Analysis of the impact factors on carbon emission in Fujian province

Zhiyuan Liu*, Haoquan Tan, Fengrui Wang, and Xuemei You
School of Shandong Normal University, Shandong, China

*Corresponding author e-mail: liuzhiyuan@sdnu.edu.cn

Abstract. The constant increase in carbon dioxide emissions has caused many problems in environment as well as people’s health. As a big carbon emission country, China has responsibility to reduce them. Fujian province is an important region leading the development of west bank of straits, and it’s more necessary to build a low carbon economy at the same time. Based on the STIRPAT model, a new model of carbon emissions for Fujian province is build. Besides the population, economic, urbanization factors, a new factor evaluating the non-fossil energy is introduced into the model. The results show that our model can well fit the real carbon emission values. Several suggestions for reducing carbon emissions according to the results are proposed at last.

1. Introduction
Since the industrial revolution, the world economy has developed rapidly while carbon emissions have continued to increase. The increasingly serious problem that the global carbon emissions caused has attracted wide public concerns all over the world. Scientific researches show that the increase in carbon emissions is a major factor for global warming, sea level rise, greenhouse effects, bad weather as well as people’s health. Therefore, how to reduce carbon emissions become an imminent problem.

China, as a developing country, has caused a huge increase in carbon emissions. But as a responsible big country, China pledged to peak carbon dioxide emissions around 2030 and tried to reduce at least 60% emissions compared to those in 2005. Fujian province is located along the coast of Southeast China with a wide mountain area, facing Taiwan across the straights. Under the influence of the national policy and the Taiwan issue, it was on a war footing for a long time. Therefore, the economy of Fujian province started relatively late, but it has already stepped in a rapidly developing stage. The Carbon emissions of Fujian increased from 4480 million tons in 1996 to 22245 million tons in 2016, nearly 5 times. Exploring an efficient and rational way to achieve carbon emission reduction on the premise of ensuring sustained economic growth is conducive to the development of Fujian.

Factors like economic, population, urbanization are closely linked to carbon emissions. Studying the effect of a single factor on carbon emissions can help explore in detail this factor’s impact on carbon emissions in different periods more accurately, put forward measures and suggestions. Lwei Tang et al. [1] studied the nonlinear relationship between urbanization and life carbon emissions and concluded that there was a threshold effect between them. Changsha Tina et al. [2] studied the effect of population age structure on carbon emissions, and the result indicated that the future changes for population age structure in China have the possibility of slowing the acceleration of carbon emissions. Qiaoqiao Zhu et al. [3] analyzed the relationship between the carbon emissions from two kinds of industries. The result
showed that the positive impact of carbon emissions on industrial economic growth in the resource-based industries tends to go up and then go down.

There also exist studies about how multiple factors affect carbon emissions, and STIRPAT model is generally used. Xiamen Wang et al. [4] quantitatively analyzed the influence degree of each factor based on the extended model STIRPAT. Cacao Chen et al. [5] adopted STIRPAT model to evaluate the influence factors of carbon footprint on the urban energy consumption. Shenyang Shay et al. [6] also adopted STIRPAT model to analyze three levels of 125 nations’ data. It is concluded that the factors affect the degree of carbon emissions from large to small are affluence, technical level and population.

So far, there are not many studies on carbon emissions in Fujian province. Therefore, based on the STIRPAT model, our research analyzed how the multiple factors affect carbon emissions, and provided several measures to reduce them. The following sections are organized as follows. Section 2 describes the data, and the model construction and solution are described in section 3, then several suggestions are proposed for reducing carbon emissions in section 4 and finally is the conclusion.

2. Data description
The data of Fujian province from 1996 to 2016 used in this study are from the statistical yearbook of Fujian province issued by Fujian statistics bureau. The required parameters include permanent population at the end of the year, urban population, per capita GDP and regional GDP index, the added value of the secondary industry and the second industrial added value index, total export volume and total energy consumption. The gross regional product (GDP) index is converted into a comparable price in 1996. The carbon dioxide emissions coefficients required to calculate carbon dioxide emissions comes from the IPCC's guide to greenhouse gases and the national development and reform commission.

As to the carbon emission, China has not released official data so far. Therefore, carbon dioxide emissions need to be calculated based on energy supply data. The three types of energy consumptions are selected to calculate carbon emissions which are raw coal, oil and natural gas.

According to the IPCC guidelines for greenhouse gas emissions, the calculation formula for carbon dioxide emissions is as follows:

\[
\text{CO}_2 \text{ emissions} = \sum_i \text{consumption}_i \times \text{standard coal coefficient}_i \times \text{CO}_2 \text{ emission coefficient}_i
\]

The standard coal coefficients comes from China energy statistics yearbook and i is for different kind of energy. The IPCC guidelines for greenhouse gas emissions does not provide the carbon dioxide emission coefficient for oil, so the coefficient is based on the data provided by the national development and reform commission's energy research institute.

| Types of energy | CO2 emissions coefficient |
|-----------------|---------------------------|
| Raw coal        | 0.7559 KgCO2/Kgce        |
| Oil             | 0.5825 KgCO2/Kgce        |
| Natural gas     | 0.4483 KgCO2/Kgce        |

3. STIRPAT model for carbon emissions in Fujian province

3.1. Model construction
To analyze people’s activities effects on carbon emissions, STIRPAT model can be adopted. This model is extended from IPAT. In 1970, Barry Commoner [7], Paul R. Ehrlich and John Holden [8] first proposed the IPAT model to describe the impact of human activities on the environment. The parameter I in the model refers to environmental pressure, P refers to population, A refers to affluence, and T refers to technological progress. Population, affluence, and technological progress are of equal proportions in the model.

\[ I = P \times A \times T \] (1)
With the development of research, the IPAT model has been unable to meet the studies about environmental. Dietz and Rosa [9] modified the IPAT model in 1994 and established the model STIRPAT which is shown as formula (2). In which, a refers to the model coefficient, and b, c and d refer to the elasticity indexes for population, affluence and technological progress respectively, to explain the degree of influence of this factor on the environment, μ refers to a random disturbance term. The STIRPAT model can analyze the potential non-equivalence relation and influence degree between population, affluence and technological progress.

\[ I = a P^b A^c T^d \mu \] (2)

In practical matters, besides population, technological progress and affluence, there are other factors that influence environmental pressure. Therefore, our study adds four factors: urbanization rate, export dependency ratio, secondary industry proportion and energy consumption structure in the model. The logarithm form of the formula is as follows.

\[ \ln I = \beta_1 \ln P + \beta_2 \ln A + \beta_3 \ln EN + \beta_4 \ln U + \beta_5 \ln S + \beta_6 \ln EX + \beta_7 \ln NF + \mu \] (3)

In formula (3), the variables and their descriptions are shown in Table 2.

| Variable | Meaning | Unit | Description |
|----------|---------|------|-------------|
| I        | CO2 emissions | Ten thousand tons of CO2 emissions |
| P        | Population | Ten thousand people | Permanent population at the end of the year |
| A        | Affluence | Yuan/person | GDP per capita (unchanged at 1996) |
| EN       | Energy intensity | the/ten thousand Yuan | Total energy |
| U        | Urbanization rate | % | Urban population/ permanent population at the end of the year |
| S        | Second industry proportion | % | The added value of the secondary industry/GDP |
| EX       | Export dependency | % | Total export/GDP |
| NF       | Non-fossil energy consumption share | % | Primary electricity and other energy consumption/total energy consumption |

3.2. Model testing

3.2.1 Unit root test. Most of the analysis and models proposed for time-series data are on the premise that the time-series data is stationary. The so-called stationary of the data means that the statistical characteristics of time-series data do not change with time. If we directly analyze the variables without examining the stationary of them, though the regression result may get a higher coefficient of determination, we cannot rule out the causes that variables perform a consistent trend in a certain period. And this is usually called “spurious regression”.

To avoid “spurious regression”, the unit root test is conducted among the various influencing factors and estimate the stationary of the variables. As for time-series data, the most common method of unit root test is ADF [10] test developed from DF test by Dickey Fuller. The ADF test is executed on data in
levels and first differences. Not all the null hypotheses of a unit root fail to be rejected at the level, which indicates that not all the eight variables are non-stationary in levels. Only land and lens, two variables are stationary. Under these circumstances, we can’t directly construct the regression equation. However, all the eight variables can reject the null hypothesis in 1st difference, which indicates the variables are stationary in the first difference.

3.2.2 Integration test. In fact, most of time-series data of economic variables is non-stationary and have trends. For such data, we usually difference it to eliminate trends and turn it to stationary data. But the consequence of this is that some useful information that is essential to the analysis of the problems could be ignored. In order to solve the above problem, integration theory is used to deal with the data of those variables. When all variables have the same integration order, there can be an integration relationship among variables. That’s to say, there is a long-run equilibrium relationship among non-stationary variables.

From subsection 3.2.1, we know that all the variables are stationary in the first difference, that’s to say all the variables are integrated of order one I (1) and integration test could be applied to estimate the existence of the long-run equilibrium relationship among the variables. Johansen test is performed here and the results show that there is a long-run equilibrium relation among the variables. Therefore, the regression analysis can be carried out.

3.3. Ridge regression

To eliminate multi-collinearity, the ridge regression method was used to build model. Ridge regression is dedicated to collinear data analysis. Based on the data of Fujian province from 1996 to 2016, the regression coefficients of each variable were obtained the normalized ridge regression equation is as follows:

\[
\ln l = 3.07 \ln P + 0.32 \ln A - 0.03 \ln EN - 0.20 \ln U + 1.97 \ln S + 0.01 \ln EX + 0.09 \ln NF - 26.30
\]

![Figure 1. Ridge regression results and real value comparison.](image)

The unit root test and co-integration test prove that the data is stable and there is a long-term co-integration relationship, indicating that the ridge regression model is effective and accurate. According to the results of ridge regression, for every 1 percent increase in population, carbon dioxide emissions will increase by 3.0693 percent. For every 1 percent increase in per capita GDP, carbon dioxide emissions will increase by 0.3222 percent. For every 1 percent increase in energy intensity, CO2 emissions will fall by 0.0274 percent. For every 1 percent increase in non-fossil energy, CO2 emissions
will fall by 1.2074 percent. For every 1 percent increase in the second industry, carbon dioxide emissions will increase by 0.97 percent. For every 1 percent increase in export dependence, carbon dioxide emissions will increase by 0.0081 percent. For every 1 percent increase in urbanization, carbon dioxide emissions will increase by 0.0939 percent. The comparison between the real value and ridge regression results is shown in figure 1.

4. Suggestions and conclusion
From the regression results, we can find that the increased population, affluence, dependence on exports, and urbanization rates could increase carbon dioxide emissions. However, the increase in non-fossil energy sources, the proportion of secondary industries and the increase in energy intensity can reduce carbon dioxide emissions.

Combining the actual situation of Fujian province and the analysis of the main factors affecting the carbon emission in Fujian Province, the following suggestions are put forward for the carbon emission reduction in Fujian province.

1). Improve people’s awareness of environment protection and increase supervision for government. According to the STIRPAT model, population is the primary factor affecting carbon emissions. In the context of the country's comprehensive two-child policy, population growth accelerates in recent years. It is a powerful measure for carbon emission reduction to improve people's awareness of environmental protection. Fujian provincial government should increase publicity and supervision, encourage green innovation and green inventions, enhance students' awareness of environmental protection through discipline education, and enhance people's awareness of carbon emission through rational carbon tax collection etc.

2). Increase the proportion of non-fossil energy and develop new and renewable energy sources. Giving full play to the geographical advantages of Fujian Province, rational exploitation and utilizing of coastline, sea area, island, and other resources is a good way.

3). Enhance economic support for technology development to encourage public innovation and social innovation. It is beneficial for developing new technologies to improve energy utilization and promoting industrial transformation. Learning and introducing foreign advanced technology and resources to develop ourselves is also a good method.

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