Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1732-1746
Article History: Received: 02 April 2022, Revised: 15 April 2022, Accepted: 24 April 2022, Publication: 04 May 2022

Study on the Correlation between the Industrial Structure and the Energy Demand in China

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Abstract:

This paper analyzes the correlation between the industrial structure and energy demand from two perspectives. First, the proportions of the three industries are used to build the value of Moore structure change, which measures industrial structure changes, and the non-linear Granger causality test is carried out to determine the correlation and influence direction between the industrial structure changes and the energy demand in China. Second, from the perspective of the internal development of the industrial structure, the influence of the industrial structure on the energy demand is studied through the dual fixed effects model, especially the promotion function of energy-intensive industries on the energy demand. The results have shown that the optimization and upgrading of the industrial structure will have influence on the demand for energy consumption, and the constraint of energy demand will restrict the industrial restructuring to some extent. In addition, the development of energy-intensive industries has a significant positive influence on the level of energy demand.

***Keywords**: Industrial Structure, Energy Demand, Non-linear Granger Causality, Energy-intensive Industries.*

I. INTRODUCTION

Energy is an indispensable resource in the economy and the society, as well as a necessary guarantee of the improvement of people's living standard. Over the past 40 years since the reform and opening up, energy consumption maintained a relatively rapid growth in the beginning with the sustained and rapid growth of Chinese economy and the accelerated development of heavy industry. However, since 2012, with the slowing growth of Chinese economy, the growth rate of energy consumption has been falling year by year. At present, China has entered the "new normal" of medium-to-high-speed growth after over thirty years of high-speed growth, which means that China has entered a new age of building socialism with Chinese characteristics, where the optimization and upgrading of the economic structure and the transformation of the driving force economic growth will both affect the demand of energy consumption in the future.

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In the report of the 19^{th} CPC National Congress, it's clearly pointed out that pollution prevention and control would be one of the decisive combats in building a moderately well-off society in an all-round way. Changes in the total volume and structure of energy demand will have important influence on the work of pollution control and emission reduction, and will be directly related to the global climate changes. In addition, as the energy demand in China keeps growing, the foreign-trade dependence of energy has also been constantly increasing. In the future, not only will the changes in the energy demand be related to the energy security of China, they will also have direct influence on the scale of the international energy industry and the price fluctuations. However, scientifically and accurately predicting the future trend of energy demand in China requires in-depth studies on the factors influencing the energy demand of China.

In the economic growth of China, it is a distinguishing feature of China's economic growth at the present stage to achieve the goal of green development through continuous upgrading and adjustment of the industrial structure. With the optimization and upgrading of the industrial structure and the acceleration of economic growth, the demand for energy consumption will be influenced. At the same time, the constraint of energy consumption will in turn restrict the adjustment of the industrial structure. If energy-intensive industries account for a high proportion, the energy demand of the whole national economy will increase; on the contrary, if the proportion of energy-intensive industries is low, the energy demand of the whole national economy will decrease. In addition, China has a vast territory, and different provinces, cities and regions have different resources as well as different industrial structures, and the heterogeneity of the industrial structures of different regions will lead to different influences on energy demand. At present, as China continues to cut overcapacity, the model of economic development is gradually changing, and the growth of high energy-consuming industries has been slowing. Therefore, studying the correlation between the industrial structure and the energy demand is of great theoretical and practical significance to the formulation of energy development strategies, the optimization of the industrial structure, the construction of the national economic system of green development, as well as the promotion of the coordinated development of resources, environment and economy.

Since the end of 2019, the outbreak of COVID-19 worldwide continues to impact the world economy and has a huge impact on the industrial structure and energy demand. From the perspective of industrial structure, the COVID-19 epidemic has a great impact on the secondary industry, while the tertiary industry is also seriously affected. The COVID-19 epidemic has a major impact on the secondary industry in three aspects. At first, it causes work stoppage, production capacity vacancy and order loss. Second, supply chain is damaged, capacity recovery need to be taken a long time. Third, the labor cost is huge, the enterprise burden is heavier during the shutdown peirod. The impact of COVID-19 on the tertiary industry mainly lies in the fact that the epidemic has promoted the industry to develop in the direction of online, intelligent and digital, and there are many commercialization scenarios, such as online office, online education and telemedicine, etc. Meanwhile, it has exerted a negative impact on the catering and other service industries. Due to the fundamental changes in China's economic foundation and industrial structure, the specific degree of influence is also closely related to domestic and foreign policies. From the perspective of energy demand, the spread of COVID-19 is the biggest shock to the global energy system in nearly 70 years, with global energy demand is predicted to fall by 6% in 2020. Whether this demand shock

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will continue to lead to changes in the equilibrium state of the energy system remains to be further studied.

This paper mainly studies the correlation between the industrial structure and the energy demand, as well as the future trend of energy demand in China. First, the proportions of the three industries are used to construct the Moore structural change value, which measures the change of the industrial structure; and the correlation and influence direction between the industrial structure and the energy demand in China are judged through the non-linear Granger causality test. Second, from the perspective of the internal development of the industrial structure, this paper studies the influence of the changes in the industrial structure on the energy demand through the dual fixed effects model, especially the promoting function of the development of energy-intensive industries on the energy demand. Finally, some policy suggestions on the direction of China's industrial structure adjustment are put forward based on the results of the empirical study. Compared with existing research results, this paper has made progress in the following aspects: first, it uses the non-linear Granger causality test to explore the non-linear correlation between the industrial structure and the level of energy demand, thus no longer limiting the research of correlation to linear influences and correlation coefficients, and enriching the research results of the correlation between the industrial structure and the energy demand. Second, it measures the changes in the industrial structure from different perspectives and conducts an in-depth analysis of the influence of energy-intensive industries on the energy demand, and considers the issue of regional heterogeneity in quantitative research, thus making up for the deficiencies in previous studies.

The structure of this paper is arranged as follows: the second part sorts out and reviews the relevant literature from two aspects, respectively the correlation between the industrial structure and the energy demand and the prediction of energy demand in the future; the third part studies the correlation between the change of industrial structure and the level of energy demand in China; the fourth part analyzes the influence of the development of energy-intensive industries on the level of energy demand; the fifth part is conclusion and inspirations.

II. LITERATURE REVIEW

The correlation between the industrial structure and the energy demand in the process of economic development has attracted wide attention in academic circles. Scholars at home and abroad have analyzed the correlation between the industrial structure and the energy demand from different perspectives and with different research methods. This paper mainly summarizes and sorts out relevant literature from the correlation between the industrial structure and the energy demand.

Mukhopadhyay and Chakraborty (1999) found in their research that the heavy industrialization of India and the changes in the industrial structure it caused were the main factors affecting the short-term energy demand [1]. By analyzing the relationship between the relationship between the energy demand, foreign trade and the changes in the industrial structure, Jacobsen (2000) found a strong correlation between the energy demand and the industrial structure [2]. Krausmann and Haberl (2002) found a strong correlation between the total volume and structure of energy consumption and the changes in industrial structure [3].

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On the basis of the analysis the intensity and elasticity of energy consumption, Zhang et al. (2004) specifically analyzed the impact of China's industrial structure transformation on energy consumption, and judged the impact trend through the industrial structure index of energy consumption [4]. Wu and Mao (2010) analyzed the industrial structure and energy consumption of five major cities in China (Beijing, Chongqing, Guangzhou, Shanghai and Tianjin) to assess the effect of the national industrial structure on the energy consumption [5]. Zhang and Wang (2011) analyzed the energy consumption and the industrial structure of Shaanxi Province with the method of time series, and found that the level of primary industry structure was the Granger reason of the growth in energy consumption, and that there was a two-way Granger causal relationship between the structure of the secondary and tertiary industries and the energy consumption [6]. Adom et al. (2012) held that different industrial natures would also lead to differences in energy demand [7]. Fan and Xia (2012) decomposed the driving factors with the hybrid-units energy input-output model so as to determine the influence of driving factors on the change in energy intensity. The results showed that the structure of energy input, the industrial structure and technological advances had significant influence on the energy demand, and that the growth would be better promoted by adjusting the energy structure, the industrial structure and enhancing the technological improvement [8]. Mi et al. (2015) held that industrial restructuring was one of the important influencing factors of energy demand [9]. Li et al (2017) analyzed the influencing factors of energy consumption in China's energy-intensive industries with the Log-Mean Divisia Index (LMDI), the decomposition factors included energy structure, energy intensity, industrial structure, total demand, the structure and total effect of the final demand. The results have shown that the reduction of energy consumption in energy-intensive industries mainly depended on energy intensity and the industrial structure [10]. Haas and Kempa (2018) theoretically analyzed the observable development of energy intensity using a model involving technological changes. Based on empirical evidences, the change in total energy intensity was decomposed into industrial structure changes and energy efficiency improvement within the sector. And the relative importance of these two effects depended on the growth in energy price and the productivity of the sector, that is, when the research object is labor-intensive sector, industrial structure changes were the main driving force of the change in energy intensity; when the research object is energy-intensive industry, the efficiency effect would dominate the development of energy intensity [11].

As can be seen from the above review of existing literature, it can be seen that domestic scholars mostly conducted empirical studies on the relationship between the energy demand, the changes in the three industries and the changes in the internal structure of each industry based on data of time series, and rarely used panel data to consider the regional heterogeneity. In terms of the relationship between the industrial structure and the energy demand, most studies conducted analysis with linear models, but the relationship between the two is not necessarily linear in real life. At the same time, when studying the relationship between the two, the measurement of the industrial structure is mostly the changes of the three industries, and the role of the development of energy-intensive industries is rarely considered. In addition, the prediction of China's energy demand in the future is made mostly with a single prediction method, rarely carrying out horizontal comparison of the accuracy of multiple prediction methods.

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III. THE CORRELATION BETWEEN THE INDUSTRIAL STRUCTURE AND THE ENERGY DEMAND IN CHINA

3.1 Descriptive Analysis

In the past two decades, with the sustained and rapid development of the economy and the increasing economic aggregate, the industrial structure of China has undergone major changes. As shown in Figure 1, the proportion of the primary industry in China's GDP has been decreasing year by year, which had dropped to less than 10% after 2009 and dropped to 7% in 2018; however, the proportion of the tertiary industry has been gradually increasing, which had exceeded 50% after 2015; the amplitude of variation of the secondary industry is relatively small, with a slight trend of decline in recent years. Since 2013, China's overall industrial structure has changed from "secondary > tertiary > primary" to "tertiary > secondary > primary", that is, in the GDP composition of China, the proportion of the tertiary industry is greater than those of the secondary and the primary industries, reflecting the process of continuous optimization of China's industrial structure. In terms of the growth rate of the total energy consumption, there was a trend of sharp rise before 2004, followed by a trend of sharp decline. Through an analysis of the relationship between the proportion of the three industries, the growth rate of the economy and the changes in energy consumption, a corresponding trend of change has not been seen between the growth rate of energy consumption and the growth rate of GDP, and its relationship with the changes in the proportions of the three industries, which requires further studies.

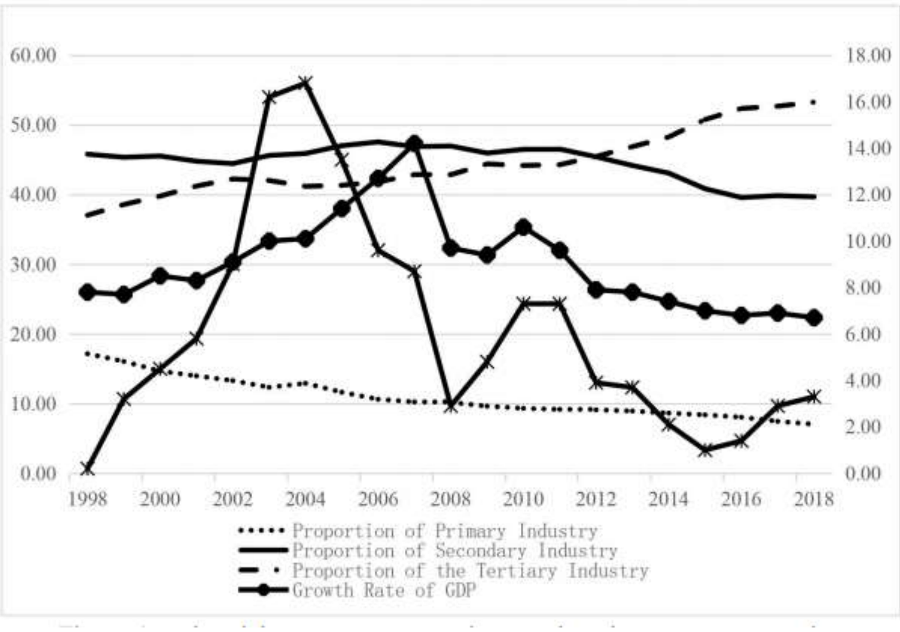

Figure 1: Industrial structure, economic growth and energy consumption

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3.2 Granger Causality Analysis

In this paper, the non-linear Granger causality test is used to further judge the correlation and influence direction between the industrial structure and the energy consumption in China.

3.2.1. Definitions of main variables

When studying the changes in industrial structure, scholars mainly use the following four indices: the index of structural change value, the entropy index of industrial structure, the index of overstepping coefficient of industrial structure and the index of Moore structure change. In this section, the index of Moore structure change is used to measure the changes in the industrial structure. This index adopts the method of spatial vector measurement, in which the industries are divided into n sectors, thus producing a set of n-dimensional vectors, and the included angle of two sets of variables in two periods is used to measure the degree of industrial structure changes. The structural changes of all industries in the overall economic system are obtained through the cumulative totaling of all included angle changes. The larger the included angle of industrial vectors in different periods, the greater the changes in the industrial structure, and vice versa. The formula of the index is as follows:

$$M_l^+ = \frac{\sum_{i=1}^{n} W_{i,t} W_{i,t+1}}{\sqrt{\sum_{i=1}^{n} W_{i,t}^2 \sum_{i=1}^{n} W_{i,t+1}^2}}, \theta = \arccos M_l^+$$

In this formula, M_l^+ stands for the index of Moore structure change; θ stands for the degree of Moore structure change; $W_{i,t}$ stands for the proportion of the i industry in the t period; and $W_{i,t+1}$ stands for the proportion of the i industry in the t+1 period.

In this section, relevant data of the three industries of China from 1998 to 2018 are selected, and the value and degree of structural changes in our country during this period are calculated with the above formula, the results are as shown in Figure 2.

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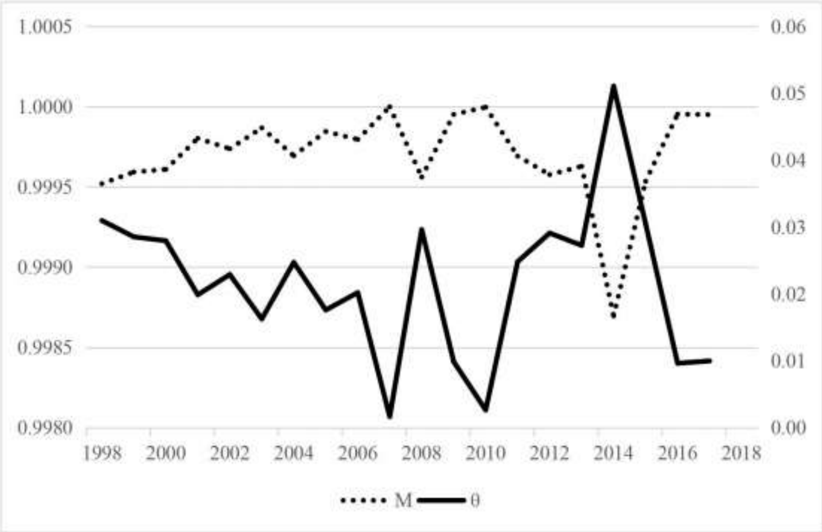

Figure 2: M, the index of Moore structure change, and θ, the degree of change.

The variable studied in this section is the industrial structure change in China, which is measured with θ, the degree of Moore structure change. Another important variable in the study is the level of energy demand, which is measured with E, the total energy consumption. All the above empirical data are from the wind database.

3.2.2. Stationarity test

For data of time series, in order to eliminate the phenomenon of “spurious regression”, stationarity test must first be done to the data before carrying out the non-linear Granger causality test. In this section, ADF test and PP test are used to carry out the unit root test. The results of the unit root test of θ, the industrial structure change and E, the level of energy demand, are as shown in TABLE 1.

TABLE 1. Results of the unit root test

Variable	Form	ADF test	PP test	Conclusion
θ, industrial structure change	Primitive root	-3.2403**	-3.2377**	stationary
E, level of energy demand	Primitive root	-1.9840	-1.9840	Non-stationary
	First order	-3.2815**	-3.2608**	Stationary

Note: ***, ** and * respectively mean being significant at 1%, 5% and 10%, the same below.

As can be seen from TABLE 1, the original sequence of θ, the variable of China’s industrial structure, is significant at 5%, that is, a stationary sequence; the original sequence of E, the variable of energy

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demand is not significant at 5%, and its first-order difference is significant at 5%, showing that both variables are first-order integrated variables with a co-integration relationship, thus having a stationary relationship.

3.2.3. Non-linear test

Before the causality test, a non-linear test is first carried out to determine whether there is a non-linear trend between θ, the industrial structure change and ΔE, the change in the level of energy demand. In this section, BDS test, McLeod-Li test and RESET test are used for the non-linear test of the relationship between the industrial structure and the energy demand in China. During the test, the VAR model is used to estimate the interaction between the two and filter the linear dependence between them. Then a non-linear test is carried out on the residual sequence of the estimated results. The results of the non-linear test are as shown in TABLE 2.

TABLE 2. Results of the non-linear test

Test Method	Statistical value	P value	Conclusion
BDS test	3.3878***	0.0007	Existence
McLeod-Li test	40.8814***	0.0000	Existence
RESET test	6.2601**	0.0441	Existence

As can be seen from TABLE 2, the test results of the three methods have all indicated the existence of a non-linear trend between θ, the industrial structure change and ΔE, the change in the level of energy demand.

3.2.4. Non-linear Granger causality

The non-linear Granger causality test of θ, the industrial structure change and ΔE, the change in the level of energy demand. In this paper, this method is used for the intuitive analysis of the existence of a dynamic correlation between the industrial structure and the energy demand in China. After filtering the linear relationship between the two with the VAR model, their residuals were tested, and common lag oders 1 were selected. The results of the test are as shown in TABLE 3.

TABLE 3. Results of the Granger causality test

Original hypothesis	Lag order	T statistical value	P value
θ is not the Granger cause of ΔE	1	3.7395**	0.0187
ΔE is not the Granger cause of θ	1	2.8778*	0.0981

It can be seen from the test results of the above-mentioned different lag orders that θ, the industrial

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structure change is the Granger cause of ΔE, the change in the level of energy demand, that is, industrial structure changes can cause changes in the level of energy demand. And the original hypothesis that ΔE, the change in the level of energy demand is not the Granger cause of θ, the industrial structure change is only refused at the significance level of 10%, meaning that the change in the level of energy demand only restricts the industrial structure change to a certain degree.

To sum up, the optimization and upgrading of the industrial structure will have influence on the demand of energy consumption. At the same time, the constraint of energy demand will also restrict industrial restructuring to some extent.

IV. THE INFLUENCE OF ENERGY-INTENSIVE INDUSTRIES ON THE ENERGY DEMAND IN CHINA

4.1 Descriptive Analysis

Since the direct driving effect of the economic aggregate on the energy demand is gradually weakening, the development of energy-intensive industries has a great influence on the change in the energy demand in China from the perspective of the internal development of the industrial structure. In terms of the industrial distribution of energy consumption, industrial consumption of energy accounts for 68%, in which the energy consumption of six energy-intensive industries, including steel, cement and chemical engineering, has reached 49%. As can be seen from Figure 3, the output and total energy consumption of energy-intensive industries represented by cement and crude steel show a certain degree of convergence in their variation trend, that is, the output and total energy consumption of energy-intensive industries largely show a trend of synchronous change.

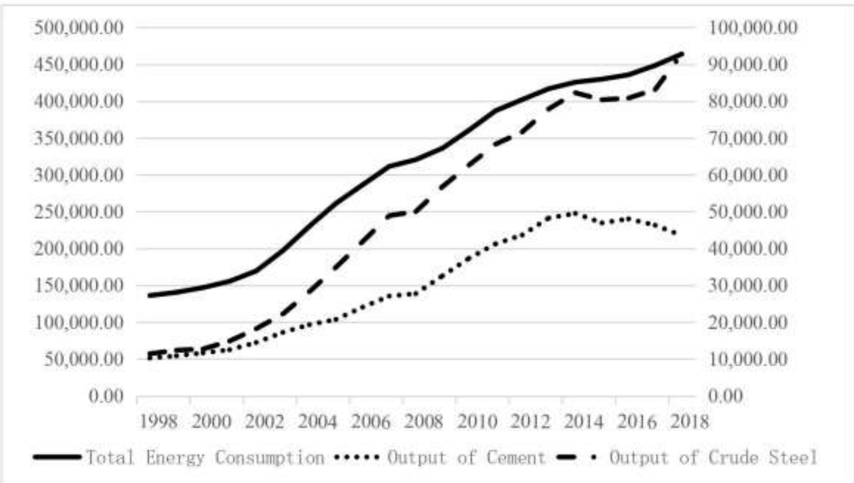

Figure 3: Energy-intensive industries and energy consumption

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Then, an intuitive analysis is made on the correlation between the total energy consumption in each province and the output of the two energy-intensive industries from 1998 to 2017[1]. Figure 4(a)(b) show the correlation between the output of cement, the output of crude steel and the total energy consumption. The scattered points in the figure stand for the observed value of the output of energy-intensive industries and the total energy consumption, and the dotted line is the line of linear fitting.

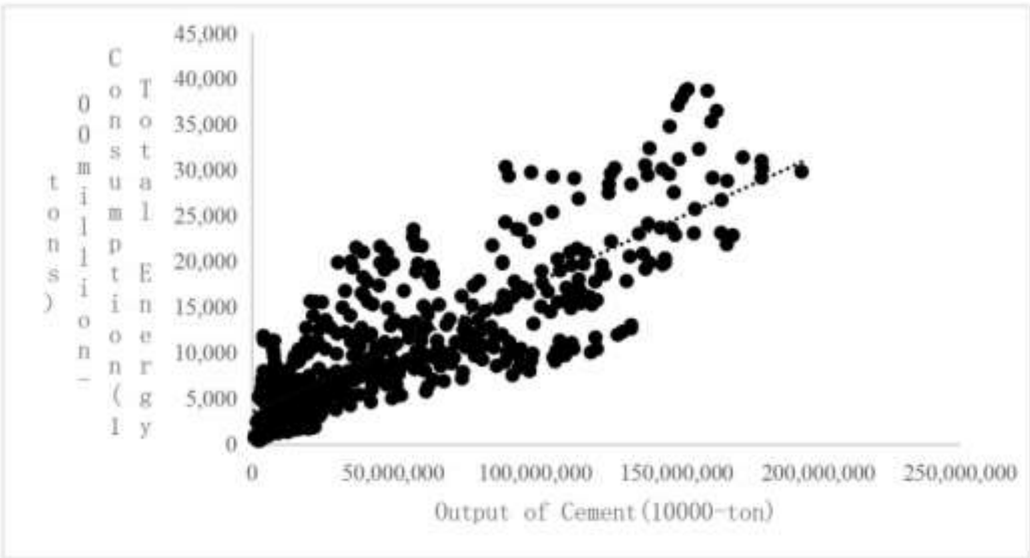

Figure 4(a): the correlation between energy-intensive industries and energy consumption

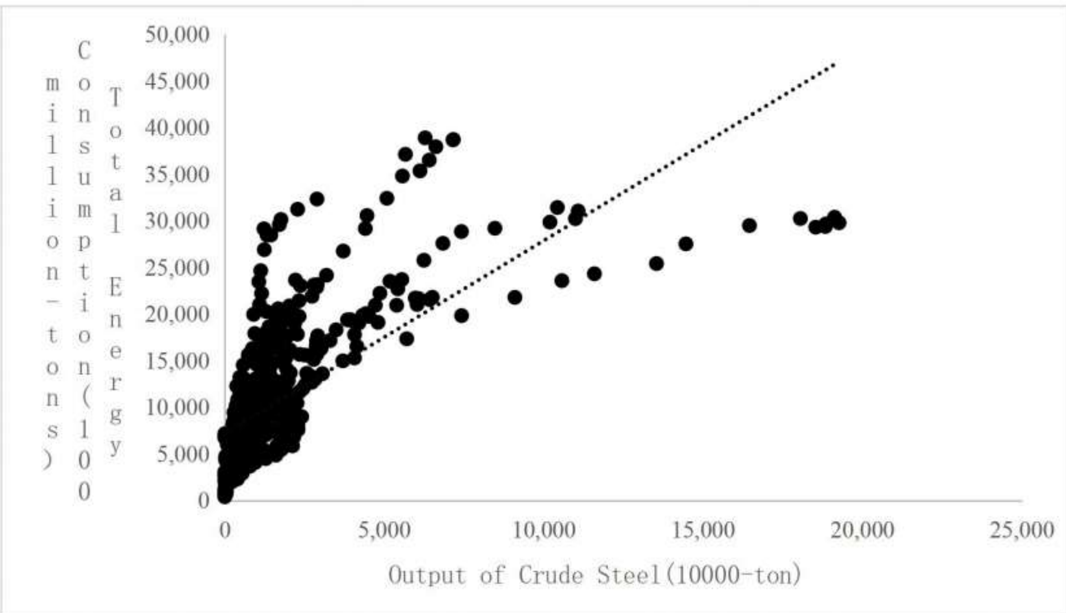

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Figure 4(b): the correlation between energy-intensive industries and energy consumption

According to the figure of correlation between the output of energy-intensive industries represented by cement and crude steel and the total energy consumption, and in combination with the two sets of correlation coefficients, there is a rather strong positive correlation between the output and the total energy consumption of energy-intensive industries. The correlation coefficient of the output of cement and the total energy consumption is 0.8205, the the correlation coefficient of the output of crude steel and the total energy consumption is 0.7068. In addition, both of them are significant at the level of 1%.

4.2 Empirical Analysis

In order to demonstrate the influence of industrial structure changes on energy demand, especially the driving effect of the development of energy-intensive industries on the energy demand, a panel data model is built in this section for an in-depth exploration.

4.2.1. Specification of the model and definitions of variables

A simplified function model of the level of energy demand and the main influencing factors is built according to the general form of energy demand models, which is as shown below:

$$E_{i,t} = f\left(Y_{i,t}, Z_{i,t}, p_{i,t}, Tec_{it}\right)$$

In this model, $E_{i,t}$, the energy demand, is the function about $Y_{i,t}$, the economic aggregate, $Z_{i,t}$,the industrial structure, $p_{i,t}$, the energy price and Tec_{it}, the technological level. According to theories of economics, a preliminary judgment can be made that there is a positive correlation between the energy demand and the economic aggregate, there is a negative correlation between the energy demand and the energy price and the technological level, while there is an uncertain relationship between the energy demand and the industrial structure. On the basis of the results of descriptive analysis, the industrial structure change is described with the development of energy-intensive industries and the proportion of the tertiary industry, the specification of the model is as follows:

$$\ln E_{it} = \beta_{1j}\sum_{j=1}^{J}\ln Z_{it,j} + \beta_2 Ter_{it} + \beta_3 \ln Y_{it} + \beta_4 \ln P_{it} + \beta_5 Tec_{it} + \mu_i + \nu_t + \varepsilon_{it}$$

This main variables involved in this section are as shown in TABLE 4.

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TABLE 4. The definitions of main variables

Type of the variable	Symbol	Definition of the variable
Explained variable	E	Level of energy demand measured by the total energy consumption
Explanatory variable	Z	Output of energy-intensive industries, represented by crude steel, cement and coke
Control variable	Ter	Proportion of the tertiary industry
	Y	Economic aggregate measured by regional GDP
	P	Energy price measured by the purchasing price index of fuels and power
	Tec	Technological level measured by patent applications which be approved

Based on the availability and integrity of the data, the panel data of 28 provinces in China (excluding Beijing, Hainan and Tibet) from 1998 to 2017 were selected in this section. In the case of a few missing values, the mean values of the previous and the following years are used. All data were from the wind database, except for the output of coke, and the output data of coke were from the database of China Economic Information.

4.2.2. Analysis of the empirical results

According to the above-mentioned results of analysis, and in combination with previous studies, there is not a necessary two-way causality between the industrial structure and the energy demand. But in order to avoid possible endogenous problems caused by a reverse causality, the lagged variables of the main explanatory variables are used in this section as the instrumental variables. Then, a two-stage least square regression is carried out for the model estimation. On that basis, the two-period lagged variables of the output of energy-intensive industries are used in this section as the instrumental variables, and the estimation is made with the dual fixed effects model. The results of the estimation are as shown in TABLE 5.

TABLE 5. Estimation results of the influence of energy-intensive industries on the energy demand

	(1)	(2)	(3)	(4)
Ter	-0.0115***	-0.0109***	-0.0061**	-0.0047**
	(-4.81)	(-4.01)	(-2.22)	(-2.28)
lncement		0.0541**	0.0924***	0.0663***
		(2.42)	(3.76)	(3.44)
lnsteel			0.1408***	0.0382*

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			(5.98)	(1.90)
lncoke				0.1348***
				(8.78)
lnY	0.5935***	0.5797***	0.3951***	0.4036***
	(27.07)	(26.51)	(10.67)	(13.57)
lnP	-0.2402***	-0.2635*	-0.2551*	-0.3513***
	(-4.27)	(-1.87)	(-1.92)	(-3.09)
Tec	-0.0019	-0.0050**	-0.0056***	-0.0070***
	(-0.49)	(-2.46)	(-3.23)	(-3.36)
cons	3.0858***	2.1915***	2.0583***	1.7716
	(8.76)	(2.76)	(2.70)	(2.71)
Year Effect	control	control	control	control
Provinces Effect	control	control	control	control
Observed Value	560	504	495	491

Note: Values in the brackets stand for the T statistical values of the estimation coefficient.

Column (1) only considers the influence of the proportion of the tertiary industry and the control variable on the level of energy demand, in columns (2)-(4), variables of energy-intensive industries represented by cement, crude steel and coke are gradually introduced. As can be seen from the estimation results, the regression results of the proportion of the tertiary industry on the level of energy demand are significantly negative at the level of 5%, showing that the proportion of the tertiary industry is negatively correlated with the level of energy demand, that is, as the proportion of the tertiary industry increases, the level of energy demand significantly decreases. The regression results of energy demand of the output of cement, the output of crude steel and the output of coke are all positive, indicating that the output increase of energy-intensive industries will improve the level of energy demand. After the introduction of coke output, the influence of crude steel output on the energy demand becomes insignificant, which may be caused by the mutual influence of coke and crude steel, the former being the main raw material of the latter. In addition, the influences of the three control variables on the energy demand are all significant, the increase of the economic aggregate will improve the level of energy demand, while the increase of the technological level and the energy price will reduce the level of energy demand, which is consistent with the judgement made based on theories of economics.

To sum up, the development of energy-intensive industries has influence on the level of energy demand, that is, if the output of energy-intensive industries increases, the level of nergy demand will also increase; while if the output of energy-intensive industries decreases, the level of energy demand will also increase.

V. CONCLUSIONS AND INSPIRATIONS

This paper analyzes the correlation between the industrial structure and the energy demand from two perspectives. First, the proportions of the three industries are used to built the value of Moore structure

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Article History: Received: 02 April 2022, Revised: 15 April 2022, Accepted: 24 April 2022, Publication: 04 May 2022

change, which measures the industrial structure changes, and the non-linear Granger causality test is used to determine the correlation and influence direction between the industrial structure and the energy demand in China. The results have shown that the optimization and upgrading of the industrial structure will have influence on the demand of energy consumption. At the same time, the constraint of energy demand will restrict the industrial restructuring to some extent. Second, from the perspective of the internal development of the industrial structure, the dual fixed effects model is used to study the influence of the industrial structure change on the energy demand, especially the promoting function of the development of energy-intensive industries on energy demand. The results have shown that the development of energy-intensive industries has influence on the level of energy demand, that is, if the output of energy-intensive industries increases, the level of energy demand will also increase; while if the output of energy-intensive industries decreases, the level of energy demand will also increase.

According to the research conclusions, this paper can give us the following inspirations. First, China should accelerate the upgrading of its industrial structure. The industrial structure changes will promote the changes in the level of energy demand. The increase in the proportion of the tertiary industry will promote the upgrading of China's industrial structure. This process of industrial restructuring will directly influence the level of energy demand, that is, the level of energy demand can be reduced to a certain degree by adjusting the structure of the three industries. Second, China should attach importance to the optimization of the internal structure of the industries. The continuous increase of the energy demand can only be restricted by controlling the development of energy-intensive industries. At present, energy-intensive industries account for a large proportion in the energy demand, but the level of demand has become relatively stationary, indicating a limited space of growth. This shows that with the industrial restructuring, the foundation of the sharp growth of energy-intensive industries will no longer exist, which will cause the level of energy demand in China to become stationary or even decline.

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Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1732-1746
Article History: Received: 02 April 2022, Revised: 15 April 2022, Accepted: 24 April 2022, Publication: 04 May 2022

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