Spatial Impact of Economic Structure Reform on China's Energy Consumption——Perspective of Satellite Lighting Data from Prefecture-level Areas

Nan Zhao*
Beijing Normal University, Beijing, China – zhaonan@bnu.edu.cn

Xuguang Song
Beijing Normal University, Beijing, China – songxuguang@bnu.edu.cn

Tao Wang
Beijing Normal University, Beijing, China –912259041@qq.com

Abstract

With the acceleration of China's economic De-Capacity and structure reform process, the total amount and internal structure along with the using efficiency of energy consumption are also presenting new tendency. From the perspective of China's prefecture-level areas, this paper is concerning on the impact degree and mechanism of energy consumption variation caused by economic structure change. Using spatial regression model proposed by LeSage and Pace (2009), we constructed a series of Spatial Durbin Models (SDM), Spatial Lag Models (SLM) and Spatial Error Models (SEM) to decompose the impact of economic structure reform on energy consumption into direct effect, indirect effect and combined effect, and measured the spatial spillover effects of economic structure changes on energy consumption.
Keywords: Economic Structure Reform; Energy Consumption; Spatial Spillover Effects; Satellite Lighting Data.

1. Introduction

With the rapid development of China's economy, China's energy production and consumption continued to increase, which makes that China is facing greater pressure on energy-saving and environmental protection. It was indicated in the report of "Energy Working Guidance in 2017" by the National Energy Bureau that: in 2017 the total energy consumption should be controlled at 4.4 billion tons of standard coal. It's important to strengthen structural reform of the energy supply, eliminate outdated industrial capacity, promote the development and utilization of clean energy, and optimize the energy structure. The economic development and energy consumption vary from region to region. Though we can obtain the statistical data at China's provincial level easily, it's rare to find the energy consumption data at prefecture level published. And the data we have obtained will face problems such as the lack of unified statistical caliber, man-made factors, missing value and so on. These problems bring us certain difficulties in comprehensively and accurately grasping energy consumption and making plans of energy-saving emission reduction.

Nighttime lights data, economic growth and energy consumption are highly correlated, which has been confirmed and recognized by Chinese domestic and foreign scholars. Taking into account the difficulty of obtaining energy data at the prefecture level, we try to estimate total energy consumption of prefecture-level areas combined with the nighttime lights data and GDP. And we want to analyze the spatial distribution pattern, time trend and spatial agglomeration characteristics of China's energy consumption. The results show that, the accuracy of estimation based on the nighttime lights data and GDP is guaranteed. There is a certain degree of spatial agglomeration in China's energy consumption at prefecture level or above.

Changes in the three industrial structure are closely related to energy consumption. So the adjustment and optimization of industrial structure will inevitably affect China's total energy consumption and energy efficiency. On the basis of estimating energy consumption at prefecture level or above, this paper uses the dynamic spatial Durbin model, considering the time lag effect, spatial lag effect and space-time lag effect of energy consumption, in order to clearly and accurately measure the impact degree and mechanism of energy consumption variation caused by industrial structure changes. The results indicate that, China's energy consumption has obvious spatial spillover effects and spatial aggregation characteristics. There is a significant inverted U shape curve relationship between energy consumption and the proportion of tertiary industrial output value. When the proportion of tertiary industrial output value reaches a certain critical value, adjustment and optimization of industrial structure will help to reduce energy consumption and promote energy efficiency.

The contribution of this paper are as follows: firstly, the concentration on spatial spillover effects of the energy consumption variation as the result of the economic structure reform, can observe comprehensive effects more clearly and accurately due to the complex economic behavior interactions between those geographical proximity regions; Secondly, the data level of prefecture area can provide a more microscopic and specific observation, and the increasing of variable degrees of freedom can also significantly improve estimation accuracy; lastly, satellite light data sets have been used to evaluate the degree of economic structure reform and simulate related variables of energy consumption which are still rare in this area.

2. Data

Nighttime light data can be obtained by the OLS sensor from the DMSP satellites which is available from 1992 to 2013 at the website of National Geographic Data Center (National Geophysical Data Center, hereinafter referred to as NGDC).

The sample of this paper includes 325 China prefecture-level administrative divisions (284 prefecture-level areas, 8 districts, 30 autonomous prefectures and 3 national minority league) and 4 municipalities, with a total of 329 prefectural and above administrative units. Considering the availability of official statistical data, the time interval studied in this paper is from 2005 to 2013. We define the sum of the digital number (DN) values in a certain region as the intensity of the light, which is as follows:

$$I = \sum_{i=1}^{DN_m} (DN_i \times n_i)$$

Using the light intensity as weight, we estimate energy consumption data for prefecture-level based on the availability of provincial official energy data:

$$E_{pro,\mathrm{int}en,t} = \frac{I_{pro,t}}{I_{cn,t}} \times E_{cn,t} \quad t = 2005, 2006, \cdots, 2013$$

The figure.1 shows the map of China in prefecture-level areas based on the quantity of energy consumption.

A certain degree of spatial agglomeration is also discovered. We calculated the Moran’s index of energy consumption in prefecture-level areas in China (figure.2). The results show that all the Moran's I indexes of energy consumption is significantly positive over years, both have passed the test at 1% significance level, which shows that China's energy consumption exits the spatial distribution of positive correlation, i.e. areas with the high energy consumption level are usually adjacent to those areas whose energy consumption level are also high. From the trend of Moran's I index, the Moran's I index of total energy consumption shows a decreasing trend, indicating that the correlation between energy consumption at the prefecture level is decreasing year by year, which reflects the gradual trend of energy saving policies between regions In the independent, not affected by the policy of neighboring areas.

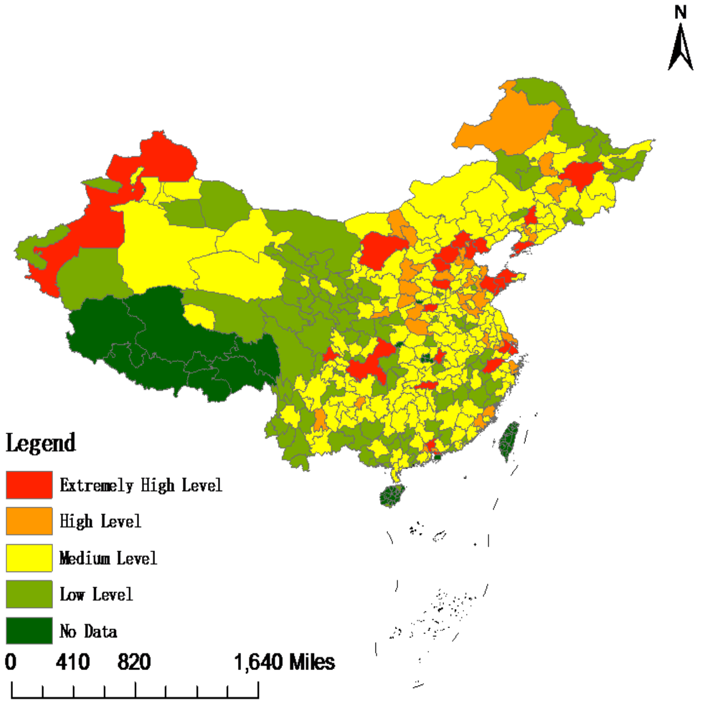

Fig.1 energy consumption in China prefecture-level areas

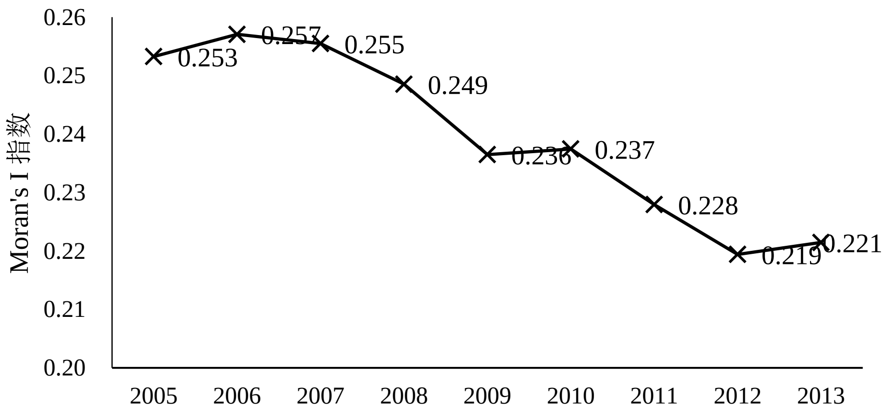

Fig.2 Moran's Index of energy consumption in prefecture-level areas over years

3.Models

In this study, the effects of factors such as industrial structure on energy consumption (total energy consumption and energy intensity) were analyzed by two-way fixed effect Spatial Durbin Model (SDM) and Dynamic panel Spatial Durbin Model (DSDM). The estimation results of the two models are compared, and finally choose the optimal model. The basic formulas of the two models are:

SDM: $y_t = l\,Wy_t + X_t b_1 + WX_t b_2 + a + e_t$

DSDM: $y_t = g\,y_{t-1} + l\,Wy_t + t\,Wy_{t-1} + X_t b_1 + WX_t b_2 + a + e_t$

y and X are dependent and independent variables respectively. t is time dimension indicator. y_{t-1} is the first order lag of the dependent variable. $l\,Wy_t$, τWy_{t-1} and $WX_t\beta_2$ are the spatial lag of the dependent variable, the first order lag of the dependent variable and the independent variables respectively. $|\lambda|<1$, $|\tau|<1$, $\varepsilon_t \sim N(0,\sigma_\varepsilon^2 I_N)$.

Table.1 Descriptive of Model Variables

Variables	Descriptive
Energy Efficiency (y)	Energy intensity, i.e., energy consumption per capita GDP
Industrial Structure (gdp3)	the output value of the tertiary industry as the proportion of gross domestic product, consider the quadratic term （gdp3sq）
Revenue (czzb)	the general budget revenue as the proportion of GDP
Investment (tzzb)	The proportion of fixed assets investment to GDP
Consumption (lszb)	Total retail sales of social consumer goods as a percentage of GDP
Foreign Trade (ckzb)	The proportion of exports to GDP
Urbanization (jyzb)	Percentage of urban workers in total population
Population (rkmd)	Population density
Education (jsxs)	Ordinary secondary school teachers per capita number of students
Industrial Enterprises (qy)	Numbers of Industrial Enterprises above Designated Size
Environmental Factor （fspf）	Emission of Industrial Waste Water

4.Conclusions

Table.2 provides the following conclusions:

Firstly, we find significant spatial agglomeration characteristics between the energy intensity in prefecture-level areas of China. The DSDM can better explain the mechanism of the industrial structure and other factors on the energy intensity of the mechanism because of the higher adjusted coefficient of determination.

Secondly, coefficient of spatial lag (λ =0.408) is significant in 1% level, indicating that the improvement of energy intensity in adjacent areas will have a positive impact on the local energy intensity. Coefficient of time lag (γ =0.707) is significant in 1% level, indicating that there is a significant temporal correlation in energy intensity, i.e., a higher level of energy intensity will have a positive impact on the next period.

Thirdly, there is a significant inverted U-shaped relationship between the intensity of energy and the proportion of tertiary industry in GDP. The relationship between the optimal adjustment of industrial structure and energy intensity has the trend of “First rise and fall down”. When the proportion of output value of tertiary industry reaches a certain critical value (40.44%), the optimization of industrial structure will be beneficial to reduce energy intensity and improve energy utilizing effectiveness.

Table.2 Spatial Econometric Results

variables	SDM	DSDM
timelag		0.707***
spacetimelag		-0.148***
gdp3	0.306***	0.233***
gdp3sq	-0.430***	-0.288***
jyzb	-0.001	0.006
czzb	0.000***	0.000***

ckzb	0.000	0.000
tzzb	0.000***	0.000***
lszb	-0.012	0.031**
qy	0.000	0.000
rkmd	-0.064***	-0.024***
jsxs	0.000	0.000
fspf	0.000	0.000
W*gdp3	0.248	-0.190*
W*gdp3sq	-0.442**	0.210
W*jyzb	-0.024**	0.003
W*czzb	0.000*	0.000***
W*ckzb	0.000**	0.000
W*tzzb	0.000	0.000***
W*lszb	-0.016	0.008
W*qy	0.000	0.000*
W*rkmd	0.036*	0.034**
W*jsxs	-0.001**	0.000**
W*fspf	0.000	0.000
W*dep.var.	-0.236***	0.408***
R-squared	0.950	0.977
corr-squared	0.130	0.483

6.References

Elvidge, C. D., Baugh, K. E., Kihn, E. A., Kroehl, H. W., Davis, E. R. and Davis, C. W.(1997). "Relation Between Satellite Observed Visible-Near Infrared Emissions, Population, Economic Activity and Electric Power Consumption", *International Journal of Remote Sensi*ng, 18(6): 1373-1379.

Henderson, J. V., Storeygard, A. and Weil, D. N.(2012). "Measuring Economic Growth From Outer Space", American Economic Review, 102(2): 994-1028.

Wang, K., Wei, Y. M. and Zhang, X.(2012). "A Comparative Analysis of China'S Regional Energy and Emission Performance: Which is the Better Way to Deal with Undesirable Outputs?", *Energy Policy*.