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# Empirical Research on the Influencing Factors of the Low-carbon Economy Development in Heilongjiang Province - Extension based STIRPAT Model Analysis

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**Abstract:** The characteristics of low-carbon economy is to build the economy development system based on low energy consumption and low pollution, including low-carbon energy system, low-carbon technology and low-carbon industrial system, which takes reducing greenhouse gas emission as the target. The development of low-carbon economy is not only the objective requirement of improving energy utilization efficiency and adjusting economic growth pattern, but an important measure to tackle climate change and improve the happiness of people. On the basis of carbon emission estimation of primary energy consumption from 2000 to 2014 in Heilongjiang Province adopting carbon emission coefficient, this paper brings population structure and industrial structure into the STIRPAT model and conducts empirical research on the carbon emission in Heilongjiang Province and its influencing factors applying multiple regression quantitative analysis method. The results indicate that economic growth and improvement of urbanization rate exert evident positive impact on the increase of carbon emission in Heilongjiang Province while the energy intensity exerts inhibiting effect on the increase of carbon emission. Based on the results, this paper further proposes countermeasures and suggestions to realize the development of low-carbon economy like pushing industrial structural transformation, strengthening energy conservation and emission reduction technological innovation and reducing the cost of emission reduction.

***Keywords:*** *carbon emission; influencing factors; STIRPAT model*

## 1. Introduction

With the coming of economic new normal, fundamental changes have taken place in the economic growth mode in our country. It has been moving from resource and energy dependent to integration, high-end oriented and low-carbon. Provinces respond to the state's requirement of leading new normal, formulating medium and long term strategic developing plans to boost the development of low-carbon technique and industry and actively promote the low-carbon economy transformation. Heilongjiang Province, as a major province of energy in our country, possesses rich resources like coal, oil and natural gas. Therefore, we can see that energy industry has become one of the pillar industries in Heilongjiang Province. In 2014, the gross industrial output value in Heilongjiang Province reaches ¥1342.35 billion, of which heavy industry reaches ¥864.86 billion, accounting for 64.4% of total value. The rich resources in this region determine the way of energy consumption dominating by coal and oil consumption. According to statistics, the proportion of raw coal average consumption reaches up to 64.6% of the primary energy consumption from 2000 to 2014 in Heilongjiang Province.

The number for crude oil is 29.9% while the proportion of clean energy consumption, like water power and wind power is relatively low. This kind of energy consumption structure dominated by coal and supplemented by oil is not favorable for reducing carbon emission, bringing about the characteristics of big volume and rapid growth of carbon emission. This paper takes Heilongjiang Province as research object and explores its carbon emission intensity and influencing factors, which has important strategic significance for boosting the energy use efficiency and developing low-carbon economy; meanwhile, the research achievements have certain value for the old industrial bases in central and western regions to some extent.

## 2. Research Method and Data Sources

### 2.1. Research Method

At present, there exist three methods in terms of the research on the influencing factors and influencing degree of carbon emission: measurement model analytical method, input-output analytical method and index decomposing analytical method. Extensive researches have been done by scholars at home and abroad. However, most of the researches are carries out from the aspect of state or industry while empirical researches aiming at certain region. Therefore, this paper adopts measurement model analytical method and takes urbanization and industrial structure into account. Moreover, relevant data from 2000 to 2014 in Heilongjiang Province is selected and multiple regression analytical method is adopted to conduct quantitative research on the carbon emission in Heilongjiang Province and its influencing factors.

In environmental economics, Erlich et al. first proposed the environmental load model (IPAT model): I=P*A*T to reflect the relationship among environmental impact (I) and population (P), economic growth (A) and technological level (T). Later, Dietz et al. built random model (STIRPAT model) on the basis of IPAT model and conducted relevant researches through the change of random model on non-proportional influencing factors like population and carbon emission, the model of which is:

$$I=kP^aA^bT^ce \quad (1)$$

In formula (1), I,P,A and T represents environmental impact, population, economic development and technological level respectively; k is the coefficient of this model; a,b and c is the driving index for population (P), economic growth (A) and technological level (T); e is the random error of the model. When 1=b=c=1, the STIRPAT model is equal to IPAT model. The different levels of impact on environment by three driving factors, the population, economic development and technological level are reflected through index introduction, which solves the proportionate variation problem in the IPAT model.

This paper adopts extended STIRPAT multivariable nonlinear model, taking urbanization and industrial structure into consideration. On the one hand, city is the concentration of population, energy consumption and carbon emission. On the other hand, city is also the frontier of technological innovation and energy conservation and emission reduction. The level of urbanization will undoubtedly exert impact on the carbon emission; in addition, different industrial structure will lead to different energy consumption and carbon emission. The final energy consumption of secondary industry reaches up to 60%. Therefore, in area where the secondary industry holds higher proportion, the amount of carbon emission will be larger. This paper selects five indexes, the population, urbanization rate, GDP per capita, industrial structure and energy intensity as the influencing factors of carbon emission in Heilongjiang Province based on the comprehensive consideration of energy consumption and present economic and social situation in Heilongjiang Province. This paper uses population and urbanization rate to represent population index (P); uses GDP per capita and proportion of secondary industry to represent economic growth index (A); uses energy intensity to represent technological level (T). Based on the above-mentioned analysis, the STIRPAT model of carbon emission and driving factors is:

$$C=kPa1Ua2Ab1Ib2Qce \quad (2)$$

In formula (2), C represents the amount of carbon emission (10,000 tons standard coal) and is the measurement index of environmental impact; k is constant term; P is population (10,000 people); U represents the urbanization rate (%), measuring by the proportion of urban population with the total population; A represents GDP per capita (Yuan); I represents industrial structure (%), measuring by the proportion of secondary industry GDP with total GDP; Q represents energy intensity, measuring by the energy consumption per unit GDP (t standard coal/ 10,000 Yuan); e is random variable. $a_1$, $a_2$, $b^1$, $b_2$ and c are independent variable elastic coefficient. To facilitate the research and take the logarithm of time series data, linear function model is transformed:

$$Ln(C)=Ln(k)+a1Ln(P)+a2Ln(U)+b1Ln(A)+b2Ln(I)+c\,Ln(Q)+Ln(e) \quad (3)$$

### 2.2. Data Sources and Processing

The data needed in this research all comes from the *Statistical Yearbook of Heilongjiang Province* from 2001 to 2015. To avoid the impact of price change on economic variable, the nominal GDP of each year is measured at comparable price by taking 1990 base period. At the moment, the statistical agencies in China haven't released the data of $CO_2$ emission. There exist three main measurement methods of carbon emission: carbon emission coefficient method, life cycle method and environmental input and output method. The carbon emission coefficient method is the most widely method. The Energy Research Institute of National Development and Reform Commission has given the carbon emission coefficient of primary energy and listed the concrete calculation method of carbon emission. This paper adopts this method to calculate the carbon emission of energy consumption in Heilongjiang Province. The specific formula is:

In this formula, C represents the total amount of carbon emission of energy consumption; $E_i$ is the consumption amount of i energy; $c_i$ is the carbon emission coefficient of i energy. This research mainly calculates the carbon emission of primary energy consumption (coal, oil, natural gas, water power and wind power). Because there is no carbon emission in the consumption process of water power and wind power, the carbon emission coefficient is 0 and the carbon emission coefficient of other energy is shown in Table 1. We can calculate the carbon emission of each year based on the primary energy consumption and the carbon emission coefficient of energy.

***Table 1**: Carbon emission coefficient of energy*

| Variety of energy | Raw coal | Crude oil | Natural gas | Water power/wind power |
|---|---|---|---|---|
| Carbon emission | 0.7476 | 0.5825 | 0.4435 | 0 |

After processing and calculation, the original data of carbon emission and various influencing factors from 2000 to 2014 in Heilongjiang Province is shown in Table 2.

***Table 2**: Original data of carbon emission and various influencing factors from 2000 to 2014 in Heilongjiang*

| Year | Carbon emission (10,000t standard coal) | Population (10,000 people) | Urbanization rate (%) | GDP per capital (Yuan) | Industrial structure (%) | Energy intensity (standard coal/ 10,000 Yuan) |
|---|---|---|---|---|---|---|
| 2000 | 3778.91 | 3807 | 51.9 | 8901.1 | 55.0 | 1.797 |
| 2001 | 3873.56 | 3811 | 52.4 | 9328.0 | 52.3 | 1.720 |
| 2002 | 4157.50 | 3813 | 52.6 | 10153.7 | 50.7 | 1.706 |
| 2003 | 4243.68 | 3815 | 52.6 | 11141.3 | 51.4 | 1.555 |
| 2004 | 5128.20 | 3817 | 52.8 | 12673.7 | 52.4 | 1.582 |
| 2005 | 5173.68 | 3820 | 53.1 | 15075.6 | 53.9 | 1.382 |
| 2006 | 5210.76 | 3823 | 53.5 | 16854.5 | 54.2 | 1.233 |
| 2007 | 5434.30 | 3824 | 53.9 | 18630.2 | 52.0 | 1.120 |
| 2008 | 5738.20 | 3825 | 55.4 | 21757.6 | 52.0 | 1.015 |
| 2009 | 5775.62 | 3826 | 55.5 | 23675.8 | 47.3 | 0.986 |
| 2010 | 6522.13 | 3833 | 55.7 | 27519.5 | 48.4 | 0.932 |
| 2011 | 6796.98 | 3834 | 56.5 | 32785.9 | 47.4 | 0.800 |
| 2012 | 6774.47 | 3834 | 56.9 | 36576.1 | 44.1 | 0.733 |
| 2013 | 6463.83 | 3835 | 57.4 | 38982.9 | 40.5 | 0.672 |
| 2014 | 6191.68 | 3833 | 58.0 | 40860.2 | 36.9 | 0.620 |

Annotation: the data source is the *Statistical Yearbook of Heilongjiang Province* of each year; GDP per capital is calculated at comparable price taking 1990 as base period; urbanization rate is calculated by permanent resident population.

The unit of measurement of each index is different; this paper adopts Z-score method to conduct standardized processing of original data to avoid dimensional difference. The data acquired is shown in Table 3.

***Table 3**: Evaluating value of original data after standardized processing*

| Year | C | P | U | A | I | Q |
|---|---|---|---|---|---|---|
| 2000 | -1.58 | -1.76 | -1.30 | -1.14 | 1.10 | 1.49 |
| 2001 | -1.49 | -1.33 | -1.05 | -1.10 | 0.59 | 1.30 |
| 2002 | -1.21 | -1.11 | -0.96 | -1.02 | 0.28 | 1.26 |
| 2003 | -1.13 | -0.90 | -0.96 | -0.94 | 0.41 | 0.89 |
| 2004 | -0.28 | -0.68 | -0.86 | -0.80 | 0.61 | 0.96 |
| 2005 | -0.23 | -0.36 | -0.71 | -0.59 | 0.89 | 0.47 |
| 2006 | -0.20 | -0.04 | -0.51 | -0.43 | 0.95 | 0.11 |
| 2007 | 0.02 | 0.07 | -0.32 | -0.27 | 0.53 | -0.17 |
| 2008 | 0.31 | 0.18 | 0.42 | 0.01 | 0.52 | -0.43 |
| 2009 | 0.34 | 0.29 | 0.47 | 0.18 | -0.37 | -0.50 |
| 2010 | 1.06 | 1.04 | 0.56 | 0.52 | -0.16 | -0.63 |
| 2011 | 1.33 | 1.15 | 0.96 | 0.99 | -0.35 | -0.95 |
| 2012 | 1.31 | 1.15 | 1.15 | 1.33 | -0.98 | -1.12 |
| 2013 | 1.01 | 1.26 | 1.40 | 1.54 | -1.67 | -1.27 |
| 2014 | 0.75 | 1.04 | 1.69 | 1.71 | -2.36 | -1.39 |

Annotation: C represents carbon emission; P represents population; U represents urbanization rate; A represents GDP per capital; I represents industrial structure; Q represents energy intensity.

## 3. Empirical Research

### 3.1. Analysis of Carbon Emission and Change of each Influencing Factors

Scatter diagrams are drawn based on C with P, U, A, I and Q respectively (Figure 1). From 2000 to 2011, the overall carbon emission in Heilongjiang Province has shown a rapid growth trend and reached its peak in year 2011 with 67.9698 million 10,000t standard coal; since 2012, the carbon emission has gradual declined. Overall, evident positive correlation can be detected between carbon emission and population, urbanization rate and GDP per capital in Heilongjiang Province based on Figure1. In other words, the carbon emission in Heilongjiang Province increases with the increase of population, urbanization rate and GDP per capital. We can see from this Figure that the energy intensity in Heilongjiang Province decreases year by year. That is to say, the GDP produced by unit energy consumption increases year by year. Reverse relationship is bend found between energy intensity and carbon emission, which shows certain inhibiting effect on carbon emission. The proportion change of GDP created by secondary industry with the total GDP is irregular, but is on the decline on the whole. In recent years, the GDP created by tertiary industry in Heilongjiang Province is on rise year by year, dominating by service industry and tourism industry, which has little dependency on coal and oil. Therefore, it has certain inhibiting effect on carbon emission, but cannot change the overall rising trend of carbon emission.

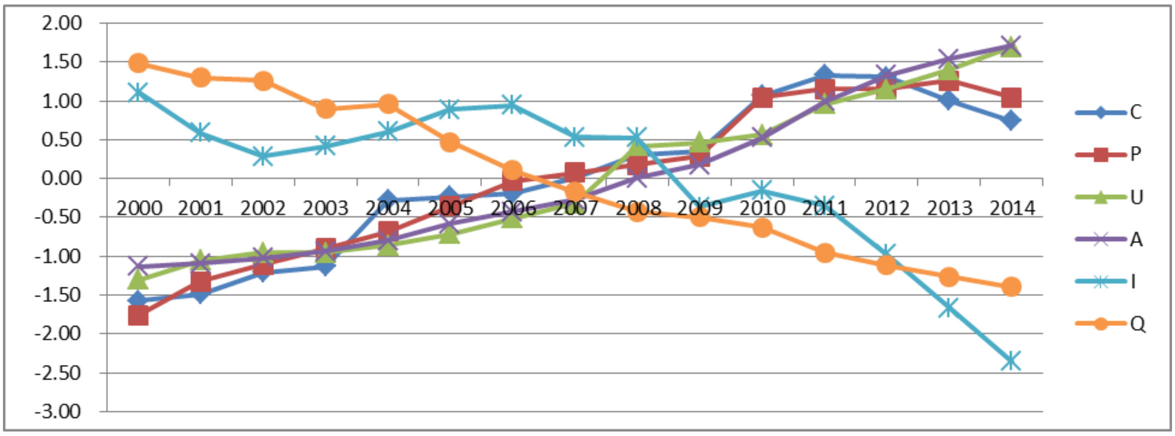


***Figure 1**: Variation trend of carbon emission and influencing factors from 2000 to 2014 in Heilongjiang province*

### 3.2. Empirical Research of Driving Factors

The measurement model of carbon emission influencing factors is built based on formula (3). Multiple regression analysis is conducted based on the data in Table 3. Least square method (OLS) processing adopting SPSS 22.0 analysis software and the result is shown in Table 4 to Table 6.

***Table 4**: Model summary*

| Model | R | R square | R square after adjustment | Standard skewness error |
|---|---|---|---|---|
| 1 | .990[a] | .981 | .970 | .17433 |

***Table 5**: Analysis of variance*

| | Model | Square sum | df | Average value square | F | Significance |
|---|---|---|---|---|---|---|
| 1 | Regression | 13.759 | 5 | 2.752 | 90.542 | .000[b] |
| | Residual | .274 | 9 | .030 | | |
| | Sum | 14.032 | 14 | | | |

***Table 6**: Coefficient[a]*

| Model | | Unstandardized coefficient | | Standardized coefficient | T | Significance |
|---|---|---|---|---|---|---|
| | | B | Standard error | Beta | | |
| 1 | (Constant) | .001 | .045 | | .022 | .983 |
| | Ln (P) | 1.112 | .239 | 1.112 | 4.653 | .001 |
| | Ln (U) | .484 | .382 | .483 | 1.265 | .238 |
| | Ln (A) | .317 | .347 | .317 | .913 | .385 |
| | Ln (I) | .392 | .148 | .392 | 2.644 | .027 |
| | Ln(Q) | .608 | .349 | .607 | 1.741 | .116 |

Results of regression modeling needs to be tested next. The first is test of goodness of fit ($R^2$ testing). If the results are closer to 1, then the fitting effect of this regression model is better. We can see from Table 4 that the $R^2$=0.970 after adjustment, which indicates the goodness of fit of this regression equation is high. Then, significance testing of equation of the results are conducted (F testing). We can see from Table 5 that the F value is 90.542. This regression result can indicate the existence of linear relationship between variable carbon emission (C) and all explaining variables through joint testing. However, we can see form Table 6 that the t value of some explaining variables cannot pass the testing and the the coefficient of industrial structure and energy intensity is positive number. The practical data is inconsistent with the experience. Therefore, judgment can be made that multiple co-linear problems exist in the regression equation. Based on this, adjustment need to be made on the original regression model. According to the degree of correlation between variables, some explaining variables are removed adopting stepwise regression method. Finally, regression equation that has fine fitting effect and is able to pass the testing is determined as follow:

$$Ln(C)=0.477Ln(A)+0.291Ln(U)-1.156Ln(Q)+k \quad (4)$$

## 4. Conclusion and Solutions

For recent years, with advancing economy and society and booming population, the carbon emission in Heilongjiang province has kept rising steadily, which mainly results from the per capita GDP(A), urbanization rate(U) and energy consumption intensity (Q) based on the above regression analysis. The rise of 1% of per capita GDP and urbanization rate leads to 0.477% and 0.291% more of the total carbon emission amount of the province. And the elastic coefficient of the energy intensity is -1.156, which means the lowered energy consumption per unit GDP helps decrease the carbon emission. The most effective method of reducing carbon emission is to raise the energy use rate.

(1) Among factors that may increase the carbon emission, per capita GDP has the biggest elastic coefficient, meaning that the economic growth is the main reason for carbon emission increase for recent years. In Heilongjiang province, the traditional and heavy industry base in China, the second industry such as steel, oil and chemicals, equipment manufacturing and building materials takes up a relatively big proportion of the economic structure (no less than 50% before recent years), becoming the driving force of the economic development of this province. However, these industries, with high energy consumption and heavy pollution, lead to sharp increase of carbon emission. Heilongjiang province has long been troubled by the dilemma between economic growth and carbon emission. Thus, the industrial structure should be adjusted to strictly limit the excessively fast growth of high energy-consumption and emission industries with excessive production capacity and to die out lagged production capacity. Also, great efforts should be made to conduct major energy-conserving and carbon-reduction projects and to tighten management on the energy conservation by major energy-consumption departments. Only in this way, can we achieve the balance between medium-high speed economic growth and low carbon emission.

(2) The rise of urbanization rate has significant influence on the carbon emission of Heilongjiang province. On the one hand, the raised urbanization rate may increase the energy consumption and enlarge the economic scale which leads to more carbon emission. On the other hand, the urban development gathers population, capital and technology, helpful to technological innovation and spreading and to form the scale effect of input factors for energy conservation and emission reduction such as capital, human resources, technologies and equipment for a lower emission reduction cost. In 2014, Heilongjiang witnessed the urbanization rate of 58.01%, higher than the national average rate of 54.77%, but witnessed the per capita GDP of 40860.2 yuan, much lower than the national average level of 46629 yuan, which demonstrates the obvious discrepancy of economic development level and urbanization rate. For Heilongjiang province, the continuing urbanization drive has pushed strongly its economic development, but barely helped the technology innovation in carbon emission reduction and cost lowering. Thus, urbanization quality should be raised to enhance the positive influence of urbanization on the carbon emission reduction.

(3) The energy intensity index shows the dependency degree of economic growth on the energy consumption and is used for represent the regional technological level. As technology advances, energy intensity keeps decreasing. In this sense, the decrease of energy consumption per unit GDP leads to less carbon emission. In 2000 to 2014, the energy intensity of Heilongjiang province kept decreasing, which means the government began to prioritize the upgrading of economic growth pattern and gradually changed the previous development model over dependent on energy and resource consumption. However, the current technology just helps decrease carbon emission slightly, and cannot change its increasing trend with each passing year. Thus, the government should accelerate researches on carbon-free technology, develop clean energy and renewable energy and push the transformation of energy consumption structure. Moreover, researches on and development of carbon-removing technology should be enhanced such as carbon capture, utilization and storage technology to increase carbon sink.

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The Study on the protection mechanism of forest carbon sink industrialization development after the natural forest resources protection project in Heilongjiang Province (12db-10).

## References

[1]Xueshi Liang, Li Li, Impact of Urbanization on Carbon Dioxide Emissions in Heilongjiang Province Based on Ridge Regression, Territory & Natural Resources Study, No.4, 30-32, 2015.

[2]Xiaohang Bi, The impact Mechanism of Urbanization on Carbon Emissions, Shanghai Journal of Economics, No.10, 97-106, 2015.

[3]Lihong Xie et al, Analysis on industrial energy carbon emission factors decomposition and emission reduction in Heilongjiang Province, Territory & Natural Resources Study, No.1, 50-52, 2013.

[4]Jun Qin, Muyao Tang and Xueli Liu, The Grey Comprehensive Evaluation on the Development

of Low-Carbon Economy, Ecological Economy, Vol. 30, No. 4, 14-28, 2014.
[5]Shuguang Wang, Wenmei Wang, The Impact of Carbon Emissions and Fiscal Policy Suggestions in Heilongjiang Province based on the Low-Carbon Economy Perspective, Journal of Harbin University of Commerce (Social Science Edition), No.2, 92-103, 2015.
[6]Yeying Hong, Sijie Xiang and Jinxin Chen, Impact of Demographic Factors on Carbon Emission in Chongqing City : A Study base on Stirpat Model, Northwest Population Journal, No.3, 13-17, 2015.
[7]Shuhua Liu, Xuehong Tan, Mei Chen, Driving Factors Analysis of Carbon Emissions Based on STIＲPAT Model, A Case Study of Heilongjiang Province, Resource Development & Market,vol.30, No.9,1086-1091, 2014.
[8]Jingxia Cai, Xiuhui Qi, Penghua Qiao, Carbon Emission and Economic Growth—An Empirical Analysis and Test Based on Heilongjiang Province, Science and Technology Management Research, No.4, 214-218,2013.
[9]Ying Li, Regional Energy Consumption, Carbon Emissions and Economic Growth-An Empirical Analysis Based on the Decoupling Theory, Journal of Industrial Technological Economics, No.8, 31-39, 2015.
[10]Weixing Hou, Jianzhong Gao, Empirical evaluation of city low-carbon economy based on factor analysis, Taiyuan sample, Enterprise Economy, No.6, 15-19, 2012