# Research on Influence Factors of Carbon Emission Based on STIRPAT Model in Jilin Province

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**Abstract**
A method was used to assess carbon emission to calculate the total carbon emission in Jilin Province in addition to describing. IPAT model and STIRPAT model were combined to confirm the main influence factors that affected carbon emission from three aspects, which were wealth per capita, population and social and technological progress. Moreover, the carbon emission influence factors were verified and analyzed based on ridge regression model. According to above analysis, the final conclusion is that population, wealth per capita and social and technological progress affect carbon emission in Jilin. Population had a greater influence while effect by wealth per capita was relatively lesser.

**Key words:** *carbon emission; ridge regression; STIRPAT model; influence factors; Jilin Province*

## 1 Introduction

As the social economy develops, people gradually require more energy sources every year. After entering Industrial Revolution, developed western countries similar to the UK required more and more coal. The great amount of burnt coal caused greenhouse gases and harmful gasses. London also was known as "City of Smog". Until 1952, heavy smog led to taking many lives of Londoners, which eventually made the British government determined to solve the "poisonous smog" issue. Not only the UK, but various countries in the world sped up economic development after industrial revolution, facing with issues in energy consumption. Energy consumption caused global warming, melting glaciers and rising sea level. The environment deteriorated, becoming the accessory of increased concentration of carbon dioxide. At that time, the "low carbon" concept emerged. It is urgent to study influence factors of carbon emission as they have important and practical significance.

Abnormal global climate and severe environmental pollution have triggered attention from many scholars to conduct in-depth studies in carbon emission problem. Regarding energy consumption, in the perspective of economic development, A. S.Pereira et al.[1] (2016) studied and assessed energy consumption and carbon emission by Brazilian residents. The final results indicated that population that overcome poverty could affect the scale of growing energy source demand.Regarding population, B. Liddle[2] (2014) analyzed the effect of population scale, age structure, urbanized level and population density on carbon emission and energy consumption. The final result showed that the family scale and population density had negative correlation to energy consumption and carbon emission. This means the larger family scale or the higher population density is, the lesser energy consumption and carbon emission was shown. Urbanized level showed positive correlation with energy consumption and carbon emission. in the perspective of energy consumption, L. Yan [3] (2015) analyzed industrial structure in developed and developing countries. From that, difference and variation trend of carbon emission levels were found under different industrial structure. For developed countries, Germany and Japan had low carbon emission while developing countries emitted more carbon than developed countries. This is because developed countries have already stepped into post-industrialization development. Economic development relies more on tertiary industry and industrial industry is more reasonable. To sum up, domestic and international scholars have conducted thorough research in carbon emission mainly from aspects of energy consumption, population, and economic development. For energy consumption, a lot of scholars suggested changing the method of energy supply and industrial structure in order to lower energy consumption. Regarding population, scholars researched how population structure influences carbon emission. Plenty of scholars believed that social development and technological progression are advantageous in suppressing carbon emission, but others argued that speeding up social development and increasing per capita income promote carbon emission. Thus, further studies need to be conducted.

## 2 Analysis of current carbon emission status in Jilin

### *2.1 Calculation of total carbon emission in Jilin*

In the last century, the environmental pollution problem was getting worse day by day in western developed countries. Many scholars realized the importance of measuring and calculating carbon emission so the governments and relevant organizations in the developed countries finally confirmed the standard system and methods for calculating carbon emission after conducting a great amount of researches. Regarding standard system, there are two types of carbon emission calculations that are currently used internationally. One is a standard system of top-down carbon emission calculation whereas the other one is a standard system of down-top carbon emission calculation. The former is proposed according to “IPCC National Greenhouse Gasses Guide” with specific method that conducts primary classification through carbon emission source in China. On the basis of this classification, it is further classified into primary level. The breakdown of carbon emission source is achieved through levelled classifications for the convenience of calculation. Moreover, this type of method can accord to the data in “IPCC Guide” so that the final calculated results are persuasive and comparable. Bottom-top carbon emission calculation is in a microscopic perspective based on the accounting system of a company. This means summary is conducted at the lowest level and the ultimate summary is national or government data. What is worth noticing is that the main inspected object of this type of bottom-up calculating system is the enterprise and the accuracy of total carbon emission calculation is relatively low. Thus, top-bottom standard system is mostly used as the method to calculate the total carbon emission in a certain country or region.

Using the example of total carbon emission calculation provided by “2006 IPCC Greenhouse Gases Guide”, this method stated that through calculating carbon emitted from burning various types of energy sources and totally this value, the total carbon emission generated from burning fossil fuel can be achieved. Its formula is:

$$EC = \sum E_i \times \delta_i \quad (1)$$

In the above formula, EC is total carbon emission and is the consumption quantity of various fossil fuel types and ten thousand tons of standard coal turned from fossil energy. It shows the carbon emission coefficient of various types of fossil energy. From the above formula, it can be seen that the carbon emission of various types of fossil energy is the product of the consumption quantity of ten thousand tons of standard coal turned from fossil energy and its carbon emission coefficient. It is obvious that carbon emission coefficient has an important function in the calculation of carbon emission. The carbon emission coefficients from authorities are different but not by much. In order to have a more accurate carbon emission coefficient, these coefficients on authorities become weighted average, which becomes the final carbon emission coefficient. Currently, four research institutes have published the carbon emission coefficients of various energy types. These four institutes are Energy Research Institute of National Development and Reform Commission, Climate Change Project of State Science and Technology Commission, the Institute of Energy Economics, Japan and the US Energy Information Administration (EIA). Carbon emission of all energy consumption types published by each research institute can be seen in table 1：

*Table 1* – Carbon emission coefficient

| Research insititute | Coal | Oil | Gas |
|---|---|---|---|
| Energy Research insititute national development and reform commission | 0.748 | 0.583 | 0.444 |
| National Science and Technology Commission Climate Change Project | 0.726 | 0.583 | 0.409 |
| Energy Economics Institute of Japan | 0.756 | 0.586 | 0.449 |
| EIA | 0.702 | 0.478 | 0.389 |
| Mean | 0.733 | 0.588 | 0.423 |

In addition, this paper used primary energy consumption for calculation. Therefore, there is no carbon emission coefficient of electricity.

### *2.2 Analysis of total carbon emission in Jilin*

According to the earlier introduction of carbon emission calculation method, carbon emission in Jilin from 1978-2014 was calculated. The situation of carbon emission in Jilin was divided into four stages:

The first stage is from 1978 to 1997. In this stage, the annual growth rate of total carbon emission in Jilin was very slow, and thus this stage is called the slow rising phase of carbon emission. The second stage is between 1998 and 2000, when Jilin showed annual declining trend in total carbon emission, but difference in total emission is not much. Therefore, this stage is called the slow declining phase of carbon emission. The next twelve years make up the next stage, which had a long duration time. Carbon emission increased rapidly. This stage may be called the rapid rising phase of carbon emission. From 2012 to 2014, Jilin’s carbon emission decreased with a quicker decreasing rate compares to the second stage. Thus, this period is called the rapidly declining phase of carbon emission.

It can be seen that from 1987 until now, total carbon emission in Jilin has shown a rising trend, and due to influence of economic development, Asian economic crisis affected China between 1998 and 2000. For a moment, Chinese economy was hurt and carbon emission also slightly decreased. After 2000, China and even Jilin entered the rapid development phase along with a rapid increase of carbon emission in Jilin. However, at this period, people realized the importance of environment. All countries and regions were discussing how to balance the relationship between economy and environment. Through several years of effort, carbon emission in Jilin shows a decreasing trend now.

### 3 Analysis of influence factors of total carbon emission in Jilin

As the development of IPAT model, DIETZ and ROSA proposed the STIRPAT model in 1994. STIRPAT model is expressed as follows:

$$I = aPbAcTde \quad (2)$$

In the above formula, I represent environmental pressure. In this paper, I represent carbon emission, P is population scale, T is technological progress, a is the coefficient of the model, b, c and d represent independent variables P, A and T respectively and e is residual. Finally, parameter estimation can be used to solve coefficient a and indexes b, c and d. A linear model is achieved in the end:

$$LNI=a+bLNP+cLNA+dLNT+e \quad (3)$$

This model shows that when every 1% change occurs in population size while other factors remain unchanged, environmental pressure will also change to b%. When every 1% change occurs in per capita wealth while other factors remain the same, environmental pressure will also change to c%. When every 1% change occurs in technological progress while other factors remain the same, environmental pressure will also change to d%.

Through the introduction of IPAT model and STIRPAT model, it can be seen that environmental pressure is mainly affected by population, per capita wealth, and technological progress. Therefore, the structure of index system in the model was considered in these aspects. Finally, population, tertiary industry proportion and per capita gross regional production were selected as the ultimate modelling variables. Analysis and results are shown in table 2.

*Table 2* –regression model

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 35.472 | 15.564 | 2.279 | 0.029 |
| LNpeople | -4.013 | 2.171 | -1.848 | 0.073 |
| LNpotation | -0.200 | 0.336 | -0.596 | 0.555 |
| LNwealth | 0.528 | 0.071 | 7.487 | 0.000 |

Through the above model, it can be seen that the P values of t test in parameter statistics of LNpeople and LNpotation are 0.073 and 0.555 respectively. Values above 0.05 do not pass the test. It is believed that colinearity existed between independent variables. Therefore, the model had to be revised. Ridge regression model is a regression method that conducts biased estimate on colinearity data. This can build a better model. The final k value is normally determined by k value variation chart, ridge tracing diagram and coefficient of determination with k value variation chart. See fig. 1 for specific ridge tracing diagram.

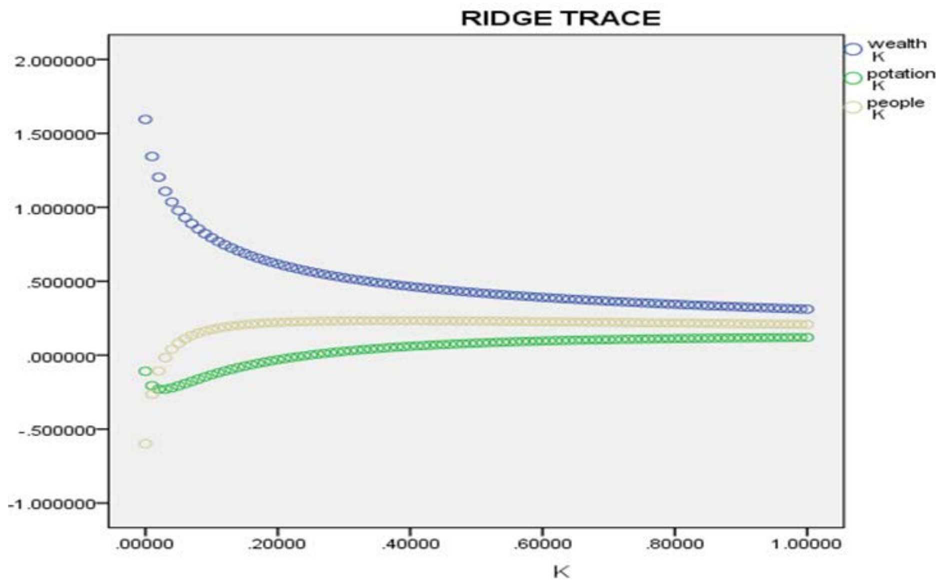


*Fig.1* – Ridge trace

From fig. 1, it is known that when the k value is 0.22, coefficient of determination in the equipment tends to be stable. The regression coefficient of independent variables LNwealth, LNpotation and LNpeople also become stable. The coefficients are 0.594, -0.017 and 0.225 respectively. The final equation achieved is:

$$\mathrm{LNY} = 0.594 \times \mathrm{LNwealth} - 0.017 \times \mathrm{LNpotation} + 0.225 \times \mathrm{LNpeople}$$

The regression result of ridge regression is the coefficient after standardization. For better application, a non-standardized ridge regression equation is always further sought for. Moreover, since standardized ridge regression model does not have constant term, appropriate conversions are needed for corresponding ridge regression equations. Their conversion formulae are:

$$\mathrm{b} = \mathrm{S}(\mathrm{LNY})/\mathrm{S}(\mathrm{LNwealth}) \quad (4)$$

$$\mathrm{c} = \mathrm{S}(\mathrm{LNY})/\mathrm{S}(\mathrm{LNpotation}) \quad (5)$$

$$\mathrm{d} = \mathrm{S}(\mathrm{LNY})/\mathrm{S}(\mathrm{LNpeople}) \quad (6)$$

In the above formulae, S(j) represents standard deviation of each variable and M(j) is the mean value of each variable. Relevant data are substituted in to calculate constant term and each parameter value. Through calculation, the following can be obtained

$$a = 7.795 - 0.032 \times 8.354 - 1.849 \times 3.41 - 6.707 \times 7.825 = -51.259 \quad (7)$$

$$b = 0.503/1.517 = 0.332 \quad (8)$$

$$c = 0.503/0.272 = 1.849 \quad (9)$$

$$d = 0.503/0.075 = 6.707 \quad (10)$$

From this, non-standardized ridge regression equation can be obtained:

$$\mathrm{LNY} = -51.29 + 0.332 \times \mathrm{LNwealth} - 1.849 \times \mathrm{LNpotation} + 6.707 \times \mathrm{LNpeople} \quad (11)$$

The above ridge regression equation was used in the analysis of carbon emission and variable response of driving factor in Jilin, and the following conclusion was achieved. The elastic coefficient of total carbon emission and per capita gross regional production in Jilin was 0.332. This means for every 1% increase in per capita gross regional production in Jilin, its total carbon emission rises 0.332%. The elastic coefficient between total carbon emission and proportion of tertiary industry in gross output is -1.849. This means for every 1% increase in proportion of tertiary industry in gross output in Jilin, its total carbon emission lowers 1.849%. To conclude, population has the greatest effect on carbon emission in Jilin followed by proportion of tertiary industry in gross output. The least effect is gross regional production by Jilin residents.

## 4 Conclusions

Industrial developments in Jilin are mainly automobile and petrochemical industry. Although they contribute enormously in Jilin's economic development, carbon emission increases due to high energy consumption and high pollution in these industries. Moreover, it is relatively lower when comparing the output value of tertiary industry with the well economic development in eastern region of Jilin. In other words, development between different industries in Jilin is imbalanced. The main development in this province mainly relies on industries that consume high energy and produce severe pollution. Industries of low energy consumption and low pollution are not prosperous and this caused and increase in total carbon emission in Jilin.

Since development in Jilin relies on industries, it is important to develop new energy resources, carry out energy conservation and emission reduction and to encourage companies to go on a low-carbon road. All of these require technological and social progress as footstone. Therefore, slow social and technological progress is an important factor that restricts Jilin to go for low-carbon development.

Jilin is located in northeastern part of China with cold weather in winter. Long-term heating is required. Heating in cities mainly adopts central heating, and this is achieved through burning coal. In rural areas, dried firewood and straw are burnt to keep warm. These types of heating method undoubtedly increase carbon emission. That is why smog is severe during winter in Jilin.

Jilin is known as Detroit in China with the reputation of automobile city. More people are willing to buy private cars and thus, car ownership is relatively higher than other regions. Of course, gas emitted from car exhaust also effects Jilin's carbon emission.

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