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International Oil Price's Impacts on Carbon Emission in China's Transportation Industry

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Abstract:

Purpose: This paper analyses the impact mechanism of international oil price on the industrial carbon emission, and uses the partial least squares regression model to study international oil price's impact on carbon emissions in China's transportation industry.

Design/methodology/approach: This paper chooses five independent variables of GDP (Gross Domestic Product), international oil price, private car population, passenger and freight transportation volume as impact factors to investigate industrial carbon emissions, the paper also analyses the impact mechanism of international oil price on the industrial carbon emission, and finally the paper uses the PLSR (partial least squares regression) model to study international oil price's impact on carbon emissions in China's transportation industry. With the independent variables' historical data from 1994 to 2011 as a sample, the fitting of the industry carbon emissions is satisfying. And based on the data of 2011, the paper maintains the private car owning, passenger and freight transportation volume to study international oil prices' impact on the industry carbon emissions at different levels of GDP.

Findings: The results show that: with the same GDP growth, the industry carbon emissions increase with the rise in international oil prices, and vice versa, the industry carbon emissions decrease; and lastly when GDP increases to a certain extent, in both cases of international oil prices' rise or fall, the industry carbon emissions will go up, and the industry carbon emissions increase even faster while the energy prices are rising.

Practical implications: Limit the growth in private-vehicle ownership, change China's transport sector within the next short-term in the structure of energy consumption and put forward China's new energy, alternative energy sources and renewable energy application so as to weaken the dependence on international oil, and indirectly slowdown China's GDP growth rate, which are all possible solutions to reduce China's transportation industry carbon emission.

Originality/value: The paper presents a method to study international oil prices' impact on the industry carbon emissions at different levels of GDP; and draws some corresponding proposals on industry carbon emission reduction.

Keywords: international oil price, transportation industry, carbon emission, PLSR model

1. Introduction

In July 2010, the IEA (International Energy Agency) released a report saying that China has become the world's first energy consumer with a consumption of 2.252 billion tons of oil in 2009, which is 4 % more compared to USA's total oil consumption of 2.17 billion tons. China's transportation industry as an important basic industry and service sector is also one of the fastest growing energy consuming industries of the country. The 1996-2011 statistics from the People's Republic of China Bureau of Statistics show that the total energy consumption of China's transportation (including storage and postal services) in 1995 is 58.63Mt (million ton) TCE (A ton of coal equivalent or ton of coal equivalent (TCE) is a conventional value of 7 Gcal (1Gcal=10^9calorie) = 29.3076 GJ (1GJ=10^9Joule). accounting for 4.5% of the total energy consumption of the whole society. By 2009, the national transportation energy consumption has attained the level of 236.92Mt TCE, which is about 3 times more than that of 1995, and its proportion to the country's total energy consumption has also rose to 7.47%.

Seen from the energy consumption structure, the energy consumption in transportation industry is mainly concentrated in the fuel consumption, which is constituted mainly of three refined oil: gasoline, kerosene, diesel fuel, where fuel oil's consumption is relatively small and crude oil consumption is even minimal. In 2008, the consumption proportions of gasoline, kerosene, diesel and fuel oil for the whole society are respectively 50.3%, 90.8%, 57.3% and 41.4%, representing respectively 21.4%, 8.13%, 52.4% and 7.68% of the transportation industry's total energy consumption. In other words, about 70% of the oil consumption in China is consumed by its transportation industry. From this, it is clear that, although the energy consumption of the transportation industry itself accounts only for a small part of the energy consumption in the whole society, its energy consumption exerts direct impacts on and determines the energy saving of the entire Chinese society.

The experiences from developed countries show that, the more developed the economy is, the greater transportation's proportion in the country's total energy consumption will be. In the next 10-20 years, China will be in a critical period of industrialization, urbanization and modernization, where, with the deepening of industrialization and urbanization, with the fastened mechanization, and with the rapid economic and social development, the demand for transportation will unceasingly grow, resulting in a rapid increase in transportation needs and services, and energy consumption in the transportation field will eventually enlarge the transportation energy consumption (especially consumption of petroleum products). At the same time, transportation as the key industry in oil consumption is one of the important sources of greenhouse gases and air pollution emissions. As the statistics of the United Nations Development Program (UNDP) show that, up to 2008, China's carbon dioxide emission reductions have accounted for about 1/3 of the global market. In the Copenhagen Climate Change Conference of 2009, China's government has determined a strategic deploy to actively tackle climate change, with a commitment to reduce its per unit GDP carbon dioxide emissions in 2020 by 40%-45% compared to that of 2005. Taken into account the facts that China's energy utilization rate in transportation at present on the whole is still 7.2% lower than that of the United States, and 10% lower than of Japan, therefore China's transportation industry still has a great energy-saving space. And as defined in "the Construction of low carbon transportation system guidance" by the government issued on February 21, 2011, the transportation is one of the three major industries with the characteristic of low carbon emissions, it is thus identified as a solution to the country's climate change working deploy. To help to achieve the above goal, it is of academic value and practical importance to investigate carbon emissions in China's transportation industry and to study its influencing factors, which will become an important premise to make contributions to energy saving and emission reduction in the whole society and to realize China's energy-saving and emission reduction plan.

2. Literature Review

Energy occupies a strategic position in a country's economy, especially in the development of its transportation industry. At the present, a number of scholars have used various forecasting methods and models to study and predict energy consumption and carbon emissions in the transportation, and some other scholars have set up some variable scenarios affecting energy consumption and carbon emission to unfold energy consumption and carbon emission prediction, where the impacts of energy price changes in the industry is becoming a major research theme. As for the energy-saving and emission reduction plan and target in China's transportation industry, if a study of international oil price's impact on the carbon emissions in its transportation industry is necessary, it is essential to study the double influence mechanism of international oil prices affecting indirectly on its carbon emissions in the transportation industry via domestic oil price, and to adopt certain forecasting methods and models to predict, at certain GDP level, international oil prices' impact factors and theirs influences on China's transportation industry.

Among the related researches on GDP and energy, China's economic development is heavily dependent on the levels of investment and energy use, and pointed out the existence of bilateral causality between its GDP and overall energy consumption (Yuan, Kang, Zhao & Hu, 2008). The three factors affecting the price of crude oil by EMD (Empirical Mode Decomposition): short-term fluctuations caused by daily imbalance between supply and demand or caused by other market activities, significant event shocks and long-term trends (Zhang, Yu, Wang & Lai, 2009). Through a comparison of proposed algorithms, the particle swarm optimization technology was suggested that it can effectively reduce the prediction error, and he then forecasted Turkey's energy supply and demand in 2025 (Unler, 2008). The energy efficiency is a key parameter for policies reduce energy consumption while maintaining or even enhancing economic growth, where the main option influencing energy efficiency is the change of relative prices, i.e. to increase energy prices or to introduce new technologies to increase the unit energy productivity through economic means (Prices, 2000). The panel data of about 2500 energy-intensive large and medium-sized industrial enterprises in China for the period 1997-1999 was analyzed. The results indicate that the enhancement of relative energy prices and the changes in China's industrial structure are the main driving force of decreases in China's energy intensity (Fisher, Jefferson, Liu & Tao, 2004). Such independent variables were selected as GDP, population and traffic (km) to develop a genetic algorithm model for transportation energy forecast (Haldenbilen & Ceylan, 2005). Energy efficiency is an important factor to develop the energy policy, and an empirical research on the influence of China's energy structure on its energy efficiency from 1978 to 2003 is mainly related to the preliminary estimation of the marginal efficiency and energy substitution rate of China's coal and oil (Han, Fan, Jiao, Yan & Wei, 2007). The impact of energy prices with time is asymmetry, and the industry adjustment leads to the decrease in total energy intensity (Hang & Tu, 2007). A forecasting for transportation energy in Turkey based on harmony search algorithm is undertaken (Ceylan, Ceylan, Haldenbilen & Baskan, 2008).

As for the academic efforts in China, scholars focused mainly on relative forecasting in two aspects of transportation energy consumption and carbon emission. Based on EMD (Empirical Mode Decomposition) combined with SVM (Support Vector Machine), energy consumption forecasting model was built, and the energy consumption conditions in China analyzed and predicted (Zhang & Jin, 2011). Energy demand and carbon emission of China's transportation system in different future scenarios is analyzed and predicted by using the LEAP (Laboratory Environmental Analysis Proficiency) model (Zhu, 2001). Economic and technological developments exert significant influences on the development trends of China's overall carbon emission (Qu & Guo, 2010). Through historical and economic growth data of transportation products in the transportation industry, and by linear regression method, Jiancui Liu studied the transportation products for China's future transportation industry, and she also calculated its energy consumption, carbon emissions and potential energy saving capability (Liu, 2011). Taoxin Zhang et al. put forward and elaborated the concept of low carbon city transport, and they then analyzed the energy consumption situation of China's urban transportation and carbon emission since 2000, and by these, they proposed some strategies and measures for the construction of urban low-carbon transport (Zhang, Zhou & Zhao, 2011). All the above have illustrated the importance and necessity to investigate the impacts of GDP, energy consumption and prices on the energy saving plan and its realization in China's transportation industry. As the goal of economic development is a sensitivity factor affecting total energy demand, the energy price changes will have either promoting or handicapping effects on the whole coordinated GDP economy development in the country.

Concerning the researches on the volumes of private car ownership, passenger and freight, with the development of national economy and GDP growth, China's transport demand will continue to increase, resulting in remarkable growth in regard to private car population, passenger and freight transportation volume in China's transportation industry. As the total freight volume of China's transportation has been ranked among the world's top three, and as the country is becoming a great transportation power, the industry has also become the third energy-consuming industry after the industrial and domestic consumptions. And this will certainly affect carbon emission in China's transportation industry. Zhang developed PLSR model to predict China's transportation energy, in which independent variables are GDP, urbanization rate, passenger transportation volume (persons per km), freight transportation volume (ton per km) (Zhang, Mu, Li & Ning, 2009). Zong Woo Geem applied artificial neural network model in the case of Korea's transportation energy demand prediction, where he took into account different independent variables such as population, GDP, oil price, vehicle registration and passenger transportation volume, and he then compared the forecasting results from the 5 variables regrouped into four groups models with those from the multivariate linear regression model (Geem, 2011). Tianrong Xie and Jing Wang studied and calculated the carbon emission and the unit turnover volume of various transportation modes, completed by carbon emission from main transportation method (Xie & Wang, 2011).

Based on the inventory guideline report of IPCC (Intergovernmental Panel on Climate Change), Yanan Xu and Zhiping Du calculated the carbon emission of China's transportation industry for the period of 1995-2008, and by STIRPAT model where they undertook a factor decomposition of carbon emission, where they conducted an analysis impact of demographic factors (divided into two groups by age) and economic factors on the transportation carbon emission (Xu & Du, 2011). Inspired by the classical STIRPAT model of carbon emission, Jianyue Ji and Jiaojiao Kongestablished a STIRFDT model for marine transportation industry while estimating the model parameters, and by China's Ocean-related data, they applied scenario simulation to China's marine transportation data to predict its carbon emission value and peak, and they proposed some emission reduction countermeasures and suggestions as well (Ji & Kong, 2012).

From the synthesis of the existing literature, it can be observed that the low carbon research on the transportation industry are relatively late and are of a limited nature, where the forecasting is conducted mainly from two angles: transportation energy consumption and carbon emission reduction, which include the relational model of energy consumption, carbon emission and their impact factors in order to undertake forecasting and to investigate carbon emission peaks in different scenarios. The models adopted in these efforts are mainly genetic algorithm, HS algorithm, multiple regression models, neural network model, SVM, STIRPAT model, etc. No doubt, the use of energy prices as a economic lever will play an active role in promoting the comprehensive, coordinated development of the national economy and in the sustainable development of the energy industry itself, where this lever will not only motivate all those are concerned, enhance economic development, improve efficiency, curb excessive demand, and guide consumption pattern transformation in our country as well (Chai, Guo & Wang 2012). All the above have laid the theoretical foundation and provided a valuable reference for this paper to forecast and to analyze carbon emission in the transportation industry in regard to the influence mechanism of international oil price on China's carbon emission in the industry. By these, this paper chooses five independent variables of GDP, international oil price, private car population, passenger and freight transportation volume as the impact factors to investigate the industrial carbon emission of the transportation industry.

3. Influence Mechanism and Analysis Method

3.1. Influence Mechanism

China's dependence on foreign petroleum is increasing year by year, where its dependence degree is reaching 50%. According to the current "Oil price management method (Trial)", the price adjustment principle for the refined oil pricing mechanism is that when the international oil prices is above $80 per barrel, the refined oil price will be calculated by the deduction of processing profits until zero profit. China's Development and Reform Commission also expressed similar approach, where the refined oil price adjustment is mainly based on the current pricing mechanism for domestic refined oil, taken into account also recent oil price changes in the international market. Up to July 9, 2012, the moving-average price in the international market for the three major crude oil types linked to domestic oil prices has fallen by more than 4% for 22 working days, reaching the boundary condition for domestic refined oil price adjustment. Therefore the international oil price fluctuation has an important reference value on the Chinese oil price adjustment, which will certainly exert a critical impact on China's transportation industry.

As international oil prices affect indirectly, by way of domestic oil price, on the influence factors associated with the carbon emission in China's transportation industry, they will eventually have impacts on its carbon emissions in the transportation industry. In some specific industries, the reduction of refined oil price will reduce the cost in such sectors as aviation, maritime, logistics and transportation as well as the chemical industry, and it will boost China's transportation industry, which will influence carbon emission in its transportation industry. Cutting oil prices is beneficial to further soften inflation pressures, and as the refined oil is the most important production material, its price reduction will help to economize industrial economic operation costs and thus will promote domestic oil price decrease, where these will stimulate China's GDP growth, support more private car population, and sustain more passenger and freight volume, which will eventually lead to carbon emission increase in China's transportation industry; conversely, the international oil price increase will cause domestic oil price to increase, handicapping indirectly China's GDP growth, and these will limit private car population, as well as passenger and freight volume, and which will finally exert impacts on the carbon emission in the transportation. In other words, for the influence mechanism of international oil price on carbon emission in China's transportation industry, the international oil price plays a double role, as shown in Figure 1.

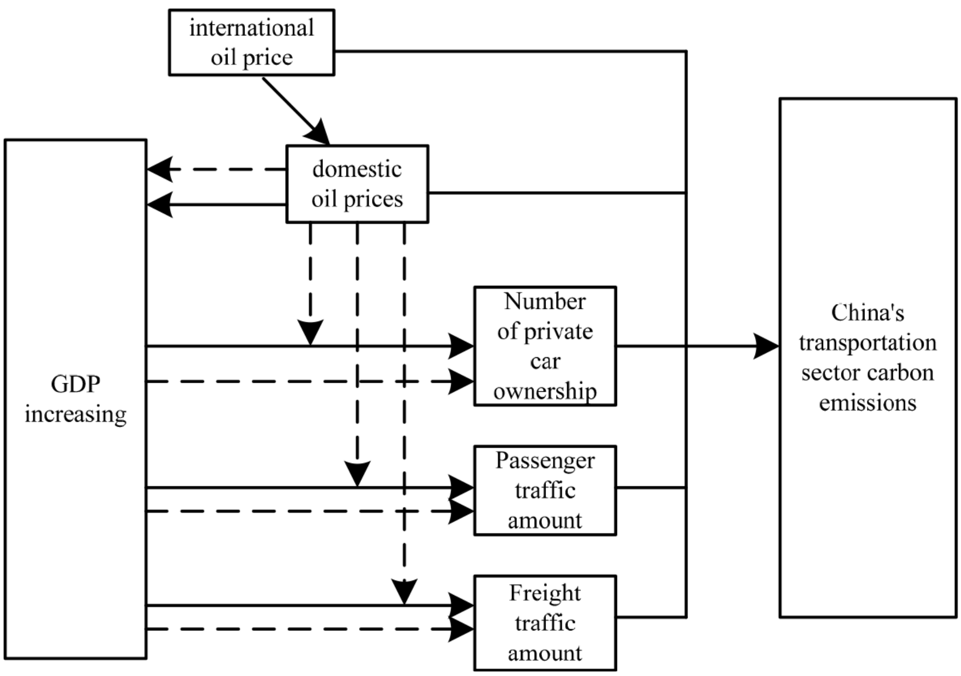

Figure 1. Influence Mechanism of Oil Price on Carbon Emissions

3.2. Analysis Method

According to the mechanism analysis shown in Figure 1, the international oil prices are highly correlated, in an indirective manner, to GDP, private car population, passenger and freight volume by influencing domestic oil price, which causes an information overlap of variable information influencing carbon emissions in China's transportation industry. Therefore, it is necessary to carry out their composition analysis, followed by regression analysis, then by the model to investigate explanation degree of the model variables on carbon emission, and finally to conduct the forecasting. Taken into consideration of the sample size problem of carbon emission data in China's transportation sector, this paper adopts the method of PLSR to study the influence factors of carbon emission in China's transport industry, and to observe its historical emission as well as its mechanism. It concerns mainly the regression model formation of multiple dependent and independent variables. In the case of highly internal linear correlated variables, it is more effective to utilize PLSR analysis to construct a model than to conduct multiple regressions for each dependent variable, where the conclusions of the former are more reliable and more integral. As the PLSR combines the advantages of three analysis methods, which are principal component analysis, canonical correlation analysis and multiple linear regression analysis, it will consider not only the information from independent variables, but also dependent variables as well. Therefore, it can effectively solve the existence of multi-collinearity problems among the independent and dependent variables in the multiple regression analysis, and in this case no special requirement for the sample size is needed (Wang, Ma & Zhai, 2011). The principal component analysis method aims at extracting maximum data reflecting the variation, while the PLSR method not only studies the independent variable matrix but also is a "response" matrix. Consequently, it is endowed with forecasting capability. And compared with LS (least square) or other modeling methods like neural network, the PLSR is simple, robust with less amount of calculations with higher precision, and it will not remove any explanatory variables or sample points. By all these advantages, the PLSR method can be effectively and widely applied in various methods of data analysis (Tang & Meng, 2011). As a result, it can help to construct more scientific and reasonable methods for carbon emission predictions in China's transportation industry, and to further consolidate the theoretical foundation for China's climate change policy formulation and effective participation in international climate change negotiations.

4. Data, Fitting Results and Carbon Emission Impact Forecasting Analysis

4.1. Data and Fitting Results

In this paper, the calculation of carbon emission is based on the final energy consumption statistics of China's transportation industry (1994-2011), and the transportation industry-wide carbon emission in 1994 -2011 is calculated by way of the emission factor method, the formula of which is as follows:

$$C=\sum_{i=1}^{n} E_i * f_{ci}, n=1,2,\ldots,n \quad (1)$$

Where C stands for the carbon emissions, E_i is the consumption of energy i measured by standard coal (TCE), f_{ci} is for the carbon emission coefficient of energy i. Shuyan Cao calculated carbon emission coefficients for diverse energies in China (Cao & Xie, 2010), in which the actual value of carbon emission coefficient for all energies except electricity and thermal energy is equal to their theoretical value (IPCC, 2010) and oxidized fraction (Beijing: Tsinghua University Press, 2001). The carbon emission coefficients of for electricity and thermal energy were comprehensively calculated by Shuyan Cao et al. whose calculations are based on the energy input, output, loss and power structure in the processing and conversion of electricity and thermal energy in 2007. In this paper, the results shown in Table 1 are directly referenced.

Energy	Actual carbon emission coefficients (t CO_2/tce)	Energy	Actual carbon emission coefficients (t CO_2/tce)
Raw coal	2.49	Diesel oil	2.17
Coke	2.98	Fuel oil	2.22
Crude oil	2.10	Natural gas	2.16
Gasoline	1.99	Power	6.11
Kerosene	2.05	–	–

Data Source: Shuyan Cao calculated carbon emission coefficients for diverse energies in China in 2010

Table 1. Actual Carbon Emission Coefficients of Energies

According to the formula (1) and carbon emission coefficients of energy shown in Table 1, and combined with the energy consumption of China's transportation industry shown in Table 2(a), this paper calculates the carbon emission in China's transportation industry for the period of 1994-2011, the results are shown in the last column in Table 2(b).

Energy / Year	Raw coal consumption (Mt)	Coke consumption (Mt)	Crude oil consumption (Mt)	Gasoline consumption (Mt)	Kerosene consumption (Mt)
1994	1873.44	7.31	52.97	900.16	200.01
1995	1315.10	10.10	156.77	982.30	250.01
1996	1175.94	6.64	159.00	991.32	298.86
1997	1431.20	6.47	164.69	1183.16	420.10
1998	1390.60	10.30	168.85	1216.61	390.48
1999	1294.26	10.14	169.49	1265.52	505.62
2000	1139.94	11.24	175.02	1387.79	536.40
2001	1050.88	11.68	169.81	1419.37	560.69
2002	1054.95	11.44	177.94	1503.00	616.74
2003	1067.33	10.79	148.31	1861.64	621.68
2004	832.12	1.79	123.82	2308.46	819.71
2005	815.34	1.07	126.87	2470.05	882.42
2006	724.80	0.85	163.66	2722.35	1000.54
2007	685.45	0.55	163.66	2763.19	1129.98
2008	665.41	0.29	165.66	3090.43	1174.59
2009	640.89	0.14	153.42	2881.59	1314.25
2010	639.04	0.12	158.00	3204.93	1601.08
2011	645.85	0.09	105.4	3373.52	1646.35

Table 2(a). Energy Consumption and Carbon Emissions of China’s Transportation Industry

Energy / Year	Diesel consumption (Mt)	Fuel oil consumption (Mt)	Natural gas consumption (Bm^3)	Power consumption (kW.h)	Energy consumption (Mtce)	Carbon emissions (Mt)
1994	997.89	227.63	1.30	164.04	56.26	106.75
1995	1246.56	227.45	1.57	182.30	58.63	104.27
1996	1261.06	224.46	4.01	197.83	59.94	103.18
1997	1379.53	582.23	3.70	255.88	75.43	130.00
1998	1901.93	565.56	3.68	255.63	82.45	140.18
1999	2221.65	840.00	4.80	254.78	92.43	154.11
2000	2543.81	850.00	5.81	281.20	99.16	162.32
2001	2671.01	855.00	5.96	309.32	102.57	165.72
2002	2964.80	872.10	6.37	338.00	110.86	177.30
2003	3485.20	940.29	6.82	396.94	127.40	200.60
2004	4182.24	1150.44	11.16	449.65	151.04	229.99
2005	5019.41	1161.02	16.43	430.34	166.72	251.42
2006	5747.32	1280.60	17.24	467.37	185.83	278.08
2007	6794.36	1389.95	16.89	531.91	206.43	309.61
2008	7649.31	1142.77	71.55	571.82	229.17	333.23
2009	7891.96	1250.64	91.07	617.01	236.92	341.90
2010	8518.56	1326.65	106.7	734.53	260.68	369.28
2011	9485.20	1345.16	138.35	848.42	285.35	398.04

Energy consumption are from the annual reports of National Bureau of Statistics of the People’s Republic of China 1996-2013
Note: Bm^3=billion m^3

Table 2(b). Energy Consumption and Carbon Emissions of China’s Transportation Industry

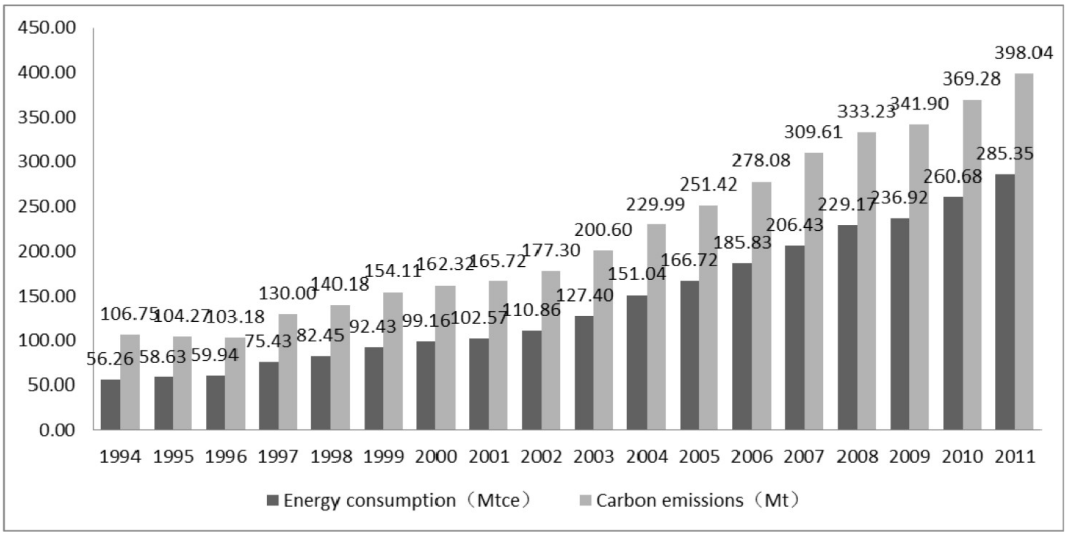

Figure 2. Energy Consumption and Carbon Emissions of China's Transportation Industry 1994-2011

Seeing from Figure 2, the total energy consumption of Chinese transportation sector has increased from 56.26Mtce in 1994 to 285.35Mtce Mt TCE in 2011; while carbon emission has increased from 106.75Mt in 1994 to 398.04Mt in 2011, which has shown remarkable similar development tendencies.

Variables / Year	GDP (Billion yuan)	Internaional oil price (yuan/ton)	Number of private car ownership (Million)	Passenger traffic amount (Billion persons)	Freight traffic amount (Billion ton)
1994	48108.5	3045.20	205.42	109.29	118.04
1995	53365.8	3055.33	249.96	117.26	123.49
1996	58706.9	3211.34	289.67	124.54	129.84
1997	64164.9	3138.40	358.36	132.61	127.82
1998	69191.2	2652.14	423.65	137.87	126.74
1999	74463.4	2860.82	534.00	139.44	129.30
2000	80741.7	3624.66	625.33	147.86	135.87
2001	87443.5	3383.55	770.78	153.41	140.18
2002	95385.2	3130.29	968.98	160.82	148.34
2003	104947.9	3559.82	1219.23	158.82	156.45
2004	115531.9	4112.94	1481.66	176.75	170.64
2005	128598.6	4878.80	1848.07	184.70	186.21
2006	144900.5	5367.09	2333.32	202.42	203.71
2007	165421.8	5685.18	2876.22	222.78	227.58
2008	181359.7	6367.97	3501.39	286.79	258.59
2009	198070.5	3952.88	4574.91	297.69	282.52
2010	218747.3	4111.00	5938.71	326.95	324.18
2011	238872.1	4275.44	7326.79	356.23	369.69

Data Source: China Statistical Yearbook 2012; http://www.docin.com/p-267488753.html

Table 3. Historical Data of Carbon Emission Impact Factors

The paper first constructs the corresponding numerical matrix of the five independent variables: GDP (x_1), the international oil price (x_2), private car population (x_3), passenger and freight transportation volume (x_4) (x_5), then the paper transforms it into a standard numerical matrix, which is then input into the PLSR prediction model to obtain an explained degree table as well as a correlation coefficient table for the dependent and independent variables. The two tables are shown respectively in Figure 3 and Table 4.

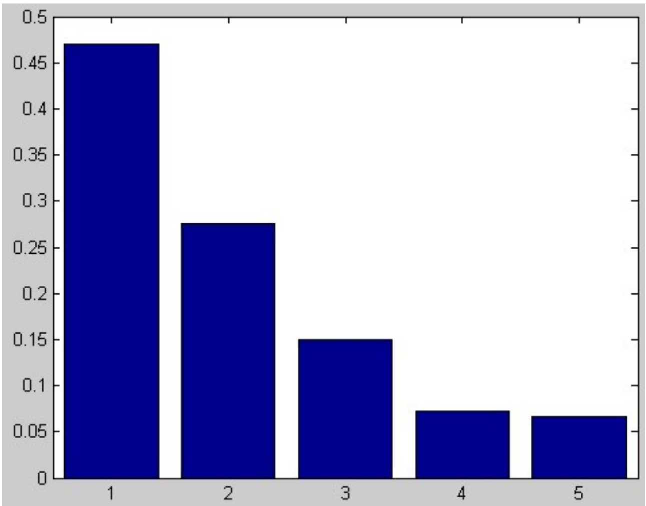

Figure 3. Explained degree of all independent variables

Correlation coefficient	y	x_1	x_2	x_3	x_4	x_5
Y	1.0000	0.8123	0.9832	0.9753	0.9840	0.9940
x_1	0.8123	1.0000	0.7498	0.7571	0.7897	0.8419
x_2	0.9832	0.7498	1.0000	0.9839	0.9967	0.9646
x_3	0.9753	0.7571	0.9839	1.0000	0.9864	0.9567
x_4	0.9840	0.7897	0.9967	0.9864	1.0000	0.9666
x_5	0.9940	0.8419	0.9646	0.9567	0.9666	1.0000

Table 4. Correlation coefficient table

It can be observed Figure 3 that, GDP's explained degree is the highest in the case of China's transportation carbon emission, followed by international oil price, private car population, and passenger and freight transportation volume. And from the correlation coefficient table for independent and dependent variables in Fig.3, the five independent variables (GDP, international oil prices, private car population, passenger and freight transportation volume) are highly correlated to one dependent variable (carbon emissions of China's transportation industry). The PLSR equation derived from regression model is:

$$y = 13.3548 + 0.0008x_1 + 0.0203x_2 + 0.0093x_3 + 0.1062x_4 + 0.1056x_5 \quad (2)$$

Among them, the regression coefficient for the international oil price shows that, when the other factors affecting carbon emissions of China's transportation sector do not change, the average change degree of carbon emission, as an independent variable, caused by the per unit change of international oil price is 0.0203, and they are positively correlated.

Input the historical data of relative dependent variables affecting carbon emission in Table 3 into the PLSR equation (2), the fitting result of the carbon emission forecast data of China's transportation industry from 1994 to 2011 with the original carbon emissions data is shown in Figure 4.

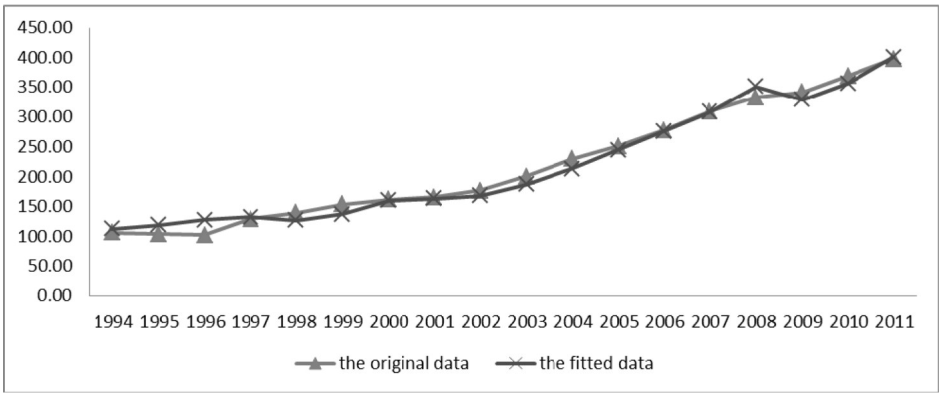

Figure 4. Fitting results of carbon emissions based on PLSR model

By comparing with the historical data 1994-2011 of carbon emission in China's transportation industry, it can be seen that, it is of significant effectiveness to use PLSR prediction model to fit the relationship between the carbon emission in China's transportation industry for the period of 1994-2011 and GDP, international oil price, private car population, and passenger and freight transportation volume.

4.2. Influence Prediction Analysis on Carbon Emissions

From the GDP data of 1994-2011 in Table 3, we know that China's annul average GDP growth rate is about 9%. The 17th session of the Fifth Plenary Session held by Communist Party of China in Beijing in October 2012 has pointed out, China's "12th Five-Year" plan is "having the scientific development as the major theme, and having the accelerated transformation of economic development mode as the main line", where annual growth rate is lowered, fixed at 7% as GDP's expected annual growth target.

The petroleum consumption growth rate of the whole society from 2000 to 2005 is 7.7%, while that of oil consumption in China transportation industry (including storage and postal services) in the same period is 12.0%, which is 4.3% higher that of social average energy consumption growth rate. By common international estimation, at present, the energy consumption of China's transportation industry accounts for about 10% of the total national energy consumption, where oil and gas, accounting for about 40 percent of national oil consumption, in which about 95% gasoline, 60% of diesel and 80% of kerosene are consumed by various types of transport. Severe energy situation requires more attentions to transportation energy saving and consumption reduction.

In consequence, according to relevant national policies and China's future economic development prediction, and based on the data of 2011, the paper maintains private car population, passenger and freight transportation volume to investigate international oil price's impact on the carbon emissions in China's transportation industry at different GDP levels, that is, to study the influence mechanism between GDP, international oil price and carbon emissions in China's transportation sector. Their inter-relationship is shown in Figure 5, where the vertical axis indicates the changes in carbon emissions, and there are two axes in the horizontal plane, one representing the energy change of international oil prices and the other one the change in GDP.

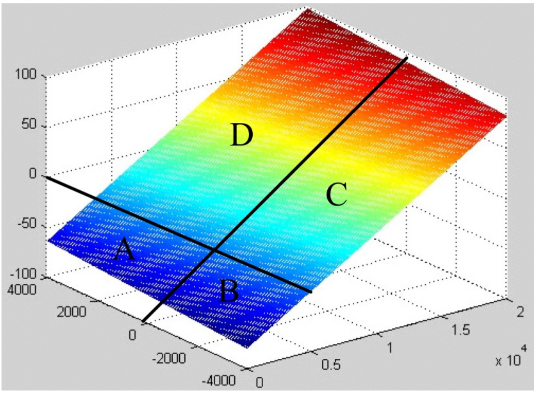

Figure 5. Relationship between GDP, International Oil Price and Carbon Emissions

From Figure 5, it can be observed that, if China's GDP still rises in future, carbon emission in China's transportation industry will continue to rise. In the case of moderate GDP growth, namely in area A and B, whether the international oil price is up or down, the value of carbon emission increase is always negative, i.e. carbon emission in China's transportation sector will decrease, and when the international oil price drops, namely in area B, carbon emissions decreases even faster, which may be due to the global economy as a whole tends to decline, although China's GDP slightly increased through investment, residents' disposable income may decline, therefore, in the region A and B traffic transport sector carbon emissions decline, and the decline in international oil prices shows that the continued economic weakness in Europe and America, adding to China's economic crisis, and thus the carbon emissions of the transport sector in the region B will decline faster; For the area A, China's transport sector within the next short-term in the structure of energy consumption changes not too large, China's new energy, alternative energy sources and renewable energy applications is relatively backward, and the consumption structure depending largely on oil affect its energy supply capacity, which may further lead to the international oil prices rising, and indirectly inhibit the increase of the GDP, thus result that the increase in carbon emissions of China's transportation industry value is negative.

In the case of substantial GDP growth, namely in area C and D, whether the international oil price is up or down, the value of carbon emissions increase is always positive, and when the international oil price rises, namely in area D, carbon emissions increases even faster. The substantial increase in GDP plays a role in boosting the carbon emissions of the transport sector, therefore, in the region C and D the transportation sector carbon emissions are increasing. The rising in international oil prices shows that Europe and the United States economy is out of the Depression, which will further stimulate the development of China's economy, so the carbon emissions of the transport sector in the region D are rising faster. At the same time, this may also be due that, in the foreseeable future, new energy technologies did not significantly reduce carbon emissions in the transportation sector in China; For the area C, this may be due to the development and use of new long-term energy and other alternative technologies, which will make the decreasing rate of the transportation industry, oil and other energy consumption may presented to the accelerated trend in international oil prices, and make international oil prices fall. However, China will indirectly inhibit GDP increasing probably because of the new energy technology innovation huge cost, which will lead to the increasing rate of China's transportation industry carbon emissions decline.

In addition, China's energy futures market which formats and impacts on energy pricing mechanism has only just begun, whose affecting capacity is limited. At present, China's energy through futures and spot imports completely passively accepts foreign energy market price mechanism, and is influenced by the "Asian premium" every year. China's energy reserves is smaller, and the existing energy reserves is mainly oil, which only meets the oil demand of 5-7 days. This further increases the difficulty in protecting the domestic energy supply. Therefore, the fluctuation in international oil price has thus an important reference value to petroleum price adjustment in China, and its dual influence mechanism is bound to exert a crucial impact on the carbon emissions of China’s transportation industry.

5. Conclusions and Recommendations

Through the analysis of the interaction mechanism between oil prices and variable factors affecting carbon emission in China’s transportation sector, this paper first establishes a PLSR model for carbon emission in transportation industry, GDP, international oil price, private car population, passenger and freight volume, the paper then analyzes the high correlation between carbon emission and its five influencing factors, and by constructing a linear correlation model, the paper explains the dynamic factors of the carbon emission in China's transportation industry, thus providing a reasonable and effective quantitative analysis method for historical carbon emissions in China's transportation industry, as well as its affecting factors. Finally, according to China's future economic development prediction and national policies in regard to climate change, this paper conducts a predictive analysis of the carbon emission in the transport sector with its influencing factors of GDP and international oil prices, and thus offering a directly description of carbon emission trend for the transportation industry in the near term.

At the "car, boat, road, harbor" meeting of low carbon transport special action review for 1000 enterprises and of the opening low carbon city transportation system pilot programs held on February 24, 2011, Hongfeng Gao, Vice Minister of Chinese Ministry of Transport, solemnly announced that, up to 2020, China will strive to achieve remarkable results in terms of structural low-carbon energy and technical energy saving, and realize the target of a decrease by 16% concerning operating trucks' energy consumption of unit transportation volume, that of operating ships by 20%, and that of port handling units by 10%, compared to that of 2005. And by these efforts, to construct a national transportation system in line with national policies to climate change and having the characteristic of low carbon emission. In view of this, and combined with the conclusions above, this paper proposes the following recommendations for energy saving plans and objectives in China's transportation industry:

Firstly, according to China's "12th Five-Year" plan to "have the scientific development as the major theme, and to have the accelerated transformation of economic development mode as the main line", it is advised that the annual average growth rate is moderately lowered, fixed at 7% as GDP's expected annual growth target. In the twenty-first Century, the explosive growth of China's heavy chemical industry and the national economic growth are all dependent on the high input, high consumption of energy resource. If, in the building process of all-around moderate prosperous society, China still advances with the traditional development model of high energy consumption with heavy industrialization and urbanization, it is unrealistic. The impact and contribution rate of structural factors on energy consumption for various industries is about 70% (Da, Zhou & Zhu, 2004), which shows the importance of energy consumption control in the realization of national economic development goals, in the optimization of its economic structure and in the transformation of its economic development mode, and China needs to get rid of the situation of relying heavily on the coal and the imbalance between supply and demand. Therefore, efforts should be made to promote the adjustment of energy-saving industrial structure, to accelerate the development of service industries, especially manufacturing services and new types of services, and to properly control the industrial sector growth rate, so as to moderate the negative energy-saving effect formed by the industrial structure adjustment. The attentions should be underlined concerning the optimization and adjustment of industrial structure within the industry, concerning the advances of new-style industrialization as the main direction of structural energy saving, and accents should be made to have a stricter control of growth rate in high energy-consumption industries and to further accelerate the development of industries with high added value and high-tech.

Secondly, if, in the medium and long term, international oil prices remain a negative growth tendency, it will reflect, from an aspect, the emergence of alternative energies or of new transportation methods and tools, new energy automobile for instance. This will effectively improve the energy consumption rate, having significant effects on the industry's carbon emissions. In recent years, the global renewable energy has witnessed a rapid development, whose technical applications have been in a constant growth of 10% -60% for the period 2001-2010, where the annual average of PV energy integrated into the national grid network in the past five years average is 60%, and that of biodiesel production growth is 51% (Beijing: China New Energy Chamber Commerce, 2012). In 2007, the "White Paper on China's Energy Conditions and Policies" stressed that any project included in the national energy planning, in addition to laws and regulations clearly prohibited, is all open to private capital. Remove the administrative monopoly to ease bottlenecks of private investment, encourage private capital to participate in the exploration and development of energy resources, oil and gas pipeline construction, and power construction, and continue to support the private capital to comprehensively access to new energy and renewable energy industry, improving energy universal service level.

Thirdly, the oil price formation mechanism should be in line with the international market. A complete refined oil price mechanism can clearly not limit itself to the industry cost compensation, but also it should pay attention to the price change trends with timely responses, rationalizing the price formation mechanism, and further advance the implementation of the reform of the price mechanism, contributing to guide the speculative behavior of market players towards the goal of supply-demand equilibrium (Liu & Chen, 2005). The construction of the oil price market is the key to the energy saving in China's transportation industry. Only by linking up with the international oil price system can the China's market integrate into the international supply and demand mechanism, where the resource scarcity can be correctly reflected to motivate spontaneous energy saving efforts. Meanwhile, the development of China's future energy or new energy industry needs to active participations in the international cooperation. China is assuming a rising leading position in the new energy cooperation with the United States, Russia and Japan, where an overall cooperation situation has been established with summit meetings to establish the strategic framework, the functional departments to provide policy support, and local governments and research institutions and enterprises to concretely implement (Kang, 2009). It is of great significance for China to effectively refer to the international energy price of oil, so as to promote energy saving in its transportation industry, to ensure China's energy security, to develop low carbon economy, and to realize its sustainable economic and social development.

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