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***ARTICLE***

# REGIONAL DIFFERENCES AND SPATIAL CORRELATION NETWORK CHARACTERISTICS OF POWER CONSUMPTION IN CHINA UNDER DUAL-CARBON TARGETS

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**ABSTRACT**

In order to achieve the goal of peaking carbon emissions before 2030, promoting high-quality economic development and continuously improving ecological environment quality is crucial. The spatial disparities in electricity consumption must be fully recognized and the spatial distribution of new energy resources ought to be arranged in a rational manner. In this paper, the Dagum Gini coefficient and subgroup decomposition method are utilized to identify the spatial disparities in power consumption in China based upon inter-provincial power consumption data from 2000 to 2020. Our results demonstrate that: (1) Overall, the spatial disparities in China's electricity consumption showed a trend of fluctuation and decline during the period of 2000-2020, indicating that the regional disparities in electricity consumption are gradually narrowing. (2) The regional disparity in electricity consumption in eastern China is much greater than in other regions. (3) Inter-regional differences in power consumption are the main source of the overall power consumption distribution, and the difference between the eastern and western regions is the largest, but exhibits a decreasing trend.

**KEYWORDS**

Two-carbon target, power consumption, spatial disequilibrium, Dagum Gini coefficient

## 1. INTRODUCTION

As the global climate issue draws much attention, all economies are working together to build a global climate governance system. As the G20 has pointed out, we need to speed up the green transformation of development mode, develop green and low-carbon industries, and promote green and low-carbon production and lifestyle. Our country at present takes economic construction as the center of the development guidance and relatively extensive development way, on the one hand causes regional economic development level and unbalanced number of population. On the other hand, the spatial correlation network structure of power consumption is not clear and the interactivity is poor.

As one of the most important forms of energy consumption, the utilization rate of electric power consumption has a direct bearing on whether economy and low carbon can develop in harmony. In recent years, the spatial correlation network structure relationship of electricity consumption is gradually complicated, and its development structure characteristics need further analysis. How to judge the relationship between different regional electric power consumption development difference and electric power consumption structure and analyze the optimization path of new energy spatial pattern is worth studying deeply. Existing studies are mainly divided into the following three categories. The first type of literature focuses on the analysis of the relationship between electricity consumption and economic growth, and comes up with two different views: some scholars actively believe that electricity consumption promotes economic growth [1] and that the economy has different coordination to electricity consumption in different historical periods [2]. Other scholars believe that there is a significant threshold effect between power investment and economic growth, and electricity consumption has no substantial impact on the economy or has little impact [3]. The second kind of literature focuses on the perspective of regional differences in Chinese power consumption. From the existing research results, the power consumption difference between China's provinces and neighboring provinces is the main research perspective, and some studies are evaluated with the city or province as the research unit [4]. Some scholars observe regional differences from the perspective of neighboring provinces or key development areas [5]. The third type of literature is about the regional selection of electricity consumption correlation network. The spatial network correlation structure of electricity consumption can reflect the development trend and change level of electricity consumption. As for the regional selection of electricity consumption correlation network, some scholars have investigated the Xizang Economic zone such as Yang Kang (2021) [6]. The correlation of electricity consumption among farmers and herdsmen in semi-agricultural and semi-pastoral areas of Tibet was analyzed. Liang Zhaohui (2010) [7] used panel data modeling of prefecture-level cities in China to study the influencing factors of urban power consumption in eastern China, so as to obtain the regional relationship between urbanization rate and power consumption.

There is a lack of evaluation studies based on different regional perspectives, and there are relatively few studies on regional differences and spatial relationships of electricity consumption.

Therefore, the purpose of this paper is to explore the regional differences and spatial correlation network structure of China's electricity consumption under the background of dual-carbon target, and at the same time to promote the power cooperation and mutual benefit between regions, so as to realize the optimal allocation and utilization of electricity resources.

## 2. THEORY AND METHOD

### 2.1 Dagum Gini coefficient and subgroup decomposition method

The Dagum Gini coefficient and its subgroup decomposition method are employed in this paper for measurement purposes. Currently, the Dagum Gini coefficient has been widely applied to measure differences in financial development, economic development, and industrial structure upgrading. The measurement methods and formulas for the Gini coefficient used in this paper are derived from Dagum (1997).

Prior to the 1990s, the Gini coefficient was believed to be indivisible. However, Dagum (1997) proposed the subgroup decomposition method of the Dagum Gini coefficient, which was capable of decomposing regional disparities into intra-regional disparities, inter-regional net worth disparities, and super-variable density. This method successfully resolved the issue of the source of regional disparities.

### 2.2 Two-carbon theory "carbon peaks and carbon neutralization"

Carbon peaking refers to the point at which annual carbon dioxide emissions in a region or industry reach their highest point, followed by a continuous decline. Carbon neutrality is defined in a narrow sense as a state of equilibrium between the amount of carbon dioxide emitted and absorbed, and in a broad sense as a measure to offset carbon dioxide emissions by other means. The core of the two-carbon theory is to reduce carbon dioxide emissions to deal with global climate change and achieve sustainable development. Achieving carbon peaking and carbon neutrality is the fundamental precondition for realizing the goal of these dual-carbon targets.

## 3. SPATIAL DISEQUILIBRIUM CHARACTERISTICS OF POWER CONSUMPTION IN CHINA

### 3.1 Overall situation of electricity consumption in China

As shown in Table 1. Based on the data analysis results, it is apparent that western, northeastern, and some central regions have lower levels of power consumption, while eastern regions have higher levels of power consumption. Furthermore, the overall trend depicts a decline in electricity usage across the east, middle, and west. Such a trend can be attributed to the uneven distribution of population density across regions. The eastern area has a higher population density with a more substantial power consumption base. Also, the eastern region boasts a thriving economy with a high level of industrial development, leading to an increase in industrial energy consumption.

### 3.2 Structural changes of China's energy consumption

China's rapid economic development has resulted in an increase in energy demand, accompanied by significant changes in the energy consumption structure. Firstly, fossil energy remains dominant in China's energy consumption structure, although its proportion has gradually decreased, it still accounts for the vast majority of China's total energy consumption. In 2019, fossil fuels accounted for 83.6 percent of China's energy consumption. Secondly, the ratio of clean energy consumption, particularly in the power sector, has increased significantly, becoming a crucial source of electricity consumption in China. In 2019, clean energy, including hydro, nuclear, wind, and solar, represented over 28 percent of the national electricity consumption. Thirdly, the consumption of new energy is gradually rising, and the development of industries such as new energy vehicles and logistics has promoted its growth. Fourthly, there are significant regional variations in the energy consumption structure. Eastern China has a lower proportion of fossil fuel consumption with a more significant proportion of clean energy consumption, in contrast to the Western region. In Western China, fossil fuel consumption accounts for over 90 percent, while clean energy consumption is minimal. These disparities are largely influenced by the level of economic development and the distribution of energy resources.

## 4. SPATIAL DECOMPOSITION AND CORRELATION CHARACTERISTICS OF CHINA'S ELECTRICITY CONSUMPTION

### 4.1 Features of spatial difference decomposition

As shown in Table 2. Regional imbalances and inadequate development are significant characteristics of China's social and economic development. The consumption of various forms of energy, particularly electric power consumption, is a vital factor that can affect this development. In this context, this discussion aims to estimate and analyze the gap in terms of two significant factors that affect the regional differences, namely the overall gap and supervariable density. Over time, the contribution rate of regional differences in the Western and Northeastern regions to the overall gap has tended to rise. Between 2000 and 2008, the overall gap witnessed a gradual increase. However, from 2009 to 2014, it showed a downward trend before it began to rise steadily from 2014 to the current day. Meanwhile, the supervariable density has also shown a consistent growth trend.

A comprehensive analysis highlights a significant decline in the Gini coefficient in 2008, indicating that the utilization and development of electric power energy in all regions of the country achieved better results. Reasonable policies and scientific planning related to electric power energy consumption played a pivotal role in stimulating the development of the social economy. Further breakdown of the Gini coefficients of various regions shows that from 2000 to 2020, the Gini coefficients of the east and the west were constantly ranked as the highest and lowest, respectively. The Gini coefficient gap between the western and northeastern regions narrowed from 2000 to 2013, only to widen year by year afterward. Additionally, the Gini coefficient of power consumption level in different regions demonstrated a trend of fluctuation and rise, except for the central region. Intra-regional differences in the central regions experienced a slow rise from 2000 to 2008, followed by a rapid decline. However, on the whole, the differences within the regions exhibited a widening trend.

As shown in Table 3. When the eastern, central, western, and northeastern regions were paired and compared, differences in the level of electricity consumption among the regions were found. In 2000, the differences were mainly witnessed between the east and west, east and central, and central and northeast regions. In 2020, the East-northeast, East-west, Central-west and West-northeast regions showed a significant difference in electricity consumption in descending order. Regarding specific values, the peaks of East-central, East-west, East-Northeast, West-west, West-northeast, and West-northeast occurred in 2020, 2005, 2020, 2001, 2019, and 2000, respectively. The differences between regions exhibited significant fluctuations, and the differences between the East and Central regions mainly fluctuated between rising

**Table 1.** Power consumption intensity in the three regions

| Year | Gini coefficient | | |
|---|---|---|---|
| | East | Midland | West |
| 2000-2004 | 0.125-0.120 | 0.142-0.123 | 0.171-0.160 |
| 2004-2008 | 0.120-0.100 | 0.123-0.102 | 0.160-0.150 |
| 2008-2020 | 0.100-0.062 | 0.102-0.061 | 0.150-0.102 |

and falling. The differences between the east and northeast and between the central and northeast have been steadily increasing, while those between the west and west-northeast have been dropping. Although the specific inflection points vary, the overall trend remains the same.

As shown in Table 4. From the evolution trend, the contribution rate of inter-regional differences to the overall difference demonstrated a downward trend, while the contribution rate of intra-regional and super-variable density to the overall difference showed an upward trend. A horizontal comparison between 2000 and 2020 reveals that the contribution rate of inter-regional gaps was higher than that of intra-regional gaps, making it the primary factor affecting the power consumption level gaps in each region during this period. Meanwhile, the contribution rate of the regional gap decreased annually, but it did not diminish its significance in impacting electricity consumption in every region. However, the contribution rate of intra-regional gaps experienced steady development during this period without significant fluctuations. In conclusion, reasonable measures should be taken to narrow the social and economic development gaps between various regions, and the development direction should focus primarily on the main structure of economic development and unbalanced and inadequate development to reduce discrepancies in the power energy consumption of different regions annually.

### 4.2 Network structure characteristics of spatial correlation of power consumption

#### *4.2.1 Overall network structure characteristics and evolution trend*

To better visualize the spatial correlation network structure of inter-provincial power consumption, network density and network correlation degree were analyzed. The results showed a typical network structure of China's inter-provincial electricity consumption, as depicted in the figure below.

1. Network density. During the sample study period, the spatial network density of electricity consumption fluctuates and declines, and the standard deviation of the spatial correlation density also shows the same evolution trend. This indicates that the spatial correlation of energy consumption among provinces in China is increasingly distant.

2. Network correlation degree. The network correlation degree of each year is 1, indicating that the inter-provincial power consumption in China is closely related with obvious spatial correlation and spillover effect. The measurement results of power consumption network level indicate that the network level of spatial correlation of power consumption in China's provinces is basically unchanged during the investigation period. The measurement results of the network efficiency show that the network efficiency of the spatial correlation of power consumption in each province increases first, then decreases and then increases. After comprehensive consideration of the measurement results of network correlation, network level and network efficiency, the conclusion is drawn: with the continuous development of urbanization, the ability of autonomous power consumption is enhanced, and the phenomenon of power consumption is not strict has not changed. Governments and markets need to exercise control over the power sector and carbon emissions.

#### *4.2.2 Analysis of condensed subgroups*

Cohesive subgroup analysis is based on the strength of power consumption relations between provinces to explore the clustering phenomenon of small groups gathering in neighboring provinces within the power consumption cluster. Through this analysis, it was

**Table 2.** Spatial differences of power consumption in different regions of China

| | Overall gap | The east | Central region | The west | Northeast China | Supervariable density |
|---|---|---|---|---|---|---|
| 2000 | 0.3622 | 0.3304 | 0.1957 | 0.2653 | 0.2060 | 0.1919 |
| 2001 | 0.3718 | 0.3343 | 0.2065 | 0.2814 | 0.2065 | 0.1923 |
| 2002 | 0.3790 | 0.3403 | 0.2147 | 0.2776 | 0.2117 | 0.1875 |
| 2003 | 0.3784 | 0.3506 | 0.2120 | 0.2857 | 0.2010 | 0.1890 |
| 2004 | 0.3851 | 0.3610 | 0.2104 | 0.2780 | 0.2270 | 0.1874 |
| 2005 | 0.3956 | 0.3633 | 0.2116 | 0.2782 | 0.2390 | 0.1742 |
| 2006 | 0.3968 | 0.3677 | 0.2109 | 0.2804 | 0.2430 | 0.1796 |
| 2007 | 0.3981 | 0.3691 | 0.2196 | 0.2864 | 0.2439 | 0.1892 |
| 2008 | 0.3931 | 0.3672 | 0.2165 | 0.2808 | 0.2367 | 0.1908 |
| 2009 | 0.3893 | 0.3634 | 0.1991 | 0.2803 | 0.2409 | 0.1935 |
| 2010 | 0.3858 | 0.3627 | 0.1970 | 0.2728 | 0.2496 | 0.2013 |
| 2011 | 0.3779 | 0.3652 | 0.1933 | 0.2654 | 0.2493 | 0.2227 |
| 2012 | 0.3736 | 0.3678 | 0.1876 | 0.2632 | 0.2502 | 0.2338 |
| 2013 | 0.3696 | 0.3688 | 0.1802 | 0.2633 | 0.2575 | 0.2462 |
| 2014 | 0.3688 | 0.3724 | 0.1718 | 0.2735 | 0.2563 | 0.2540 |
| 2015 | 0.3770 | 0.3779 | 0.1571 | 0.2866 | 0.2535 | 0.2442 |
| 2016 | 0.3816 | 0.3798 | 0.1507 | 0.2918 | 0.2535 | 0.2366 |
| 2017 | 0.3790 | 0.3819 | 0.1500 | 0.2927 | 0.2535 | 0.2457 |
| 2018 | 0.3778 | 0.3820 | 0.1447 | 0.2973 | 0.2569 | 0.2547 |
| 2019 | 0.3765 | 0.3838 | 0.1292 | 0.3090 | 0.2587 | 0.2658 |
| 2020 | 0.3829 | 0.3920 | 0.1265 | 0.3213 | 0.2543 | 0.2711 |

**Table 3.** Inter-regional differences in electricity consumption

| | East-Central | East-West | East-Northeast | Central - West | Mid-Northeast | West-Northeast |
|---|---|---|---|---|---|---|
| 2000 | 0.3370 | 0.5110 | 0.3187 | 0.3343 | 0.2178 | 0.3583 |
| 2001 | 0.3436 | 0.5217 | 0.3370 | 0.3477 | 0.2198 | 0.3548 |
| 2002 | 0.3552 | 0.5301 | 0.3617 | 0.3472 | 0.2276 | 0.3399 |
| 2003 | 0.3640 | 0.5219 | 0.3798 | 0.3289 | 0.2234 | 0.3112 |
| 2004 | 0.3658 | 0.5301 | 0.3986 | 0.3347 | 0.2407 | 0.3173 |
| 2005 | 0.3843 | 0.5436 | 0.4288 | 0.3308 | 0.2496 | 0.3101 |
| 2006 | 0.3919 | 0.5391 | 0.4454 | 0.3226 | 0.2565 | 0.2994 |
| 2007 | 0.3888 | 0.5348 | 0.4577 | 0.3325 | 0.2691 | 0.2944 |
| 2008 | 0.3867 | 0.5287 | 0.4547 | 0.3229 | 0.2679 | 0.2860 |
| 2009 | 0.3844 | 0.5238 | 0.4612 | 0.3109 | 0.2708 | 0.2857 |
| 2010 | 0.3828 | 0.5163 | 0.4652 | 0.3051 | 0.2776 | 0.2855 |
| 2011 | 0.3801 | 0.5001 | 0.4695 | 0.2900 | 0.2821 | 0.2768 |
| 2012 | 0.3779 | 0.4894 | 0.4752 | 0.2796 | 0.2838 | 0.2800 |
| 2013 | 0.3775 | 0.4793 | 0.4824 | 0.2654 | 0.2913 | 0.2846 |
| 2014 | 0.3825 | 0.4715 | 0.4862 | 0.2571 | 0.2897 | 0.2877 |
| 2015 | 0.3925 | 0.4812 | 0.5010 | 0.2590 | 0.2868 | 0.2935 |
| 2016 | 0.3940 | 0.4887 | 0.5090 | 0.2641 | 0.2883 | 0.2983 |
| 2017 | 0.3918 | 0.4817 | 0.5114 | 0.2592 | 0.2912 | 0.3048 |
| 2018 | 0.3897 | 0.4770 | 0.5145 | 0.2577 | 0.2960 | 0.3140 |
| 2019 | 0.3880 | 0.4719 | 0.5149 | 0.2530 | 0.2926 | 0.3239 |
| 2020 | 0.3965 | 0.4759 | 0.5233 | 0.2565 | 0.2899 | 0.3314 |

**Table 4.** Contribution analysis of electricity consumption level

| Year | Contribution rate | | |
|---|---|---|---|
| | Intra-district | Interregional | Supervariable density |
| 2000-2020 | 0.22-0.23 | 0.58-0.45 | 0.18-0.23 |

observed that the power consumption levels of each province have a relatively close and strong connection. At the secondary level, the spatial correlation network of power consumption among provinces in China can be roughly divided into four subgroups. The analysis results are closely related to the geographical locations of provinces within the region, with the power consumption levels within the same cohesive subgroup demonstrating a strong correlation.

From the current development status, the first cohesive subgroup is significantly related to electricity consumption, with a strong correlation between the three northeastern provinces that are rich in real estate power consumption resources and the first cohesive subgroup centered in Beijing. However, population-related issues render Shandong and Henan provinces with a considerable gap in the power consumption level compared to other provinces, lacking meaningful manifestation of radiation and diffusion effects of central cities. Despite these differences in power consumption levels, power consumption remains closely related and significantly influences other cohesive subgroups.

The second and fourth coagglomerated subgroups are located in the central minority areas and exhibit weak correlation in power consumption levels with significant differences. This well explains the phenomenon of the sparse structure of the power consumption network and the non-formation of a cluster pattern, and the absence of a driving role for central cities. The third cohesive subgroup, however, maximizes the influential and radiating role of Shanghai as the central city. Power consumption levels have a high degree of correlation, with a unified development level and the most close network correlation structure for power consumption.

As a whole, there are great differences in the network correlation level of power consumption, and the development situation of various regions is complex. The main bodies of provinces need to further strengthen regional communication and cooperation, promote the free flow of regional power resources and other factors, and gradually form a multi-center, networked coordinated development pattern.

#### *4.2.3 Block model analysis*

In this paper, the maximum segmentation depth of 0.2 is adopted to divide 30 provinces into four power consumption plates.

As shown in Table 5. The first electricity consumption plate has 10 members, mainly distributed in the northern region. The northern region is dominated by thermal power and has a high demand for energy in the winter heating period. Therefore, the external power consumption of the northern region is much lower than that of other regions, which is a typical “net income” plate. The second power consumption plate has 4 members, belonging to the Northwest region. Due to the low population density, coal energy reserves are abundant, and the demand for electricity in the region is not high. The implementation of the west-east power transmission project makes the electricity energy converted from coal energy in the northwest constantly transported to the eastern region. Therefore, the spillover relation of this plate is greater than the receiving relation, which is a typical “net spillover” plate. The third power consumption plate has 8 members, mainly in the southern region. It has spillover effects on both the inner and outer plates, which belongs to the bidirectional overflow plate. The fourth power consumption Plate has seven members, mainly located in southwest China, including

**Table 5.** Spillover effect of spatially related plates of electricity consumption

| Plate | Total number of receiving relationships (PCS) | | Total number of relations issued (PCS) | | Expected internal relationship ratio (%) | Actual internal relationship ratio (%) |
|---|---|---|---|---|---|---|
| | intraplate | off-plate | intraplate | off-plate | | |
| Plate one | 44 | 28 | 44 | 8 | 31 | 85 |
| Plate two | 14 | 8 | 14 | 31 | 14 | 31 |
| Plate three | 41 | 29 | 41 | 12 | 24 | 77 |
| Plate four | 29 | 10 | 29 | 24 | 21 | 55 |

Guizhou, Yunnan, Guangdong, Guangxi, Hainan, Chongqing and Sichuan.

## 5. DISCUSSION AND CONCLUSION

This study analyzes the data of China's inter-provincial power consumption from 2000 to 2020, uses the Dagum Gini coefficient and its subgroup decomposition method to identify the spatial disequilibrium characteristics of China's power consumption, and explores the rational allocation of new energy spatial pattern in order to achieve the carbon peak before 2030.

### 5.1 Research conclusion

(1) The spatial difference of China's electricity consumption shows a trend of fluctuation decline, but there is still an obvious spatial imbalance;

(2) The regional differences of electricity consumption in the eastern region are much greater than those in other regions, and inter-regional differences in electricity consumption are the main source of the overall differences in electricity consumption.

(3) China's inter-provincial electricity consumption presents a complex spatial correlation network structure, and the network density is gradually increasing.

(4) The rational allocation of new energy spatial pattern is of great significance for the realization of China's carbon peaking and carbon neutrality goals.

### 5.2 Policy suggestions

(1) Understanding the spatial correlation and structural characteristics of inter-provincial electricity consumption is essential to promote green electricity consumption and implement necessary policies, including allocating national green electricity consumption targets to each province. Carbon reduction targets can also be allocated based on geographical, economic, and resource factors. The Time-Of-Use (TOU) price policy can further encourage electricity market trading services. It is essential to continually adjust and optimize the spatial correlation network structure of electricity consumption, enhance the spatial allocation efficiency of electricity energy, and promote coordinated development of green electricity consumption across regions.

(2) Adopting various reasonable measures to narrow the social and economic development gaps between different regions and prioritize the development direction towards unbalanced and inadequate development can help to reduce the gap in the power energy consumption of different regions annually.

(3) Formulating energy optimization policies based on the characteristics of the spatial correlation network of electricity consumption plate is crucial. For sectors with high power demand, promoting industrial structural reforms can aid in reducing industries with high energy consumption and pollution. Additionally, nurturing the development of the tertiary sector, focusing on renewable energy, and implementing circular economy practices can further promote energy efficiency. For plates with abundant energy reserves but low energy utilization rates, improving power energy utilization rate and controlling power consumption intensity is essential. Lastly, for plates that act as "bridges," the connection and conduction functions should be strengthened to narrow the gap of power consumption intensity in different regions.

## REFERENCES

[1] Xing, X. 2021. Strengthening economic resilience and Promoting Sustainable Recovery of Growth: Based on Correlation Analysis of Xi'an Electric Power and Economic Big Data. Macroeconomic Management,2021(02), 70-76.

[2] Xie, P., Sun, F., Wang, M. 2017. The Synergy of Power Cycle and Business Cycle in China: Based on Markov System Transfer Model. Technology Economics, 36(07), 75-83.

[3] Li, J., Zhou, R. R. 2018. Research on the Relationship Between Electric Power Consumption and Economic Growth in China — based on the Perspective of Industrial Structure Optimization. Research World, 2018(2), 40-44.

[4] Xia, Z., Wang, M., He, W. 2021. An Empirical Study on the Relationship between Industrial Structure, Electricity Consumption and Economic Growth in Shanghai. China Business Theory, 2021(3), 42-47.

[5] Yang, G., Chen, Y., Wang, D., Zhang, J. Decoupling and Regional Differences of Electricity Consumption in China. Power Grid and Clean Energy, 36(08), 1-8.

[6] Yang, K. 2021. Research on the Development Status of Private Enterprises in Xizang. Modern Trade Industry, 42(17), 10-11.

[7] Liang, Z. 2010. The Influence Factors of Urban Electricity Consumption in China: An Empirical Analysis based on the Panel Data of Prefecture-Level Cities. Shanghai Economic Research, 2010(07), 22-30.