close relationship between transportation carbon emission and all relevant factors in Jilin Province, their order of grey relational grade was GDP > urbanization rate > population number > unit GDP energy consumption > transportation investment > private cars quantity. Among them, grey relational value between transportation carbon emissions and GDP was largest.

According to prediction model and current situation of economic development in the next five years, transportation carbon emissions in Jilin Province will continue to show slowing growth tendency. In order to ensure economic growth rate and realize early negative growth of transportation carbon emissions, Jilin Province must take some effective measures.

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