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Research on Regional Technical Efficiency under the Constraint of Energy Consumption

Qingyun Zhang[1, a]

[1]School of Economics, Jinan University, Guangzhou, China

[a]sophienye@163.com

Abstract: Fully consider the impact of energy consumption on regional technical efficiency, incorporate energy consumption into the technical inefficiency equation, and use the stochastic frontier analysis method of logarithmic Douglas production function to construct the calculation model of regional technical efficiency in China, and use the provincial panel of 2005-2014. Data, from the national and sub-regional levels, measured the regional technical efficiency under the constraints of energy consumption, and objectively analyzed the differences. The empirical results show that both capital investment and labor input have positive effects; energy consumption has a significant role in promoting technical efficiency; under the constraints of energy consumption, the technical efficiency trends in the eastern, central and western regions of China are relatively stable, and the difference is small.
Keywords: Stochastic frontier analysis; technical efficiency; energy.

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1. INTRODUCTION

1.1 Background

China's current energy situation is not optimistic, resource constraints are increasing, and the energy security situation is grim. On the one hand, extensive development has led to an excessive growth in China's energy demand, and the dependence on foreign oil has increased from 26% at the beginning of this century to 57% in 2011. At the same time, China's oil and gas import sources are relatively concentrated, the import channels are subject to people, the ocean's independent transportation capacity is insufficient, the financial support system needs to be strengthened, the energy reserve emergency response system is not perfect, the ability to cope with international market fluctuations and unexpected events is insufficient, and energy security guarantee pressure huge. On the other hand, China's energy resources are in short supply, and the sustainable supply capacity of conventional fossil energy is insufficient. The per capita residual recoverable reserves of oil and gas are only 6% of the world average, and the annual output of oil can only be maintained at around 200 million tons. The new output of conventional natural gas can only meet about 30% of new demand. Super-strength mining of coal. In addition, the utilization efficiency of energy is quite different from that of other countries. It still follows the development model of “high energy consumption and low output”. The development mode is still extensive and the energy efficiency level needs to be improved. The development of China's service industry lags behind. The energy-intensive industries are over-developed at a low level and the proportion is too large. The energy consumption of steel, non-ferrous metals, building materials and chemical industries accounts for about half of the total energy consumption, and the energy consumption per unit of output value is high. China's per capita energy consumption has reached the world average, but per capita GDP is only half of the world average; energy consumption per unit of GDP is not only higher than that of developed countries, but also higher than developing countries such as Brazil and Mexico. The lower energy efficiency level is related to the development stage of China and the pattern of international industrial division of labor. It reflects the outstanding problems of China's extensive development mode and unreasonable industrial structure. It is urgent to implement dual control of energy consumption intensity and total consumption. The mechanism is forced to push for substantial progress in the way of transfer and restructuring.

In order to achieve sustainable development, the Chinese government proposes to build a resource-saving society, reduce the consumption of resources, especially energy, by improving the efficiency of the entire society in the use and allocation of resources, and clearly stipulates 10,000 yuan in the "Eleventh Five-Year Plan". The GDP energy consumption is reduced by 20%. However, according to the statistics of the National Bureau of Statistics, the target for 2006 was not completed. Therefore, how to improve energy efficiency has become the top priority of energy conservation and consumption reduction. The “Twelfth Five-Year Plan” also re-emphasizes the improvement of energy efficiency. The main line of policy orientation is: focus on “two innovations”, namely, technological innovation and institutional mechanism reform and innovation; promote “two changes”, that is, energy production mode changes and The transformation of energy use mode; the realization of "two improvements", that is, improving the efficiency of energy processing conversion, gradually building a modern energy industry system, improving energy efficiency, and rationally controlling the total energy consumption. From the “Eleventh Five-Year Plan” to the “Twelfth Five-Year Plan”, the policy priorities of the energy strategy can be seen that improving energy efficiency is a key measure to enhance regional competitiveness and ensure healthy and sustainable economic development.

1.2 Literature review

The most commonly used method of technical efficiency is the stochastic frontier analysis. Foreign scholars mainly study technical efficiency from the enterprise and industry level. Domestic scholars have relevant research at the industry level and research at the regional level. Therefore, the research results of domestic scholars are more relevant to this paper.

Some scholars mainly carry out research from the perspective of measuring the technical efficiency of the region. Chen Qingqing, Long Zhihe et al. (2011) used the stochastic frontier analysis method to estimate the inter-provincial technical efficiency of China from 1996 to 2006 on the basis of the hypothesis of heteroscedasticity and random error term. The empirical analysis results show the difference in technical efficiency between the three regions of China. More obvious and there is a convergence trend. Zhou Chunying et al. (2008) calculated the economic and technical efficiency of China's three major regions based on China's 1996-2005 provincial panel data and stochastic frontier production function. The analysis shows that China's regional differences are significant and have a clear upward trend. Yu Junbo (2006) used the stochastic frontier model to measure the technical efficiency of the provinces since the reform and opening up in China. It is concluded that the technical efficiency of China has not increased significantly, even after 1995. It can be seen from the above research that in the same period, the results of scholars' evaluation of regional technical efficiency are inconsistent, and the trend of change is that the result is rising, some are falling, and some are not obvious. Therefore, it is necessary to analyze and discuss this phenomenon. In addition, scholars have studied the factors that influence regional technical efficiency from different perspectives. Yan Lilin et al. (2011) used the SFA model to estimate the technical efficiency of 28 provinces and cities in China from 2000 to 2006. The results show that the regional regional technical efficiency shows a downward trend and the regional differences are more serious. There is a significant positive correlation between factors and technical efficiency. Zhu Chengliang and Yue Hongzhi (2010) empirically analyzed their influence on technical efficiency from the perspective of human capital stock and human capital. The results show that only part of the human capital structure is the technical efficiency of the university. Has a significant positive effect. Tang Dexiang et al. (2008) and Luo Ji (2013) successively analyzed the influence of R&D on technical efficiency and the difference between regions from the perspective of R&D. The results show that there is a significant difference between R&D and technical efficiency. Positive relationship.

The above research results analyze the influencing factors of technical efficiency to a certain extent, but there are many factors affecting the change of technical efficiency. At present, most of the literature research on technical efficiency is mainly from the perspective of labor, human capital and capital stock. Energy elements can be included in the research framework, without considering energy factors, ignoring the influence of internal and external factors such as ecology, resources and environment on technical efficiency. In addition, the research perspective on regional technical efficiency is mainly based on time or spatial dimension, while the perspective of space-time dimension is lacking. Finally, technological innovation is carried out under the support of the national innovation system, but the lack of technical efficiency research, such as the construction of “resource-saving and environmentally friendly” two-type society, ignores energy consumption, carbon emissions, scientific research input, The effects of various direct factors such as technology management on regional technical efficiency make the research results too narrow.

Therefore, considering the above problems, this paper believes that it is necessary to further explore and quantitatively study the regional technical efficiency from more new perspectives, and fully consider the impact of energy consumption is a new discussion to be done in this paper. In the macro-policy context of the two-type society, combined with the idea of resource conservation, this paper fully considers the internal and external factors such as ecology, constructs the provincial-level panel data from 2005 to 2014, and constructs the regional region by using the stochastic frontier analysis method of logarithmic Douglas production function. The technical efficiency measurement model measures the regional technical efficiency under the energy consumption constraint from the two levels as a whole and the sub-region, objectively analyzes the regional differences and their influencing factors, and draws relevant conclusions and revelations based on the measurement results, which helps The state and the provincial and municipal macro levels as well as the specific unit micro level to develop and implement energy conservation policies according to local conditions.

2. RESEARCH METHODS AND DATA PROCESSING

2.1 Generation of the SFA method

In economics, the concept of technical efficiency is widely used. Koopmans first proposed the concept of technical efficiency. He effectively defined technology as: under certain technical conditions, it is impossible to increase any output without reducing other output, or it is impossible to reduce any input without adding other inputs. The input and output are said to be technically effective. For the first time, Farrell proposed a cutting-edge measurement method for technical efficiency, which was widely recognized by the theoretical community and became the basis of efficiency measurement.

In practical applications, the frontier surface needs to be determined. There are two main methods for determining: one is to statistically estimate the parameters of the frontier production function through the econometric model, and on this basis, the technical efficiency is measured. This method is called the “statistical method” or “the efficiency evaluation”. The parameter method"; the other is to determine the production frontier by solving the linear programming in mathematics, and to determine the technical efficiency, this method is called "mathematical planning method" or "non-parametric method". The characteristic of the parameter method is to determine the production frontier surface by determining the parameters of the leading edge production function. The production functions determined for different research objects are also different. The measurement of technical efficiency has certain pertinence, while the non-parametric method only needs to solve Linear programming to determine the production frontier, the method is simple and easy to use, and widely used.

The parameter method depends on the choice of production function. Common production functions include Cobb-Douglas production function and Translog production function. The development of parametric methods has gone through two phases: deterministic frontier models and stochastic frontier models. Aigner et al. and Afriat respectively proposed their respective deterministic frontier models to solve the frontier production function without considering the influence of random factors. However, since the deterministic frontier model measures all random factors that may have an impact as technical inefficiency, the technical efficiency measurement results are deviated from the actual efficiency level. In order to eliminate this defect of the deterministic frontier model, Meeusen and Vanden Broeck, Aigner, Lovell and Schmidt, and Battese and Corra proposed a stochastic frontier model (SFA method) to distinguish the error terms in the model and improve the technical efficiency. The accuracy of the measurement.

The general evaluation method compares the efficiency of the same type of decision-making unit. It is necessary to compare the input and output indicators of the decision-making unit first, and obtain a comprehensive score by weighting, and then reflect the merits and demerits of the results by the scores of each decision-making unit. The data envelopment analysis algorithm subtly constructs the objective function and transforms the fractional programming problem into a linear programming problem through the Charnes-Cooper transformation (called-transformation), without the need for a uniform indicator dimension, and without the need for a given or calculated input. The weights are derived, but the weighting process is used to determine the weights, making the evaluation of the decision-making unit more objective. The evaluation of architectural design firms is well suited to the evaluation model of data envelopment analysis.

The DEA method also has some shortcomings: First, when the total number of decision-making units is close to the total number of input-output indicators, the technical efficiency obtained by the DEA method deviates greatly from the actual situation; secondly, the DEA method cannot compare the technical effective units; Since the effects of random factors in the system are not taken into account, the technical efficiency results of the DEA method will be greatly affected when there are special points in the sample. Peng Xiaoying et al used factor analysis to screen and synthesize indicators, and then use DEA method to evaluate, solve the problem of the number limit of DEA method, and evaluate the ecological economic development of coal resource-based cities.

Both the SFA and DEA methods are front-end efficiency evaluation methods, which all calculate technical efficiency by constructing the production frontier. Compared with the DEA method, the SFA method uses the production function to construct the production frontier, and uses the conditional expectation of the technical inefficiency term as the technical efficiency. The result is less affected by the special point and the efficiency value is not the same and is 1 the situation, reliability, comparability is better. The SFA method also has some shortcomings. For example, when dealing with multiple outputs, it is not as convenient as the DEA method. It is necessary to combine multiple outputs into one comprehensive output. When the input indicators are too much, the results are reliable due to the correlation between the indicators. Sex has an impact. Zhou Chunying et al. Hou Qiang used the SFA method to evaluate the regional economic and technical efficiency of China and the technical efficiency of Liaoning Province.

2.2 SFA method

According to the basic principle of SFA proposed by Battese and Coelli, based on the provincial panel data of China from 2005 to 2014, the log-type Cobb-Douglas production function is used to calculate the regional technical efficiency of China considering energy consumption. The specific research model is as follows:

$$\ln y_{it} = \beta_0 + \beta_1 \times lnl_{it} + \beta_2 \times lnk_{it} + (v_{it} - u_{it}) \tag{1}$$

$$TE_{it} = \exp(-u_{it}) \tag{2}$$

$$u_{it} = \beta(t) \times u_i \tag{3}$$

$$\beta(t) = \exp[-\eta(t - T)] \tag{4}$$

$$\gamma = \frac{\sigma^2}{\sigma_v^2 + \sigma_u^2} \tag{5}$$

$$m_{it} = \delta_0 + \delta_1(e) \tag{6}$$

The model has the following assumptions:

1. Random error term $v_i \sim iidN(0,\sigma_v^2)$ is mainly caused by uncontrollable factors, such as natural disasters, weather factors and so on.
2. Non-negative error term $u_i \sim iidN^+(0,\sigma_u^2)$, taking a truncated normal distribution (truncating the part of <0), and u_{it}, v_{it} are independent of each other.
3. u_{it}, v_{it} and the explanatory variable x_{it} are independent of each other.

Where i denotes the serial number of 30 provinces and cities (i=1, 2,..., N, N=30), and t denotes the serial number of time 2005-2014 (t=1, 2,..., T, T=7, In 2005, it corresponds to the serial number 1, and the others are analogous. In the formula (1), Yit represents the actual GDP of the province in the t-th year of the i-th province, and Lit represents the province in the t-th year of the i-th province. Employed personnel, Kit said the capital stock of the province in the t-th year of the i-th province and city, β0 is the intercept term, β1, β2 parameters to be estimated, β1, β2 respectively indicate the degree of influence of labor and the degree of influence of capital; -uit) is the error term of the composite structure, vit∈iid and obeys N(0, σ2v), indicating the influence of random disturbance such as observation error, uit∈iid and obeying N+(mit, σ2u), and ｖit and uit are independent of each other; Equation (2) can reflect the technical efficiency status of 30 provinces and cities. When uit=0, TEit=1, indicating that the technology is effective. If uit>0, 0<TEit<1, technical inefficiency; formula (3), 4) Quantitative description is the degree of influence of time t on uit, η is the parameter to be estimated; in equation (4), the set random head model can be judged according to the value of γ

Whether it is reasonable, that is, the applicability of the test model. If γ=0 indicates that 30 provinces and cities are located on the production frontier surface, it can be analyzed using OLS. Otherwise, the SFA method needs to be used for analysis and analysis; formula (5) represents the inefficiency function. Δ0, δ1, δ2 are three parameters to be estimated, reflecting the impact of energy consumption on technical efficiency. If the estimated value is positive, it will have a negative impact, and vice versa.

2.3 Data processing

This paper takes the energy consumption, labor and capital stock of 30 provinces, municipalities and autonomous regions in China (hereinafter referred to as the province for convenience) as input factors in 2005-2014, and uses the GDP of each province as the output factor to conduct energy efficiency analysis. It is divided into the eastern, central and western regions to reflect the differences in energy technology efficiency in different regions of China. Among them, the eastern region includes 11 provinces and cities including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. Provinces and cities; the western region includes 11 provinces and cities including Chongqing, Sichuan, Guangxi, Guizhou, Inner Mongolia, Yunnan, Shaanxi, Gansu, Ningxia, Xinjiang and Qinghai. A brief description of the data covered in this article is as follows:

GDP output: The GDP and GDP deflator for each province in the year was derived from the 2005-2014 China Statistical Yearbook and was converted at a constant price in 2000. In order to maintain the uniformity of the caliber, the data of Chongqing City was merged into Sichuan Province.

Energy consumption: The energy consumption of each province is expressed by the annual energy consumption of the provinces, mainly from the “China Energy Statistics Yearbook” of the corresponding years, which has been converted into standard coal.

Labor: The main data comes from the China Statistical Yearbook 2005-2014. The number of employed people in that year is calculated according to (the number of employed people at the end of the year + the number of employed at the end of the previous year)/2, because the data on the per capita education level of each province is not available here. Therefore, it does not include differences in the quality of labor in each province.

Capital stock: Generally use the “permanent inventory method” to estimate the actual capital stock of each year. The calculation method is: $K_{i,t}=I_{i,t}+(1-\delta_i)K_{i,t-1}$, where $K_{i,t}$ is the region i t The annual capital stock, $I_{i,t}$ is the investment of the region i in the t-year, and δ_i is the depreciation rate of the fixed assets of the region i. Here, the main research results of Zhang Jun and others are mainly referred to, and the constant price is calculated in 1952.

Table 1. Input-output evaluation index system

Indicator	Index Name	References	Selection Basis
Input indicators	Total energy consumption	HU et al, Yang Hongliang, Xu Guoquan, Wei Chu, etc.	Standard coal conversion
	Number of employees	HU et al, Yang Hongliang, etc., Wei Chu, SATO SHI, etc.	(number of employed at the end of the year + number of employees at the end of the previous year)/2
	Capital stock	Zhang Jun et al.	Perpetual inventory method $K_{i,t}=I_{i,t}+(1-\delta_i)K_{i,t-1}$
Output Indicators	Gross Domestic Product	HU, etc., Yang Hongliang, etc., Wei Chu, Xu Guoquan, etc., AZADEH, etc.	Converted at a constant price in 2000

From the input point of view, the above three input indicators comprehensively consider the input of decision-making units from the perspectives of material resources, manpower and financial resources. For output indicators, the economic output indicators better reflect the scale of output of energy utilization and Economic benefits.

Table 2. Descriptive statistics of variables

Variable	Obs	Mean	Std.Dev.	Min	Max
e	300	13435	8673	554.2	46476
l	300	2563	1703	291.0	6607
k	300	23759	19804	1512	108004
y	300	10238	8897	465.1	49660
lne	300	9.266	0.771	6.318	10.75
lnk	300	9.728	0.893	7.321	11.59
lny	300	8.854	0.953	6.142	10.81
lnl	300	7.575	0.815	5.673	8.796

Through the above data processing, this paper gives a simple statistical overview of the variables used, as shown in Table 2. It can be seen from the above descriptive statistics that there is a large variation between the observed values of the variables, which provides the possibility for the following measurement estimation.

Table 3. Energy consumption of provinces in China from 2005 to 2014

(Unit: 10,000 tons of standard coal)

Area	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Beijing	5254	4806.15	5318.966	5656.454	6031.035	5611.312	6,995.40	7,177.68	6,724.00	6,831.00
Tianjin	4627.71	4874.42	5231.59	5520.973	5958.05	6988.41	7,598.45	8,208.01	7,882.00	8,145.00
Hebei	24084.94	25672.22	25396.42	26124.53	27204.19	33767.88	29,498.29	30,250.21	29,664.00	29,320.00
Shanxi	20093.39	21886.13	22258.32	23146.74	23361.22	28059.72	18,315.12	19,335.59	19,761.00	19,863.00
Inner Mongolia	14145.82	16704.51	18934.26	23131.48	25092.68	27706.85	18,736.91	19,785.71	17,681.00	18,309.00
Liaoning	16085.8	17464.13	18961.99	19461.52	22831.67	24970.28	22,712.20	23,526.40	21,721.00	21,803.00
Jilin	7855.84	8748.094	9630.231	13181.66	12537.64	11257.46	9,103.04	9,443.04	8,645.00	8,560.00
Heilongjiang	9731.66	10451.66	11244.85	12288.73	12508.08	13727.64	12,118.50	12,757.80	11,853.00	11,955.00
Shanghai	8164.56	8231.47	8792.832	9111.174	9021.366	9578.764	11,270.48	11,362.15	11,346.00	11,085.00
Jiangsu	19988.33	21912.26	23629.58	25755.19	26965.44	31524.88	27,588.97	28,849.84	29,205.00	29,863.00
Zhejiang	12318.93	14003.35	16862.12	17679.44	18914.9	18665.81	17,827.27	18,076.18	18,640.00	18,826.00
Anhui	8845.75	9505.819	10449.94	11680.55	13994.18	16278.19	10,570.23	11,357.95	11,696.00	12,011.00
Fujian	6685.73	7388.603	8383.75	9056.42	9816.67	10611.74	10,652.60	11,185.44	11,190.00	12,110.00
Jiangxi	4983.06	5410.64	6116.31	6282.95	7315.53	7425.517	6,928.17	7,232.92	7,583.00	8,055.00
Shandong	28378.07	30218.8	35735.2	39941.67	42119.43	46475.54	37,132.00	38,899.25	35,358.00	36,511.00
Henan	19161.17	22655.11	24039.66	25305.8	27013.81	29497.86	23,061.88	23,647.11	21,909.00	22,890.00
Hubei	10430.04	11764.1	12878.79	13151.66	14124.78	16073.08	16,579.23	17,674.66	15,703.00	16,320.00
Hunan	10640.25	12774.56	14107.69	13509.53	14501.89	17450.38	16,160.86	16,744.08	14,919.00	15,317.00
Guangdong	16109.43	17862.09	19754.75	20805.35	21289.02	24011.01	28,479.99	29,144.01	28,480.00	29,593.00
Guangxi	5063.98	5657.28	6478.673	6578.766	7240.28	10560.18	8,591.36	9,154.50	9,100.00	9,515.00
Hainan	554.21	632.8599	754.9998	916.66	1042.68	1050.96	1,600.62	1,687.98	1,720.00	1,820.00
Chongqing	4331.73	4699.94	5127.32	6736.263	7670.447	7695.963	8,791.96	9,278.41	8,049.00	8,593.00
Sichuan	9200.27	10170.38	11253.22	12887.01	14535.22	14389.1	19,696.19	20,575.00	19,212.00	19,879.00
Guizhou	8787.43	10046.52	12060.48	11183.89	12099.61	12856.86	9,067.85	9,878.38	9,299.00	9,709.00
Yunnan	7674.14	8413.723	8863.737	9139.907	10069.86	10805.73	9,540.28	10,433.68	10,072.00	10,455.00
Shaanxi	6267.17	6937.029	7577.327	8440.809	9868.877	11860.31	9,760.77	10,625.71	10,610.00	11,222.00
Gansu	4683.97	4993.06	5483.4	5793.25	6709.96	6831.72	6,495.78	7,007.04	7,287.00	7,521.00
Qinghai	988.64	1262.51	1416.954	1731.544	1769.092	1838.229	3,189.03	3,524.06	3,768.00	3,992.00
Ningxia	3372.81	3746.863	4299.318	4540.043	4839.867	5794.818	4,316.33	4,562.39	4,781.00	4,946.00
Xinjiang	4957.93	5538.574	6359.44	6701.35	8044.19	8928	9,926.50	11,831.39	13,632.00	14,926.00

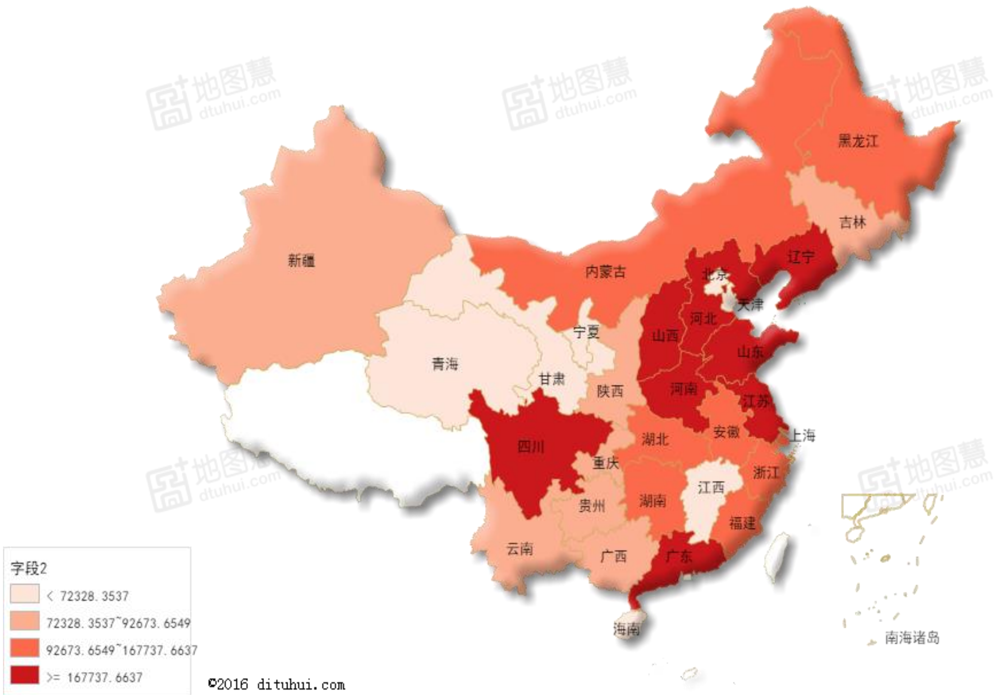

Figure 1. Total energy consumption in China's provinces from 2005 to 2014

Next, we analyze the total energy consumption of China's provinces in Table 3 from 2005 to 2014, and plot 1 to examine the energy consumption of the provinces in the past decade. As shown in Figure 1, the regional differences in the total energy consumption of various provinces in China are very obvious. The highest total energy consumption is the smallest total energy consumption. If these provinces are divided into the eastern, central and western regions according to their reflection and spatial representation, it can be seen that the total energy consumption of the provinces in China shows a gradual transition from the east to the west in terms of space from high to low. It has a good correlation with the economic gradients of the three regions of China's eastern, central and western regions. The highest consumption is mostly located in the economically developed regions of the east and central regions. This shows that China's eastern and central regions consume too much energy in the process of economic development, but blindly increasing resource input may not be the best choice. How to integrate the input resources to achieve economies of scale in energy use is the most for these regions. Need to study and explore.

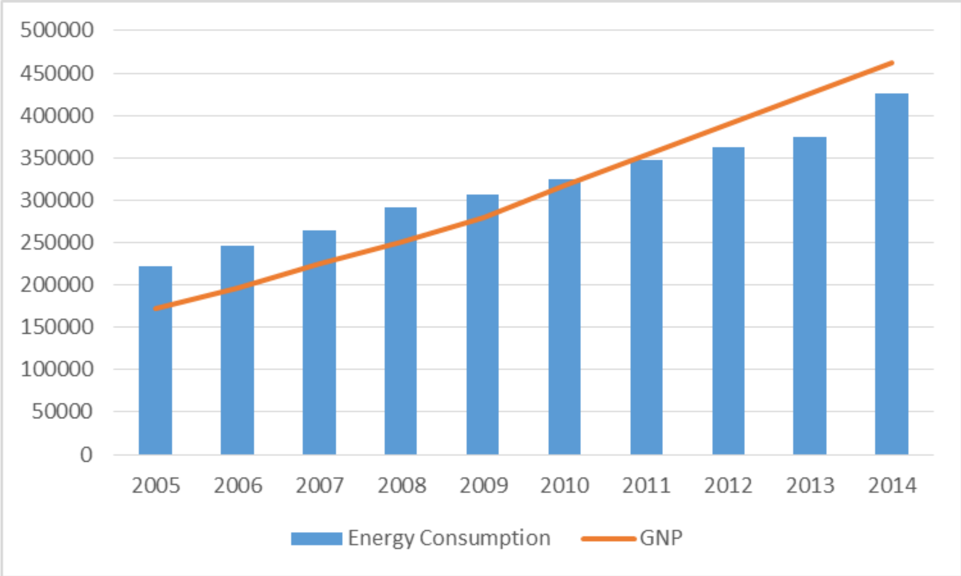

Figure 2. Chart of total energy consumption and gross national product

It can be seen from Figure 2 that as energy consumption continues to increase, China's gross national product continues to increase. National economic energy is the driving force for economic growth, the material basis for economic development, and stipulates the scale and speed of economic growth. While economic growth is driven by energy, it is in turn a condition or basis for energy development.

Energy consumption promotes economic development. From the perspective of economic development, the main driving force for the development of energy economy is energy consumption. It can be said that the consumption of energy and energy products is the main form of energy economy, but with the rapid development of the economy. The energy supply will show up. The production of new energy products can have a significant impact on the energy economy. In addition to fossil energy, other new energy research and development are in the category of new energy sources, such as biomass, hydrogen, wind, solar and so on. From the current point of view, the development and utilization of secondary energy has also achieved some achievements in China, but it cannot replace the huge role of mainstream energy products in life, but is limited to specific application fields, and its development speed is too slow. At the same time, insufficient supply of energy will become a bottleneck restricting economic development. In order to change this situation, we must improve the efficiency of energy use, vigorously develop new energy and renewable energy, encourage low-carbon economy, and promote the development model of circular economy.

3. THE ANALYSIS OF EMPIRICAL RESULTS

3.1 Ols result analysis

First, we perform a simple ols analysis on the above data and set the regression equation to

$\ln y = \beta_0 + \beta_1 lne + \beta_2 lnl + \beta_3 lnk + \mu$

Table 4. Ols results analysis

Source	SS	df	MS	Number of obs	=	300
Model	259.1	3	86.35	Prob>F	=	0
Residual	12.70	296	0.0429	R-squared	=	0.953
Total	271.8	299	0.909	Root MSE	=	0.207
lny	Coef.	Std.Err.	t	P>|t|	95% Conf.	Interval
lne	-0.0394	0.0296	-1.330	0.185	-0.0976	0.0189
lnl	0.273	0.0246	11.12	0	0.225	0.321
lnk	0.876	0.0232	37.75	0	0.830	0.921
cons	-1.371	0.147	-9.320	0	-1.660	-1.081

According to the above results: lnyhat=-1.371-0.0394lne+0.273lnl+0.876lnk

R^2=0.953, indicating that the model fitting effect is very good. Analysis of the economic meaning of each estimated coefficient shows that β_0=-1.371, indicating that when the energy input, labor input and capital input are zero, the economic output logarithm is -1.771, which has no obvious economic significance. B_1=-o.o394, indicating that for every 1 percentage point increase in energy consumption, economic output is reduced by 0.0394 percentage points. The economic significance of β_1 is inconsistent with common sense, which may be caused by data error or improper estimation model. B_2=0.273, indicating that for every 1 percentage point increase in labor input, the economy will expand and the economic output will increase by 0.273 percentage points. B_3=0.876, indicating that for every 1 percentage point increase in capital investment, the economic scale will increase and the economic output will increase by 0.876 percentage points. Therefore, in this model, labor input and capital investment are significant factors affecting economic output, and energy input is not a significant factor affecting economic output.

To get more in-depth results, we use the SFA model to continue the analysis.

3.2 SFA results analysis

Table 5. Random Frontier Function and Efficiency Equation Estimation Results

variable	Estimated coefficient	Standard deviation	T statistic
Production function part:			
Constant term	-1.440941	.2912054	-4.95
lnk	.8592814	.0195411	43.97
lnl	.2571434	.0214814	11.97
Inefficient part:			
Constant term	.0122943	.0000782	157.28
e	-1.79e-10	5.36e-09	0.03
other information:			
μ	-1.83469	50.80285	-0.04
σ_u	.1511984	2.563303	0.06
σ_v	.2060269	.0171218	12.03
γ	.3500481		
Log likelihood function value	47.7192		

It can be seen from the above table that γ = 0.35, and the maximum likelihood test is passed. The γ value is neither close to nor close to 0, indicating that there is inefficiency in each region in the innovation process, and there are 35 in the random error term. % comes from the influence of technical inefficiency, and 65% of the impact comes from external influence factors such as statistical error. The contribution of each influencing factor to inefficiency should be further stripped to find the source of inefficiency. Higher gamma estimates indicate a significant composite structure in the error term, so it is necessary to use SFA techniques for these up to 10 years of panel data. The log-likelihood function value is 47.7192, indicating that the whole model fits well. Capital input and labor input are significant positive correlations with output in the production function.

The average technical efficiency of provinces in 2005-2014 is 0.95, which is higher than the actual efficiency value in life. It may be due to data processing errors or improper selection of models. In fact, the inefficiency of energy use in various provinces in China is widespread. On the other hand, it shows that China has great energy saving potential, and analyzes the factors affecting technical efficiency, in order to find out effective ways to improve regional technical efficiency through scientific methods, and further improve economic output on the basis of existing investment.

As for the estimation results of technical efficiency in the three provinces and the eastern, central and western regions, considering the constraints of energy consumption, the differences in the average technical efficiency of the three regions in China are small, and the technical efficiency trends of various provinces and cities are relatively stable. In the horizontal comparison, the highest technical efficiency is in the eastern region. The average value in 2005-2014 is 0.97, but the technical efficiency in the central and western regions is lower than that in the eastern region.

This is mainly because this paper incorporates energy consumption into the analytical framework of technical efficiency. China's energy regions are geographically distributed in three regions. The coal resources in the central and western regions account for 85%, and about 86% of oil and natural gas are in the eastern region. If energy consumption constraints are not considered, there is a significant difference between regional technical efficiency in China, but from the calculation results of this paper, it can be analyzed that the technical efficiency difference between the three regions is small considering energy consumption. In fact, the economic development, science and technology, and technological innovation in the eastern part of China are higher than those in the central and western regions. The technical efficiency of the central and western regions is very different from that in the eastern region. One of the main reasons is high energy consumption and high investment. Therefore, this paper believes that while accelerating the rapid development of the central and western regions, the energy conservation policy must be strictly implemented. Otherwise, the high pollution and harsh environment will eventually slow down the regional economic development and even contain and negative growth. This also confirms that the continuous growth of the regional economy requires an increase in energy consumption, which also indicates that the difference in energy consumption is a major cause of regional technical efficiency differences, which is also in line with the different energy storage conditions in various provinces and cities in China. That is, there are differences in energy consumption among provinces and cities. However, by comparing the trends in energy consumption and technical efficiency, there is a bias between the two. The energy consumption of various provinces and cities is increasing and the technical efficiency is increasing but very slow. This is just like the point raised in this paper, that the excessively high energy consumption has a positive effect on the regional economic development and technological efficiency improvement, and the environmental quality problems that are gradually caused are getting worse.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the inter-provincial panel data and stochastic frontier analysis method SFA from 2005 to 2014, this paper measures and analyzes the technical efficiency of 30 provinces and cities in China under the constraint of energy consumption. Due to energy consumption constraints, the technical efficiency differences between the three regions of China's eastern, central and western regions during 2005-2014 are relatively small and the overall growth trend is slow, or the growth is slow or stable. This is mainly due to the energy resources of the three regions of China. The equilibrium of distribution leads to a fundamental balance between the energy consumption of the three regions and the technical efficiency. Although energy consumption can reduce the loss of technical efficiency, the effect is not obvious, energy consumption is too high and technical efficiency is slow. Excessive energy consumption causes the environment to deteriorate, but it has a negative effect on the growth of technical efficiency. Based on this, this paper believes that while focusing on the role of resources in promoting regional economic development, the state should formulate relevant policies in line with the development of low-carbon economy, improve the technological level, strengthen the transformation and upgrading of technological innovation-driven industries, and improve the efficiency of energy use and improve. The comprehensive ability of the labor force to reduce carbon emissions and achieve the construction of a two-type society.

Under the new normal economy, while improving technological efficiency, realizing the transformation and upgrading of industries, especially resource-based enterprises, and strengthening the sustainable development of regional economies, the impact of energy efficiency cannot be ignored, except for issues such as energy structure adjustment and technological innovation. It is also necessary for the national government to formulate effective policies for energy conservation, technological upgrading and personnel training at a macro level, break the deep-seated impact of high energy consumption and high input system thinking, truly realize the overall improvement of energy use efficiency, and promote the sustainable development of regional economy. .

Therefore, we should accelerate the transition from a mode of economic development to a quality and efficiency. China's economic growth is still built on the traditional development mode of high energy consumption and high pollution. To improve the current status of energy inefficiency, we must adapt to the new normal of economic development, accelerate the mode of economic development from scale-type extensive growth to quality-efficient intensive growth, actively implement dual-control actions on total energy consumption and energy consumption intensity, and develop energy-efficient leaders. Leading the way to promote efficient and efficient use of energy conservation. Implement contract energy management, implement enterprise energy conservation actions, improve energy efficiency by adopting new equipment and new technologies, fully tap the energy saving potential of high energy consumption industries, promote the formation of green development methods, and improve the quality and efficiency of economic development.

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