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# DRIVING FORCES OF ELECTRICITY CONSUMPTION GROWTH IN CHINA'S THREE INDUSTRIES BASED ON KAYA-LMDI METHODS

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**ABSTRACT**

Electric power plays an important role in the development of a nation's economy, and it improves human life. Therefore, understanding the driving forces behind the growth and consumption of electricity will help leaders plan energy savings and create economic policies. Using the LMDI that is based on the Kaya identity, this paper decomposes the factors driving the growth of electric power consumption in the Chinese production sector into the effects of population size, economic development, regional economic structure, regional industrial structure, and electricity consumption intensity. The study finds that the national electricity consumption for production increased by 2,143 TWh from 2007 to 2016. The increasing power consumption intensity inhibits the growth of electric power consumption for production, which has led it to decrease by 1,408.2 TWh, and the suppression effect is more significant in the secondary industry. Economic growth is the main driving force behind the growth of electricity consumption for production, which has led it to increase by 3,770.6 TWh, most obviously in the eastern region. Population growth promotes electricity consumption; however, the impact of this has been relatively small. The regional economic structure has a negative effect on power consumption growth; however, there is a big difference among provinces. To delay the growth of electric power consumption, it is necessary to strengthen technological innovation and management, as well as to pay attention to industrial structure adjustment and energy conservation technology promotion in the central and western regions. Furthermore, we should improve the consumption efficiency of the secondary industries.

**Keywords:** Electricity consumption growth, Driving forces, LMDI, Energy saving

**NONMENCLATURE**

| | |
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| *Abbreviations* | |
| LMDI | the log-mean divisia index |

## 1. INTRODUCTION

Electricity is the foundation of economies and human life [1]. Supported by weak global economic recovery, the continuous promotion of energy and resource savings, and improved energy efficiency, the consumption of primary energy and electricity in major economies has slightly grown or decreased in recent years. Owing to the fundamental role played by electricity in the national economy, the relationship between electric power consumption and economic development has always been the focus of international research [2]. According to the BP Statistical Review of World Energy from June 2018, electricity production in 2017 was only 2.8% higher than it was in 2016. China is the world's leading producer of electricity and has supported the largest increase in history; 6,495.1 TWh of electric power was produced in2017, 6.2% higher than it was in 2016 and 25.4% more than the rest of the world.

The most common method of analyzing the driving factors of research objectives is the use of a factor decomposition method that can decompose factors on the basis of the direction and degree of the target. Among these, LMDI is an important branch of index decomposition analysis. It has features such as no residuals or residual values, total decomposition, ease-of-use, and multiplication decomposition with addition

[3]. The LMDI method is mainly used for research on energy, the environment, and the economy and can be used to analyze the impact of economic growth, industrial structure changes, and industrial technology improvements. Therefore, analyzing the driving factors of electric power consumption growth, on the basis of LMDI, will help to improve electricity efficiency and allow policymakers to control electricity consumption growth. However, more research is needed in order for electricity consumption at the national level to become the focus, particularly regarding the differences in economic development and industry efficiency between different countries and regions. This paper studies the effects of regional heterogeneity on electricity consumption changes.

Considering the large differences in regional economic development in China and the power efficiency of different industries, this paper decomposes the driving forces of electric power consumption growth into population size, economic development, economic structure, industrial structure, and electricity consumption intensity for three industries across 31 Chinese provinces.

## 2. METHOD AND DATA

### *2.1 STUDY AREA*

Economic development in China is enjoying a steady and progressive trend. The gross domestic product (GDP) has increased by approximately eight times in the past 20 years. With the development of new industries and formats, the electric power consumption of Chinese society has risen by 4.3 times from 1997 to 2016. However, the growth rate of consumption has slowed down since 2007. Electric power consumption for production accounts for 86.5% of China's total power consumption. This paper performs a quantitative analysis of the driving factors of electric power consumption for production. According to the National Bureau of Statistics in China, the western region includes 12 provinces, the central region comprises eight provinces, and 11 provinces constitute the eastern region.

### *2.2 METHOD*

#### 2.2.1 Kaya identity for driving forces

The Kaya identity is widely used to study the energy economy and environment. It has been used to examine the relationship between $CO_2$ emissions and the population, economy, energy intensity, etc. This paper considers five driving factors of electricity consumption growth in three production industries from the 31 provinces. According to extant results and theories, the Kaya identity model is obtained as follows:

$$\mathrm{E} = \sum_{ij} E_{i,j} = \sum_{i,j} P \frac{Q}{P} \frac{Q_i}{Q} \frac{Q_{i,j}}{Q_i} \frac{E_{i,j}}{Q_{i,j}} = \sum_{i,j} P \cdot Y \cdot S_i \cdot M_{i,j} \cdot U_{i,j}, \quad (1)$$

where E and $E_{i,j}$ represent the total electricity consumption for production and the electricity consumption of j industry in i province. P is the total population; Q is the GDP; $Q_i$ is the total GDP of i province; and $Q_{i,j}$ is the j industrial production value of i province. P represents the population index; Y = Q/P, the per capita GDP, which represents the economic development index; Si = $Q_i$/Q, which signifies the economic portion of i province in China, representing the regional economic structure index; $M_{ij}$ = $Q_{ij}$/$Q_i$, denotes the structure of production, which represents the regional industrial structure; and $U_{ij}$ = $E_{ij}$/$Q_{ij}$, which indicates the electric power intensity of j industry in i province, representing the technical index.

#### 2.2.2 LMDI method of electricity consumption growth in three industries

The factors contributing to the electricity consumption growth can be described by using LMDI as follows:

$$\Delta E = E^t - E^0 = \Delta P + \Delta Y + \Delta S + \Delta M + \Delta U, \quad (2)$$

where $E_t$ and $E_0$ are the total electric power consumption for production in three industries during periods T and 0. ΔP, ΔY, ΔS, ΔM, and ΔU represent the population effect, economic development effect, regional economic structure effect, regional industrial structure effect, and electricity intensity effect, respectively. They can be calculated as follows:

$$\Delta \mathrm{P} = \sum_{i=1}^{31} \sum_{j=1}^{3} \frac{\left(E_{ij}^t - E_{ij}^0\right)}{\left(lnE_{ij}^t - lnE_{ij}^0\right)} ln\left(\frac{P^t}{P^0}\right), \quad (3)$$

$$\Delta \mathrm{Y} = \sum_{i=1}^{31} \sum_{j=1}^{3} \frac{\left(E_{ij}^t - E_{ij}^0\right)}{\left(lnE_{ij}^t - lnE_{ij}^0\right)} ln\left(\frac{Y^t}{Y^0}\right), \quad (4)$$

$$\Delta S = \sum_{i=1}^{31} \sum_{j=1}^{3} \frac{\left(E_{ij}^t - E_{ij}^0\right)}{\left(lnE_{ij}^t - lnE_{ij}^0\right)} ln\left(\frac{S_i^t}{S_i^0}\right), \quad (5)$$

$$\Delta \mathrm{M} = \sum_{i=1}^{31} \sum_{j=1}^{3} \frac{\left(E_{ij}^t - E_{ij}^0\right)}{\left(lnE_{ij}^t - lnE_{ij}^0\right)} ln\left(\frac{M_{ij}^t}{M_{ij}^0}\right), \quad (6)$$

$$\Delta \mathrm{U} = \sum_{i=1}^{31} \sum_{j=1}^{3} \frac{\left(E_{ij}^t - E_{ij}^0\right)}{\left(lnE_{ij}^t - lnE_{ij}^0\right)} ln\left(\frac{U_{ij}^t}{U_{ij}^0}\right). \quad (7)$$

### *2.3 DATA*

The study period chosen is 2007–2016, and the total population, gross national product, GDP, and industrial added value of each province are obtained from the

China Statistical Yearbook, converted from different years to the constant price of 2007. The provincial- and industrial-level electricity consumption levels are derived from the Compilation of Statistics on the Power Industry.

## 3 RESULTS

### *3.1 Time difference in the effect of production electricity consumption decomposition factors*

The national electricity consumption for production increased by 2,143 TWh during the 2007–2016 period. There was an increase of 3,770.6 TWh caused by economic development and an increase of 220.2 TWh because of the increased population size. Adjustments to regional economic and industrial structures have reduced electric power consumption for production by 234.5 TWh and 416.2 TWh, respectively. The optimization of electric power consumption intensity in different industries has led to a decrease in electric power consumption for production by 1,408.2 TWh. Economic development and population size during different periods have always been factors leading to the growth of electric power consumption for production. Except for 2014–2015, electricity consumption intensity has generally inhibited electric power consumption for production, and the effect of the regional industrial structure and economic structure changed from promotion to inhibition in 2011 and 2012, respectively. However, the impact was relatively small.

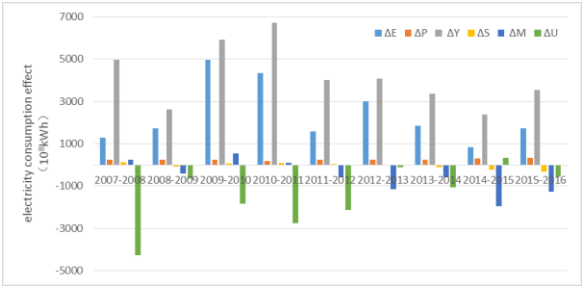


Fig 1. Decomposition factor effect of electric power consumption growth in China in 2007–2016

### *3.2 Spatial differences in the effects of electric power decomposition factors for production*

Electricity consumption in the eastern, central, and western regions increased by 1,806.7, 454.9, and 601.4 TWh, respectively. The economic development effect in the eastern region was the largest, which was followed by the western region. The smallest effect was in the central region. Economic development is the decisive factor in the growth of electric power consumption for production in the three regions. The increase in power consumption for production brought about by economic development completely offsets the inhibiting effects caused by the optimization of the regional industrial structure and power consumption intensity. This is related to the rapid development of the eastern economy. The lower initial economic levels in the western provinces have great potential for development. The economic structure of the eastern region suppresses electric power consumption for production, which is related to the ongoing decline in its share of total income.

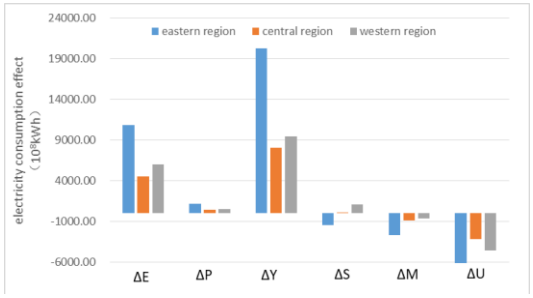


Fig 2. Decomposition factor effect of electric power consumption growth in the eastern, central, and western regions

### *3.3 Industrial differences in the decomposition factor effect of electric power for production*

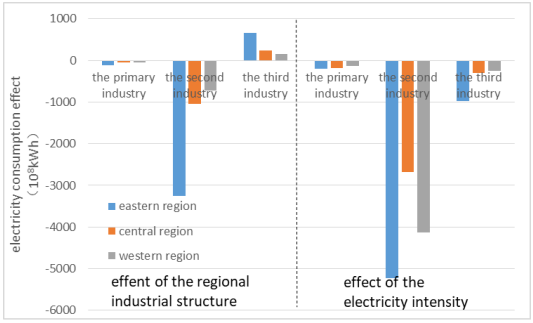


Fig 3. Industrial differences in the decomposition factor effect on electric power consumption growth in 2007–2016

Although there has been a negative effect on the growth of electric power consumption for production in primary and secondary industries, the tertiary industry has produced growth. The regional industrial structure effect has hindered growth, with the largest impact in the eastern region, followed by the central region. The smallest impact was in the western region. For the secondary industry, the eastern and western regions have had a greater inhibitory effect, indicating that the electric power consumption efficiency of the secondary

production industry has attracted attention in the eastern and western regions. The impact of consumption intensity in the three industries on the growth of electric power consumption for production is most significant in the eastern region, indicating that energy-saving technologies and management are strongly promoted there.

## 4 DISSCUSION AND CONCLUSION

Temporally, it was found that economic growth and population size were the driving forces behind the growth of electric power consumption for production. Growth brought about by rapid economic development and population increases has offset the suppression caused by the regional structure, industrial structure, and utilization efficiency, resulting in a 2,143 TWh increase from 2007 to 2016.

Spatially, production power consumption growth in the eastern region was 1.8 times that in the western region, and it was 2.4 times that in the central region. The economic development effect in the eastern region led to a 2,023 TWh increase. However, the effect of power consumption intensity had a pronounced inhibitory effect—of the order of 639.5 TWh. With the implementation of the "Western Development" and "Rise of Central China" strategies, the economic proportions of the central and western regions increased within the national economy. Economic development promoted the increase of electric power consumption for production in the central and western regions; however, the control of growth in the central and western regions was less than that in the eastern region. Therefore, it is necessary to strengthen technological and management capabilities in the field of energy conservation and consumption reduction in the central and western regions.

Across the various industries, the effect of regional industrial structure and power consumption intensity in the secondary industry was the greatest, and its positive and negative values determined the promotion or inhibitive effects. With the increasing share of the tertiary industry, regional industrial structure in the tertiary industry was a factor that promoted the increase of production power consumption of the order of 66 TWh in the eastern region, 23 TWh in the central region, and 16 TWh in the western region.

The regional industrial structure effect reduced electric power consumption for production by a certain extent; however, its role was weaker than the optimization of the intensity of power consumption, particularly with the secondary industry. There is plenty of room for the adjustment of industrial structure to inhibit the growth of electric power consumption for production. In the long term, it will be useful to guide the upgrades to the regional industrial structure to reduce the electric power consumption for production.

As an important input factor for economic development, economic scale expansion will inevitably lead to an increase in electric power consumption for production. Moreover, China's economy remains in a period of slow economic growth, but local economies maintain rapid growth. In particular, the economy of the eastern region will show an overall stable and superior situation, resulting in increased electricity consumption for production. Because of the lack of primary energy resources in the eastern area, it is important to convert the coal resources in the northwest region and the hydropower resources in the southwest region into power resources and transport them to the eastern region, where electricity is scarce. Expanding the scale of "West–East Power Transmission" will ensure that the electricity demand in the eastern region is met in the future. Simultaneously, the western region's share of the national economy has gradually increased, and the positive effect on the increase in production power consumption has been highlighted. There is an urgent need to strengthen energy-saving technological innovations and to improve power consumption efficiency, particularly in the secondary industry.

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