Analysis of the Threshold Effect of Industrial Structure on Renewable Energy Supply

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Abstract

In this paper, 30 provinces of China were taken as the research object, and the energy investment level was taken as the threshold variable, and the dynamic panel threshold model was established to investigate the dynamic investment energy threshold effect of industrial structure on renewable energy supply. The results show that there is a single threshold effect of energy investment level in the model. When the investment level of renewable energy is low, the industrial structure has an insignificant inhibitory effect on renewable energy supply. When the investment level of renewable energy exceeds the threshold value, the hindering effect of industrial structure on renewable energy supply will be transformed into a significant promoting effect. Therefore, each region should increase the level of investment in renewable energy, drive technological progress, improve the overall work efficiency of the society, and strive to rationalize the energy consumption structure.

Keywords

Industrial structure, Renewable energy supply, The level of energy investment, Threshold effect.

1. Introduction

Faced with the new requirements of "accelerating the reform of ecological civilization system, promoting the revolution of energy production and consumption, and building a clean, low-carbon, safe and efficient energy system" proposed in the new era, China urgently needs to grasp the basic rules of renewable energy development to ensure sustainable development. In addition, as the contradiction between China's energy supply and demand intensifies, the energy production structure with the proportion of non-renewable energy cannot meet the huge total energy demand, and the gap between supply and demand tends to increase year by year. Therefore, it is urgent to improve the supply level of renewable energy. At the same time, the supply capacity of renewable energy restricts the transformation process of China's economy from high-speed development to high-quality development. Therefore, it is of great significance to study the supply characteristics of renewable energy for China's energy transformation and economic development. As for the way to improve the supply of renewable energy, most of the researches are analyzed from the perspective of technological innovation. Bretschger [1] believe that technological progress can effectively remove the restriction of insufficient energy supply and effectively improve the supply efficiency of energy. In fact, technological innovation does not directly improve the supply of renewable energy, but mainly promotes the transformation and structural optimization of the energy industry through the upgrading of industrial structure [2]. With the continuous optimization of industrial structure, different industries depend on different energy consumption structure and have specific demands for renewable energy. Therefore, industrial structure has become a key factor of renewable energy supply.

Driven by future demand, energy supply is influenced by many uncertain factors such as energy investment, resource reserves, industrial structure, technological progress, economic growth and energy price [3] [4]. There are abundant literatures on energy supply and its influencing factors at home and abroad. However, there are few achievements to systematically study the impact of industrial structure upgrading on renewable energy supply from the perspective of supply side, and to conduct empirical research on the development of heterogeneous renewable energy in various provinces and cities. Based on the nonlinear influence of industrial structure upgrading on renewable energy supply, this paper constructs a panel threshold model to discuss the influence of industrial structure upgrading on renewable energy supply and its mechanism under the threshold of energy investment level.

2. Development Status of Renewable Energy

Renewable energy mainly refers to the type of energy that can be recycled in nature. It is renewable after consumption, will do little or no harm to the environment, and is conducive to ecological virtuous cycle and sustainable development. It usually includes solar energy, water energy, wind energy, biomass energy, geothermal energy and ocean energy. Due to different perspectives, the definition of renewable energy is still not uniform. In his research on energy substitution strategies, Yu Lihong [5] believes that renewable energy includes nuclear energy, while China's relevant policies regard nuclear energy as an effective alternative to fossil energy. Considering the availability of data, nuclear energy is classified as a renewable energy when studying the supply of renewable energy in this paper.

2.1 The scale of development continues to expand

In recent years, the production and consumption of renewable energy have grown rapidly, giving a strong impetus to the building of a clean and low-carbon green energy system, continuously optimizing the energy mix, steadily increasing the proportion of renewable energy, and entering a new stage of high proportion of incremental replacement of renewable energy and regional stock replacement. In terms of installed capacity, by the end of 2018, China's installed capacity of renewable energy was 730 million kw, accounting for 38.3 percent of the total installed power capacity, including 184 million kw of grid-connected wind power, 170 million kw of photovoltaic power, and 17.81 million kw of biomass power. By the end of 2019, China's installed power-generating capacity will be around 2 billion kilowatts, up 6 percent year-on-year [6]. In terms of electricity generation, the country's renewable energy generation capacity reached 190 million kwh in 2018, up 10.1 percent year on year and accounting for 26.7 percent of total electricity generation.

2.2 Diversified development

Hydropower has always been in the leading position in China's renewable energy, but its proportion in renewable energy has decreased significantly. 2013 was the peak year for new hydropower installations in China, adding 30 million kilowatts of capacity. Since 2013, installed hydropower capacity has been declining year by year, and the share of hydropower in renewable energy generation has dropped from 87 percent in 2011 to 66 percent in 2018. The share of wind power, solar power and biomass power increased significantly. Wind power has been developing steadily. In 2018, China's total wind power generation capacity reached 366bn kwh, accounting for about 19% of renewable energy generation capacity, while wind power generation accounted for only 12.8% in 2014. Solar energy started relatively late but developed rapidly. Since the State Council standardized the price of photovoltaic power generation in 2013, the photovoltaic power generation market has developed rapidly. Pv will generate 177.5 billion kilowatt-hours of electricity in 2018, accounting for more than 9 percent of total renewable power. Due to the rapid development of biomass technology, its installed capacity and power generation continue to set new highs. In 2018, biomass power generation accounted for 90.6 billion kwh, accounting for 4.8%, and 3.8% in 2014. Nuclear power generation has been growing steadily, its installed capacity has been expanding, and the amount of electricity generated has increased simultaneously. In 2018, China's nuclear power generation capacity reached 294.4 billion kwh, up 24.7 percent year-on-year [7].

2.3 Improved energy efficiency

Wind and solar abandoning has always been a key problem of inefficient utilization of renewable energy, one of the main reasons is that the grid infrastructure and system peak regulation level do not match the pace of renewable energy development [8]. In recent years, China's industrial technology level and technological innovation capacity in the field of renewable energy have improved by leaps and bounds, and China has formed the largest solar photovoltaic and wind energy utilization industry in the world. The efficiency of renewable energy was significantly improved, and wind and light abandonment were significantly reduced. In 2018, the national average wind abandoning rate was 7%, down 5% year on year, and 27.7 billion kilowatt hours. The national average light abandonment rate was 3%, down 2.8% year on year, with 5.49 billion kilowatt hours [9]. Whether on the consumption side or the supply side, technological innovation is the core and key support for improving energy utilization efficiency. Technologies such as smart energy, energy storage, electric vehicles and 5G will continue to be important driving forces for improving energy efficiency.

3. Model

3.1 Model setting

The panel threshold model proposed by Hansen (1999) [10] can analyze the stage effect of explanatory variables on explained variables under the influence of threshold variables with different strengths. Based on the research focus and data selection in this paper, the following model is constructed.

$$Y_{it} = \mu_i + \beta_0 Z_{it} + \beta_1 X_{it} \cdot I(q_{it} \le \gamma_1) + \beta_2 X_{it} \cdot I(q_{it} \succ \gamma_1) + \varepsilon_{it} \quad (3\text{-}1)$$

$$Y_{it} = \mu_i + \beta_0 Z_{it} + \beta_1 X_{it} \cdot I(q_{it} \le \gamma_1) + \beta_2 X_{it} \cdot I(\gamma_1 \prec q_{it} \le \gamma_2) + \beta 3 X_{it} \cdot I(q_{it} \succ \gamma_2) + \varepsilon_{it} \quad (3\text{-}2)$$

Equations (3-1) and (3-2) are single threshold and double threshold models respectively. I stands for provinces and cities in China, t stands for time, and Y_{it} stands for the renewable energy production capacity of I province (city) in period t, and is the explained variable. Q_{it} is the threshold variable and X_{it} is the core explanatory variable affected by the threshold variable, namely the industrial structure. Z_{it} is a group of variables that have significant influence on renewable energy production except industrial structure, including per capita GDP, energy endowment, urbanization rate, energy intensity and energy investment level. β0, β1, β2, β3 are the corresponding coefficients, and γ is the specific threshold value. I(·) is an indicative function, which takes the value of 1 when the condition in parentheses is true, and 0 when the condition is not. I reflects the non-observable individual effects in the provinces and cities, it is a random disturbance term. The software used in this paper is STATa 14 and xthreg, a panel threshold regression program written by Mr. Wang Qunyong.

3.2 Index selection

Due to the temporary lack of some data in Tibet, Tibet is not included in the study, and in consideration of the availability of data, this paper selects the panel data of the other 30 provinces and cities in Mainland China from 2005 to 2017 for empirical analysis. The data are from the National Bureau of Statistics, China Energy Statistical Yearbook and statistical yearbooks of all provinces and cities.

Explained variable is renewable energy supply (RES). Since the renewable energy production data of some provinces and cities cannot be obtained, and power generation is the most important and largest utilization method of renewable energy, so this paper represents the renewable energy supply quantity, including solar energy, nuclear energy, wind power and hydropower generation.

Core variable is industrial structure. Appropriately reducing the proportion of the secondary industry and increasing the proportion of the tertiary industry is conducive to adjusting the shortage of energy supply and promoting the development of renewable energy supply [11]. Referring to the method of Chai Zeyang (2016) [12], this paper uses the ratio of the value added of the tertiary industry in the t year of the province and city as the proxy variable of the industrial structure. The larger the index is, the more reasonable the industrial structure is.

Threshold variable is level of energy investment (EI). The level of energy investment refers to the renewable energy investment, expanding renewable energy industry investment will introduce more scientific and technical personnel and more advanced technology to speed up the renewable energy technology research and development, so as to promote more cheap, clean and renewable energy development, stimulate the renewable energy consumption, increase renewable energy supplies. In this paper, electricity, steam, hot water production and supply industry investment in the energy industry is used to represent the renewable energy investment level, and 2005 as the base period to convert according to the CPI of various provinces and cities.

Controlled variables conclude GDP per capita (GDP), energy endowment degree (ER), urbanization rate (CR), energy intensity (EQ). As for the GDP, different levels of economic growth require different amounts and types of energy to adapt to their development, and the level of economic growth affects energy supply to a certain extent [13]. Based on the CPI of various provinces and cities in 2005, this paper conducts conversion according to the impact of population size and price effect, which can effectively reflect the level of economic growth of various provinces and cities. About ER, under a certain technical level, the energy supply is limited, and its supply depends largely on the abundance of natural resources. The total energy production includes non-renewable resources and renewable resources, which can truly measure the abundance of natural resources in various regions. In this paper, the ratio the total energy production of the province and the national total energy production is used to represent the energy endowment degree. Due to the lack of energy production data in Shanghai province from 2006 to 2008, the linear interpolation method is adopted to complete the energy endowment degree. Urbanization affects renewable energy supply mainly through the improvement of energy consumption structure [14]. With the acceleration of urbanization, on the one hand, residents' demand for clean energy increases, and the corresponding renewable energy supply needs to develop in step with it. On the other hand, better urban infrastructure offers opportunities for renewable energy supply. This index is the ratio of the urban population of the province to the population at the end of the year. EQ refers to the energy consumption per unit GDP, reflecting the economies' degree of dependence on energy and renewable energy, when the energy intensity reduction, economic growth, the lower the degree of dependence on energy consumption, energy transformation and increase the economic cost of renewable energy consumption smaller, the society is expanding renewable energy supply. This index is the ratio of the energy consumption to the actual GDP.

4. Empirical Research

In this paper, with the help of the measurement software STATA14.0, the stationarity of the data series was first tested to avoid the pseudo regression phenomenon, and then the panel threshold model estimation method was used to test whether the threshold effect existed. If the threshold effect existed, the specific threshold value was determined, and the parameter values under different threshold intervals were estimated. Finally, the estimated results were analyzed.

4.1 Stationarity and co-integration test

Table 1 Unit root test

	The original sequence			First order difference sequence		
Variable	LLC	IPS	ADF	LLC	IPS	ADF
RES	4.292	6.197	45.785	-18.457*	-13.079*	253.010*
IS	7.791	8.722	15.605	-5.913*	-2.223**	87.187**
EI	0.880	3.624	48.431	-12.046*	-8.754*	180.988*
GDP	1.664	7.494	22.770	-6.496*	-3.029*	91.217*
ER	4.460*	0.280	59.654	-15.025*	-10.187*	202.904*
CR	2.508	8.287	24.581	-10.951*	-7.643*	163.808*
EQ	8.051*	-0.142	74.838***	-10.581*	-6.442*	148.585*

Note: *, **, and *** respectively represent significance at the level of 1%, 5%, and 10%.

Before model estimation, three panel unit root test methods, LLC, IPS and ADF, were used to test the stability of the data, and the test results were shown in Table 1. The original sequence of all variables is not stable, all are first-order integral sequences, and the three panel unit roots are stationary sequences when they pass the test at the same time. Therefore, the panel co-integration test is used to determine again whether there is a long-term co-integration relationship between the related variables. The t value of KAO co-integration test is -1.431, which rejects the null hypothesis that there is no co-integration relationship at the significance level of 10%, indicating that there is a long-term equilibrium relationship between the data.

4.2 Threshold model test

The energy investment level was introduced into the model as a threshold variable, and the threshold number and value were tested by "self-sampling" method for 300 times, as shown in table 2. The test results show that the single threshold effect of energy investment level passes the test at the significance level of 5%, while the double threshold effect is not significant at the significance level of 10%. Therefore, it is considered that there is a single threshold and no double threshold in this model. In the single threshold model, the threshold value of energy investment level is 910.920, corresponding confidence interval is [891.135, 911.380], indicating that the estimated threshold value is roughly accurate.

table 2 Threshold model test

Explained variable	Model	F statistics	P values	The critical value		
				10%	5%	1%
RES	A single threshold	45.340	0.050	34.362	43.425	94.706
	Double threshold	6.740	0.793	26.074	33.096	57.078

4.3 Threshold model estimation

In this paper, a single threshold regression estimation is performed for the model, and the results are shown in table 3. The influence of industrial structure on renewable energy supply varies greatly due to the different energy investment levels, and there is a single threshold effect of energy investment levels. When the investment level of renewable energy is low, the industrial structure has an insignificant restraining effect on the supply of renewable energy. The main reason is that under the low investment level, the supply cost of renewable energy is high, and the adjustment of industrial structure will rely on cheaper fossil energy, thus hindering the development of renewable energy. At present, the market situation of the proportion of fossil energy supply in China has not changed, and the adjustment of industrial structure cannot significantly affect the renewable energy supply. When the investment level of renewable energy exceeds the threshold value, the hindering effect of industrial structure on renewable energy supply will be transformed into a significant promoting effect. Higher levels of investment are bound to promote the development of cheaper and cleaner renewable energy, and industrial restructuring will shift to reliance on renewable energy.

The results of the model also show that the energy investment level of most provinces and cities is lower than the threshold value, only a few provinces and cities are higher than the threshold value, and the years that are higher than the threshold value are mainly from 2014 to 2017. Although the investment in renewable energy in various provinces and cities has been strengthened in recent years, the energy investment level nationwide is generally at a low level, and the promotion role of industrial structure on renewable energy supply has not been fully brought into play. Once the investment level is increased, the adjustment of industrial structure will rapidly promote renewable energy supply.

In terms of controllable variables, factor endowment and urbanization rate have a significant positive promotion effect on renewable energy supply. The energy intensity has an obvious inhibitory effect on the renewable energy supply coefficient. The promotion effect of per capita GDP on the supply of renewable energy did not pass the significance test, indicating that the promotion effect of per capita GDP on the supply of renewable energy was not obvious. Since renewable energy and traditional energy are fungible in the short term, economic growth may not effectively promote the development of renewable energy without environmental regulation.

Table 3 Estimation results of threshold model

Explanatory variables	Coefficient	T value	P values
GDP	3.750	0.290	0.768
ER	15.468	2.040	0.042
CR	8.362	2.990	0.003
EQ	-183.709	-20.829	0.000
IS(EI≤ γ_1)	-53.716	-1.410	0.158
IS(EI> γ_1)	153.334	3.37	0.001

5. Conclusions and Suggestions

Based on the data of 30 provinces in China (except Tibet) from 2005 to 2017, this paper takes the investment level of renewable energy as the threshold variable, establishes the panel threshold model, and empirically analyzes the threshold effect of industrial structure on renewable energy supply. The main conclusions and extended Suggestions are as follows.

First, the industrial structure has an obvious threshold effect on the supply of renewable energy. When the energy investment level is lower than the threshold value, the industrial structure has an insignificant inhibitory effect on the supply of renewable energy. When the energy investment level is higher than the threshold value, the industrial structure has a significant promotion effect on the renewable energy supply. This shows that at different investment levels, industrial structure has different effects on renewable energy supply. Renewable energy is a capital-intensive industry. The expansion of energy investment level will bring "economic effect" and "technological effect", and will also guide energy production, thus affecting the production structure and finally determining the consumption structure. Therefore, each region should increase the level of investment in renewable energy, drive technological progress, improve the overall work efficiency of the society, and strive to rationalize the energy consumption structure. At the same time, all provinces and cities should combine regional characteristics, according to their own resource endowment, leading industrial system and characteristic industrial scale, and take innovation as driving force to promote industrial structure optimization and upgrading.

Second, urbanization level and energy intensity also have a significant impact on renewable energy supply. To some extent, urbanization intensifies the pressure on energy supply, reducing the dependence on traditional energy and increasing the demand for renewable energy. China's current level of urbanization is relatively low compared with the world level. Therefore, more attention should be paid to the development of urbanization to promote the production of renewable energy. Energy conservation and consumption reduction is one of the strategies to promote the development of renewable energy, among which energy intensity reduction is the key. In addition to the spillover effect of technological progress, the reduction of energy intensity also requires the government to adopt differentiated energy conservation and emission reduction measures for different regions, carry out scientific and reasonable location planning for the industries to be undertaken, and formulate a series of policies to reduce the negative externalities caused by excessive agglomeration of energy-intensive industries.

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