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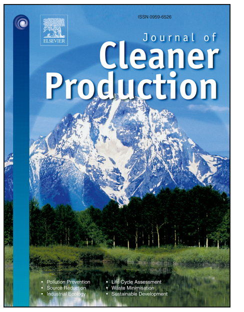

Energy consumption and the influencing factors in China: A nonlinear perspective

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Ting Wang: Data curation, Methodology, Software, Writing- Original draft preparation

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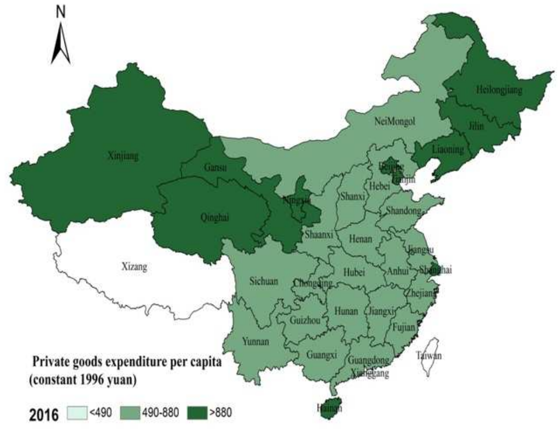
- An important feature of China's economic development is investment-driven and demographic dividend，and government expenditure plays a very important role.
- Different parts of income have a non-linear effect on energy consumption.
- Government may not be always inefficient in terms of energy consumption or cleaner production.
- The growth of government expenditure will become a powerful driving factor on energy consumption.
- When China's energy consumption is studied，regional grouping according to energy consumption levels may be one of the better options.
- The distribution of energy consumption levels in China's provinces is consistent with the distribution of government expenditure levels.

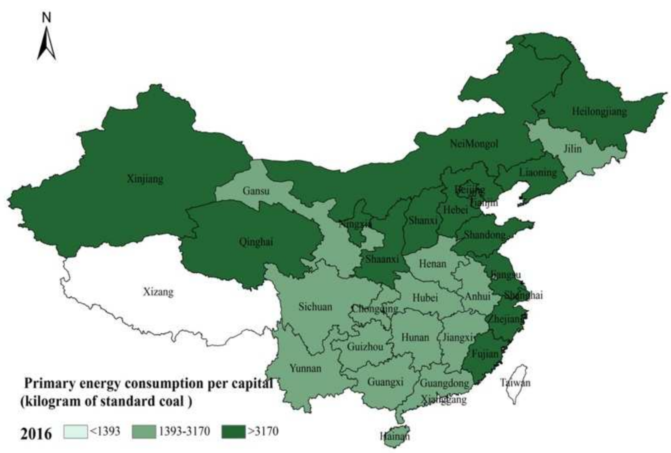
Spatial distributions of government public goods expenditure based on Model I



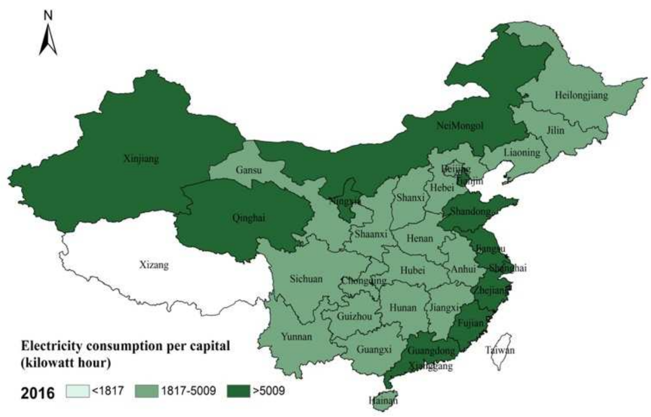
Spatial distributions of government private goods expenditure based on Model II

Spatial distributions of government public goods expenditure based on Model III

Spatial distributions of government private goods expenditure based on Model IV



Spatial distributions of primary energy consumption based on Model V



Spatial distributions of electricity consumption based on Model VI

Energy consumption and the influencing factors in China：a nonlinear perspective

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Abstract

Different from many studies on Energy Kuznets Curve, this paper does not directly consider income factor but conducts a nonlinear study on per capita primary energy consumption and electricity consumption in China, whose economic development is considered investment-driven, in which government macroeconomic policies, especially government expenditure plays a very important role. In particular, this paper attempts to compare the different impacts of government expenditures and the other influencing factors on energy consumption. Based on the results of the threshold regression, in the future, with the further development of the economy, the driving force of labor population growth will slow down. Comparing with primary energy, the relationship between electricity consumption and its influencing factors will change later, and the difference in the effects of the influencing factors is mainly reflected in the formation of capital stock (investment) and the development of urbanization. Government expenditure on private goods may not be always as inefficient in energy consumption and cleaner production as previously thought in the literature. Meanwhile, the growth of government expenditure on public goods will become a powerful driving factor which indicates that the government needs to assess its overall impact on energy consumption and energy efficiency when participating in the provision of public goods. The paper also found that when studying the issue of energy consumption and regional differences in China, the geographic classification of eastern, central and western regions may not be appropriate. Grouping according to energy consumption levels may be one of the better options. And the distribution of energy consumption levels in China's provinces is consistent with the distribution of government expenditure levels. The estimation results also provide us with important policy implications: the government expenditure in education is of great importance, and it can produce a strong energy-saving effect through technological progress.

Keywords: Energy consumption; Energy Kuznets Curve; Threshold model; Government expenditure

1. Introduction

The rapid growth of China's energy consumption in recent decades is linked to the rapid growth of the economy. At the same time, an important feature of China's economic development is investment-driven, in which government macroeconomic policies, especially government expenditure, plays a very important role. According to World Bank statistics (WordBank, 2019), as shown in Figure 1, the intuitive feeling is that China's large-scale expansion of government expenditure since 1978 has been accompanied by rapid growth in energy consumption (Wang and Lin, 2019). Figure 1 demonstrates that the growth of government expenditure and capital formation is highly volatile. For example, in 1984, 1992 and 1999, there was a sharp growth in government expenditure around these years. These years are also years in which the private sector is also encouraged to invest to expand domestic demand. During such years, energy consumption, especially electricity consumption, seems to have strong consistency with these variables.

Figure 1 here

In terms of expenditure method and the statistics of World Bank (WordBank, 2019), compared with many developed OECD countries, China's gross capital formation accounts for a high proportion of GDP, while government final consumption expenditure and households final consumption expenditure ratio are relatively low (Figure 2). On the other hand, the investment and the resulting gross capital formation, as well as the demographic dividend, are seen as the main driving forces of China's economic growth. At the same time, due to the different stages of development, there are also differences in the growth factors of income in different regions of China. Most existing research on energy consumption only based on income as a direct influencing variable tends to ignore the differential effects of different stages and income growth factors in these regions.

Figure 2 here

Taking into account these factors, or these departments, the role of government cannot be ignored, and the impact of government expenditures is particularly worth studying. As an influential policymaker and participant in the market economy, the government has shown a certain regular progress trend in its policy direction. Governments in many countries have promoted economic growth through government purchases and investments. At the same time, due to the guiding role of macroeconomic policies, the scale and structure of government expenditures will also have an impact on energy consumption trends. Borg et al. (1998) (p.1) pointed out that government-related institutions are often the largest energy users in a country and the most important customers of energy products and services. On the other hand, due to the external characteristics of energy consumption and environmental pollution, the government is often the foremost bearer of energy security and environmental protection.

As the global economic growth slows down, the Chinese economy has also entered the "new normal", and the government still has the impulse to adopt expansionary macroeconomic policies to stimulate the economy. At the same time, compared with many developed countries, the proportion of government expenditure in GDP is still low. There is still a considerable gap in the supply of public goods and quasi-public goods such as education, medical care, health, environmental protection, etc., especially in rural areas. Therefore, government expenditure should also play an important role in making up for market defects. In this context, in addition to the purpose of promoting economic development and improving national welfare, the formulation of government expenditure policies also needs to consider energy and environmental effects. For example, although the private sector is seen as more efficient than the government in many respects, whether there are some stages of development, in which more government participation will be more efficient than the private market, especially in terms of energy consumption and cleaner production？ The answer to this question will help to make the government a true leader in energy conservation and emission reduction. Some countries have also paid attention to this issue. For example, the United Kingdom recently proposed that "Improving the energy efficiency of the public sector estate will be part of the Treasury's upcoming pan-Whitehall spending review" and that "If we build schools, hospitals and public buildings we want commissioning authorities in the first instance to be thinking about what is the most modern, efficient way of building. We would like that to flow through into energy efficiency. " (Blackman, 2018)

Energy consumption and its associated carbon emissions have been widely studied in literature to test energy and environmental Kuznets Curve hypothesis. According to the Energy Kuznets Curve hypothesis, the effects of the influencing factors on energy consumption often change with the income level of economic development. GDP is typically used as the income variable in their test. However, which part of the income plays the role of driving the transition of energy consumption, few people discuss. Therefore, unlike most existing research on the relationship between energy consumption and income, the most important influencing factor GDP will be divided based on growth factors in this paper. Government expenditures would also be classified by their use and included as growth factors. Data from 30 provinces in China will be used, and the panel threshold model will be adopted in order to validate the Energy Kuznets Curve hypothesis. Primary energy consumption and electricity consumption will be compared. In particular, this paper attempts to compare the different impacts of government expenditures and the private investment on energy consumption, in order to answer such question: whether there are some stages of development, in which more government participation will be more efficient than the private market, especially in terms of energy consumption？

The rest of the paper is organized as follows: the second part is the introduction of related research. Based on the literature review, the empirical strategy, variables, and data used in the empirical tests are discussed in Section 3. Section 4 reports the main results of the empirical tests based on panel data of 30 provinces. Section 5 summarizes the main conclusions of this study and presents some policy implications.

2. Literature Review

There have been a lot of articles on the factors affecting energy consumption. Whether it is linear or nonlinear research, most of them use GDP as an income variable. Some studies consider the impact of factors such as investment or trade, urbanization development, technology, etc., but most of these variables are considered as structural variables at the same level as GDP, rather than from the perspective of income decomposition. Particularly, there is less research on the influence of government expenditures on energy consumption.

There have been many studies on the impact of government expenditures on the environment in recent years. In today's world, environmental issues are usually closely related to energy consumption issues, and studies on these two issues often have similarities. As Halkos and Paizanos (2014) (p.6) put it, SO_2 emissions are mainly from power generation and industrial processes, CO_2 emissions are mainly from transportation, and the burning of fossil energy. It can be said that pollutant emissions are by-products in the process of economic development, and energy consumption is a necessary input that is closely connected with it. Numerous studies on environmental pollutant emissions use energy consumption as an explanatory variable. Therefore, when studying the issue of energy consumption, the existing research ideas and research methods on the environmental impact of government expenditures are worth learning.

For example, Heyes (2000), Lawn (2003), and Sim (2006) made theoretical contributions to the interaction between government expenditure, environmental quality, and economic welfare. McAusland (2008) and López et al. (2011) analyzed the specific mechanism of government spending from the perspective of consumption and supply, and from the perspective of income effect, structure effect, technology effect, and scale effect. López et al. (2011) modeled and measured the impact of the pattern of fiscal spending on the environment. Halkos and Paizanos (2013) examined the impact of government spending on the environment using panel data from 77 countries over the period 1980-2000. They estimated both the direct and indirect effects of government spending on pollution (Halkos and Paizanos, 2013). Galinato and Islam (2014) developed a theoretical model that elucidates the relationship between the quality of governance, the composition of government spending and pollution as a by-product of the consumption process. Halkos and Paizanos (2015) examined the effect of economic policy on air quality using US quarterly data from 1973 to 2013. They analyzed the short-run and long-run interactions between fiscal and monetary policies with CO_2 emissions using time series techniques of co-integration, Granger multivariate causality and vector error-correction modeling (Halkos and Paizanos, 2015). Adebumiti and Masih (2018) investigated the nonlinear asymmetric relationship between energy consumption and economic growth by incorporating government expenditure and oil prices into a production function using Nigerian economy data from 1980-2014, and they mainly studied the impact of government expenditure and energy consumption on economic growth.

Most of the above studies are built on linear perspective. Since Grossman and Krueger (1991) (p.19) first empirically studied the relationship between environmental quality and per capita income, pointed out that pollution rises with per capita GDP at low-income levels and decreases with GDP growth at high-income levels, the Environmental Kuznets Curve hypothesis has been widely tested to study the relationship between environmental pollution and economic growth. Mohammed Saud et al. (2019) examined the role of government expenditure and financial development in environmental degradation in the context of the Environmental Kuznets Curve hypothesis for the Venezuelan economy. In their research, energy consumption was also introduced into the model as an explanatory variable affecting the environment (Mohammed Saud et al., 2019). Hua et al. (2018) also considered both direct and indirect impact on the environment of fiscal spending, and investigated if education spending affects air pollution through human capital accumulation, known as the composition effect, and if R&D spending affects air pollution through clean-technology adoption, known as the technique effect, considering the nonlinear problem, verifying the Environment Kuznets Curve, using GDP as a quadratic term. Zhang et al. (2017) used the city-level panel data on 106 Chinese cities over the 2002-2014 period to investigate the direct and indirect impacts of government expenditure on the emissions of three typical pollutants: sulfur dioxide, soot, and chemical oxygen demand. The estimation results indicate that the total effects of government expenditure on these three pollutants are very different: for sulfur dioxide (SO_2), soot and chemical oxygen demand, the total effects are decreasing, inverted-U and U-shaped, respectively, and they also used GDP as a quadratic term. He (2015) utilized the provincial panel data during the period 1995–2010 in China to study the nexus of fiscal decentralization and environmental pollution, considering the nonlinear problem and also using the GDP quadratic term. As the Environmental Kuznets Curve hypothesis was first proposed based on the relationship between income levels and the environment, many other studies on pollutant emissions have also adopted the GDP quadratic term when verifying the Environmental Kuznets Curve hypothesis ((Xu et al., 2016), (Dong et al., 2017), etc.). However, this approach can only test the nonlinear impact change of GDP on the environment, basically assuming the linear effects of other influencing factors.

In fact, in order to study the nonlinear relationship between variables, the threshold method has been applied in the field of economics since the 1980s. Threshold means that the relationship between variables is different in the process above the threshold and in the process below the threshold, therefore, this model is somewhat similar to a piecewise function. It can simultaneously capture the asymmetry interaction between variables in a process. By using a threshold model, Wu et al. (2017) illustrated that increasing the level of corruption could directly reduce regional total factor productivity and that the effect of the government expenditure structure on total factor productivity has a single threshold. Both Lee and Chang (2007a) and Huang et al. (2008) studied the nonlinear relationship between GDP and energy consumption. Lee and Chang (2007b) used Taiwan's time series data and used gross energy consumption as a threshold variable and found that there is an inverse U relationship between energy consumption and income.

In many pieces of literature, technological progress, economic growth, energy prices, and regulatory mechanisms are improved as important factors influencing energy demand or energy intensity. However, for China, because the government has a strong impulse to drive economic growth, its behavior will often have an important impact on energy consumption and energy intensity. There have been some studies examining the impact of government expenditure on energy intensity: Yuxiang and Chen (2010) used panel data to conduct empirical tests, pointing out that government expenditure has had a significant impact on energy intensity since the Asian financial crisis, and that the expansion of Chinese government expenditure tends to increase energy intensity; Wei and Shen (2007) used the data envelopment analysis method to calculate provincial energy efficiency under the framework of total factor energy efficiency, indicating that the increase in government fiscal expenditure as a percentage of GDP will lead to a decline in energy efficiency, but this negative impact is gradually decreasing; Chen (2014) conducted a causal relationship test between the scale of fiscal expenditure, industrial structure, and energy intensity in Xinjiang, and concluded that the scale of government expenditure and industrial structure are Granger reasons for changes in energy intensity, and both have a positive impact on energy intensity changes; Qu and Yuan (2009) compared Chinese regional differences in energy intensity, and the results show that government intervention (take the proportion of fiscal expenditure in GDP as the representative variable) has played a reverse role in the reduction of energy intensity in the three regions; Li and Yu (2015) studied the factors affecting energy intensity by constructing spatial lag model and spatial error model, selecting the proportion of fiscal expenditure to GDP, industrial structure, energy structure, and foreign direct investment as the explanatory variables, believing that appropriate reduction of government expenditure is conducive to reducing the intensity of energy consumption.

However, research on the impact of government expenditures on energy consumption is relatively small, lack of comparison of different energy consumption, and lack of classification discussion on government expenditures. The existing research on the influencing factors of energy consumption still uses GDP as the main income variable. When considering the Energy Kuznets Curve, most of them introduce the quadratic term of GDP in the empirical test equation. Which part of the income plays the role of transition, few people discuss. Therefore, as far as the existing literature is concerned, there is a lack of testing from a macroeconomic perspective on the nonlinear relationship between government expenditures and energy consumption. What's more, when considering the regional differences in China, most of these studies consider the division of China into the eastern, central and western regions based on geographical distribution. Is this really reasonable？ It is also a question worth studying.

This paper will make a preliminary attempt to respond to the above questions. Referring to Kuznets's viewpoints, this paper selects China's provincial data, distinguishes between government expenditures on public goods and private goods, uses a panel threshold model to study the possible impact of government expenditures on energy consumption and the possible changes of other influencing variables. In particular, this paper attempts to compare the different impacts of government expenditures and the other influencing factors (especially the investment of private sector) on energy consumption. What's more, the comparison of regional differences is based on the division of the threshold model, which is different from the previous division of the eastern, central and western regions.

3. The empirical strategy and the Data

This study refers to the Cobb-Douglas production function of López et al. (2011) (pp.181-182) and the method of classifying government expenditures. López et al. (2011) (p.181) classified the government expenditures into expenditures on public goods, which are complements to private input, and expenditures on private goods that may be substituted for private capital, and introduced such expenditures into the Cobb-Douglas production function. As Halkos and Paizanos (2014) (p.6) concluded that CO_2 emissions are mainly derived from the consumption of fossil energy, and the long-term and short-term factors affecting CO_2 emissions and energy consumption could include: demographic changes（Zhu and Peng (2012)）, economic development (Grossman and Krueger (1995); Sobrino and Monzon (2014)), energy prices (Hang and Tu (2007)), trade (Cole and Elliott (2003)), and consumer habits（Baiocchi et al., 2010). That is, energy consumption can also be written as a function of these factors, and the economic development variable or income factor can further be divided based on the Cobb-Douglas production function and the government expenditures are also included.

This paper employs panel data at the provincial level to study the relationship between energy consumption and influencing factors. When selecting the data, the representativeness and availability of data are considered together. And refereeing Wang and Lin (2019) (p.160), variables and data sources can be noted in Table 1， the main source is National Bureau of Statistics of China (NBSC (2018) and NBSC (2017)). For comparison, the energy consumption data selected in this paper includes the primary energy consumption and electricity consumption of each province, and the per capita primary energy consumption (enc) and per capita electricity consumption (elc) are calculated according to the total energy consumption and population data.

Since GDP in this paper is decomposed based on the Cobb-Douglas production function, per capita capital stock will be adopted, and this variable can represent the investment of the private sector to some extent. Referring to the methods of Shan (2008), Zhang and Zhang (2003), and Zhang et al. (2004), their estimated capital stock data, the province's gross capital formation data each year, and fixed asset investment index (1996 is the base year), per capita capital stock of each province is estimated (Capital stock = nominal gross capital formation/deflator index + (1-0.1) * capital stock of last period); referring to relevant literature, such as López et al. (2011) (p.196), the ratio of the population of 15-65 years old to total population is selected as a representative for the labor population variable (pop); per capita export and import (exp and imp) of each province is obtained based on the data of the total value of exports and imports of destinations and catchments.

Government expenditures and the classification data need to be given more explanation. López and Galinato (2007) (p.1074) and López et al. (2011) (p.181) divided government expenditures into expenditures on public goods and expenditures on private goods. Depending on the classification, government expenditures on public goods include education expenditure, medical expenditure, environmental protection expenditure, R&D expenditure, cultural diffusion expenditure, and some other expenditures on traditional public goods and services. Government expenditures on public goods can overcome market failure and externalities in some ways. For example, when only the family department invests in education and medical care, it is prone to underinvestment. R&D expenditures provided solely by the market often face market failure. The private sector is rarely interested in environmental protection. Some legal institutions and departments also need government investment. On the other hand, government expenditures on private goods often include energy consumption subsidies, energy production subsidies, credit subsidies and some subsidies for specific industries or enterprises. Government expenditures on private goods may result in crowding-out effects on the private sector and may also result in inefficiencies. This paper refers to the classification methods of OECD (2011) and López et al. (2011) (p.181). And considering that China began to adopt new government revenue and expenditure subjects in 2007, with reference to "2007 Government Revenue and Expenditure Classification Subject Setting and New and Old Subject Conversion Methods", "Notice of the Ministry of Finance on Printing and Distributing the Classification of Government Revenue and Expenditure in 2018" and the specific subjects of government expenditure in the Statistical Yearbook, and taking into account whether the expenditure can be supplemented or replaced by the market, the public goods expenditures selected in this paper are listed in Table 2: the left column is the public goods expenditure subjects after 2007, and the right column is the public goods expenditure subjects from 1998 to 2006. Although since 2007 government expenditure subjects have changed, as this paper only considers two categories of public goods and private goods of government expenditure, the detailed classification method is also supported by the above literature. Therefore, as far as the data of the two categories is concerned, there is still continuity.

In China, since central government expenditures are responsible for national affairs, government expenditures for each province only support local finance, this paper also assumes that there is an average province of the nation, its total government expenditure includes both central government expenditure and the sum of local expenditure of provinces, and its per capita expenditure is calculated based on the national population. Based on the data of gross fiscal expenditure and government expenditure on public goods classified above, government expenditure on private goods could be calculated by the difference.

In addition to the above variables and data, the level of technological development related to education (tec), the urbanization rates that reflect lifestyles and are considered to have an impact on energy consumption (urb), and the energy consumption price (epr) will be introduced into this study. Among them, the level of technological development is constructed based on the education level data of the population. According to the data of the China Statistical Bureau and referring to the census data for people over 6 years old, the illiterate population is given an index of 1, the index of the primary school graduate population is 2, the junior high school graduate population index is 3, the senior high school graduate population index is 4, and the population with college or higher education has an index of 5. Taking the proportion of the corresponding population to the total population as the weight, a comprehensive education level index is obtained, and can be used as data for technological variables; The urbanization rate is the ratio of the urban population to the total population of each province; Energy prices, because it is difficult to collect long-term complete data, this paper used the relative price, that is, the ratio of the energy price index (1996 is the base year) to the GDP deflator index (1996 is the base year). In addition, with the observation of energy consumption and electricity consumption levels in various provinces in China, it can be found that the provinces with superior energy resources endowments have relatively high levels of total energy and electricity consumption. Therefore, in order to study the impact of resource endowments, the variable per capita fossil energy production (enp) to represent resource endowments will be introduced.

The relationship between per capita energy consumption (e) and its influencing factors constructed in this paper can be written as in equation (1), which is similar to the equation used by Adebumiti and Masih (2018) (p.6), whose focus is on the impact of energy consumption and government expenditure on economic growth.

$$e = f(cap, pop, pub, pri, \exp, imp, urb, tec, enp, epr) \tag{1}$$

Considering the availability of data, the data span of empirical research is 1998-2016. Table 3 is the descriptive statistics of the data. In order to avoid the heteroscedasticity problem in the empirical test, the above data are logarithmically processed. Then the variables in the empirical test are listed as: lnelc, lnenc, lncap, lnpop, lnpub, lnpri, lnexp, lnimp, lnurb, lntec, lnenp, and lnepr.

Table 1 here

Table 2 here

Table 3 here

Assuming a linear relationship between the influencing factors and energy consumption, a panel data model can be constructed as equation (2): i represents the cross-sectional unit of the regional province, and t represents the year. The term μ_i is a regional effect that can be fixed or random, ζ_t is a time effect common to all regions and ε_{it} is a disturbance term with the usual desirable properties. If the impact of influencing factors on energy consumption is non-linear, a threshold effect is assumed to exist, and a threshold regression model should be introduced. The threshold models will be defined in the empirical test section.

$$\ln e_{it} = \mu_i + \zeta_t + \beta_1 \ln cap_{it} + \beta_2 \ln pop_{it} + \beta_3 \ln pub_{it} + \beta_4 \ln pri_{it} + \beta_5 \ln \exp_{it} + \beta_6 \ln imp_{it} + \beta_7 \ln urb_{it} + \beta_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it} \quad (2)$$

4.Empirical test

In order to verify the relationship between primary energy consumption, electricity consumption, and their influencing factors, the RESET test must be firstly conducted to see if there is a nonlinear relationship. 4.1 presents this test and the linear relationship is rejected. Estimations of the threshold models are further provided in sections 4.2 and 4.3. Government expenditure is selected as a threshold variable in section 4.2 to study the changes of energy consumption and the influencing factors; for comparison and verification, energy consumption itself is selected as a threshold variable in Section 4.3; Section 4.4 summarizes the results of the above empirical tests. First, the relationship between primary energy consumption and electricity consumption and their influencing factors is discussed, and the differences between the two are compared, and then the influence differences in government expenditure on public goods and government expenditure on private goods are also compared.

4.1 Linear relationship test

Referring to equation (2), the linear relationship between per capita primary energy consumption and electricity consumption and the influencing factors in empirical tests can be written as (3) and (4).

$$\ln enc_{it} = \mu_i + \zeta_t + \beta_1 \ln cap_{it} + \beta_2 \ln pop_{it} + \beta_3 \ln pub_{it} + \beta_4 \ln pri_{it} + \beta_5 \ln \exp_{it} + \beta_6 \ln imp_{it} + \beta_7 \ln urb_{it} + \beta_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it} \quad (3)$$

$$\ln elc_{it} = \mu_i + \zeta_t + \beta_1 \ln cap_{it} + \beta_2 \ln pop_{it} + \beta_3 \ln pub_{it} + \beta_4 \ln pri_{it} + \beta_5 \ln \exp_{it} + \beta_6 \ln imp_{it} + \beta_7 \ln urb_{it} + \beta_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it} \quad (4)$$

The fixed effects test and the linear relationship test are performed firstly. In general, equations constructed from regional data mostly use fixed-effects models. Hausman test and over-identification test are conducted to determine the selection of either random or fixed-effects model. Depending on the results in Table 4, the fixed-effects model is selected in this paper. According to the RESET test results of Table 5, it can be seen that there may be a nonlinear relationship between the influencing factors and per capita energy consumption. Since the focus of this paper is on the impact of government expenditures on energy consumption, this paper studies the nonlinear relationship between energy consumption and influencing factors from two aspects: firstly, taking the government expenditure as the threshold variable, the paper studies the non-linear effects of the main influencing factors on energy consumption; secondly, for comparison purposes, energy consumption is used as the threshold variable to study the non-linear relationship.

Table 4 here

Table 5 here

4.2 Threshold Model Testing and Estimation — Government Expenditure as a Threshold Variable

From the perspective of macroeconomic, compared with economic variables such as investment, import, and export, government expenditure is more anthropogenic, especially when fiscal policy is used as a macro policy tool. At the same time, from the perspective of expenditure method, government expenditure as an important part of GDP, its absolute level of per capita can also roughly represent the economic development level of a province. Therefore, whether there is a threshold effect in the process of government expenditure growth is first tested. The essence is also whether the impacts of the influencing variables on energy consumption would change with the development of the economy. This part is mainly to test four models: Model I, Model II, Model III and Model IV, as shown as equation (5), (6), (7), and (8) respectively.

Model I:

$$\ln enc_{it}=\begin{cases}\beta_0+\beta_1\ln cap_{it}+\beta_2\ln pop_{it}+\beta_3\ln pub_{it}+\beta_4\ln pri_{it}+\beta_5\ln \exp_{it}+\beta_6\ln imp_{it}+\beta_7\ln urb_{it}+\beta_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pub_{it}\le\gamma_1\\ \beta_0+\beta'_1\ln cap_{it}+\beta'_2\ln pop_{it}+\beta'_3\ln pub_{it}+\beta'_4\ln pri_{it}+\beta'_5\ln \exp_{it}+\beta'_6\ln imp_{it}+\beta'_7\ln urb_{it}+\beta'_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it},\gamma_1<pub_{it}\le\gamma_2\\ \beta_0+\beta''_1\ln cap_{it}+\beta''_2\ln pop_{it}+\beta''_3\ln pub_{it}+\beta''_4\ln pri_{it}+\beta''_5\ln \exp_{it}+\beta''_6\ln imp_{it}+\beta''_7\ln urb_{it}+\beta''_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pub_{it}>\gamma_2\end{cases}\qquad(5)$$

Model II:

$$\ln enc_{it}=\begin{cases}\beta_0+\beta_1\ln cap_{it}+\beta_2\ln pop_{it}+\beta_3\ln pub_{it}+\beta_4\ln pri_{it}+\beta_5\ln \exp_{it}+\beta_6\ln imp_{it}+\beta_7\ln urb_{it}+\beta_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pri_{it}\le\theta_1\\ \beta_0+\beta'_1\ln cap_{it}+\beta'_2\ln pop_{it}+\beta'_3\ln pub_{it}+\beta'_4\ln pri_{it}+\beta'_5\ln \exp_{it}+\beta'_6\ln imp_{it}+\beta'_7\ln urb_{it}+\beta'_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it},\theta_1<pri_{it}\le\theta_2\\ \beta_0+\beta''_1\ln cap_{it}+\beta''_2\ln pop_{it}+\beta''_3\ln pub_{it}+\beta''_4\ln pri_{it}+\beta''_5\ln \exp_{it}+\beta''_6\ln imp_{it}+\beta''_7\ln urb_{it}+\beta''_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pri_{it}>\theta_2\end{cases}\qquad(6)$$

Model III:

$$\ln elc_{it}=\begin{cases}\beta_0+\beta_1\ln cap_{it}+\beta_2\ln pop_{it}+\beta_3\ln pub_{it}+\beta_4\ln pri_{it}+\beta_5\ln \exp_{it}+\beta_6\ln imp_{it}+\beta_7\ln urb_{it}+\beta_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pub_{it}\le\gamma'_1\\ \beta_0+\beta'_1\ln cap_{it}+\beta'_2\ln pop_{it}+\beta'_3\ln pub_{it}+\beta'_4\ln pri_{it}+\beta'_5\ln \exp_{it}+\beta'_6\ln imp_{it}+\beta'_7\ln urb_{it}+\beta'_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it},\gamma'_1<pub_{it}\le\gamma'_2\\ \beta_0+\beta''_1\ln cap_{it}+\beta''_2\ln pop_{it}+\beta''_3\ln pub_{it}+\beta''_4\ln pri_{it}+\beta''_5\ln \exp_{it}+\beta''_6\ln imp_{it}+\beta''_7\ln urb_{it}+\beta''_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pub_{it}>\gamma'_2\end{cases}\qquad(7)$$

Model IV:

$$\ln elc_{it}=\begin{cases}\beta_0+\beta_1\ln cap_{it}+\beta_2\ln pop_{it}+\beta_3\ln pub_{it}+\beta_4\ln pri_{it}+\beta_5\ln \exp_{it}+\beta_6\ln imp_{it}+\beta_7\ln urb_{it}+\beta_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pri_{it}\le\theta'_1\\ \beta_0+\beta'_1\ln cap_{it}+\beta'_2\ln pop_{it}+\beta'_3\ln pub_{it}+\beta'_4\ln pri_{it}+\beta'_5\ln \exp_{it}+\beta'_6\ln imp_{it}+\beta'_7\ln urb_{it}+\beta'_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it},\theta'_1<pri_{it}\le\theta'_2\\ \beta_0+\beta''_1\ln cap_{it}+\beta''_2\ln pop_{it}+\beta''_3\ln pub_{it}+\beta''_4\ln pri_{it}+\beta''_5\ln \exp_{it}+\beta''_6\ln imp_{it}+\beta''_7\ln urb_{it}+\beta''_8\ln tec_{it}+\beta_9\ln enp_{it}+\beta_{10}\ln epr_{it}+\varepsilon_{it}, pri_{it}>\theta'_2\end{cases}\qquad(8)$$

Model I as shown in equation (5), assumes that there is a double threshold effect. In this model, the variable pub is used as a threshold variable, per capita capital stock (cap), labor population variable (pop), import and export variable (exp and imp), government expenditure variables (pub and pri), urbanization variable (urb), and the technological variable related to education (tec) are core explanatory variables. As the main purpose of this paper is to study income-related variables such as capital stock (investment), labor population, import and export, urbanization and technology levels, and the possible impacts on energy consumption at different levels of government expenditures, and since energy prices are affected by many factors, such as resource conditions and energy import and export, a linear impact of energy price on energy consumption is assumed. At the same time, resource endowment is mainly determined by natural resource conditions. Its impact on energy consumption is assumed to be linear in this paper, too. Next, consider the threshold effect of per capita government expenditure on private goods on primary energy consumption, namely Model II. Model III discusses the threshold effect of the per capita electricity consumption and takes government expenditure on public goods as a threshold variable. Model IV is also about electricity consumption and takes government expenditure on private goods as the threshold variable.

Table 6 gives the threshold test of Model I, Model II, Model III and Model IV. According to the test, there is a double threshold for Model I and Model II, and a single threshold for Model III and Model IV. When searching for thresholds, the optimized search method of Hansen (1999) is adopted. Table 7 lists the thresholds of the variables. Table 8, Table 9, Table 10 and Table 11 give the coefficient estimation of these threshold models. In order to indicate the threshold value and the development history of per capita government expenditure on public goods and expenditure on private goods in each province, Figure 3, Figure 4, Figure 5 and Figure 6 are also presented.

Table 6 here

Table 7 here

Table 8 here

Table 9 here

Table 10 here

Table 11 here

Figure 3 here

Figure 4 here

Figure 5 here

Figure 6 here

4.3 Threshold Model Testing and Estimation — Energy Consumption as a Threshold Variable

For comparison, this paper also uses energy consumption as a threshold variable for comparison tests (similar to Huang et al. (2008)), which are Model V and Model VI, as shown as equation (9) and (10). According to the threshold test results in Table 12 and Table 13, both primary energy consumption and electricity consumption have a double threshold. The coefficient estimation is shown in Table 14 and Table 15. In order to more intuitively indicate the threshold value and the development history of per capita primary energy consumption and electricity consumption in each province, Figure 7 and Figure 8 are also presented.

Model V:

$$\ln enc_{it} = \begin{cases} \beta_0 + \beta_1 \ln cap_{it} + \beta_2 \ln pop_{it} + \beta_3 \ln pub_{it} + \beta_4 \ln pri_{it} + \beta_5 \ln \exp_{it} + \beta_6 \ln imp_{it} + \beta_7 \ln urb_{it} + \beta_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, enc_{it} \le \pi_1 \\ \beta_0 + \beta'_1 \ln cap_{it} + \beta'_2 \ln pop_{it} + \beta'_3 \ln pub_{it} + \beta'_4 \ln pri_{it} + \beta'_5 \ln \exp_{it} + \beta'_6 \ln imp_{it} + \beta'_7 \ln urb_{it} + \beta'_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, \pi_1 < enc_{it} \le \pi_2 \\ \beta_0 + \beta''_1 \ln cap_{it} + \beta''_2 \ln pop_{it} + \beta''_3 \ln pub_{it} + \beta''_4 \ln pri_{it} + \beta''_5 \ln \exp_{it} + \beta''_6 \ln imp_{it} + \beta''_7 \ln urb_{it} + \beta''_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, enc_{it} > \pi_2 \end{cases} \tag{9}$$

Model VI:

$$\ln elc_{it} = \begin{cases} \beta_0 + \beta_1 \ln cap_{it} + \beta_2 \ln pop_{it} + \beta_3 \ln pub_{it} + \beta_4 \ln pri_{it} + \beta_5 \ln \exp_{it} + \beta_6 \ln imp_{it} + \beta_7 \ln urb_{it} + \beta_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, elc_{it} \le \omega_1 \\ \beta_0 + \beta'_1 \ln cap_{it} + \beta'_2 \ln pop_{it} + \beta'_3 \ln pub_{it} + \beta'_4 \ln pri_{it} + \beta'_5 \ln \exp_{it} + \beta'_6 \ln imp_{it} + \beta'_7 \ln urb_{it} + \beta'_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, \omega_1 < elc_{it} \le \omega_2 \\ \beta_0 + \beta''_1 \ln cap_{it} + \beta''_2 \ln pop_{it} + \beta''_3 \ln pub_{it} + \beta''_4 \ln pri_{it} + \beta''_5 \ln \exp_{it} + \beta''_6 \ln imp_{it} + \beta''_7 \ln urb_{it} + \beta''_8 \ln tec_{it} + \beta_9 \ln enp_{it} + \beta_{10} \ln epr_{it} + \varepsilon_{it}, elc_{it} > \omega_2 \end{cases} \tag{10}$$

Table 12 here

Table 13 here

Table 14 here

Table 15 here

Figure 7 here

Figure 8 here

4.4 Discussion of empirical results

Based on the above empirical research results, a comparative discussion is provided in this section. First of all, primary energy consumption coefficients are analyzed. Referring to Table 8, Table 9, Table 14, and regional distribution map Figure 3, Figure 4 and Figure 7, the results of the threshold regression show a certain consistency, that is, whether it is based on the development of government expenditure on public goods, or the development of government expenditure on private goods, or the development of primary energy consumption itself, in the three tests, the time and place of the change in the relationship between primary energy consumption and its influencing factors were generally consistent. Relatively speaking, the increase in public goods expenditure is more likely to cause a change in the relationship between primary energy consumption and its influencing factors. Different from many subgroups on China's energy and environmental research, in this study, North East, North China, and North West have similar development paths with their influencing factors. These regions have relatively high energy consumption levels and tend to have quick changes, while the energy consumption level in the central region is relatively lower, and can be studied as a group.

From the estimation of the coefficients of primary energy consumption, with the increase of government expenditure and the growth of energy consumption, the positive pull of capital stock will decline; The positive impact of labor population growth on primary energy consumption may show a trend of rising first and then decreasing. Combining the estimation of the coefficients of the three tables (Table 8, Table 9 and Table 14), the positive effect of the growth of government expenditure on public goods shows a downward trend in a certain period, and when the government expenditure or energy consumption reach a higher level, its promotion may be enhanced. The increase in government expenditure on private goods may play a role in suppressing per capita primary energy consumption at the beginning, but with the expenditure increase or the energy consumption increase, the increase in government expenditure on private goods will also have a positive influence on per capita primary energy consumption. According to the estimation of this paper, with the development of the economy, the role of import and export is not very certain, mainly because the data included in different groups have certain differences, and in the income, the proportion of import and export is small, differences in the data samples contained in the different groups are sufficient to have a significant effect on the coefficients of the two variables. The role of urbanization has been further strengthened, and the negative effects of technological advances brought about by education on primary energy consumption have become significant and great. Unlike expectations, the richness of fossil energy resources has a very limited impact on primary energy consumption. In the current situation, the rise in the relative price of energy does not seem to play a significant role in curbing primary energy consumption.

According to the threshold estimation, the divisions of the group of the electricity consumption are as shown in Figure 5, Figure 6 and Figure 8, also showing stronger consistency. Whether it is government expenditure, or electricity consumption, Beijing, Shanghai and some provinces in the North West are at higher levels. According to the estimation of the coefficients in Table 10, Table 11 and Table 15, the driving force of capital stock increase will not decline, and may even increase. The role of labor population growth will decline. The positive effect of increased government expenditure on public goods will also increase. Government expenditure on private goods shows strong consistency. That is, at lower levels of government expenditure and electricity consumption, the increase in government expenditure on private goods will inhibit per capita electricity consumption to a certain extent, and as government expenditure and electricity consumption increase, the increase in government expenditure on private goods will boost the increase in per capita electricity consumption. The promotion of imports and exports may increase. Unlike primary energy consumption, the impact of continuous urbanization on per capita electricity consumption will go from positive to negative which shows an obvious threshold effect. The energy-saving role of technology may strengthen as government expenditure increases. The impact of fossil energy resource endowments is also relatively limited, and the inhibition influence of price is not significant.

Compared with primary energy consumption, the relationship between electricity consumption and its influencing factors would change later. The difference in the effects of influencing factors is mainly reflected in the formation of capital stock and the development of urbanization. For primary energy consumption, the role of capital stock formation or investment will continue to decline, while the impact on electricity consumption may not change significantly, or even increase. The development of urbanization will promote the increase of per capita primary energy consumption, and it will show an increasing trend, while the impact on electricity consumption will increase first and then decrease. One possible reason is that primary energy consumption includes energy consumption of human activities in more sectors. Therefore, lifestyle changes brought about by the advance of urbanization will increase per capita primary energy consumption. Although urbanization will increase per capita electricity consumption, the energy-saving effect of population concentration in towns will become more important after the economy and electricity consumption reaching a certain level.

Comparing the effects of government expenditure on public goods and expenditure on private goods, it can be observed that they have significantly different effects, both for primary energy consumption and electricity consumption. The impact of public goods expenditure on primary energy or electricity consumption is roughly positive and increasing. When government expenditure on private goods is at a low level, it will have a significant inhibitory effect on both primary energy consumption and electricity consumption. After a certain level, its increase will boost per capita energy consumption. According to López et al. (2011) (page 181), these private goods can replace private sector investment to some extent. Based on the estimates in this paper, the coefficient of government expenditure on private goods is smaller compared to the coefficient of capital stock which mainly comes from private sector investment, which also indicates that the efficiency of government expenditure is higher. Although it is impossible to obtain more detailed industry information, from the estimation of this article, the government's participation in the private market and the provision of some private goods are not ineffective in terms of energy consumption and maybe superior to the private market in energy efficiency at a certain stage.

When returning to the Energy Kuznets Curve, it should be noted that there may be more than one factor that has a non-linear effect on energy consumption. Then, as the economy develops, the total impact of income depends on the relative changes in factors such as capital stock formation or investment, labor population, government expenditures, urbanization, and technology. If China wants its Energy Kuznets Curve turning point to come as soon as possible, technological progress is still the most important, and this also points the way for the focus of government expenditures or fiscal policy.

Whether it is government expenditure as a threshold variable or energy consumption as a threshold variable, the empirical results show that the energy consumption levels of different provinces and their government expenditure levels do have a more consistent trend. Though the economic levels of some provinces in the northeast and west are relatively underdeveloped, their per capita government expenditure levels are not in low levels, and often correspond to higher per capita energy consumption levels.

5.Conclusions and policy recommendations

Considering the Energy Kuznets Curve hypothesis, this paper selects data on energy consumption and economic development in 30 provinces of China and uses panel threshold models to study the non-linear effects of multiple factors, including government expenditures on primary energy consumption and electricity consumption. This paper makes a preliminary attempt to answer these questions: Which part of the income contributes to the turning point of Energy Kuznets Curve; What is the difference between the relationships of primary energy consumption and electricity consumption with their influencing factors; How do different parts of government expenditure affect energy consumption, and in view of energy consumption or cleaner production, is government inefficient at any time and under any circumstances; Considering energy consumption, is it reasonable to divide China into the eastern, central and western regions from a geographical and economic development perspective as many previous literature on energy consumption of China.

In order to answer these questions, referring to the existing research, this paper constructs a panel threshold model including per capita primary energy consumption (or electricity consumption), per capita capital stock, government expenditures, labor population, import and export, energy price and technology variables. For a better comparison, this paper selects government expenditure, per capita energy consumption as threshold variables. Moreover, groups of different regions divided by threshold regression are quite different from the groups that are divided into east, central and west by geographical division in many previous works of literature.

Various literature studies suggest that an increase in government expenditure has increased China's energy intensity. However, according to this paper, government expenditure on private goods may not be as inefficient as previously thought in the literature. China's large-scale government expenditure is often accompanied by large investments in the private sector which become capital stock. If the relevant research which believes that government expenditure is inefficient considers the impact of these investments in private sector on energy intensity, perhaps their conclusions will be different. Therefore, when studying its impacts on energy consumption or energy intensity, government expenditures should be appropriately differentiated. In addition, based on the sub-regional division of the threshold model, using the threshold model to group regions, it is found that for China, some provinces in the east with higher energy consumption and income and provinces with higher energy consumption and lower income in the northwest may have similar responses to the influencing factors. And that provinces with higher per capita income do not mean that per capita government expenditure will be high. These findings mean that when studying the issue of energy consumption and regional differences, the widely used group method of areas in China may not be appropriate.

The above analysis shows that there exists a non-linear relationship between the variables closely related to income and energy consumption. China's economic development is mainly driven by investment in the past long period. In the future, the growth of government expenditure will become a powerful driving factor. This also indicates that the government needs to assess its overall influence on energy consumption and the interference of market energy efficiency when participating in the provision of public goods and private goods. And when government expenditure policy implementations and private sector investments experience large fluctuations, the different impacts on primary energy and electricity consumption should be treated in a timely manner. At the same time, the technological variables used in this paper are mainly derived from the scholastic level data. The estimation results also provide us with important policy implications, that the government expenditure in education will be of great significance, which can produce a strong energy-saving effect on energy consumption through technological progress. It also shows that for many regions, the energy-saving effect of technology has not been fully exerted.

For other countries or regions, although the development speed, development stage and income structure are different from those in China, the ideas of this paper still have some inspirations. First, when studying the Kuznets Curve of energy consumption, it may be necessary to decompose the commonly used GDP variables, and the expenditure method of GDP accounting could be an entry point. Second, comparing the relationship between different energy consumption and influencing factors under the same research framework, and considering the non-linear effects of other influencing factors other than income on energy consumption, it is also of practical significance for adjusting energy structure. Third, the governments, as the main setters and implementers of energy policy, should not only evaluate these policies, but also evaluate the impacts of energy consumption caused by their own actions and expenditures, so that they can play a true leader role in energy conservation and emission reduction.

Since this paper is only a preliminary exploration of the above questions, there are naturally some shortcomings. For example, the classification of government expenditures is still relatively rough. In further study on the impact of government expenditures on energy consumption, especially about the comparison with private sector investment, segmentation of industry data and research is necessary; Also because of the rougher classification, there is a lack of more in-depth discussion mechanism issues, how and to what extent the different components would influence the energy consumption remain open questions; for the research methods, the panel threshold model cannot allow for cross-sectional independence and slope homogeneity (Dong et al., 2018), which are important for more accurate estimation. In the future, detailed research on the energy impacts of various compositions of government expenditures should be conducted.

Abbreviation

CO_2 Carbon dioxide

GDP Gross domestic product

OECD Organization for Economic Co-operation and Development

SO_2 Sulfur dioxide

US United Stats

R&D Research and development

RESET test Regression specification error test

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Table 1 Variables and the data sources

Variable	Full name	Unit	Sources of raw data
enc	Per capita primary energy consumption	kgce	NBSC (2017) , NBSC (2018)
elc	Per capita electricity consumption	kwh	NBSC (2017) , NBSC (2018)
cap	Per capita real capital stock	yuan	Shan (2008), Zhang and Zhang (2003), Zhang et al. (2004), NBSC (2018)
pop	Per capita labor population	%	NBSC (2018)
pub	Per capita government expenditure on public goods	yuan	NBSC (2018)
pri	Per capita government expenditure on private	yuan	NBSC (2018)
exp	Per capita export	yuan	NBSC (2018)
imp	Per capita import	yuan	NBSC (2018)
enp	Per capita fossil energy production	kgce	NBSC (2017) , NBSC (2018)
urb	Urbanization rate	%	NBSC (2018)
tec	Technology: Per capita education index	1	NBSC (2018)
epr	Relative price of energy	1	NBSC (2018)

Table 2 Public goods expenditure subjects of government expenditure

Classification subjects from 2007 to the present	Classification subjects before 2007
Local government expenditure on national defense	Expenditure for National Defense
Local government expenditure on public security	Expenditure for Armed Police Troops
Local government expenditure on education	Expenditure for Public Security Agency, Procuratorial Agency and Court of Justice
Local government expenditure on culture, sports and media	Operating Expenses for Education
Local government expenditure on medical and health care	Operating Expenses for Culture, Sports and Broadcast
Local government expenditure on environmental protection	Operating Expenses for Health
Local government expenditure on transport	Operating expenses of industrial and traffic departments
Local government expenditure on housing security	Circulation department operating expenses
	Vehicle tax expenditure

Table 3 Statistical reviews of variables

Variable		Mean	Std. Dev.	Min	Max	Observations
elc	overall	2856.725	2168.214	450.7969	13213.7	N = 589
	between		1465.701	1291.573	7226.364	n = 31
	within		1618.22	-2362.148	9229.379	T = 19
enc	overall	2604.883	1516.228	486.2851	8328.905	N = 589
	between		1111.873	1163.12	4901.712	n = 31
	within		1049.062	-912.0825	6032.077	T = 19
cap	overall	51068.33	45544.81	4440.101	297042.4	N = 589
	between		25437.45	22121.09	123183.8	n = 31
	within		38040.43	-41625.62	224926.9	T = 19
pop	overall	72.9503	4.2637	57.1075	85.0883	N = 589
	between		3.0836	66.4467	79.3388	n = 31
	within		2.9936	60.1814	81.5153	T = 19
pub	overall	461.5095	317.9616	46.8182	1932.504	N = 589
	between		195.879	270.3562	1126.31	n = 31
	within		252.7955	-136.4571	1440.003	T = 19
pri	overall	738.3133	456.2666	116.7457	2705.09	N = 589
	between		415.7025	381.0443	2277.564	n = 31
	within		201.6449	32.1019	1456.409	T = 19
exp	overall	1454.884	2357.922	47.8237	15668.31	N = 589

	between		2269.182	101.452	10329.4	n = 31
	within		753.8148	-2261.584	6793.792	T = 19
imp	overall	1461.085	2577.67	22.3328	17200.97	N = 589
	between		2524.654	67.2111	12072.58	n = 31
	within		682.3667	-3741.077	6589.48	T = 19
urb	overall	47.1963	15.6038	14.04	89.6066	N = 589
	between		13.4125	29.5922	83.5587	n = 31
	within		8.3122	13.1692	63.5569	T = 19
tec	overall	0.5672	0.0595	0.4047	0.7936	N = 589
	between		0.0484	0.4865	0.7207	n = 31
	within		0.0356	0.4707	0.6401	T = 19
enp	overall	1646.207	2962.742	0.01	21837.7	N = 589
	between		2464.025	3.9304	10372.83	n = 31
	within		1700.671	-7161.23	13111.07	T = 19
epr	overall	0.6553	0.1906	0.2299	1.3491	N = 589
	between		0.103	0.5337	1.04	n = 31
	within		0.1614	0.1776	1.0119	T = 19

Table 4 Hausman test and Over-identifying test

Variables: lnenc lncap lnpop lnpub lnpri lnexp lnimp lnurb lntec linenp lnepr			
Hausman test statistic	Prob.	Over-identification test statistic	Prob.
39.31	0	49.096	0
Variables: lnelc lncap lnpop lnpub lnpri lnexp lnimp lnurb lntec lnenp lnepr			
Hausman test statistic	Prob.	Over-identification test statistic	Prob.
32.04	0.0008	69.07	0

Table 5 RESET test

Ho: model has no omitted variables	F-statistics	P-value	Results
lnenc model (Equation (3))	2.57	0.0537	Reject Ho
lnelc model (Equation (4))	3.5	0.0154	Reject Ho

Table 6 Threshold variable test of Model I, Model II, Model III and Model IV [1]

Model	Number of thresholds	RSS	MSE	Fstat	Prob	Crit10	Crit5	Crit1
Model I	Single	5.7743	0.0101	157.04	0.001	95.5341	108.1629	133.9755
	Double	4.8112	0.0084	114.11	0.001	74.1978	82.3243	98.1241
Model II	Single	6.0884	0.0107	119.54	0.0075	78.3699	89.6514	116.8446
	Double	5.2427	0.0092	91.94	0.0175	71.952	81.6599	100.0127
Model III	Single	7.1549	0.0126	229.1	0	104.4648	117.0457	142.3539
	Double	6.4374	0.0113	63.53	0.325	85.9638	96.5267	129.8817
Model IV	Single	7.033	0.0123	242.95	0	92.9955	105.9559	132.3372
	Double	6.2166	0.0109	74.85	0.144	79.5814	90.7507	126.3257

Note: [1] F value, the relevant critical value and 95% confidence interval in the table are the results of 1000 repeated sampling with "bootstrap". The trimming percentage is set to be 0.05 for Model I and Model II. The trimming percentage is set to be 0.1. for Model III and Model IV.

Table 7 Threshold value estimation of Model I, Model II, Model III and Model IV

	Threshold value	Threshold value
Model I	$lnpub_{it}$	pub_{it}
Th-21	5.1296	168.9495
Th-22	5.9017	365.6585
Model II	$lnpri_{it}$	pri_{it}
Th-21	6.1935	489.5566
Th-22	6.78	880.0687
Model III	$lnpub_{it}$	pub_{it}
Th-1	6.4686	644.5807
Model IV	$lnpri_{it}$	pri_{it}
Th-1	6.7731	874.0172

Table 8 Coefficient Estimation of Model I [1]

Explained variable: $lnenc_{it}$			
Explanatory variable	$pub_{it} \leq 168.9495$	$168.9495 < pub_{it} \leq 365.6586$	$pub_{it} > 365.6586$
$lncap_{it}$	0.7217***	0.5208***	0.3435***
	（8.42）	（17.28）	（9.88）
$lnpop_{it}$	0.3365*	0.504***	-0.1745971
	（1.71）	（3.53）	（-1.11）
$lnpub_{it}$	0.2468***	0.0225	0.1018***
	（3.21）	（0.45）	（2.63）
$lnpri_{it}$	-0.4582***	0.0559	0.1788***
	（-4.07）	（1.33）	（3.83）
$lnexp_{it}$	-0.0434	0.0514**	0.0647***
	（-1.03）	（2）	（3.6）
$lnimp_{it}$	-0.0462	0.0156	0.0557
	（-1.02）	（0.62）	（3.13）
$lnurb_{it}$	0.2888***	0.202***	0.7554***
	（3.37）	（3.83）	（6.23）
$lntec_{it}$	-1.5305***	0.2832	-1.4574***
	（-5.05）	（1.27）	（-5.7）
$lnenp_{it}$	0.0382***	0.0382***	0.0382***
	（5.76）	（5.76）	（5.76）
$lnepr_{it}$	0.1462***	0.1462***	0.1462***
	（3.21）	（3.21）	（3.21）
Constant	-1.5480**	-1.5480**	-1.5480**
	（-2.17）	（-2.17）	（-2.17）

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

Table 9 Coefficient Estimation of Model II [1]

Explained variable: $lnenc_{it}$			
Explanatory variable	$pri_{it} \le 489.5566$	$489.5566 < pri_{it} \le 880.0687$	$pri_{it} > 880.0687$
$lncap_{it}$	0.6934***	0.453***	0.3269***
	(15.69)	(13.97)	(5.39)
$lnpop_{it}$	0.7815***	0.7826***	-0.3813*
	(5.12)	(5.55)	(-1.85)
$lnpub_{it}$	-0.0333	-0.0348	0.2789***
	(-0.7)	(-0.8)	(5.73)
$lnpri_{it}$	-0.1190**	0.0353	0.1894**
	(-2.06)	(0.6)	(2.02)
$lnexp_{it}$	0.1092***	0.1084***	0.0469*
	(3.68)	(5.13)	(1.67)
$lnimp_{it}$	-0.0691**	0.0496***	0.0992***
	(-2.33)	(2.48)	(3.29)
$lnurb_{it}$	0.1404***	0.3525***	0.9679***
	(2.64)	(4.12)	(5.6)
$lntec_{it}$	-0.4273*	-0.4189*	-2.256***
	(-1.69)	(-1.77)	(-6.04)
$lnenp_{it}$	0.0326***	0.0326***	0.0326***
	(4.74)	(4.74)	(4.74)
$lnepr_{it}$	0.1489***	0.1489***	0.1489***
	(3.3)	(3.3)	(3.3)
Constant	-3.1423***	-3.1423***	-3.1423***
	(-4.32)	(-4.32)	(-4.32)

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

Table 10 Coefficient Estimation of Model III [1]

Explained variable: $lnelc_{it}$		
Explanatory variable	pub≤644.5807	pub>644.5807
$lncap_{it}$	0.435***	0.4911***
	(14.33)	(8.34)
$lnpop_{it}$	0.9915***	0.0417
	(6.4)	(0.18)
$lnpub_{it}$	0.098***	0.3858***
	(2.83)	(5.94)
$lnpri_{it}$	-0.0898**	0.2351***
	(-1.99)	(3.25)
$lnexp_{it}$	0.083***	0.135***
	(4.01)	(5.27)
$lnimp_{it}$	0.0439**	0.103***
	(1.99)	(3.68)
$lnurb_{it}$	0.3947***	-0.1199
	(7.45)	(-0.6)
$lntec_{it}$	0.0762	-1.2576***
	(0.31)	(-3.39)
$lnenp_{it}$	0.0327***	0.0327***
	(4.06)	(4.06)
$lnepr_{it}$	-0.0578	-0.0578
	(-1.1)	(-1.1)
Constant	-3.5917***	-3.5917***
	(-4.37)	(-4.37)

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

Table 11 Coefficient Estimation of Model IV [1]

Explained variable: $lnelc_{it}$		
Explanatory variable	pri≤874.0172	pri>874.0172
$lncap_{it}$	0.4901***	0.3814***
	(16.07)	(5.61)
$lnpop_{it}$	0.9421***	-0.4474**
	(6.28)	(-1.95)
$lnpub_{it}$	0.0373	0.3860***
	(1.08)	(7.08)
$lnpri_{it}$	-0.1212***	0.53***
	(-2.66)	(5)
$lnexp_{it}$	0.1168***	0.0514*
	(5.71)	(1.71)
$lnimp_{it}$	0.0193	0.1718***
	(0.94)	(5.17)
$lnurb_{it}$	0.4253***	0.1707
	(8.2)	(0.88)
$lntec_{it}$	0.1193	-1.5804**
	(0.49)	(-3.75)
$lnenp_{it}$	0.0250***	0.0250***
	(3.33)	(3.33)
$lnepr_{it}$	-0.0101	-0.0101
	(-0.21)	(-0.21)
Constant	-3.4940***	-3.4940***
	(-4.36)	(-4.36)

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

Table 12 Threshold variable test of Model V and Model VI [1]

Model	Threshold	RSS	MSE	Fstat	Prob	Crit10	Crit5	Crit1
Model V	Single	5.6424	0.0099	174.04	0	93.5789	102.8186	130.5945
	Double	4.1548	0.0073	204.09	0	73.5192	82.6335	99.4233
Model VI	Single	6.014	0.0106	380.7	0	101.2837	115.5167	143.1381
	Double	4.9107	0.0086	128.06	0.011	83.3875	95.9739	128.5215

Note: [1] F value, the relevant critical value and 95% confidence interval in the table are the results of 1000 repeated sampling with "bootstrap". The trimming percentage is set to be 0.05.

Table 13 Threshold value estimation of Model V and Model VI

	Threshold value	Threshold value
Model V	$lnenc_{it}$	enc_{it}
Th-21	7.239	1392.7006
Th-22	8.0616	3170.3587
Model VI	$lnelc_{it}$	elc_{it}
Th-21	7.5051	1817.287
Th-22	8.5189	5008.5413

Table 14 Coefficient Estimation of Model V [1]

Explained variable: $lnenc_{it}$			
Explanatory variable	$enc_{it} \leq 1392.7006$	$1392.7006 < enc_{it} \leq 3170.3587$	$enc_{it} > 3170.3587$
$lncap_{it}$	0.4289***	0.3192***	0.4322**
	(9.18)	(11.16)	(10.15)
$lnpop_{it}$	0.5182***	0.8475***	0.0975
	(3.42)	(6.64)	(0.65)
$lnpub_{it}$	0.1073***	-0.0068	-0.0162
	(2.47)	(-0.17)	(-0.37)
$lnpri_{it}$	0.0007	0.0606	0.2281***
	(0.01)	(1.35)	(3.96)
$lnexp_{it}$	-0.0454	0.0696***	0.0486**
	(-1.43)	(3.92)	(2.14)
$lnimp_{it}$	0.096***	0.0322*	0.0324
	(2.88)	(1.91)	(1.3)
$lnurb_{it}$	0.1519***	0.2519***	0.3088**
	(2.93)	(4.06)	(2.04)
$lntec_{it}$	-0.6589***	0.2607	-1.6209***
	(-2.76)	(1.25)	(-5.53)
$lnenp_{it}$	0.0405	0.0405	0.0405
	(6.28)	(6.28)	(6.28)
$lnepr_{it}$	0.131	0.131	0.131
	(3.43)	(3.43)	(3.43)
Constant	-1.2631	-1.2631	-1.2631
	(-1.91)	(-1.91)	(-1.91)

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

Table 15 Coefficient Estimation of Model VI [1]

Explained variable: $lnelc_{it}$			
Explanatory variable	elc≤1817.2870	1817.2870<elc≤5008.5413	elc>5008.5413
$lncap_{it}$	0.3592***	0.2823***	0.6866***
	(10.52)	(7.56)	(9.21)
$lnpop_{it}$	0.6375***	0.5267***	0.794***
	(4.42)	(3.78)	(3.25)
$lnpub_{it}$	0.1618***	0.1318***	0.1064
	(3.98)	(3.36)	(1.53)
$lnpri_{it}$	-0.1343***	0.0608	0.2624***
	(-3.05)	(1.19)	(3.44)
$lnexp_{it}$	0.0762***	0.1442***	0.1731***
	(3.12)	(8.02)	(4.58)
$lnimp_{it}$	0.0264	0.0482***	0.0446
	(1.08)	(2.61)	(1.07)
$lnurb_{it}$	0.4492***	0.3298***	-1.373***
	(9.28)	(3.05)	(-5.11)
$lntec_{it}$	0.5524**	0.2648	0.2579
	(2.42)	(1.11)	(0.53)
$lnenp_{it}$	0.0367***	0.0367***	0.0367***
	(5.12)	(5.12)	(5.12)
$lnepr_{it}$	-0.0521	-0.0521	-0.0521
	(-1.15)	(-1.15)	(-1.15)
Constant	-1.2396*	-1.2396*	-1.2396*
	(-1.7)	(-1.7)	(-1.7)

Note: [1] * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. t-statistics in parentheses.

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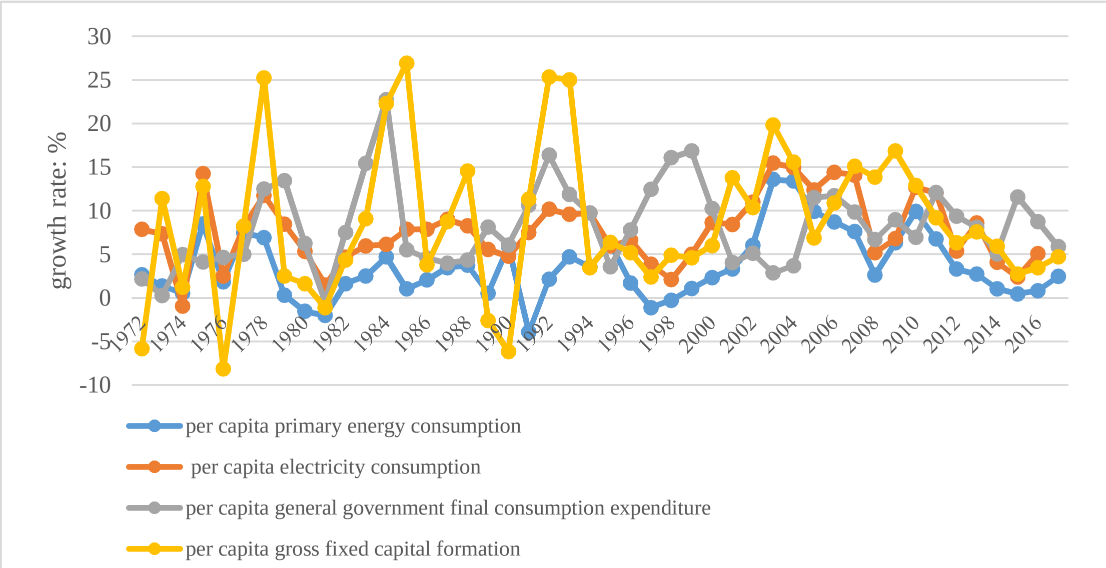

Figure 1 China's per capita primary energy /electricity consumption and per capita government expenditure/capital formation growth rate from 1972 to 2017

Sources：WordBank (2019)

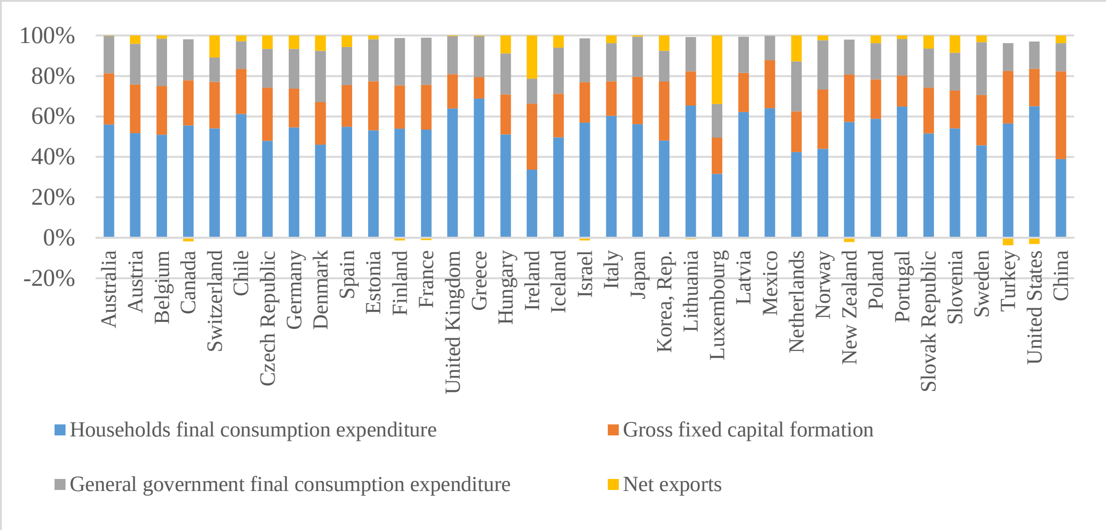

Figure 2 GDP percentage based on expenditure method of OECD countries and China in 2016

Sources： WordBank (2019)

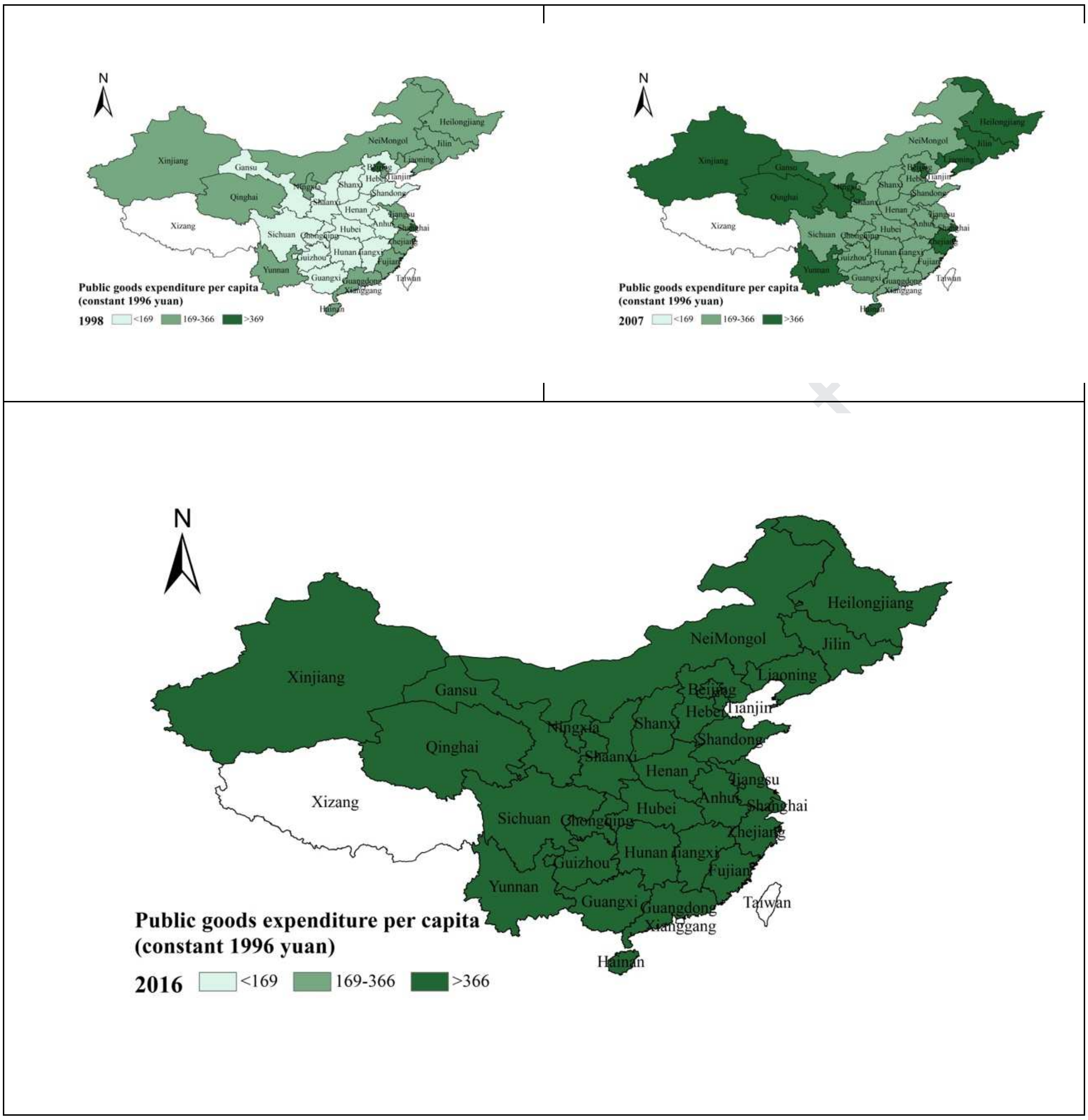

Figure 3 Spatial distributions of government expenditure on public goods based on Model I

Note: As shown, this figure contains the regional distribution of data for 1998, 2007, and 2016. Since this study does not include data for Tibet, Hong Kong, Macau, and Taiwan, these areas are not shown in color on the map. Figures 4, 5, 6, 7, and 8 are the same.

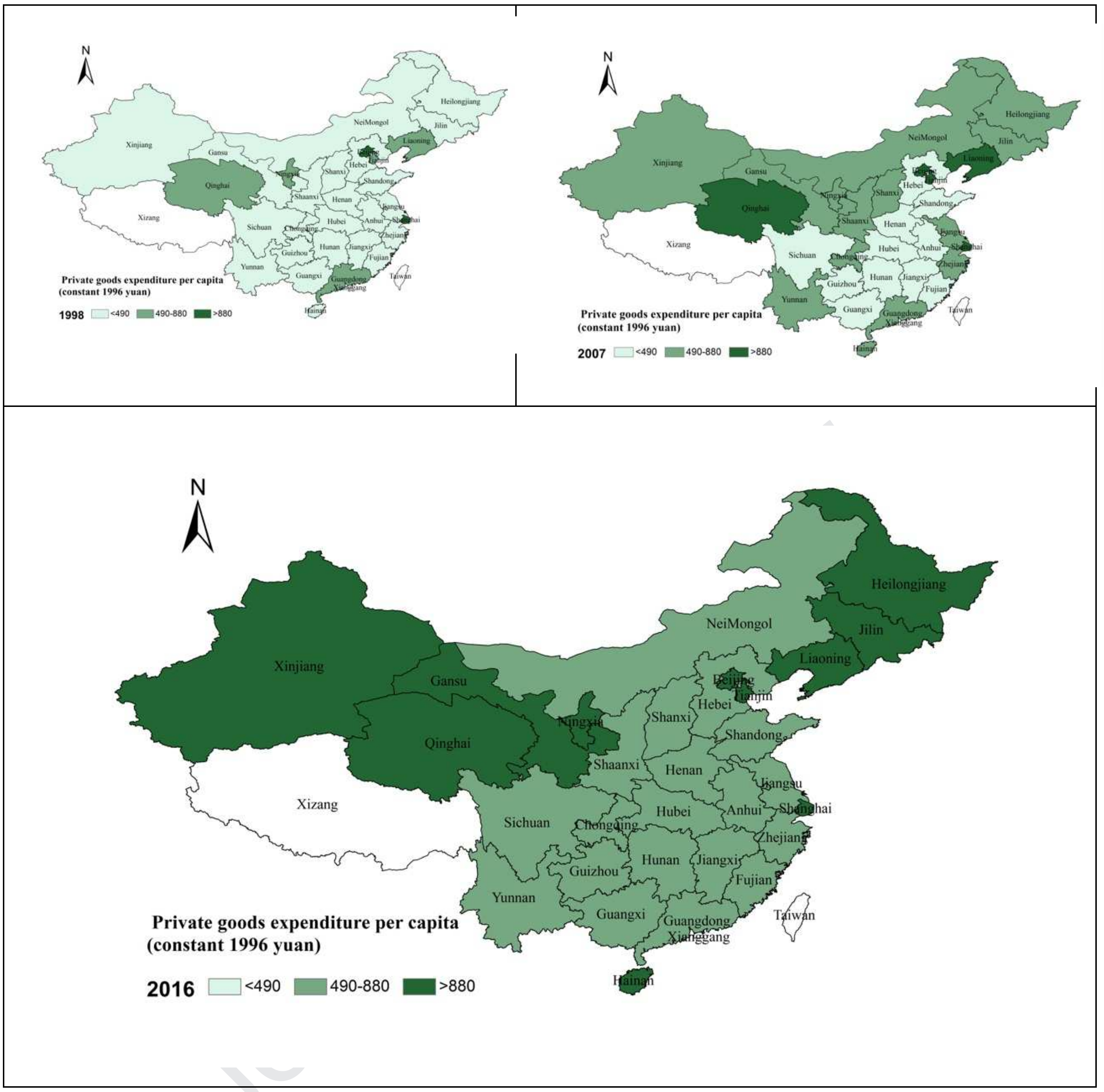

Figure 4 Spatial distributions of government expenditure on private goods based on Model II

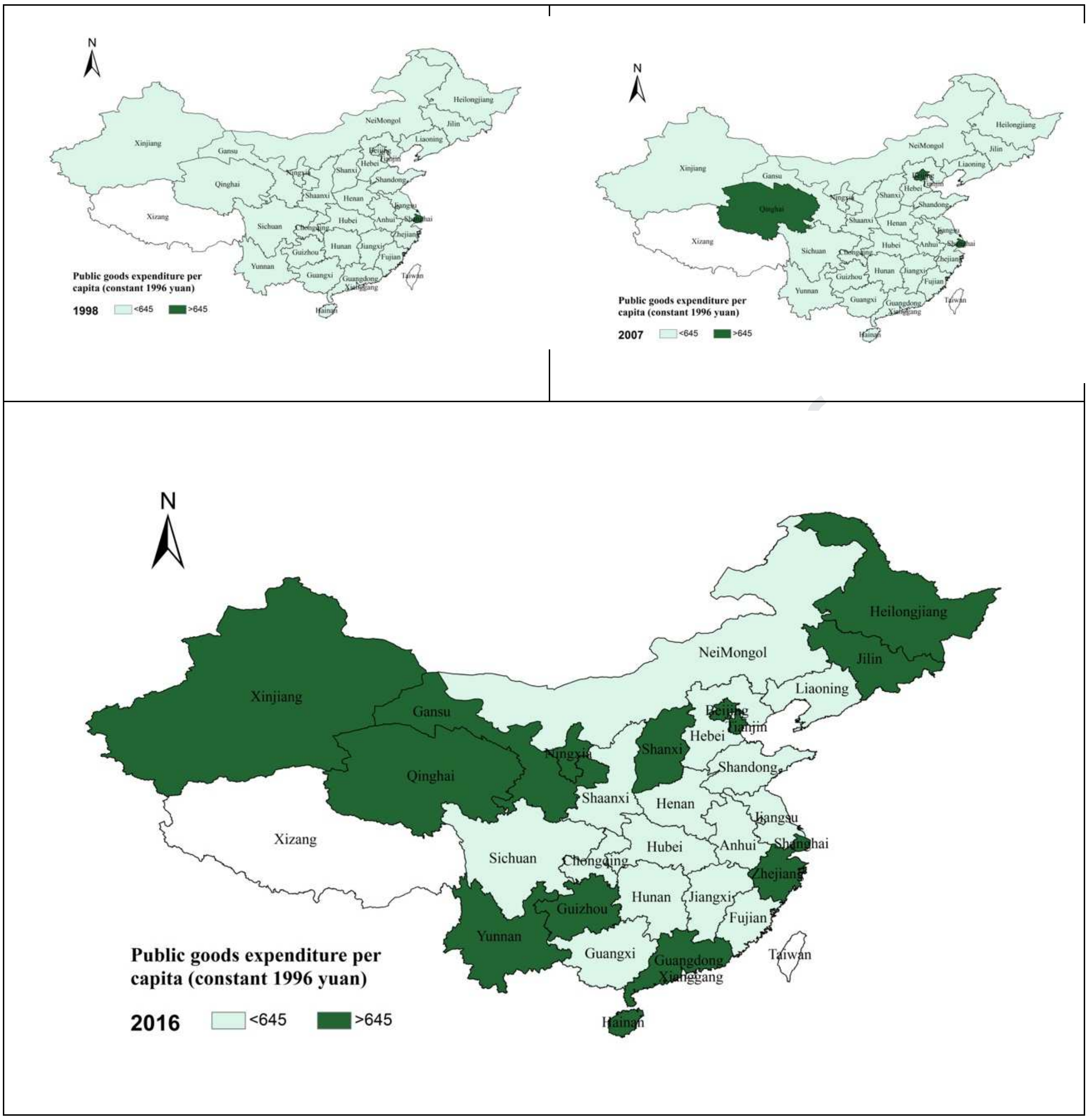

Figure 5 Spatial distributions of government expenditure on public goods based on Model III

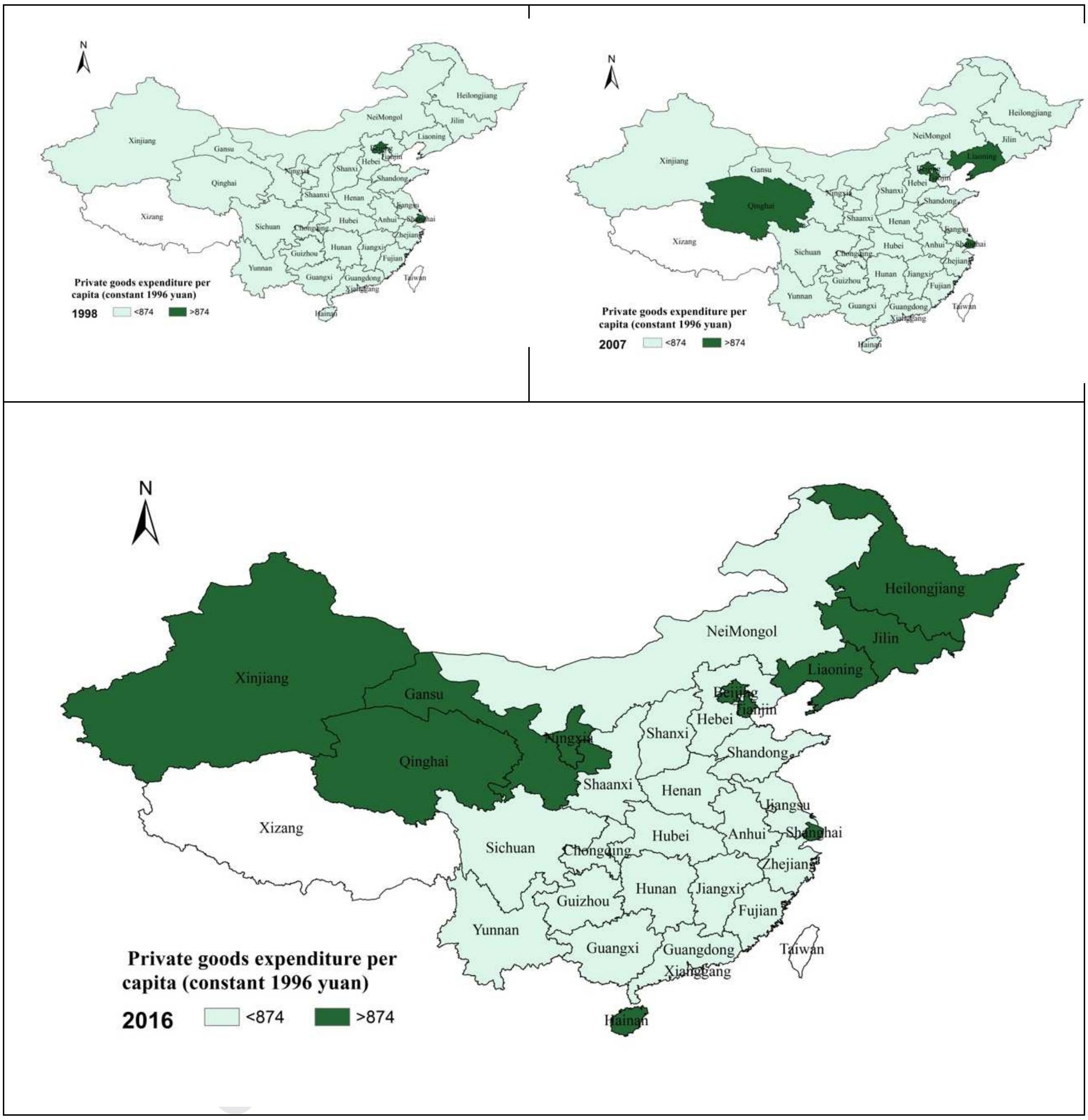

Figure 6 Spatial distributions of government expenditure on private goods based on Model IV

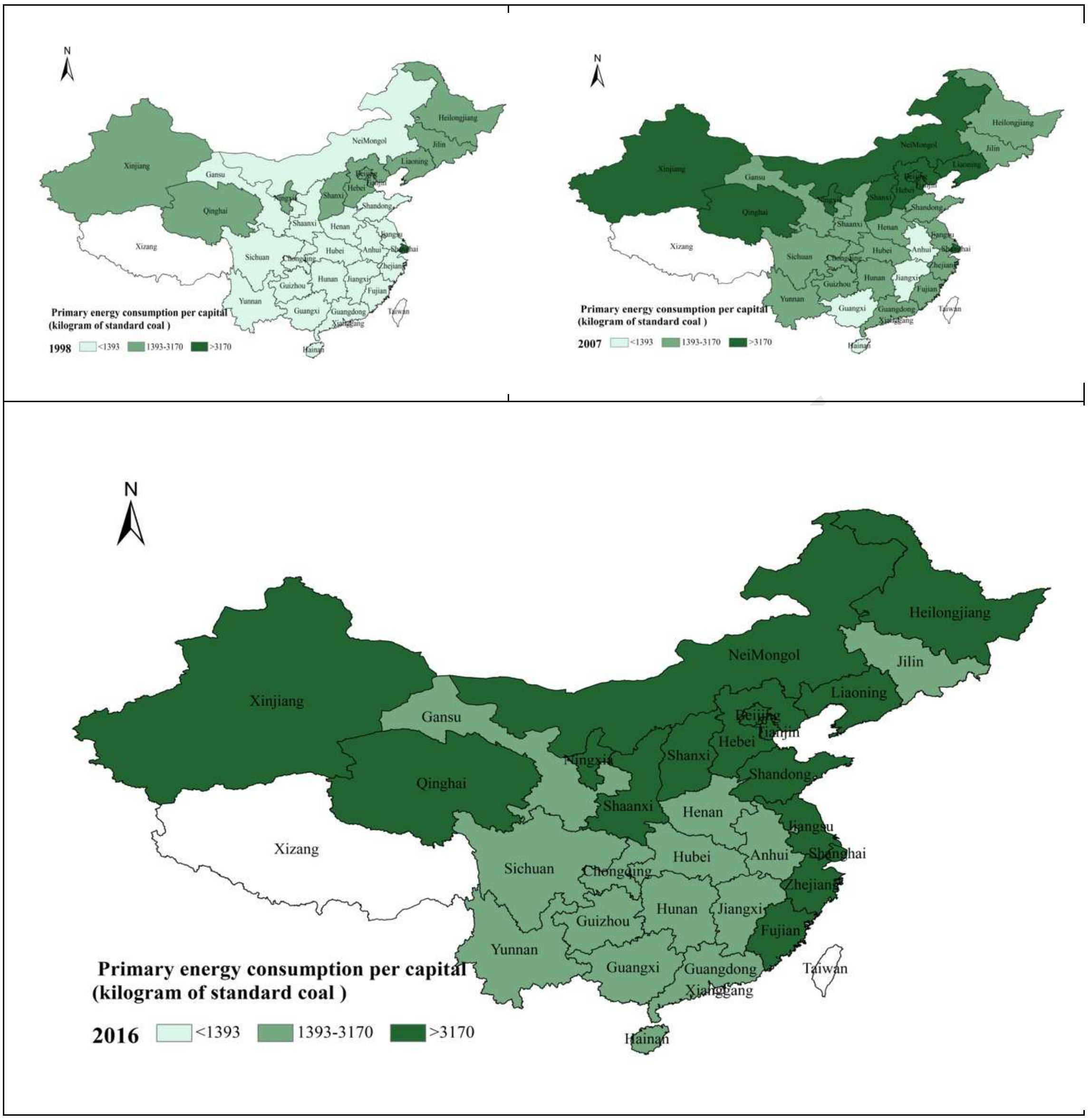

Figure 7 Spatial distributions of primary energy consumption based on Model V

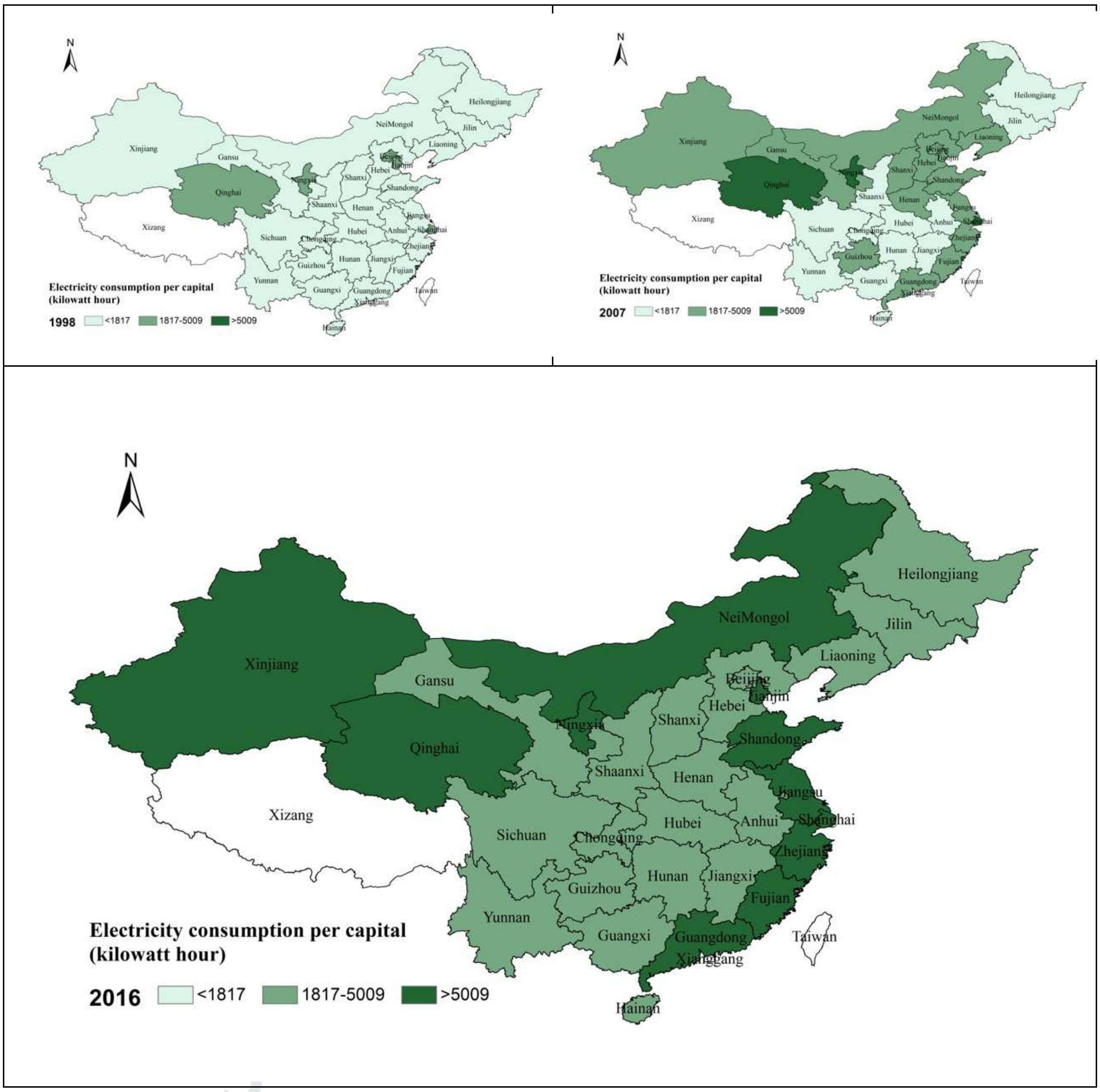

Figure 8 Spatial distributions of electricity consumption based on Model VI

WordBank, 2019. World Bank Open Data, 21/4/2019, https://data.worldbank.org.cn/.

- A comparative study on per capita primary energy and electricity consumption.
- The increase influence of labor population growth on energy consumption will slow down.
- Urbanization has different influence on different energy consumption.
- Considering energy consumption，government expenditure may not be always inefficient.
- The government expenditure in education is of great significance

We declare that there is no conflict of interest.