Research on the Decoupling of Economic Development and Energy Consumption in Sichuan Province——Based on Decoupling Elasticity Coefficient and LMDI Model

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Abstract. The relationship between economic development and energy consumption has become a hot topic for scholars in recent years. This paper studies the decoupling between economic development and energy consumption in Sichuan Province from 1999 to 2018 by calculating the elastic coefficient of decoupling. At the same time, based on the LMDI model, this paper completely decomposes the main factors affecting Sichuan's energy consumption, and analyzes the main reasons for the decoupling between economic growth and energy consumption in Sichuan Province.

1. Introduction

Energy is an important driving force for economic and social development, and economic development is inseparable from energy[1]. Through research on the economic growth and energy consumption changes in Sichuan Province in the past decade, it is found that the growth rate of energy consumption is lower than the growth rate of GDP, and there is a certain decoupling between energy consumption and economic growth. Therefore, it is necessary to analyze the status of energy consumption structure in Sichuan Province in depth, and to completely decompose the main factors affecting energy consumption, and to explore the main reasons for the decoupling of economic development and energy consumption in Sichuan Province, so as to provide reference for major economic restructuring, energy saving and emission reduction, productivity layout and other important matters.

2. Decoupling elastic analysis

Decoupling means that the rate of economic growth is faster than the rate of increase in energy consumption, that is, the dependence of economic growth on energy consumption is reduced[2]. In this paper, the decoupling elastic coefficient is calculated by the total amount evaluation method which is more in line with Sichuan's actual situation. The decoupling elastic coefficient $d=(\%\Delta EC)/(\%\Delta GDP)$, where ΔEC is the growth rate of energy consumption and ΔGDP is the regional GDP growth. In the case of economic growth rate greater than 0, $d>1$ stands for negative decoupling, indicating that the total energy consumption growth rate is faster than GDP growth rate; $d=1$ indicates the link, indicating that the total energy consumption growth rate is equal to the GDP growth rate; $d<1$ is a relative decoupling, indicating that energy consumption growth rate is slower than GDP growth rate, and the growth rate is positive; $d<0$ explains absolute decoupling, indicating that energy consumption growth rate is negative and GDP growth rate is positive. Absolute decoupling is the most ideal state.

GDP and energy consumption are basically in a relative decoupling state, and their dependence on energy is declining. From 1999 to 2007, there was a certain fluctuation in the decoupling elastic coefficient of GDP and energy consumption in Sichuan Province, but the magnitude was not large. Since the implementation of the energy conservation and emission reduction policy in Sichuan in 2008, the decoupling elastic coefficient has remained between 0 and 1, and has been declining year by year. In 2018, it fell to 0.006, close to the absolute decoupling state. In

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the future, the elasticity coefficient of decoupling between economic growth and energy consumption in Sichuan Province may be less than 0, and the ideal state of absolute decoupling will be reached, that is, economic growth will no longer depend on energy consumption.

Table 1 Decoupling elastic coefficient of energy consumption in Sichuan Province from 1999 to 2018

Year	Energy consumption decoupling elastic coefficient	First industry decoupling elastic coefficient	Second industry decoupling elastic coefficient	Third industry decoupling elastic coefficient	Industrial decoupling elastic coefficient
1999	0.359	0.945	0.422	0.322	0.533
2000	0.064	-0.665	0.229	0.677	0.202
2001	0.148	8.921	-0.450	1.656	-0.489
2002	-0.852	-4.037	-0.787	2.836	-0.807
2003	0.273	2.243	0.113	0.680	0.099
2004	0.498	0.810	0.377	0.949	0.373
2005	0.999	0.620	0.925	1.240	0.909
2006	1.995	1.055	1.682	0.904	1.570
2007	1.280	9.059	0.871	1.680	0.804
2008	0.828	1.181	0.737	1.038	0.659
2009	0.733	5.511	0.711	0.214	0.612
2010	0.652	-2.630	0.409	1.820	0.364
2011	0.595	10.213	0.391	0.641	0.364
2012	0.536	-1.577	0.409	1.196	0.413
2013	0.637	-0.967	0.442	0.978	0.403
2014	0.627	0.209	0.622	0.687	0.585
2015	0.354	1.814	0.365	0.009	0.343
2016	0.455	0.914	0.126	1.972	0.110
2017	0.408	-0.238	0.359	0.013	0.324
2018	0.006	0.835	-0.204	0.413	-0.235

The first industry decoupling elastic coefficient fluctuates greatly and has high dependence on energy. From 1999 to 2018, the decoupling elastic coefficient of the added value of primary industry and energy consumption in Sichuan Province fluctuated greatly. There is still a certain amount of energy consumed in exchange for economic growth in the development of Sichuan's primary industry. After entering the "Twelfth Five-Year Plan", the fluctuation of the elasticity coefficient of decoupling in the primary industry has obviously decreased, and there is a significant downward trend, more of which is relative decoupling, indicating that the dependence on energy has decreased, but it is still the industry with the highest dependence on energy in the three industries.

The coefficient of elasticity of the second industry decoupling is decreasing year by year, and the industrial decline is most obvious. From 1999 to 2018, the decoupling elastic coefficient of the secondary industry, industrial growth and energy consumption in Sichuan Province showed a significant downward trend. Except for small fluctuations in individual years, the other years showed a relatively decoupling state. In 2018, the second industry and industrial decoupling elastic coefficients fell to -0.204 and -0.235, respectively, both of which showed absolute decoupling. It can be seen that the growth of the secondary industry and industry in Sichuan Province is basically no longer dependent on energy consumption. In 2018, the coefficient of decoupling of industrial power consumption fell to -0.579, reflecting that industrial growth is basically no longer dependent on power consumption.

The decoupling elastic coefficient of the tertiary industry fluctuated slightly, and the energy dependence showed a downward trend. From 1999 to 2018, the decoupling elastic coefficient of the added value of the tertiary industry in Sichuan Province and energy consumption has been in a state of small fluctuations. Among them, except for 2001, 2002, 2005, 2007, 2008, 2010, 2012 and 2015, the other years are between 0 and 1, and there is a certain downward trend, which is characterized by relative decoupling and dependence on energy is relatively low.

3. Decoupling cause analysis

The LMDI model has many advantages, such as wide application, complete decomposition, and easy interpretation of results. It is widely used in the decomposition analysis of energy consumption. Therefore, according to the Kaya equation, this paper decomposes energy consumption as follows:

$$E = \sum_i E_i = \sum_i \frac{E_i}{Q_i} \times \frac{Q_i}{Q} \times Q = \sum_i I_i S_i Q \tag{1}$$

$$\Delta E = E^T - E^O = \Delta E_Q + \Delta E_S + \Delta E_I \tag{2}$$

Among them, E is the total energy consumption; $i = 1, 2, 3$, representing the first, second and third industries respectively; E_i is the energy consumption of the i-th industry; Q is the regional GDP, Q_i represents the added value of the i-th industry, indicating the scale effect of the economy; $S_i = \frac{Q_i}{Q}$, which is the proportion of the added value of the i-th industry to the regional GDP, indicating the industrial structure effect; $I_i = \frac{E_i}{Q_i}$, which is the energy consumption intensity of the i-th industry, indicating the energy intensity Effect; ΔE is the amount of energy consumption change, E^T is the energy consumption of the T year, E^O is the energy consumption of the base year, $\Delta E_Q, \Delta E_S, \Delta E_I$ represent the changes of energy consumption caused by economic growth, industrial restructuring and energy intensity changes respectively[3,4].

This paper decomposes the influencing factors of energy consumption into three aspects: economic scale effect, industrial structure effect and energy intensity effect. Since there is no corresponding output value of domestic energy consumption, in order to better explain the relationship between economic growth and energy consumption, the research in this paper does not involve domestic energy consumption, that is, the total energy consumption does not include the energy consumption of living consumption, only refers to the production part.

The expansion of the economy is the main factor in promoting the growth of energy consumption, but the promotion is gradually weakening. Economic scale effect reflects the impact of economic development on energy consumption. From 1999 to 2018, the growth of energy consumption in Sichuan Province was mainly driven by the expansion of the economic scale. Economic scale effect increased the total energy consumption of the whole industry by 20.92 million tons of standard coal, accounting for 162.2% of the total effect. The scale effect of the secondary industry accounts for the largest proportion of the scale effect of the whole industry, and it is mainly based on industry. During the "Twelfth Five-Year Plan" period, the scale effect of Sichuan's economy is gradually declining, and the promotion effect on energy consumption is gradually weakening. The scale effect of the primary industry is basically stable, the scale effect of the secondary industry and industry is declining, and the scale effect of the tertiary industry is increasing year by year.

The effect of structural adjustment on energy consumption is gradually transformed into inhibition, and the energy-saving effect is initially revealed. Industrial structure effect reflects the impact of industrial restructuring on energy consumption. Since 1999, the adjustment of industrial structure in Sichuan Province has mainly promoted the growth of energy consumption. The structural effect has increased the total energy consumption of the whole industry by 30.59 million tons of standard coal, accounting for 23.7% of the total effect. In the long run, the structural effects of the

secondary industry mainly promote the growth of energy consumption. In the long run, the structural effect of the secondary industry mainly promotes the growth of energy consumption, while the structural effect of the primary industry and the tertiary industry mainly inhibits the growth of energy consumption. The structural effect of the second industry accounts for the largest proportion of the structural effect of the whole industry, and the industry is the main one. During the "Twelfth Five-Year Plan" period, the proportion of the total effect of structural effects in Sichuan Province gradually declined, and the effect on energy consumption gradually changed from promotion to inhibition.

Increased energy efficiency is the main cause of reduced energy consumption. Energy intensity effect response energy intensity change is the impact of energy efficiency change on energy consumption. From 1999 to 2018, the decline in energy consumption intensity in Sichuan Province, that is, the increase in energy use efficiency, was the main reason for the decline in energy consumption. The intensity effect reduced the total energy consumption of the whole industry by 11.84 million tons of standard coal, accounting for - 85.9% of the total effect. During the "Twelfth Five-Year Plan" period, the proportion of Sichuan’s intensity effect to the total effect continued to increase, and the inhibitory effect on energy consumption growth increased.

4. Conclusion

This paper analyzes the decoupling between economic development and energy consumption in Sichuan Province from 1999 to 2018 by calculating the decoupling elastic coefficient. It is found that Sichuan's GDP and energy consumption are basically in a decoupling state, and the dependence on energy has declined. Among them, the elastic coefficient of the decoupling of the primary industry is relatively large, and the dependence on energy is high; the elastic coefficient of the decoupling of the secondary industry is decreasing year by year, and the industrial decline is the most obvious; the elastic coefficient of the decoupling of the tertiary industry fluctuates slightly, and the energy dependence shows a downward trend.

At the same time, based on the LMDI model, this paper analyzes the main reasons for the decoupling between economic growth and energy consumption in Sichuan Province. Among them, the expansion of economic scale is the main factor to promote the growth of energy consumption, but the promotion effect is gradually weakened; the effect of structural adjustment on energy consumption is gradually transformed into inhibition, and the energy-saving effect is initially revealed; the improvement of energy utilization efficiency is the main cause of the reduction of energy consumption.

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