Research on the Dynamic Relationship among Transportation, Economic Growth, Urbanization and CO₂ Emissions in China

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Abstract. This article analyzed the dynamic relationship among economic growth, urbanization, transportation and carbon emissions. First, it calculated carbon emissions of transportation industry. It conducted a comparative analysis of emissions structure. Then, it analysed the dynamic relationship among variables using the VAR model. Finally, the interaction between short- medium-long term variables was studied based on the impulse response model. The results show that the carbon emissions of transportation industry have grown significantly, and the optimization of energy structure has a certain role in promoting carbon emission reduction. There is a positive correlation from urbanization, economic growth, and transportation to carbon emissions. Urbanization has a positive impact on carbon emissions. The correlation from carbon emissions to economic growth and transportation is not significant.

1. Introduction
The growth of economic, urbanization and transportation demand have led to a large amount of energy consumption and greenhouse gas emissions in China. The use of traffic energy is increasing day by day, accounting for more than 40% of global energy, of which oil accounts for more than 50% of total global oil consumption. It is estimated that it will rise to more than 62% in 2020[1]. China's auto sales have grown by a double-digit percentage each year since 1992. Therefore, studying the dynamic relationship between economic growth, urbanization, transportation, and carbon emissions is conducive to more targeted proposals for energy-saving and emission-reduction strategies.

2. Research Summary
The government, society, experts and scholars are very concerned about economic growth, urbanization, and carbon emissions in the transportation industry. Transportation carbon accounting, effective emission reduction factors and approaches have become frontiers and hotspots.

Wu Jigui, Ye Azhong[2] indicated that the impacts of economic growth and transportation on carbon emissions strengthen in the short term, while the impacts moderate progressively in the long-term scale. Cai Wanhua[3] considered that there was a long-term balanced relationship among transportation, economic growth and CO₂ emissions, and dynamics effects like inverted U. Li Lingjie, Wu Qunqi[4] showed that the development of transport economy increase in the cost of carbon emissions. The higher the emissions, the higher the probability of its transferring to the high level of development. Wu Hong[5] suggested that types of emission reduction zones should be classified. It provided useful references for

the provincial emission reduction policy system and the formulation of emission reduction policies in similar regions and lessons. Lv Qian, Gao Junlian[6] calculated the emissions from transportation in Beijing, Tianjin and Hebei religion. Mercan[7] analysed casual relationships among economic growth, energy consumption and CO_2 emissions were investigated for selected eleven OECD countries.

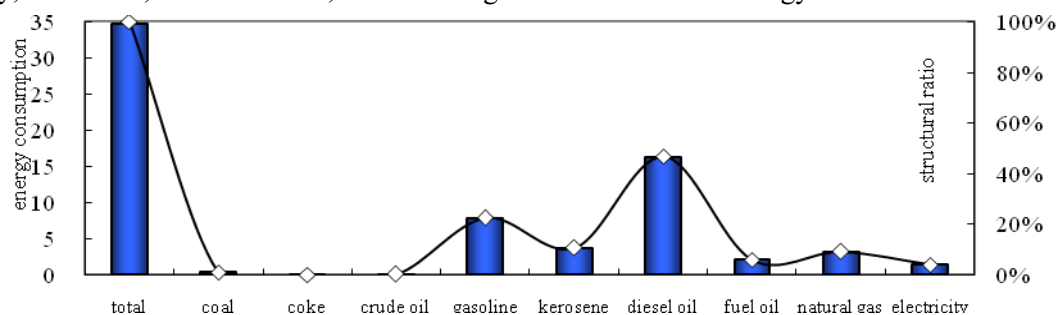## 3. Carbon Emission Accounting Methods

3.1 The structure of energy consumption tends to be optimized
According to the 2017 China Statistical Yearbook, China's transportation energy consumption includes coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, natural gas, and electricity. In order to conduct a structural analysis of China's transportation energy consumption, according to the energy standard coal index (see Table 1) in the 2017 China Energy Statistical Yearbook, a comparative analysis of the energy consumed was conducted (see Figure 1).

Table 1. Coefficient of discount coal standard of various energy types

Energy type	Coal	Coke	Crude	Gasoline	Kerosene	Diesel	Fuel oil	Natural gas	Electricity
Unit	Kg standard coal/kg							Kg standard coal/m³	Kg standard coal/kWh
Coefficient	0.7143	0.9714	1.4286	1.4714	1.4714	1.4571	1.4286	1.33	0.1229

The structure of China transportation energy in 2015, diesel is the most consumed energy, accounting for nearly 50% of the total energy consumption of transportation. Followed by gasoline, accounting for more than 22%. Due to the promotion and application of new energy vehicles throughout the country, the consumption of new energy such as natural gas and electricity has grown rapidly, which has, to some extent, reduced the growth of traditional energy sources.

Source: 2017 China Statistical Yearbook
Figure 1. Transportation energy consumption (10 million tons of standard coal) and structure (%) in 2015

3.2 Transportation carbon emission accounting model
The carbon emission accounting of the transportation industry can be measured by the mobile energy sources and energy emission factors. The measurement model is expressed as:

$$Em_t = \sum En_t \times F_i \times g \quad （1）$$

$$F_i = V_i \times C_i \times O_i \quad （2）$$

In Equations (1) and (2), Em, En, F, g, V, C and O are emissions, energy consumption, emission factors, gasification coefficients (conversion coefficients between carbon and carbon dioxide, g=44/12), average low calorific values, Carbon content and oxidation rate respectively, i is energy types, the emission factor F is shown in Table 2

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Table 2. Carbon emission factor calculation methods

Energy type	Average low calorific valueV		Carbon contentC	Carbon oxidation rate	Factor	
	Value	Conversion unit	Tcarbon/TJ		$V/10^9 \times C*O*10^3$	Unit
Coal	20908		26.37	94%	0.518263	
Coke	28435		29.5	93%	0.780114	
Crude	41806		20.1	98%	0.823495	
Gasoline	43070	KJ/kg	18.9	98%	0.797743	kg-CO2 /kg
Kerosene	43070		19.5	98%	0.823068	
Diesel	42652		20.2	98%	0.844339	
Fuel oil	41816		21.1	98%	0.864671	
Natural gas	38931	KJ/m3	15.3	99%	0.589688	kg-CO2/Cubic meter
Electricity	3600	KJ/kWh	-	-	0	kg-CO2/kWh

3.3 Empirical analysis of Carbon Emissions Accounting in the Transport Industry
According to the data in formulas (1), (2), Table 2 and the various types of energy consumption of transportation during 1995-2005, the carbon emissions and structural proportion of China's transportation can be obtained. From Table 3, it can be seen that China's transportation carbon emissions have increased year by year from 1995 to 2015, from 68,143 to 68,393 million tons, an increase of more than five times, with an average annual growth rate of about 9%. Carbon emissions from traditional energy sources contribute the most to transportation carbon emissions, reaching more than 90% in 1995. With the promotion of new energy transportation, carbon emissions from new energy sources have gradually increased and reached 14% in 2015.

4. The Dynamic Relationship

4.1 Variable Selection Analysis
Variables in the research include: traffic carbon emissions (indicated by Em), Economic growth (indicated by GDP), Urbanization Rate (represented by Ur). The source of economic growth and urbanization data is from China Statistical Yearbook. Transportation, using the Passenger and Freight Turnover for conversion measurements. The model is:

$$tran = frei_i + (pass_i \times r_i) \quad (3)$$

Among them, tran stands for Passenger and Freight Turnover, where frei is the passenger turnover volume, pass is the passenger turnover volume, r is the passenger-cargo conversion factor, i is the transport type, and the coefficient for transportation is 1 for rail, ocean, coastal, and inland rivers. For seats, the inland river is 0.33, the highway is 0.1, and the airline is 0.072.

4.2 Stability Check

In order to reduce the interpretation of the analysis results caused by the non-stationary time series, a unit root test was performed on each variable. The results show that the three variables have good stability.

4.3 Model Construction

$$Y_t = C + B_1 Y_{t-1} + B_2 Y_{t-2} + \varepsilon_t \quad (4)$$

$$Y_t = \begin{bmatrix} Tran_t \\ GDP_t \\ Em_t \\ Ur_t \end{bmatrix}, B_1 = \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} \end{bmatrix}$$

Y_t is 4×1 time series column vector. C is 4×1 order constant item column vector. β_1, β_2 is 4×4 parameter matrix, $\varepsilon_t \sim IID(0, \Omega)$ is 4×1 order random error column vector, each element is non-self-related.

5. Results and Analysis

5.1 Analysis of Empirical Results of VAR Model

The estimated R^2 values were 0.9928, 0.9993, 0.9975 and 0.9998, respectively, and the results were well explained.

The results in Table 5 show that the R2 of the equation is all above 99%, that is, the fitting degree of the equation is relatively. The VAR model analysis results can be used to establish the description. Based on the time lag effect of Urbanization Rate, GDP, Passenger and Freight Turnover, Carbon Emissions, there is a positive correlation between Tran, GDP, and Ur for Em. The overall elasticity is 16.14%. 8.03% and 46.33%. Em has a positive correlation with GDP, but Em has no significant positive correlation with Tran and Ur. The lag phase 1 and the lag phase 2 have greater positive elasticity to the growth of LG in the current period, and the overall elasticity is 82.57%. The overall elasticity of LG to LIJ is -2.21%, indicating that LG has no significant positive correlation with LI.

5.2 Impulse response analysis

The VAR analysis result needs to be explained by means of IRF. When given the shocks of Tran, GDP and Ur, the variable Em shows a significantly increasing impulse response function(See Figure 2).
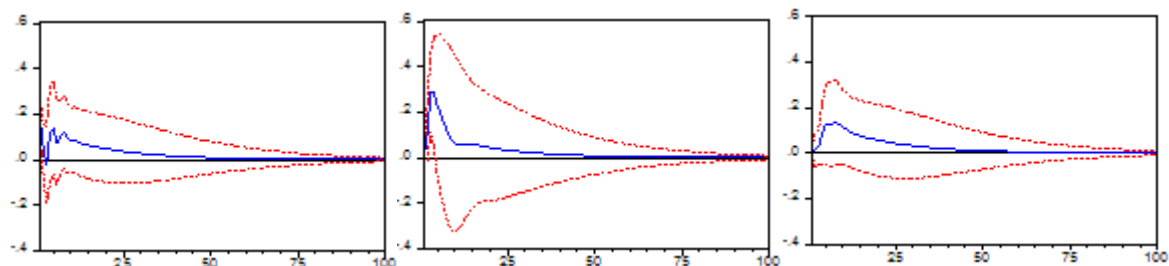

Figure 2. Response of GDP, Ur and Tran to Em

Under the positive impact of GDP, carbon emissions will fluctuate up and down, and this fluctuation will gradually shrink over time. Regardless of the impact of output itself, comparing the impulse responses of the three elements of GDP, Ur, Tran to Em, we can see that the change of urbanization rate in the short term has greater impact on carbon emissions than economic growth and passenger and freight turnover on carbon. The impact of emissions, while the three variables in the long term can stimulate carbon emissions, but the role has weakened. At this stage, the impact of urbanization on carbon emissions in China is relatively.

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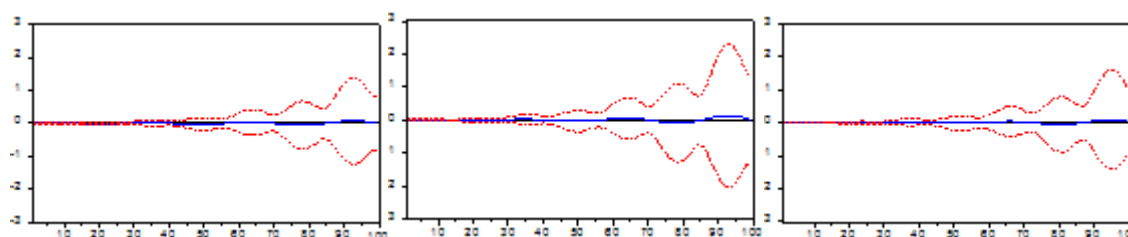doi:10.1088/1755-1315/199/2/022022

Figure 3. Response of Em to GDP, Ur and Tran

Under the positive impact of carbon emissions, it will cause GDP, Ur and Tran to fluctuate upwards in the short term, and compare the degree of response of GDP, Ur, Tran to the three elements. In the short term, the role of carbon emissions in economic growth will be greater than that of urbanization and passenger and freight turnover. Amount, and limited stimulation of three variables in the long term. It shows that the current carbon emission restraint mechanism has not yet exerted an effect on economic growth, urbanization and turnover, or that the country's carbon emission restrictions on the transportation industry are in an unenforced state and have not caused a strong impact on China's economy.

6. Conclusion

Research on the dynamic relationship among the variables is significance for carbon emission reduction, which indicates that:

(1) The gradual optimization of transportation energy structure. The proportion of new energy such as natural gas, electricity, etc. in the transportation industry has increased rapidly, and the direct emission is relatively low. Optimization of energy consumption structure can promote energy conservation and emission reduction, and play a catalytic role in decoupling transportation energy consumption and carbon emissions.

(2) Transportation carbon emissions have increased from 1995 to 2015, with an average annual growth rate of 9%. It shows that the optimized structure of traffic energy consumption has a certain role in promoting traffic reduction, and the application of transportation new energy is conducive to national energy conservation and emission reduction.

(3) There is a positive correlation among Urbanization, economic growth, transportation and Carbon Emissions. Emissions have a positive correlation to economic growth. The impact is significant from rbanization, economic growth, transportation to Carbon Emissions. Carbon emissions will stimulate economy more than urbanization and transportation.

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