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THE REGIONAL PROBLEMS OF ENERGY PRODUCTION AND CONSUMPTION IN CHINA

This paper examines the characteristics of energy production and consumption in China and the role they play. Moreover, the spatial correlation network of energy consumption and its effect are analyzed. The result shows that all provinces could be divided to four types: net receptor, net spillover, high output and high consumption, income and spillover. The correlation relationships of energy consumption in China show a typical network pattern. As for the spatial correlation network, an increasing number of correlation relationship among provinces would do good to reduce energy intensity and energy consumption and increase gross regional product.

Keywords: *spatial correlation network; correlation relationship; energy production; energy consumption; energy intensity; gross regional product; energy flow; energy spillover; network centrality; network density.*

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РЕГИОНАЛЬНЫЕ ПРОБЛЕМЫ ПРОИЗВОДСТВА И ПОТРЕБЛЕНИЯ ЭНЕРГИИ В КИТАЕ

В данной статье исследуются основные характеристики производства и потребления энергии в Китае. Кроме того, анализируется пространственная корреляционная сетевая модель энергопотребления. Полученные результаты свидетельствуют о том, что все провинции можно разделить на четыре типа: чистый потребитель, чистый производитель, провинции с высоким объемом производства и потребления, потребитель и производитель. Корреляционные отношения энергопотребления в Китае можно представить в виде сетевой модели. Пространственная корреляционная сетевая модель показала, что увеличение числа взаимосвязей между провинциями будет способствовать снижению энергоемкости и энергопотребления и увеличению валового регионального продукта.

Ключевые слова: *пространственная корреляционная сетевая модель; корреляционная связь; производство энергии; потребление энергии; энергоемкость; валовой региональный продукт; энергетический поток; переток энергии; центральность сети; плотность сети.*

Introduction. Energy is an important material basis for human existence and social development. It is related to the national economy and the people's livelihood. The rapid development of China's economy since the reform and opening up is inseparable from the stable supply of energy. However, along with the seriousness of resource and environmental constraints, the challenges of energy in the process of economic development in China would become more and more severe [1].

First of all, the total national energy consumption has been rising year by year, with a faster and larger growth rate. In 2009, China's total national energy consumption was 3213,36 mln tons of standard coal, while in 2019 this figure has increased to 4475,97 mln. And while the total energy production and consumption keep rising at a certain ratio, energy

consumption is always larger than energy production. Besides, the spatial distribution of energy production and consumption shows an obvious unbalanced trend. The distribution of energy endowment shows the characteristic of «more in the west and less in the east». The contradictory of energy production and consumption in spatial distribution is difficult to be modified due to the combination of various factors.

However, the energy production and consumption of each province is not independent. A complex spatial correlation network of energy consumption exists throughout China. The existence of this spatial correlation network allows for the deployment of multiple energy sources between China's provinces and regions, breaking through geographical constraints. The Chinese government is also promoting projects to move energy across regions, such as the West-to-East Gas Transportation, North-to-South Coal Transportation, and West-to-East Power Transmission. These measures not only increase the network density, but also make spatial correlation network of energy consumption in Chine more stable. In this context, it is important to explore the overall characteristics of spatial correlation network of energy consumption in Chine and to analyze the role and position of each province in the spatial correlation network for the purpose of the allocation and realization of energy conservation optimization.

Cluster analysis. Two-step clustering was used to classify the energy production data of each province in 2019. The 30 examined provinces can be classified into 3 clusters according to their characteristics of the energy production. The first cluster contains Guangdong, Liaoning, and Shandong, which have significant advantages in the production of Diesel Oil, Gasoline, Kerosene, Crude Oil, Fuel Oil, and Coke. In 2019, Guangdong, Liaoning, and Shandong produced large amounts of these kinds of energy sources which are significantly higher than the national average. The second cluster includes twenty provinces. The majority of provinces in China fall into this category. The provinces included in this cluster are: Anhui, Beijing, Chongqing, Fujian, Gansu, Guangxi, Guizhou, Hainan, Hebei, Henan, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Ningxia, Qinghai, Shanghai, Yunnan, Zhejiang. The provinces belonging to this cluster are characterized by a small production for all types of energy sources. The results of this analysis consist with the actual situation of most of the provinces in China. The majority of provinces in China do not have resource advantages. These provinces need a wide range of energy sources from other resource-based regions to meet their needs of energy for basic economic development. There are seven provinces in the third cluster about energy production, namely Heilongjiang, Inner Mongolia, Shanxi, Shaanxi, Sichuan, Tianjin, Xinjiang. These provinces mainly produce and export Crude Oil, Natural Gas, Raw Coal, and Coke to other regions. They have abundant reserves of primary energy such as Crude Oil, Natural Gas, Raw Coal and these regions have much experience in energy exploitation. Most of them are traditional resource-based regions in China. These provinces produce a large share of primary energy. They produced 304,446,000 tons of Raw Coal in 2019, accounting for 79.15 % of the total production. And they produced a total of 117,147,000 tons of Crude Oil, accounting for 61.13 % of the total production.

The data about energy consumption of examined provinces in China in 2019 are classified in the same way. It is optimal to classify the 30 provinces into 5 clusters. The first cluster includes Anhui, Chongqing, Fujian, Gansu, Guangxi, Guizhou, Hainan, Heilongjiang, Hunan, Jilin, Jiangxi, Ningxia, Qinghai, Shaanxi, Tianjin, Xinjiang, and Yunnan. The majority of provinces in China belongs to this category. The consumption of various energy resources in these provinces is below the average. The possible reasons are that these provinces have a small population and general economic scale. They contribute not much to Gross Domestic Product. Therefore, these provinces do not have outstanding needs for energy.

The second cluster consists mainly of Beijing and Shanghai. Their Kerosene consumption is significantly higher than the average. However, their Electricity, Diesel Oil, Coal, Coke consumption is below the average and lower than the other clusters. The statistics on

the consumption of various energy resources in different industrial sectors show that the consumption of Kerosene is mainly concentrated in the broad category of transportation, storage and postal industry. As the capital and economic center of China, Beijing and Shanghai are large cities with developed economy, good infrastructure for transportation, storage and postal industry. They have a huge demand to this industry. However, Beijing and Shanghai are not industrial cities, and they do not have high consumption of other energy used as industrial raw materials.

The third cluster includes Hebei, Jiangsu, Inner Mongolia, and Shanxi. Their main characteristics are Total Energy Consumption, Electricity, Coal, Coke, and Natural Gas consumption are significantly higher than the average, while the consumption of all other energy sources is at the national average. The industrial sector is actually the one that consumes the most Electricity, Coal, Coke, and Natural Gas. As the major provinces of primary energy production, Inner Mongolia and Shanxi have their own industrial needs for energy. When it is concerned with the industrial added value, Hebei and Jiangsu distinguished themselves.

The fourth cluster includes Henan, Hubei, Liaoning, Sichuan, and Zhejiang. Their main characteristics in terms of energy consumption are Total Energy Consumption, Electricity, Diesel Oil, Petroleum, Liquified Petroleum Gas, Gasoline, Natural Gas, and Kerosene, Coal, Fuel, Coke, Crude Oil consumption are significantly higher than average. The consumption of Kerosene, Coal, Fuel, Coke, Crude Oil are slightly above average. The structure of their energy consumption is also closely related to their industrial structure.

The fifth cluster includes Shandong and Guangdong. Their energy consumption is significantly higher than the national average. Except for Coal and Coke, which are not as much as that of the provinces in the third cluster, all other energy consumption is significantly higher than the other clusters. Shandong, Guangdong has the top two populations in the country. These two regions contribute a lot to Gross Domestic Product, accounting for 10.95 % and 7.22 % of GDP. According to the industrial added value, these two provinces are the first and third largest industrial provinces in China. Therefore, their demand for various energy sources is higher than that of other provinces.

The results of the two clustering analyses are marked on the map as shown in the fig. 1. Based on the classification of energy production and consumption in the figure it is possible to determine the role played by each province. Except for some provinces whose characteristics are not obvious, all the examined provinces could be divided into four categories playing different roles, which could be named as net receptor, net spillover, high output and high consumption, income and spillover [2].

The provinces that fall into the net receptor category are Beijing, Shanghai, Hebei, Jiangsu, Henan, Hubei, and Zhejiang, whose energy production is below the average and energy consumption is significantly higher than the average. Therefore, they need to receive energy from other regions to maintain the balance between energy consumption and energy production. Most of them are located in central China or coastal regions, such as Bohai rim regions, Yangtze River Delta regions and Pearl River Delta regions. With their rapid development, these regions have outstanding economic advantages. However, their energy endowment is poor and their resource reserves are insufficient. Their demand for energy is difficult to be met within the region, so they have to rely on the energy supply from other regions to maintain the stable economic development.

The main provinces that fall into the net spillover category are Xinjiang, Tianjin, and Heilongjiang, which are resource-based regions with high energy production and low energy consumption. They provide energy to other provinces. They are the provinces where China's traditional resource-based regions are located. With large resource reserves and extensive experiences in energy exploitation, they could provide a stable supply of energy sources. However, these provinces are marginalized in the spatial correlation network of energy consumption due to their remote location, weak economy, and undeveloped information.

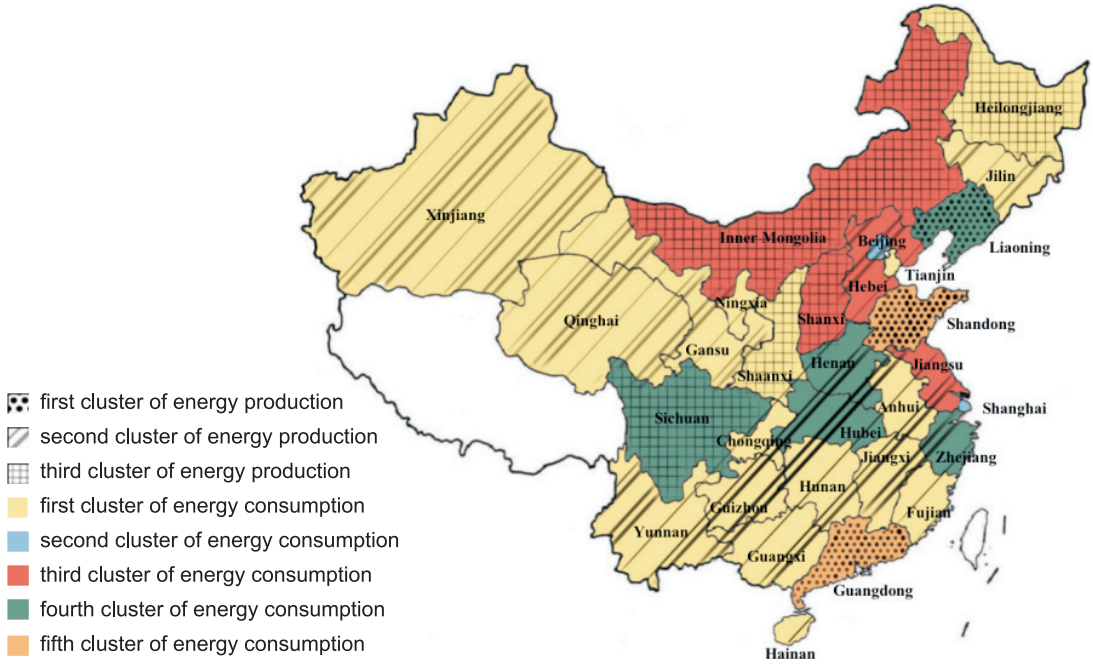

Fig. 1. Map of cluster analysis

S o u r c e: compiled by the authors based on [3].

The high output and high consumption provinces are Shanxi, Inner Mongolia, Guangdong, and Shandong. This category refers to provinces that have advantages in energy production, but they also exist as regions with high energy consumption. In addition to their strengths in mining, these provinces also excel in other industrial sectors. A part of the energy produced in these provinces is consumed or transformed within the regions as raw materials of other industries.

The income and spillover category includes Sichuan and Liaoning. The income and spillover category refers to the regions with the fact that they have strengths in some energy production but they are accompanied by a high consumption of other energy. Generally, these provinces do not produce primary energy directly, and they require primary energy supplies from other regions. They convert and develop energy sources within the regions and supply other regions. They play the roles of intermediaries or bridges. They are highly dependent on the regions producing primary energy [4].

Spatial correlation network of energy consumption and its effect in China. *Building a spatial correlation network.* The relationship matrix is established according to the modified gravity model and it is visualized as shown in the fig. 2.

Based on the relationship matrix, the network density of the spatial correlation network of energy consumption in China is 0.2379. The total numbers of relationships are 207. The correlation relationships are not tight and the number of relationships among provinces is relatively low. The number of relationships that currently exist only accounts for 23.79 % of the maximum. Moreover, there is a clear hierarchy in the network [5–7].

The structure and relationship determine the specific performance of things. Based on the spatial correlation network, we analyse the correlation between the centrality of each province and their energy intensity, energy consumption, and gross regional product (see the table).

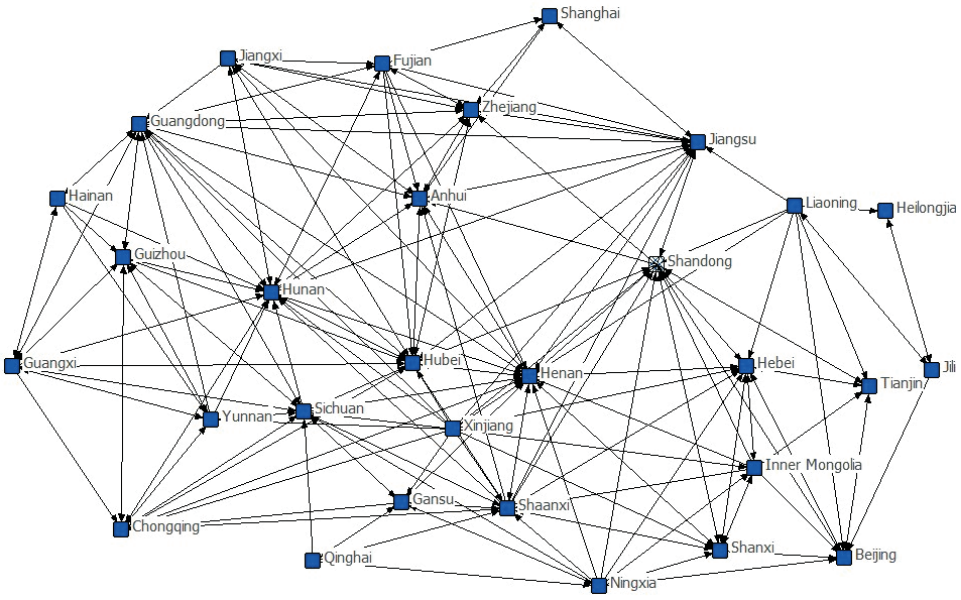

Fig. 2. The special correlation network

S o u r c e: compiled by the authors based on [3].

Canonical Correlations

Correlation	Eigenvalue	Wilks Statistic	F	Num D.F	Denom D.F.	Sig.
0.656	0.757	0.458	2.459	9.000	58.560	0.019

S o u r c e: compiled by the authors.

From the results shown in the table, we can see that the significance of the constructed model is 0.019 < 0.05. In other words, there is a significant correlation between the point centrality, betweenness centrality and closeness centrality of the spatial correlation network and the energy consumption, gross regional product and energy intensity of each province. According to the results of the correlation analysis, the degree of centrality of each province is correlated with the energy consumption, gross regional product, and energy intensity of the corresponding province. The total energy consumption is inversely proportional to the point centrality of the spatial correlation network and directly proportional to the betweenness centrality and closeness centrality. The gross regional product is inversely proportional to the point centrality of the spatial correlation network and directly proportional to the betweenness centrality and closeness centrality. The energy intensity is inversely proportional to the point centrality of the spatial correlation network and directly proportional to the betweenness centrality and closeness centrality [8, 9].

Conclusion. The above results will help us to understand the problems of energy production and consumption in each type of Chinese provinces and the structure of spatial correlation network of energy consumption in China. And it will help us find the possible solutions.

Provinces that fall into the net receptor category have the geographical advantage of being located in the center of China or in coastal areas. They have a strong dependence on

resource-based regions. For these provinces, an increasing number of correlation relationship is inevitable. A certain number of correlation relationships will ensure a stable supply of energy and their economic development will not be affected by the energy supply situation of certain provinces. Besides, we should vigorously develop the circular economy, and promote the transformation of the economic development mode for the purpose of reducing energy consumption. Provinces that fall into the net spillover category are traditional resource-based regions in China. These regions are highly polluted and deplete their resource at a high rate. It is important to develop energy conservation and environmental protection policies for these regions under the premise of ensuring energy supply nationwide. In addition, these regions should bring in advanced technology, and change the methods and structure of energy production in an attempt to reduce pollution and energy loss. Provinces that fall into the high output and high consumption category have high energy production, but a part of the energy is consumed within the region as raw materials of other industries. And in these regions, due to the high energy production, there would be an energy waste and a higher energy intensity. A strict energy-saving measures should be formulated for these regions to strengthen energy management and control. Provinces that fall into the income and spillover category generally receive primary energy from other regions. They convert and develop energy sources within the regions and supply other regions. These regions have a strong dependence on the regions producing primary energy. Therefore, it is necessary to strengthen their correlation with other regions in order to promote the development of energy conversion industries.

Spatially disaggregated energy management should be implemented to reduce energy waste and improve energy efficiency. And the spatial correlation network structure of energy consumption should be continuously adjusted and optimized. Investment in technology and economy should be increased to geographically isolated areas with small populations for the purpose of an increasing number of correlation relationship.

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