Factor Influence on Energy Carbon Emissions: a Case of Upper Reaches of The Yangtze River of China

Guangming Rao¹*, Xu Han¹, Yanping Zhu²

¹ Research Center for Economy of Upper Reaches of the Yangtze River, Chongqing Technology and Business University, Chongqing, 400067, China
² School of Entrepreneurship, Chongqing Technology and Business University, Chongqing, 400067, China

*Corresponding author, e-mail: 2421149491@qq.com

Abstract. This paper adopts STIRPAT model with ridge regression to estimate factor influence on energy carbon emissions with the case of the upper reaches of the Yangtze River of China. The result shows that seven factors have positive but different influence on energy carbon emissions, which impact coefficient of population is 5.559, and respectively is secondary industry value-added (1.054), CO₂ emissions intensity (0.597), productivity (0.416), GDP per capita (0.352), urban employment (0.309) and urbanization (0.221). For improvement of factor influence on energy carbon emissions, it is urgent to promote industrial low carbon transition, encourage R&D of low carbon technologies for clean production and advocate low carbon urbanization and life.

1. Introduction
According to An IPCC special report on the impacts of global warming of 1.5°C, the global temperature is expected to rise by 1.5°C between 2030 and 2050 compared with the pre-industrial level. Global warming is mainly caused by a large amount of carbon dioxide and other greenhouse gases produced by energy consumption since the industrial revolution. Therefore, it is of great significance to clarify the specific influencing factors on energy carbon emissions and their influencing degrees. The upper reaches of the Yangtze River is one of the most important industrial bases in China. It is of great importance to find out the influence factors on energy carbon emissions and promote low-carbon transformation of energy consumption in the upper reaches of Yangtze River. Scholars mainly adopt various methodologies to study the relationship between economic growth and carbon dioxide emissions, such as the environmental kuznets curve (EKC), Tapio decoupling model, the method of Kaya model, the method of Logarithmic Average Di-type Index (LMDI) decomposition, methods of STIRPAT model, etc. (Ehrlich P R, Holdren J P., 1971; Dietz T, Rosa E A., 1994; York R, Rosa E A, Dietz T., 2003; Dijkgraaf and Vollebergh, 2005; Lantz and Feng, 2006; Boqiang Lin, et al. 2009; Na Zhang et al., 2018; Guangming Rao et al., 2011, 2013, 2014, 2017, 2018; Shoufu Lin et al., 2018, etc.) In this paper, we would like to take new factors into the STIRPAT model and analyze the factor influence on energy carbon emissions in the upper reaches of the Yangtze River of China.

2. Methods and data

2.1. STIRPAT model
The STIRPAT model is an improvement of the classic IPAT model proposed by Diez and Rosa (1994) for Ehrlich and Holdren (1971). It is a random form of the IPAT model as Eq.(1):

$$I_t = aP_t^bA_t^cT_t^d e_t$$

(1)

In Eq.(1), $I$, $P$, $A$, and $T$ represent separately environmental impact (energy carbon emissions discussed in this paper), population, wealth, and technology, $a$ is model coefficient, and $b$, $c$, and $d$ are separately elasticity coefficient of population, wealth and technology, $e$ is a random error. The logarithm of the model can be obtained as Eq.(2):

$$\ln I_t = a + b(\ln P_t) + c(\ln T_t) + d(\ln T_t) + \ln e_t$$

(2)

With the method proposed by Shoufu Lin et al. (2018), we decompose energy carbon emissions as Eq.(3):

$$\text{CO}_2 = \frac{P}{P} \times \frac{P_{ur}}{P_{ur}} \times \frac{P_e}{P_e} \times \frac{\text{GDP}}{\text{GDP}} \times \frac{P}{P} \times \frac{\text{GDP}_{\text{II}}}{\text{GDP}_{\text{II}}} \times \frac{\text{CO}_2}{\text{GDP}}$$

(3)

In Eq.(3), $\text{CO}_2$ is amount of carbon dioxide emitted by energy consumption, $P$ is total population, $P_{ur}$ is population of city, $P_{ure}$ is number of urban employed people, $P_e$ is number of employed people, $\text{GDP}_{\text{II}}$ is added value of secondary industry. Based on the methods of equations (1) and (2), the expanded IPAT model is transformed into the extended STIRPAT model in a random form, and logarithm is taken from both sides of the model and obtained as Eq.(4):

$$\ln \text{CO}_2_t = a + b_1 \ln P_t + b_2 \ln \text{Ur} \_b_t + b_3 \ln \text{Ur} \_E_t + b_4 \ln \text{EP}_t + b_5 \ln \text{LP}_t + b_6 \ln S \_\text{Ind}_t + b_7 \ln \text{PCI}_t + b_8 \ln P \_\text{GDP}_t + b_9 \ln P \_\text{PCE}_t + \ln \text{e}_t$$

(4)

Based on Eq.(3), the variables are defined as follows in Eq.(4): urbanization level is $\text{Ur} = \frac{P_{ur}}{P}$, urban employment level is $\text{Ur} \_E = \frac{P_{ure}}{P_{ur}}$, Employment ratio is $\text{EP} = \frac{P_e}{P_{ure}}$, Labor productivity is $\text{LP} = \frac{\text{GDP}}{P_e}$, proportion of value added of the secondary industry is $\text{SInd} = \frac{\text{GDP}_{\text{II}}}{\text{GDP}}$, Population carrying capacity of real economy (PCI) is $\text{PCI} = \frac{P}{\text{GDP}_{\text{II}}}$, Per capita GDP is $\text{PGDP} = \frac{\text{GDP}}{P}$, carbon intensity is $\text{PCE} = \frac{\text{CO}_2}{\text{GDP}}$.

2.2. Data

The data of 1997-2016 used in this paper are all from the regional database on the website of the National Bureau of Statistics and the statistical yearbooks of China and those of Chongqing, Sichuan, Guizhou and Yunnan, in which, GDP and value added of the secondary industry are converted according to the 1997 base period.

(1) Data of energy carbon emissions

In this paper, according to CO$_2$ emission coefficient of energy in the guidelines for compilation of provincial greenhouse gas inventory (Climate[2011]1041) issued by the National Development and Reform Commission, PRC, the energy consumption data published on the website of the National Bureau of Statistics are calculated as follows.

The calculation formula is:

$$\text{CO}_2_{k} = \sum(E_{kj} \times EF_{j})$$

(5)

Among them, $\text{CO}_2_{k}$ indicates energy consumption of CO$_2$ emissions in area $k$, $E_{kj}$ indicates consumption of the $j$ energy consumed by the region $k$, $EF_{j}$ is for the carbon emission coefficient of the $j$ energy source, the specific coefficient values are shown in Table 1.
| Energy type | coal     | Coke    | crude   | gasoline | kerosene | Diesel | Fuel oil | natural gas | electricity |
|------------|----------|---------|---------|----------|----------|--------|---------|-------------|-------------|
| CO₂ emission coefficient (t/tce) | 1.9003   | 2.8604  | 3.0202  | 2.9251   | 3.0179   | 3.0959 | 3.1705  | 2.1622      | 0.801       |

Note: The various energy factors in the table are derived from the “Guidelines for the Preparation of Provincial Greenhouse Gas Inventories” (Development and Reform Office Climate [2011] No. 1041). The carbon emission coefficient of electricity is derived from the average carbon dioxide emissions of regional power supply in China in 2005, including that of Chongqing and Sichuan 0.801, Yunnan and Guizhou is 0.714.

(2) Data of the upper reaches of the Yangtze River

Data of the upper reaches of the Yangtze River from 1997 to 2016 were summed up according to provincial data of Chongqing, Sichuan, Yunnan and Guizhou, including data of urbanization level, urban employment level, employment ratio, labor productivity, proportion of value added of the secondary industry, population carrying capacity of real economy (PCI), per capita GDP, and carbon intensity.

3. Empirical analysis

3.1. Estimation

By estimation of equation (4) through econometric software, there is multicollinearity which is from \( \ln PCI_i \) with \( \ln EP_i \). In order to eliminate interference of multicollinearity on estimation results of the model, we abandon the least squares method and adopt the ridge regression method for estimation. Ridge regression is a biased estimation method for analyzing the data with strong collinearity which is improvement of the least squares method (Shangwei Zhu, 2015). Ridge regression is performed on equation (6). The first regression sets the ridge parameter \( k \) in the interval (0, 1). When the search step is set to 0.05, it is found that the change of \( k \) after 0.2 tends to be stable. Therefore, the adjustment ridge parameter \( k \) is subjected to the second regression in the interval of (0, 0.2), and the search step is set to 0.005, and the obtained ridge map is as shown in Fig. 1.

![Ridge Trace](https://via.placeholder.com/150)

**Fig. 1. Ridge trace**

It can be seen from Fig. 2 that each variable tends to be stable after the value of \( k \) reaches 0.05. Therefore, Eq.(6) is regressed by establishing a ridge regression equation with \( k=0.05 \), and can explain relationship between energy carbon dioxide emissions and its influencing factors in the upper reaches of the Yangtze River. The result is shown in Table 2.

\[
\ln CO_{2i} = -44.958 + 5.559 \ln P_i + 0.221 \ln Ur_{rb} + 0.309 \ln Ur_{rE} + 0.416 \ln L_P_i + 1.054 \ln St_{Ind} + 0.352 \ln PGDP_i + 0.597 \ln PCE_i
\]  

(6)
Tab. 2: Estimation results by ridge regression

| variable | coefficient | Standard deviation | Standard coefficient | t statistic | Sig |
|----------|-------------|--------------------|----------------------|------------|-----|
| lnP      | 5.559       | 0.858              | 0.116                | 6.483      | 0.000 |
| lnUrb    | 0.221       | 0.041              | 0.092                | 5.458      | 0.000 |
| lnUrE    | 0.309       | 0.057              | 0.104                | 5.418      | 0.000 |
| lnLP     | 0.416       | 0.055              | 0.131                | 7.561      | 0.000 |
| lnSInd   | 1.054       | 0.109              | 0.185                | 9.668      | 0.000 |
| lnPGDP   | 0.352       | 0.039              | 0.129                | 9.009      | 0.000 |
| lnPCE    | 0.597       | 0.040              | 0.384                | 15.103     | 0.000 |
| C        | -44.598     | 8.312              | 0.000                | -5.365     | 0.000 |

Note: $R^2=0.99758$, F statistic value is 707.055, Sig (F statistic)=0.000

3.2. Discussion
As shown in equation (6), the influencing factors on energy carbon emissions are population size (P), urbanization level (Urb), urban employment level (UrE), labor productivity (LP), industrial value added (SInd), GDP per capita (PGDP) and carbon intensity (PCE) in the upper reaches of the Yangtze River. The impact coefficients of elasticity are 5.559, 0.221, 0.309, 0.416, 1.054, 0.352, and 0.597, respectively. It means that when population increases by 1%, energy carbon emissions will increase by 5.559%; when urban population increases by 1%, energy carbon emissions will increase by 0.221%; when urban employment share increases by 1%, energy carbon emissions will increase by 0.309%; when labor productivity increases by 1%, energy carbon emissions will increase by 0.416%; when value added of the secondary industry increases by 1%, energy carbon emissions will increase by 1.054%; when GDP per capita increases by 1%, energy carbon emissions will increase by 0.352%; when carbon intensity increases by 1%, energy carbon emissions will increase by 0.597%. By the degree of influence from the result above, the seven influencing factors can be ranked as follows: population size > secondary industry value added ratio > carbon intensity > Labor productivity > GDP per capita > Urban employment ratio > Urban population.

4. Conclusion with suggestion
In this paper, we adopt the STIRPAT model with ridge regression to estimate factor influence on energy carbon emissions with the case of the upper reaches of the Yangtze River of China based on data of 1997 to 2016. The result shows that seven factors have positive but different influence on energy carbon emissions, which impact coefficient of population is 5.559, and respectively is secondary industry value-added (1.054), CO$_2$ emissions intensity (0.597), productivity (0.416), GDP per capita (0.352), urban employment (0.309) and urbanization (0.221). Following suggestions are essential for improvement of factor influence on Energy carbon emissions in the upper reaches of the Yangtze River in future.

Population is the most important factor affecting energy carbon emission in the upper reaches of the Yangtze River. By the end of 2017, there were more than 200 million permanent residents in the upper reaches of the Yangtze River, and carbon emissions from residents’ lives accounted for the largest share of energy carbon emissions. It is necessary to actively advocate a resource-saving and ecologically friendly life for achievement of low-carbon and green development by low-carbon travelling, reducing the use of air conditioners, planting trees and so on.

As an important energy-cored heavy industrial base in China, the upper reaches of the Yangtze River has concentration of a large number of energy-intensive, large capacity, high emission industries and oversize enterprise, leading to a greater influence on energy carbon emissions, therefore, needs to promote industrial structure transformation into low carbon society by reducing proportion of secondary industry in the national economic development, and vigorously developing the tertiary industry.
Technological progress plays an important role in reducing carbon emissions. We should vigorously promote technological innovation and increase the proportion of low-carbon technology investment in science and technology, such as research and development of new energy and clean production technologies and use of them in development.

The upper reaches of the Yangtze River are backward in terms of urbanization and wealth. The further improvement of urbanization level and wealth level will be accompanied with an increase in carbon emissions. Low-carbon urbanization should be promoted as early as possible, and urban population should be reasonably distributed through adjusting industrial layout and optimizing urban structure, and rural population should be actively guided to migrate to urban areas instead of following the old path of urbanization and high carbon emissions.

Acknowledgments
We would like to thank the financial supports by the key research project of the National Social Science Foundation of China (grant 17AJY006).

Reference
[1] Dietz T, Rosa E A. Rethinking the Environmental Impacts of Population, Affluence and Technology. Human Ecology Review, 1994, (1).
[2] Dijkgraaf E, Vollebergh H R J. A Test for Parameter Homogeneity in CO₂ Panel EKC Estimations. Environmental and Resource Economics, 2005(32), pp.229-239.
[3] Ehrlich P R, Holdren J P. Impact of Population Growth. Science, 1971, (171).
[4] Lantz V, Feng Q, 2006, Assessing Income, Population, and Technology Impacts on CO₂ Emissions in Canada, Where's the EKC? Ecological Economics, vol.57, pp.229-238.
[5] Boqiang Lin, Yijun Jiang. Environmental Kuznets Curve Prediction and Influencing Factors Analysis of Carbon Dioxide in China. Management World, 2009 (04), pp.27-36 (In Chinese).
[6] Guangming Rao, Yong Wang, Ke Li, Na Wang. Analysis on Chongqing Industry CO₂ Emissions Efficiency Difference and Its Emissions Reduction Potentials. Energy Procedia 5 (2011), pp.2230-2235.
[7] G.M.Rao and Y.Wang. Analysis on Chongqing’s Carbon Balance Based on Carbon Footprints. Advanced Materials Research 734-737 (2013) 1022-6680 © (2013) Trans Tech Publications, Switzerland, pp.1813-1819.
[8] Guangming Rao, Hery Andrianiaina, Yong Wang. Key driving factor analysis on industrialization and CO₂ emission: based on data of Madagascar, China and the United States. BioTechnology, 2014, 10 (24).
[9] Guang Ming Rao, Xing Hu & Huan Yuan, Yong Wang. Analysis on screening methods of key sectors of Industrial CO₂ emission. Advances in engineering research, 2017, 120, pp.1109-1114.
[10] Guangming Rao and Fengyi Yang. Decoupling Measurement of Regional CO₂ Emissions Growth: A Case Study of Chongqing Municipality. 2018 3rd International Conference on New Energy and Renewable Resources (ICNERR 2018), pp.548-554.
[11] Na Zhang, Xiaosheng Li. Research on the smooth transition of China's economic growth and carbon dioxide emissions. Statistics and Decision, 2018, 34 (22), pp.140-143 (In Chinese).
[12] Shoufu Lin, Shanyong Wang, Dora Marinova, Dingtao Zhao. Improvement and Application of STIRPAT Model. Statistics and Decision, 2018, 34(16), pp.32-34 (In Chinese).
[13] Shangwei Zhu, Jinghua Li. Two Expected Constraints of Ridge Regression Parameters. Statistics and Decision, 2015, (22), pp.71-74 (In Chinese).
[14] York R, Rosa E A, Dietz T. STIRPAT, IPAT, and ImPACT: Analytic Tools for Unpacking the Driving Forces of Environmental Impacts. Ecological Economics, 2003, 46(3).