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Study of the influence mechanism of China's electricity consumption based on multi-period ST-LMDI model

Debin Fang [a, b], Peng Hao [a, *], Jian Hao [c]

[a] School of Economics and Management, Wuhan University, Wuhan, 430072, China
[b] Center for Complexity and Management Research, China
[c] School of Business, Fuyang Normal University, Fuyang, 236037, China

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ABSTRACT

A full understand of the influential mechanism concerning electricity consumption has a crucial political reference significance for the implementation of energy conservation and consumption reduction policies. To solve the lack of correlation between the empirical results of the research regions in present researches, this paper takes China's electricity consumption from 1995 to 2016 as the research subject, uses Multi-period ST-LMDI model by setting a unified reference province as a benchmark for different regions in China to completely decompose the changes in China's electricity consumption, and further analyzes the influence mechanism of China's electricity consumption changes by combining the characteristics of the departments and regions. As the result, it's found that the economic growth has a strong impetus for power consumption while the technological progress can effectively curb it. Meanwhile, results of studying electricity consumption from the perspective of industry and region show that the economic structure and consumption intensity have obviously different influences in the eastern, central and western regions. So when it comes to formulate the policy for electricity development and reform, the characteristics of industrial structure as well as the regional differences must be taken into consideration.

1. Introduction

With forty years rapid development of China's economy after the reform and opening up, environmental issues caused by energy consumption have gradually accumulated. At present, China's economic development has gradually shifted from high-speed growth to medium-and-high-speed growth [1] and the restriction effects from energy and environment to China's economic development have also become increasingly apparent. Under such circumstances, China must seek a high-quality economic development through establishing a new economic growth model to reduce the restriction effect of energy on economic growth [2]. In the field of energy consumption, electricity, as the most widely used energy in the world today. The universality of electricity in usage scenarios and the convenience of it in usage ways determine its vital role in energy consumption and furthermore, it can be seen as the “wind vane” of economic growth, energy supply and technological progress. Under the current background that China's economy has entered the “new normal” [1], to better understand the impact mechanism of electricity consumption and determine the strength and direction of the effect of different influencing factors on domestic electricity consumption have important practical significance for bringing the economic benefits of electricity resources to the most.

Although the quick or slow growth rate of electricity consumption is usually accompanied by the increase or slowdown of economic growth, the actual data show that there is not always a simple synchronous relationship between the two. (see Section 3). Contrarily, in addition to the rise and decline in the same direction in long term between the electricity consumption and economic growth, the growth gap between them in some years shows expansion, lag or even deviation. This shows that electricity consumption is not only affected by economic growth, but other factors such as economic factors, social factors and technological factors may also have an impact on it. Therefore, it is necessary to combine the current situation of economic growth, explore other influencing factors of power consumption, and determine the impact of

* Corresponding author.
E-mail addresses: dbfang@whu.edu.cn (D. Fang), haoopeng@whu.edu.cn (P. Hao), hj15655879730@163.com (J. Hao).

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relevant factors on power consumption, and explore its intrinsic influence mechanism. From the existing literatures, the research of the relationship between energy consumption and economic growth mainly uses fossil energy consumption data that represented by coal, oil and natural gas, however, due to the large number of private mining, indiscriminate mining and smuggling problems in China, the actual scale of energy supply and demand in China is obviously underestimated, and the sample data is usually inaccurate [3]. Then, due to the existence of random error terms, the traditional measurement for the study of the relationship between electricity consumption and economic growth, such as the co-integration test and error correction model, cannot fully explain the changes or illustrate the influence mechanisms of power consumption. So, the study of China's electricity consumption problem must establish an analytical model that can fully reflect changes in electricity consumption first. Then, previous literatures targeted on Chinese electricity consumption applying index decomposition analysis (IDA) model only conducted analysis from the national macro level while lacking the contrast between different regions, or divided the country into several regions and then analyzed one by one while lacking a unified benchmark, which makes it difficult to compare the horizontal and vertical aspects of the individuals, resulting in a weak correlation between the regional empirical results.

Based on the shortcomings of previous studies, this paper applies Multi-period ST-LMDI model to make an empirical analysis by setting a unified reference province as a benchmark for different regions in China, and to divide the electricity consumption into four factors: economic scale effect, economic geographical structure effect, electricity consumption intensity effect and industrial electricity consumption structure effect. It mainly contributes to the following aspects: (1) applying Multi-period ST-LMDI model to completely decompose China's long-term power consumption without any residual value, so as to fully analyze the influence mechanism of power consumption changes; (2) decomposing China's electricity consumption year by year from 1995 to 2016, eliminating the defects of fixed influential coefficient in traditional econometric models and analyzing the dynamic influence process of different utility factors on electricity consumption changes; (3) in the past, the research of the relationship between energy consumption and economic growth mainly uses fossil energy consumption data that represented by coal, oil and natural gas, however, due to the large number of private mining, indiscriminate mining and smuggling problems in China, the sample data is usually inaccurate. At this time, this paper replaces traditional fossil energy data with more accurate electricity data to study the relationship between the two, which makes the research results more accurate and reasonable.

2. Literature review

Electricity is the main component of energy consumption. The oil crisis that occurred in 1973 has made governments and academics realize the importance of energy for national economic development and social stability. Kraft and Kraft [4] studied the relationship between energy and economy early and found that there was only unidirectional Granger causality running from GNP to energy consumption but not the vice versa, holding that the implementation of energy conservation policies would not inhibit economic growth. Since then, a large number of studies have attempted to explore the causal relationship between the two. In general, scholars believe that there are mainly four kinds of causality: one-way causality, including one-way unidirectional causality of economic growth to power consumption (Shahbaz et al. [5]; Abbas and Choudhury [6]) and one-way unidirectional causality of power consumption to economic growth (Apergis and Payne [7]; Jamil and Ahmad [8]), two-way causality (Cheng-Lang et al. [9]; Tang [10]; Polemis and Dagoumas [11]) and not have a causal (neutral) relationship (Yoo and Kwak [12]). However, due to the differences in the national conditions, economic development phase, energy consumption model and adapted measurement way of the selected sample countries, it is still controversial whether there is a causal relationship between economy and energy (Zhang and Da [13]; Schandl et al. [14]), especially when it comes to what kind of causality relation they have (Karanfil and Li [15]; Wolde-Rufael [16]; Lee and Chang [17]; Xu et al. [18]). Lin and Liu [19] believed that the adjustment of inventory investment during economic recession would cause economic growth to deviate from the electricity consumption. Ge et al. [20] took Anhui Province of China as an example to study the inconsistency of economic growth and power consumption after 2008. As a result, it was found that after the economic crisis, the original industrial structure and power intensity changed significantly, resulting in the decoupling of power consumption from economic growth.

Because the non-stationary characteristics of power consumption data and time series data of economic development were gradually realized, many scholars have applied co-integration analysis to this field. Co-integration analysis is mainly used to explain the long-term stable equilibrium relationship between non-stationary variables. Apergis and Payne [21] used panel co-integration and error correction models to examine the relationship between energy consumption and economic growth in six Central American countries and found that there was a long-term co-integration relationship among the real GDP, energy consumption, labor, and actual total fixed capital. Yuan et al. [22] combined the Hodrick–Prescott (HP) filter with co-integration analysis to study the relationship between electricity consumption and economic growth in China from 1987 to 2004, and found a long term co-integration relation existed both in the trend and cyclic terms. Zhao et al. [23], based on the introduction of the production function of power consumption data, analyzed the relationship in six northern provinces and cities in northern China (Beijing City, Tianjin City, Hebei Province, Shanxi Province, Shandong Province and Inner Mongolia Autonomous region), and the results showed that there was a long term co-integration relationship among the economic growth, electricity consumption, labor and capital investment in these places.

Although there is still disagreement about the causality and correlation of power consumption and economic growth, most studies have confirmed that electricity and economy have significant correlations, and have indicated out that electricity is an important production factor for economic development. While, in terms of the use of measurement methods, since the co-integration test relies too much on the stationarity of the sequence and assumes that the parameters do not change, the co-integration equation couldn't catch the changes in time when some economic and energy indicators such as economic scale, industrial structure, and energy efficiency change (Li et al. [24]). At the same time, the measurement models used in traditional economic analysis couldn't avoid the existence of random disturbances, which leads to the failure to fully explain the changes in the electricity consumption, making the research conclusions biased (Timmermann [25]) and the influence mechanism on electricity consumption couldn't be fully explained. In addition, because most of these models assume that the coefficient between economic development and power consumption is a fixed value, it ignores the dynamic process between the two. Therefore, this paper attempts to apply Multi-period ST-LMDI model by setting a unified reference province as a benchmark for different regions to completely decompose the changes in China's electricity consumption of every province in every year.

In recent years, decomposition analysis methods represented by the Logarithmic Mean Divisia Index (LMDI) have been widely applied to the study of influencing factors in energy consumption, economic growth, and pollutant discharge. LMDI was proposed by Ang and Liu [26] and proved that both its multiplicative and additive forms satisfy summing consistency. This method is suitable for decomposing time series data, cross-section data, or panel data containing fewer influencing factors, and has features of fully decomposing the dependent variables without generating residual value. After that, Ang [27–29] further solved the possible issues of negative-value and zero-value. Since the LMDI decomposition method was introduced into the field of energy decomposition, scholars at home and abroad have further expanded the depth and scope of application of the LMDI decomposition method. LMDI includes two different models: LMDI-I [26,30] model and LMDI-II [31] model. The difference between the two models is that the calculation methods of weight coefficients are different. Each model includes addition decomposition and multiplication decomposition. Because of the inconsistency of results between the addition decomposition and multiplication decomposition, LMDI-II model is rarely used [32].

In terms of energy, Achour and Belloumi [33] used the LMDI model to decompose the fossil energy consumption of the Tunisia transport sector between 1985 and 2014 into energy intensity, transportation structure effect, transportation intensity effect, economic output, and population scale effects, whose results showed that except energy intensity's impact on energy consumption was negative, all that of others were positive. Based on the LMDI decomposition of Guangdong's energy consumption growth from 2004 to 2014, Chong et al. [34] pointed out that per capita GDP and population growth were the dominant factors driving the growth of energy consumption, and the improvement of power supply efficiency was the main factor restraining the growth of energy consumption. Wang et al. [35] decomposed the electricity demand of Chinese industry from 1998 to 2007, and found that output and energy structure change were the main reasons for the growth of electricity demand, the impact of industrial restructuring was small and the improvement of energy efficiency was the only factor reducing the power demand. In the study of environmental pollutants, relevant researches have focused on the decomposition analysis of carbon dioxide emissions (Zhang and Da [13]; Zhang et al. [36]; Wang and Feng [37]). Although the selected factors and research samples were not the same, it is generally believed that the expansion of economic scale and the increase of fossil energy consumption were the main reasons for the increase of carbon emissions in China and the growth of carbon emissions could be curbed by increasing energy efficiency and reducing energy intensity. Yang et al. [38]'s studies of SO_2 emission in China also basically verified this opinion. Based on panel data, Chen et al. [39] used the LMDI method to decompose the influencing factors of China's wastewater emission and results showed that economic development was the decisive factor leading to the increase of wastewater emission while technological progress could effectively control it. In terms of agriculture, by means of the LMDI decomposition method, Hua [40] analyzed the grain output of China during 2003–2014 and found that compared to the area of cultivated land, the proportion of grain crops cultivated and the multi-crop index, the output of per unit area was the most powerful driving force to promote China's grain yield. Meanwhile, through the space effect decomposition of grain production, it was concluded that the six provinces (Heilongjiang, Henan, Inner Mongolia, Jilin, Anhui, and Shandong) have contributed 62% of China's grain yield increase.

At present, domestic and international research using the LMDI method are focusing on the emissions of pollutants such as carbon dioxide, sulfur dioxide, and waste water. The LMDI analysis of energy consumption mainly starts from the consumption of fossil energy. However, due to the more severe private coal mining and the existence of oil smuggling in China, the consumption of fossil energy is obviously underestimated, which results in LMDI analysis of energy consumption cannot fully reflect China's real energy consumption status. While, previous literatures focused on the decomposition of energy consumption by applying LMDI model, no matter using time series data or panel data, only decomposed and analyzed one object one time. Even it was a nationwide subregional research, it only decomposed the different regions one by one, which made the decomposition results only applicable to the interior of the region while couldn't effectively contrast different regions. ST-LMDI model integrates time data and spatial data, sets a unified benchmark, and compares the horizontal and vertical directions between individuals, so that the decomposition results between different regions are well comparable, which can not only guarantees the uniqueness of the individuals, but also maintains theirs generality inside the entirety. So this paper selects ST-LMDI model for the study.

3. Analysis of China's current situation of electricity consumption and economic growth

Almost forty years have passed since the Reforming and Opening-up, during which China's economy has grown rapidly and energy consumption has also been rising. In 2011, China's electricity consumption exceeded America's for the first time and ranked the first in the world. From then on, the gap between China and the United States in electricity consumption has continued to widen. In 2016, China's electricity consumption reached 6.13 trillion kW·h, which accounted for 24.1% of the world's total electricity consumption in that year, and was 1.35 times America's electricity consumption over the same period. The development of the national economy and the improvement of people's living standards require huge power supply. The continuous expansion of electricity consumption, on the one hand, is the manifestation of China's overall national strength, but on the other hand, it also brings many problems, especially in the case of China's coal-based energy supply structure dominated by thermal power generation. The massive combustion of electric coal has caused continuous increase of carbon dioxide emissions, making China not only have to face the huge domestic pressure on the protection of ecological environment, but also need to bear the international community's external pressure on carbon dioxide emission reduction.

Fig. 1 depicts the growth rate and the change trend of China's real GDP (based on 1978) and power consumption since the reform and opening up in 1978–2016. It can be seen that after eliminating the impact of price changes, the trajectory of China's GDP growth and the growth of demand for electricity has a high degree of consistency, which is reflected in the corresponding increase in electricity consumption in the years of rapid economic grow and in the years when GDP growth slowed down, the growth rate of electricity consumption also declined. Meanwhile, the data shows that China's real GDP grew from 367.87 billion RMB in 1978 to 11.85 trillion RMB in 2016, an increase of 32.24 times with an average annual growth rate of 9.61%; China's electricity consumption increased from 265.55 billion kW·h in 1978 to 5.81 trillion kW·h in 2016, increased by 22.62 times with an average annual growth rate of 8.79%. It can be seen that during this period, China's GDP and electricity consumption have both experienced a substantial increase, and the growth rate of GDP was higher than that of power consumption; but when it comes to the annual growth rate, the growth difference was small.

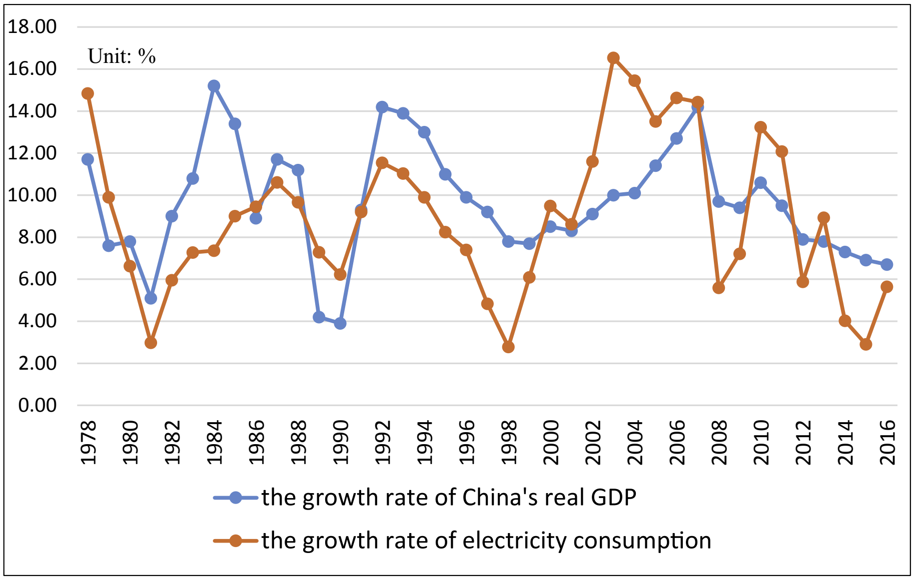

Fig. 1. The growth rate of China's real GDP and power consumption during 1978–2016.

If the contiguous two economic growth troughs are taken as a complete economic cycle, then before 2000, the cycles of GDP and power consumption changes basically coincided, and the peaks and troughs of the two are basically coincident in time. Before 2000, China has gone through three troughs of economic development: 1981, 190 and 1998. In 1990, China's economic growth rate declined was, from the economic point of view, mainly due to the reduction of investment scale, the control of credit scale, the suppression of inflation and so on (Zhang, 2013 [41]). During 1996–1998, in order to restrain the increasingly serious economic overheating problem, the Chinese government regulated the economy in 1988 and daunted the total social demand. The tightening policy made the GDP growth rate decline from 1989 to 1990, causing a decline in the industrial production rate, etc. And during the same period, the power consumption also dropped significantly (Zhang and Clovis [42]). The Asian financial crisis that started from the second half year of 1997 has affected China's exports and economic growth, resulting in a decline in China's demand for electricity. In 1998, for the first time, China experienced an oversupply of coal, electricity and oil. From 1997 to 2000, China's total energy consumption (including coal, oil, natural gas, electricity, etc.) had been on negative growth for four consecutive years.

On the other hand, it can also be seen that although the similarity of the trajectory changes in the growth rate of economic development and the increase of power demand is relatively high, the two do not show a simple one-to-one correspondence. (1) Before 2000, China's GDP growth rate was higher than that of electricity consumption in most years. Based on the historical data of this period, although China has increased investment in electric power development and has attracted social capital to invest in generating power plants, China's economy has developed at a faster rate during this phase, which resulted in that the electricity supply cannot meet demand and the supply gap is relatively big; (2) After entering the year 2000, the Chinese economy has ushered in a new round of rapid development, and the electricity consumption of the entire society, especially industrial electricity consumption, has risen sharply, and the power consumption has shifted from the previous slowdown in growth to rapid growth. Since 2003, due to the increase in the price of energy and raw materials (coal price and oil price), a large area of electricity shortage occurred in 21 provinces and cities and districts and power rationing happened in many regions, which had a great impact on the production and livelihood of the people. The data shows that from 2000 to 2007, the average annual growth rate of China's GDP was 10.54% and the average annual growth rate of electricity consumption was 13.53%, significantly higher than GDP's; (3) Till 2008, because of the impact of the global financial crisis, China's economic growth slowed down and at this time, the growth of electricity consumption also showed an overall decline with partial fluctuations. Especially after 2013, due to the overcapacity in power supply and defects in scheduling mechanism of China's power market, abandonment of wind and light happened in Xinjiang, Gansu, and Hebei, which resulted in idleness and waste of resources.

4. Research methods and data

4.1. Model construction

LMDI was put forward by Ang and Liu in 2001 to determine the relationship between economy, energy intensity, energy structure, carbon emission intensity and carbon dioxide emissions [24]. Its original form is as follows:

$$C = \sum_i^n \sum_j^m C_{ij} = \sum_i^n \sum_j^m \frac{C_{ij}}{E_{ij}} \frac{E_{ij}}{E_i} \frac{E_i}{Y_i} Y_i = \sum_i^n \sum_j^m Y_i U_{ij} S_{ij} I_i \tag{1}$$

In formula (1), i represents the economic sectors and j represents the energy categories. Because this decomposition method is simple in structure and easy to solve, and has features of fully decomposing the dependent variables without generating residual value. It is gradually being widely applied to the factor decompositions involved in environment and energy fields. However, since the LMDI model can only decompose a single object or indicator and cannot establish an effective association between multiple objects, Ang et al. [43] proposed ST-LMDI model, which integrates spatial and temporal analyses in a single analytical framework and compares the common benchmarks between all regions, which overcomes the lack of correlation between the empirical results of the research objects in present researches.

According to Cobb-Douglas production function and endogenous growth theory, energy, like the capital and labor force, is an essential element of economic growth. Technological externality and economic scale effect are also important factors to promote economic development. Therefore, this study decomposes electricity consumption into the following four factors:

1). Economic scale. Related research on production functions suggests that input factors of production functions can be either alternative or complementary, and capital and labor force can be substituted for energy [44,45]. Then the electricity demand has a high correlation with the level of economic development. Both the electricity consumption and economic scale have maintained a gradually upward trend, and also both theirs growth rates and fluctuation directions have a high correlation. Therefore, in the analysis of energy consumption, the change of economic scale is a factor that must be considered.
2). Economic structure. At the same time, combined with the analysis in the literature review part, it can also be seen that the factors influencing China's electricity consumption not only come from the continuous expansion of China's economic scale, but also due to the profound changes in China's economic structure and the share of different industries in the economic aggregate has constantly changed, the industrial structure also has an important impact on total electricity consumption;
3). Economically geographical structure. The agglomeration of population and economy in urban agglomeration can effectively improve the efficiency of economic operation through the economic externalities of the links between enterprises [46]. The best performer of the reform and opening up is the eastern coastal areas where most of the activities consuming electricity lay on. Therefore, geographical structures also have an important impact on China's electricity consumption.
4). Technical level. Endogenous growth theory holds that technological progress can improve production efficiency and reduce energy consumption, and promote sustained economic growth. The advancement of science and technology and the improvement of production processes are conducive to improving economic production efficiency and promoting the optimization of China's electricity consumption intensity.

Based on these reasons, this paper establishes the following relational expression of factor decomposition for China's electricity consumption:

$$E^t = \sum_{ij} E_{ij}^t = \sum_{ij} GDP^t \frac{GDP_i^t}{GDP^t} \frac{E_i^t}{GDP_i^t} \frac{E_{ij}^t}{E_i^t} = \sum_{ij} GDP^t \cdot S_i^t \cdot I_i^t \cdot M_{ij}^t \tag{2}$$

In the above formula, E_{ij}^t represents the electricity consumption of the jth industry in the ith district in year t; GDP represents the gross domestic product; GDP_i represents the GDP of the ith district; $S_i = \frac{GDP_i}{GDP}$ represents the share of the GDP_i in the national GDP; $I_i = \frac{E_i}{GDP_i}$ represents the electricity intensity of the ith district; $M_{ij} = \frac{E_{ij}}{E_i}$ represents the share of electricity consumption of the jth industry in the overall consumption of the ith district.

Moreover, $i = 1,2,3, \ldots \ldots ,30$, representing 30 inland provinces except Tibet in China; $j = 1,2,3, \ldots \ldots ,6$, representing 6 industries under three industries which include the primary industry (agriculture, forestry, animal husbandry and fishery), the secondary industry (industry; construction) and the tertiary industry (transport, storage and post; wholesale, retail, accommodation and catering; other sectors).

According to formula (1), the influencing factors of power consumption are decomposed into economic scale GDP_i, economically geographical structure S_i, electricity consumption intensity I_i, and industrial electricity consumption structure M_{ij}.

Different from the traditional LMDI model, which can only decompose the same region, ST-LMDI model can compare different regions. By setting reference region as benchmarks, ST-LMDI model decomposes and compares the electricity consumption of every provinces and every year. Considering the needs of empirical analysis, two models are listed as follows:

LMDI-I addition model decomposition:

$$\Delta E^{0,t} = E^t - E^0 = \Delta E\_act^{0,t} + \Delta E\_str^{0,t} + \Delta E\_\mathrm{int}^{0,t} + \Delta E\_mix^{0,t} = \sum_{ij}\left(L_{ij} \ln\frac{GDP^t}{GDP^0} + L_{ij} \ln\frac{S_i^t}{S_i^0} + L_{ij} \ln\frac{I_i^t}{I_i^0} + L_{ij} \ln\frac{M_{ij}^t}{M_{ij}^0}\right) \tag{3}$$

LMDI-I multiplication model decomposition:

$$D^{0,t} = \frac{E^t}{E^0} = D\_act^{0,t} \cdot D\_str^{0,t} \cdot D\_\mathrm{int}^{0,t} \cdot D\_mix^{0,t} = \exp\left(\sum_{ij} \tilde{L}_{ij} \ln\frac{GDP^t}{GDP^0}\right) \cdot \exp\left(\sum_{ij} \tilde{L}_{ij} \ln\frac{S_i^t}{S_i^0}\right) \cdot \exp\left(\sum_{ij} \tilde{L}_{ij} \ln\frac{I_i^t}{I_i^0}\right) \cdot \exp\left(\sum_{ij} \tilde{L}_{ij} \ln\frac{M_{ij}^t}{M_{ij}^0}\right) \tag{4}$$

Single-period ST-LMDI model:

$$D^{t,bm} = \frac{E^t}{E^0} = D\_act^{t,bm} \cdot D\_str^{t,bm} \cdot D\_\mathrm{int}^{t,bm} \cdot D\_mix^{t,bm} \tag{5}$$

Multi-period ST-LMDI model:

$$S^{0,t} = \frac{D^{t,bm}}{D^{0,bm}} = \frac{D\_act^{t,bm}}{D\_act^{0,bm}} \cdot \frac{D\_str^{t,bm}}{D\_str^{0,bm}} \cdot \frac{D\_\mathrm{int}^{t,bm}}{D\_str^{0,bm}} \cdot \frac{D\_mix^{t,bm}}{D\_str^{0,bm}} \tag{6}$$

And:

$$L_{ij} = \frac{E_{ij}^t - E_{ij}^0}{\ln E_{ij}^t - \ln E_{ij}^0}, \tilde{L}_{ij} = \frac{E_{ij}^t - E_{ij}^0 \Big/ \ln E_{ij}^t - \ln E_{ij}^0}{E^t - E^0 \Big/ \ln E^t - \ln E^0}. \tag{7}$$

Beside:

$$L\left(E_{ij}^t, E_{ij}^0\right) = \tilde{L}\left(E_{ij}^t, E_{ij}^0\right) = \begin{cases} \dfrac{E_{ij}^t - E_{ij}^0}{\ln E_{ij}^t - \ln E_{ij}^0} & , E_{ij}^t \neq E_{ij}^0 \\ E_{ij}^t \quad or \quad E_{ij}^0 & , E_{ij}^t = E_{ij}^0 \end{cases} \tag{8}$$

Meanwhile:

$$\Delta E_{tot} = \Delta E_1 + \Delta E_2 + ... + \Delta E_6 = \sum_{j=1}^{6} \Delta E_j \quad (9)$$

In equations (3)–(6), ΔE_{act}, ΔE_{str}, ΔE_{int}, ΔE_{mix}, and D_{act}, D_{str}, D_{int}, D_{mix} represent the multiplication factor and additive factor of the effects of economic scale, economically geographical structure, electricity consumption intensity and industrial electricity consumption structure on the total electricity consumption of the country.

Because of $\frac{\Delta E_{act}}{\ln D_{act}} = \frac{\Delta E_{str}}{\ln D_{str}} = \frac{\Delta E_{\text{int}}}{\ln D_{\text{int}}} = \frac{\Delta E_{mix}}{\ln D_{mix}} = \frac{E^t - E^0}{\ln E^t - \ln E^0}$, therefore the decompositions of multiplication mode and additive mode have the same explanatory power.

4.2. Data sources

The data in this paper mainly comes from the "China Statistical Yearbook", "China Energy Statistical Yearbook" and the website of the National Bureau of Statistics and so on. Regarding the lack of data of Chongqing city in 1995, this paper uses the "Sichuan Statistical Yearbook" as the basis, and selects the ratio of each industry in the corresponding sector in Sichuan Province when Chongqing city was recorded in the yearbook to estimate the power consumption in Chongqing city. At the same time, during the model construction, because the electricity consumption intensity involves the ratio of electricity consumption to GDP, in order to achieve the consistency in the electricity consumption intensity in each period and eliminate the impact of price changes in different periods, this article, according to the GDP indexes of each region, converts the GDP of each region in each period to the constant prices based on 1995. In this study, the reference province is the arithmetic average of each indicator for all provinces in 1995.

5. Empirical analysis

5.1. The LMDI decomposition of China's electricity consumption

According to Eq. (6), Multi-period ST-LMDI model is applied to annually decompose the electricity consumption changes of the entire society from 1995 to 2016 based on the economic scale effect, economic geographical structure effect, electricity consumption intensity effect, and industrial electricity consumption structure effect. The decomposition results are shown in Table 1:

Table 1
Factor-decomposing of China's electricity consumption during 1995–2016.

Year	D_act	D_str	D_int	D_mix	D
1995–1996	1.11	0.94	1.01	1.00	1.05
1996–1997	1.11	0.99	0.97	1.00	1.07
1997–1998	1.09	1.00	0.92	1.00	1.00
1998–1999	1.09	0.99	0.98	1.00	1.06
1999–2000	1.09	1.01	1.01	1.00	1.12
2000–2001	1.09	1.02	1.01	1.00	1.12
2001–2002	1.11	0.99	0.99	1.00	1.09
2002–2003	1.12	1.01	1.02	1.00	1.15
2003–2004	1.13	1.01	1.02	1.00	1.17
2004–2005	1.12	1.01	0.99	1.00	1.13
2005–2006	1.13	1.00	1.01	1.00	1.14
2006–2007	1.14	1.00	1.01	1.00	1.16
2007–2008	1.12	1.00	0.95	1.00	1.06
2008–2009	1.11	1.00	0.95	1.00	1.06
2009–2010	1.13	1.00	1.01	1.00	1.14
2010–2011	1.12	0.99	1.02	1.00	1.14
2011–2012	1.10	0.99	0.96	1.00	1.05
2012–2013	1.09	1.00	0.98	1.00	1.06
2013–2014	1.08	1.00	0.97	1.00	1.05
2014–2015	1.07	1.01	0.95	1.00	1.03
2015–2016	1.06	1.01	0.98	1.00	1.05
1995–2016	7.99	0.97	0.75	1.02	5.96

Note: The last line show the cumulative value.

From Table 1 we can see that from the perspective of the entire sample period, during the period from 1995 to 2016, the economic scale effect and industrial electricity consumption structure effect showed a positive effect (>1) on electricity consumption, while the economic geographical structure and electricity consumption intensity showed negative effect (<1). By conversion to actual electricity consumption, the absolute value of the cumulative contribution rate of each effect to the change in power consumption are: economic scale effect (7.99), industrial electricity consumption structure (1.02), electricity consumption intensity (0.75), and economically geographical structure (0.97). The yearly contribution rates of each effect are shown in Fig. 2:

From the impact values (Table 1 and Fig. 2) of each effect in the decomposition results, below conclusions can be drawn:

(1) The continuous expansion of the economy is the primary factor for the growth of electricity consumption.

Economy can't be improved without energy, all aspects of economic activity have a demand for energy consumption. According to energy consumption theory and endogenous growth theory, energy is an essential productive factor that constitutes economic growth. Correspondingly, economic growth also plays an important role in promoting energy consumption. From Table 1, it can be seen that in 1995–2016, China's electricity consumption increased by 5.96 times, while the economic scale effect led to an increase of 7.99 times, which exceeded the actual increase in electricity consumption, indicating that the expansion of the economy scale had a strong positive driving effect to the growth of electricity consumption. This was related to the continuous increase of China's economic aggregate. From 1995 to 2016, China's total GDP increased by 890.43% (according to comparable prices in 1995). It can be seen from Fig. 2 that economic scale effect of China's electricity consumption had roughly undergone the following stages: I. From 1996 to 1999, economic scale effect dropped for a while. The reason was during the same period, the growth of China's economy also dropped: it dropped from 11.69% in 1996 to 9.07% in 1999; II. From 2000 to 2007, economic scale effect improved stably. As China entered the WTO in 2000, its economy grew rapidly. During this period, China not only continued to expand its economic scale, but its total GDP increased from 9.38 trillion in 2000 to 20.45 trillion in 2007, and the economic growth accelerated noticeably, from 9.80% in 2000 to the peak 14.63% in 2007, which has led to a significant increase in electricity consumption, and electricity shortages have begun to emerge in various regions; III. From 2008 to 2011, the economic scale effect dropped first and then rose. Due to the impact of the US financial crisis in 2008, China's exports to Europe and the United States fell sharply, the economic growth rate declined, and the growth of electricity consumption slowed down. But because the Chinese government introduced ten measures to further expand domestic demand and promote stable and rapid economic growth in November 2008, the economic growth rate rapidly rebounded and electricity consumption also increased significantly; IV. After 2012, the Chinese economy gradually entered a shift period, and the economic growth rate slowed down. The Chinese government began structural reforms on the "supply side", eliminated backward production capacity, and restricted the establishment of high-energy-consuming enterprises and the power consumption growth rate also declined.

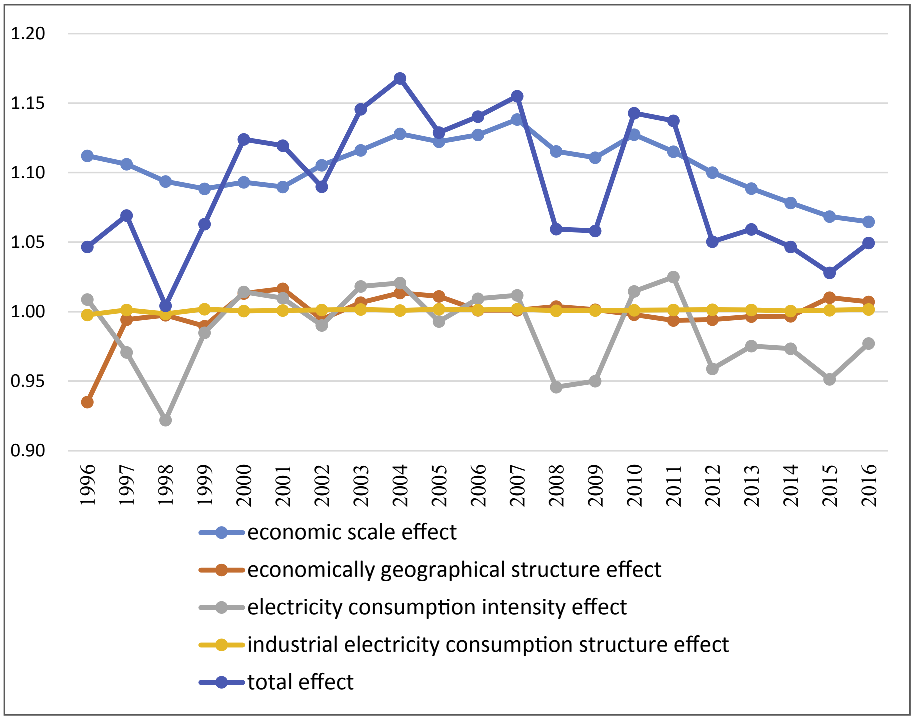

Fig. 2. Contribution rate of each effect during 1995–2016.

(2) The reduction of electricity consumption intensity , which is conducive to energy conservation and consumption reduction, is an important factor in restraining the growth of electricity consumption.

The intensity of electricity consumption refers to the amount of energy consumed by the economic output, and its formula is the Total Electricity Consumption/GDP. From the formula we can see that the lower the intensity is, the higher the efficiency of the entire energy system will be. The electricity consumption intensity reflects the economic benefits of the use of electricity resources and it is one of the most commonly used indicators for comparing the comprehensive utilization efficiency of electricity in a country or region. According to the expanded Production Function, technological progress can replace energy consumption, that is, economic growth can be achieved by upgrading the technological level without increasing energy consumption. On the whole, from 1995 to 2016, the reduction of electricity consumption intensity had restrained the growth of electricity consumption, which had reduced the growth of electricity consumption by 0.75 times, offsetting some of the increase caused by the expansion of the economic scale. The electricity consumption intensity is the main contributor to control the growth of electricity consumption. The situation implies that its decrease could effectively curb the rapid increase of the electricity consumption. From Table 1, we can see that from the perspective of the entire sample period, as China has long insisted on industrial upgrading policy, the power consumption intensity has always maintained a downward trend and gradually strengthened the inhibitory effect from its changes on power consumption. In stages, from 1996 to 1999, the effect of changes in electricity consumption intensity on the reduction of electricity consumption was not obvious; from 2000 to 2007, especially after China's entry into the World Trade Organization in 2000, on the one hand, a large amount of foreign capital flowed into China, and foreign direct investment increased sharply. However, those investments were mainly concentrated on fixed assets, and the main types were capital dependence and energy dependence. On the other hand, because of the pulling of the exports, the scale of domestic manufacturing industry continuously expanded. But theirs levels of technology were generally low, making energy utilization efficiency dropped after a number of high energy-consuming projects put into production. Due to the phase degradation of energy use efficiency in certain industries in certain regions, the power consumption intensity has risen, resulting in phase positive effect on electricity consumption during this period. After 2007, thanks to China's energy intensity limitation targets set up in the “Eleventh Five-Year” and “Twelfth Five-Year Plan” outlines, every local government has taken measures to reduce the unit energy consumption of GDP. Local governments strongly supported and developed low-energy-consuming enterprises, and issued rectification requirements and restrictions for high-energy-consuming enterprises, making the negative effect of electricity consumption intensity on electricity consumption gradually increased.

In Fig. 3, we made the electricity consumption intensity of China and its six sectors. It can be clearly seen that the power consumption intensity of the industrial sector was much higher than that of other sectors, which has pull up the country's electricity consumption intensity. At the same time, as industrial power consumption accounted for about 80%[1] of the total power consumption, it played a dominant role in the power consumption intensity. It can be seen that both the national power consumption intensity and the industrial power consumption intensity showed periodical ups and downs and overall declined trend. Specifically, from 1995 to 2016, the rates of change of electricity consumption in

1 Specific data will be provided in 5.2.

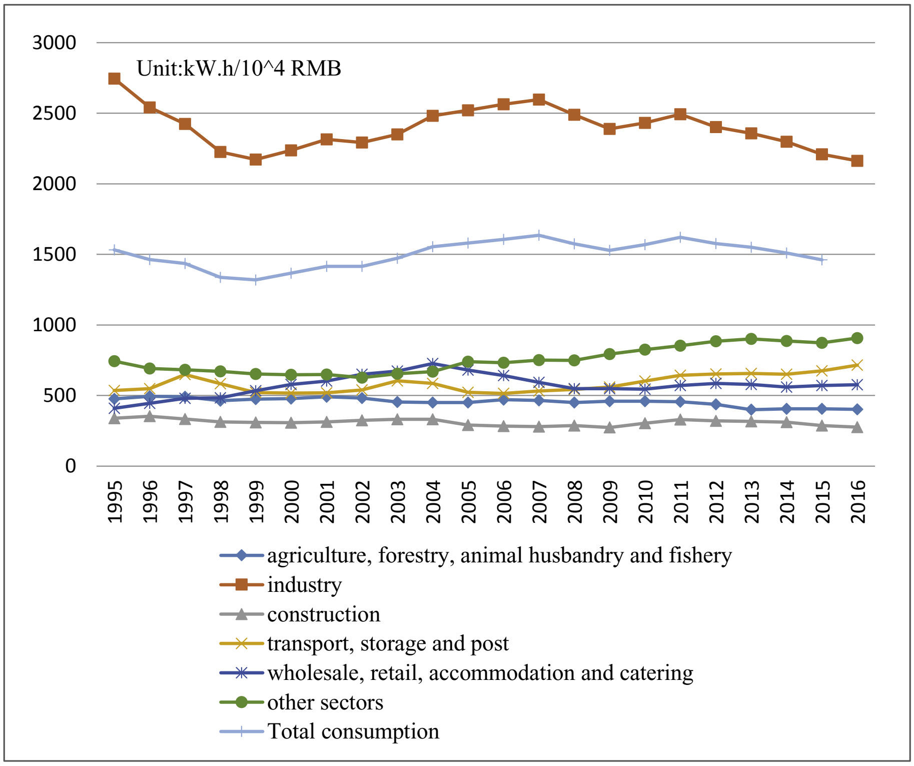

Fig. 3. 1995–2016 electricity consumption intensity of six sectors in China.

the country and various sectors were: −6.07% for the country, −15.65% in agriculture, forestry, animal husbandry and fishery, −21.22% in industry,-18.71% in construction, 33.41% in transport, storage and post, 40.62% in wholesale, retail, accommodation and catering and 22.17% for others. Furthermore, we made a tendency chart of the effect and change rate of the power consumption intensity in Fig. 4. As shown, the effect and change rate were basically synchronized, which indicated that to some extent our LMDI method can accurately reflect the impact of changes in the power consumption intensity on China's electricity consumption.

(3) The effect of electricity consumption structure shows a feeble positive effect on electricity consumption.

The electricity consumption and the electricity consumption intensity between industries is very different, which leads to changes in the proportion of industries in the GDP (industrial structure) will directly affect the power consumption. The increase in the proportion of high power consumption intensity industry

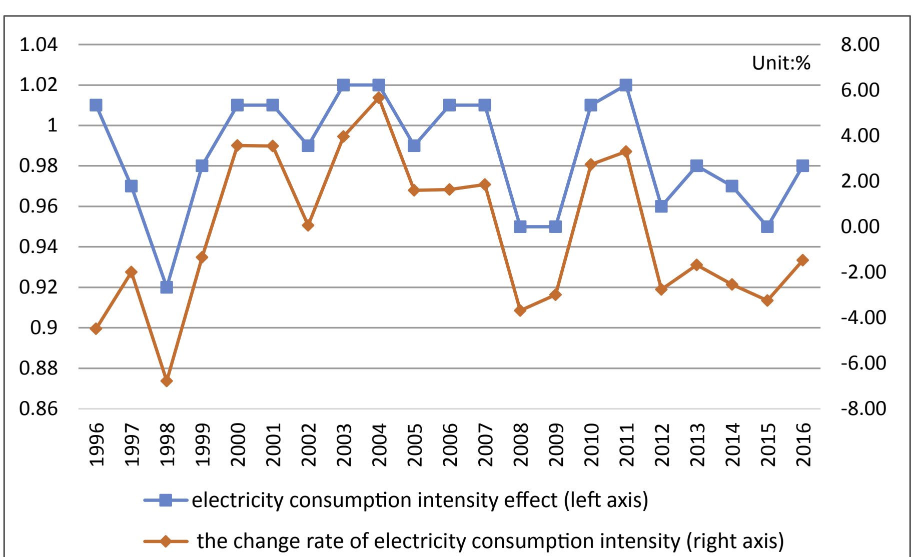

Fig. 4. The effect and change rate of electricity consumption intensity during 1995–2016.

will increase power consumption, and vice versa. As can be seen from Table 1, except from 1996, 1998 and 2013, the overall performance of the effect of industrial electricity consumption structure was a push to the electricity consumption. This was mainly due to the continuous advancement of China's industrialization road and the stable increase of the share of industrial added value in China's GDP. Combined with Fig. 5, we can see that the ratio of industrial output in GDP gradually increased from 45.85% in 1995 to 53.40% in 2016 while the ratio of agricultural added value in GDP has shown a yearly declining trend, fallen from 22.24% in 1995 to 7.93% in 2016; ratios of the construction sector, transport, storage and post sector, wholesale, retail, accommodation and catering sector did not change significantly but that of other sectors (mainly including service and residential consumption) increased obviously.

From the perspective of the entire sample period, the change in the structure of industrial power consumption increased by 1.02 times, from which its subtle impact on power consumption change can be seen. But industry is the main body of electricity consumption. During the sample period, the proportion of industry in the country's electricity consumption has always remained above 80%, causing the relatively stable industrial electricity consumption structure couldn't exert big effect China's electricity consumption. Meanwhile, it can also be seen that because the ratio of the other sectors represented by service industry has increased year by year, the contribution rate of electricity consumption structure to electricity consumption showed a declining trend, indicating China's industrial structure was under a gradually "be optimized" state. But due to the continuous advancement of the industrialization road, it can be predicted that in the short term, the industrial electricity consumption structure will still promote the power consumption.

(4) Effect of the economically geographical structure on power consumption is not significant.

The agglomeration of enterprises and population in the same region can effectively improve the efficiency of economic operation, which indirectly affects electricity consumption. Changes in economically geographical structure had a subtle negative effect on the overall performance of electricity consumption. From 1995 to 2016, changes in the economic and geographical structure led to a reduction of 0.97 times in electricity consumption. The main reason was that the geographical structure of China's economy has not changed significantly. The eastern region, as the engine of China's economic growth, has maintained a proportion of 52.57% ± 2.84% of China's total electricity consumption during the period from 1995 to 2016, the changes were slight. During the same period, the proportion of electricity consumption in the central region fell slightly, from 28.46% to 21.05%, and that of western region rose slightly, from 21.79% to 27.17%. It can be seen that while the spatial distribution of China's electricity consumption has been optimized, the basic pattern has not changed. In Section 5.3, we will further analyze the impact of economic spatial distribution on electricity consumption.

5.2. Industrial decomposition analysis of electricity consumption

In Section 5.1, we found that the industrial structure has a positive effect on the changes in China's electricity consumption, while the reduction in electricity consumption intension restrains the growth of electricity consumption. However, with the development of China's economy, the industrial structure has always gradually changed, and the energy utilization efficiency of different industries varied greatly. While the effects of different industries on China's electricity consumption were not clear enough, further analysis is necessary.

In China's economy, the industrial structure is relatively obvious. The overall performance is that the proportion of the primary industry continues to decline, the proportion of the secondary industry continues to rise and that of the tertiary industry steadily stably increases. Especially after joining the WTO, China has fully participated in the global commodity trade process and its scale of import and export has continued to expand. It has become a manufacturing base to supply industrial products in large scale in the world market, and its domestic added value has increased

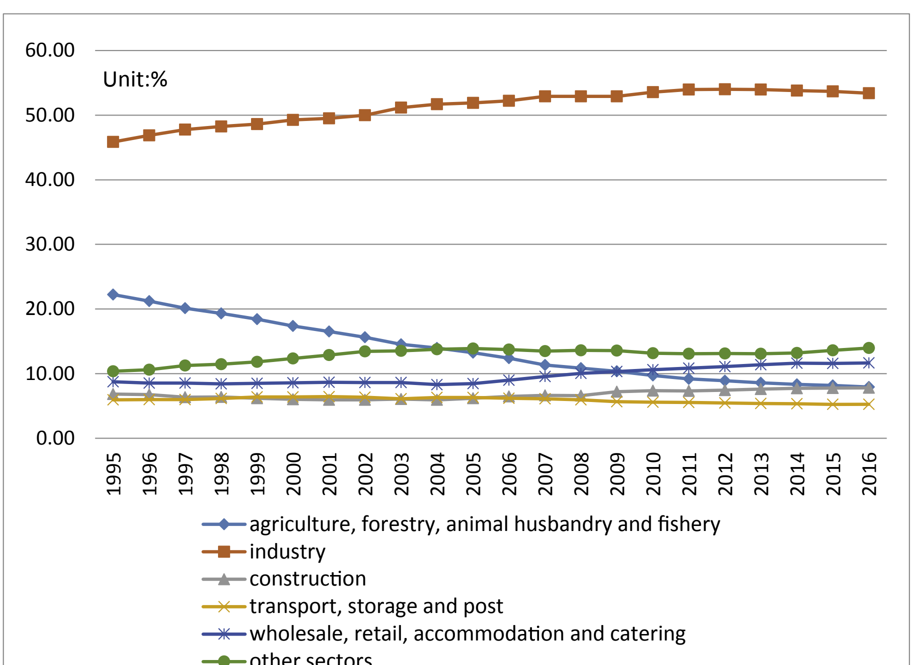

Fig. 5. 1995–2016 ratios of every industrial added value in GDP.

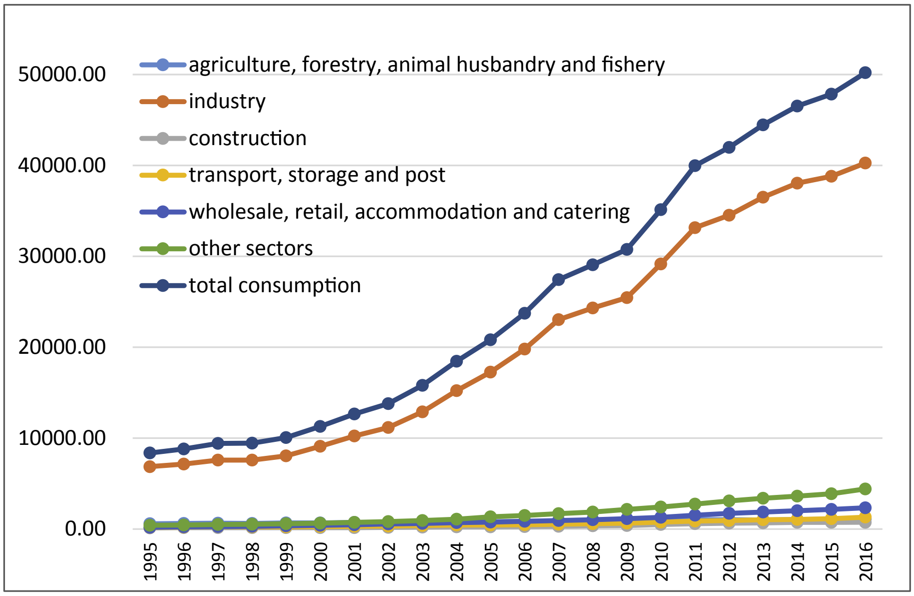

Fig. 6. 1995–2016 trend chart of electricity consumption of China's sectors.

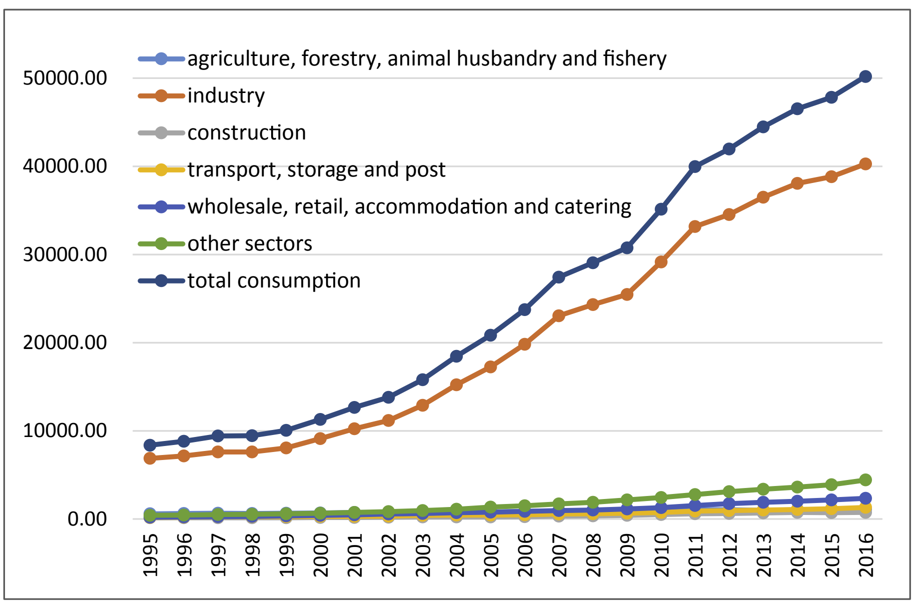

Fig. 7. 1995–2016 proportions of electricity consumption of China's sectors.

substantially. The proportion of China's industrial added value to GDP is significantly higher than that of most developed countries. According to the World Bank data,[2] in 2015, the ratio of industrial added value to GDP was 40.93% in China, 20.02% in the United States, 30.23% in Germany, 28.89% in Japan, and 24.55% in the EU from which we can see that China's industrial added value in GDP ratio is significantly higher than the world's major developed countries.

From Fig. 6 we can see that from 1995 to 2016, the total electricity consumption in China increased from 836.66 billion kW·h to 5.02 trillion kW·h, an increase of 6.01 times. In terms of sectors, the wholesale, retail, accommodation and catering industry ranked the largest growth rate by 11.95 times, followed by other industries by 10.50 times, and the transport, storage & post industry and construction industry increased by 7.52 and 5.92 times respectively. The growth of industrial power consumption was the largest, from 687 billion kW·h to 4.03 trillion kW·h, an increase of 5.86 times; the slowest growth was agriculture, which increased by 1.92 times. It can be seen that the change trend of industrial electricity consumption and national electricity consumption had a high similarity. The reason was that industrial electricity consumption was always the main component of China's electricity consumption. From Fig. 7, we can find that China's electricity consumption structure is mainly dominated by industrial power consumption. From 1995 to 2016, industrial power consumption had consistently accounted for over 80% of China's total electricity consumption, while the rest industries accounted for less than 20%. The

[2] https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?view=chart.

proportion of industrial electricity consumption reached the lowest point in 1999, which was 80.08%. After that, due to China's entry into the WTO, industrial energy consumption rose rapidly, reaching the peak of 83.99% in 2007. As the global economic crisis in 2008 resulted in a drop in demands for Chinese manufacturing, the share of industrial power consumption also fell.

Since industrial electricity consumption does not have the characteristics of spatial distribution, we used Eqs. (3) and (9) to decompose the industrial effect of China's electricity consumption from 1995 to 2016 by LMDI-I additive model. The calculation results are shown in Table 2. It can be seen that all industrial sectors basically had positive effects on electricity consumption. In some years, due to the temporary decline of power consumption in a certain industry, negative effects have also emerged (such as agriculture, forestry, animal husbandry and fishery in 2012–2013 and construction industry in 2014–2015). Seen from the decomposition results, the industrial effect was the decisive factor influencing the changes of electricity consumption. During the entire sample period, its overall contribution rate was 76.01%. The two peaks of the industrial effect contribution rate appeared in 2002–2003 (87.31%) and 2009–2010 (84.51%). The former was mainly due to the increase in demand for Chinese industrial products after China entered the WTO while the latter was mainly because after the global economic crisis in 2008, the Chinese government launched an economic stimulus plan to vigorously promote domestic infrastructure construction, thereby stimulating the expansion of domestic industrial production and the increase of industrial energy consumption. Effect of other sectors has also obviously promoted changes of electricity consumption, and has shown an overall increase in the contribution rate, which was mainly due to the gradual increase of the proportion of China's tertiary industry in the national economy, while effects of agriculture, forestry, animal husbandry and fishery, construction, transport, storage and post and wholesale, retail, accommodation and catering have shown relatively stable effects.

5.3. Regional analysis of electricity consumption

In Section 5.1, we found that the continuous expansion of the economy scale was the primary factor for the growth of electricity consumption and the decrease of the electricity consumption intensity was conducive to restraining the growth of electricity consumption. Due to the large difference of economic development levels among different regions, also the economic scale, power consumption, and power consumption intensity of them were not the same, we conducted regional analysis of China's electricity consumption.

From Fig. 8 we can see that both GDP and power consumption in eastern, central and western China showed an upward trend from 1995 to 2016, among which the eastern regions were the most obvious. From the perspective of the sample period, in 1995, the starting points of GDP and electricity consumption in all regions of China were relatively low, and both of them grew slowly. After entering the year of 2000, GDP and electricity consumption in the eastern region have increased significantly, gradually leaving the central and western regions behind. The reason was that due to China's entry to the WTO, eastern coastal areas took advantages of its geography to rapidly developed manufacturing industry which stimulated the GDP and electricity consumption to grow at a fast pace.

At the same time it can be seen that the trajectory of electricity consumption and economic growth had a high degree of similarity, but not completely synchronized. Because in Section 5.1, we found that changes in electricity consumption were not only driven by the expansion of economic scale, but also curbed by the reduction of electric power intensity. Therefore, we made the changing trends of the power intensity of the eastern, central and western regions in Fig. 9. For the eastern regions, the watershed of the electricity consumption and the GDP was the year of 2007. Through estimating, we found that before this, the growth rate of electricity consumption has always been higher than that of the GDP. After 2007, the growth rate of the GDP began to exceed that of the electricity consumption, a “decoupling” between them appeared. Combined with Figure, it can be seen that after 2007, the power consumption intensity in the eastern regions has dropped significantly, indicating that the improvement of production level in the eastern regions has prompted them to use less electricity to create bigger economic growth. This also proved that the reduction of electricity consumption intensity can effectively restrain the growth of electricity consumption. This analysis is also applicable to

Table 2
1995–2016 industrial effect decomposition of China's electricity consumption (Unit: 10^{-9} kW•h).

Year	ΔE_1	ΔE_2	ΔE_3	ΔE_4	ΔE_5	ΔE_6
1995–1996	51.88	283.97	16.45	35.93	32.84	21.32
1996–1997	18.11	442.87	−4.61	50.13	39.97	62.8
1997–1998	−15.95	0.15	3.18	−5.58	19.74	39.26
1998–1999	32.66	454.59	4.20	−0.10	58.03	45.68
1999–2000	23.74	1060.77	7.58	20.23	63.33	70.76
2000–2001	38.61	1131.89	13.66	24.42	55.61	86.39
2001–2002	6.81	919.04	21.45	34.37	82.18	73.98
2002–2003	−24.91	1740.47	26.84	62.65	75.34	128.72
2003–2004	35.93	2314.01	18.00	44.22	93.28	144.95
2004–2005	41.56	2030.83	4.75	−3.42	42.07	260.44
2005–2006	75.96	2548.56	33.34	35.82	94.6	133.02
2006–2007	20.01	3239.71	40.65	73.72	96.56	212.16
2007–2008	17.36	1268.46	38.53	51.07	69.12	184.43
2008–2009	56.75	1141.11	45.76	40.81	121.5	281.62
2009–2010	43.01	3708.75	105.4	113.47	154.11	263.92
2010–2011	36.01	4006.72	95.35	127.35	232.69	324.74
2011–2012	3.23	1369.26	37.8	68.9	201.81	331.64
2012–2013	−53.68	1963.95	54.87	67.75	157.45	296.8
2013–2014	57.46	1564.97	50.92	55.23	118.71	225.93
2014–2015	40.31	744.64	−13.45	87.39	159.73	280.3
2015–2016	29.08	1456.92	22.94	149.55	176.96	528.2
1995–2016	533.94	33391.64	623.62	1133.91	2145.63	3997.06
Contribution rate (%)	1.28	79.84	1.49	2.71	5.13	9.56

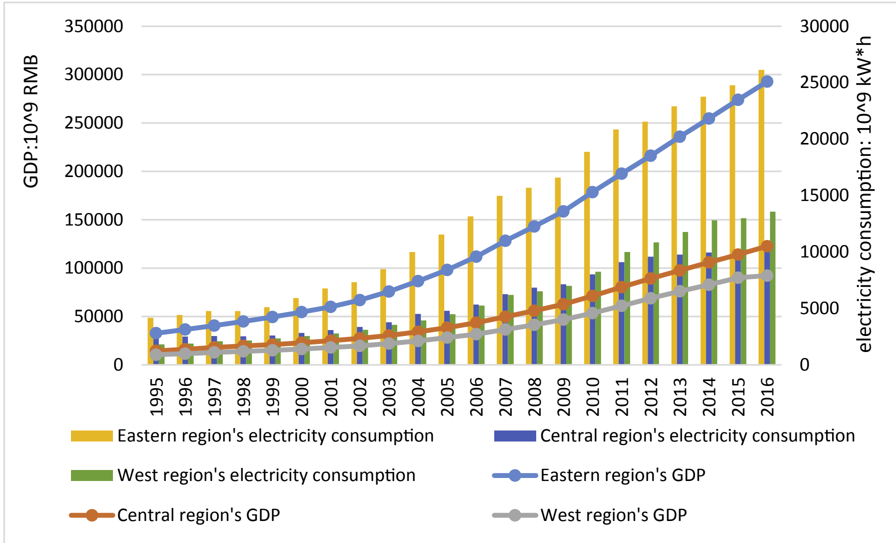

Fig. 8. 1995–2016 GDP and electricity consumption in eastern China, central China and western China. Note: GDP are converted to standard prices for the base period of 1995.

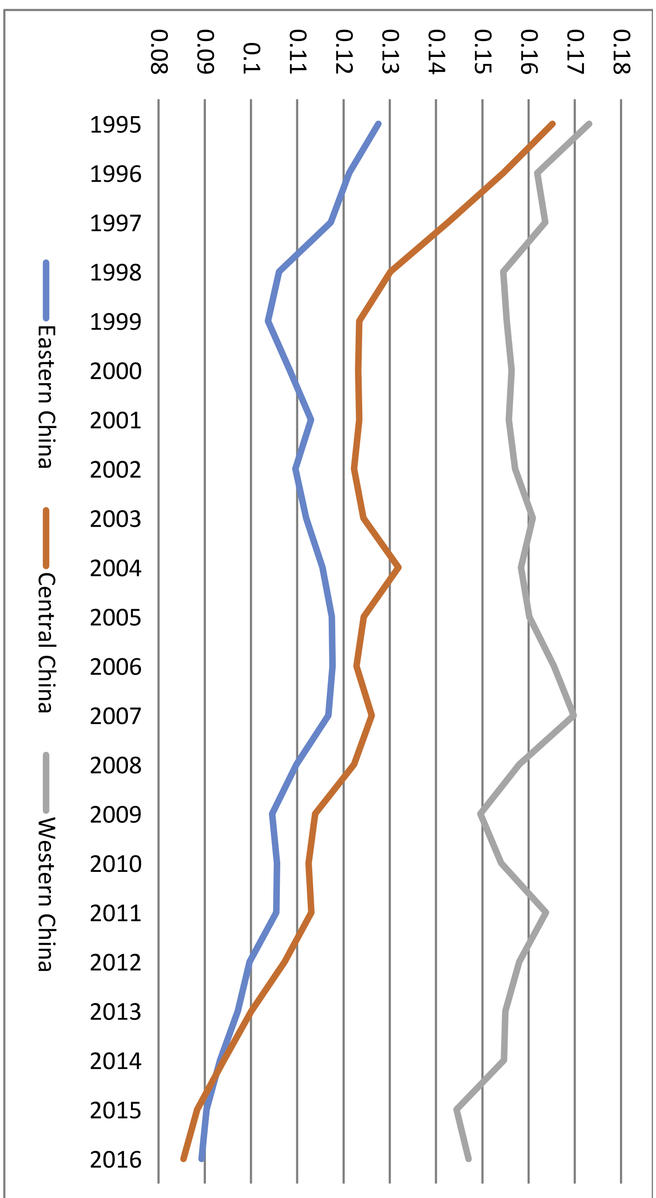

Fig. 9. 1995–2016 electricity intensity of eastern, central and western China.

the middle regions. For the western regions, as the decline of power consumption intensity was not obvious enough, they were still at a high intensity level (as shown in Fig. 9), so the growth trajectory of GDP and power consumption there was of relatively high consistency.

6. Conclusions and suggestions

This paper uses Multi-period ST-LMDI method to decompose China's electricity consumption from 1995 to 2016, and decomposes the growth of China's electricity consumption into four factors: economic scale, economically geographical structure, electricity consumption intensity and industrial electricity consumption structure, and also decomposes and analyzes the impact of China's electricity consumption by comparing the dynamic evolution process of each influencing factor during the whole sample period and different time periods. Moreover, combined with the industrial structure and regional characteristics, it further explores the impact mechanism of China's electricity consumption. Below conclusions and suggestions are gained through our study:

(1) No matter in the entire sample period or in each year, the expansion of the economic scale is a decisive factor to the growth of China's electricity consumption. Between 1995 and 2016, China's GDP grew at an average annual rate of over 9%, creating huge energy demand and directly leading to rising electricity consumption. While, according to endogenous growth theory, capital and labor force can be substituted for energy, and vice versa. As the negative impact of electricity saving on the economy can be hedged through adjustments in capital and human resources policies, China should increase its policy investment in new energy companies and education to achieve the goal of changing the economic development model and adjusting the structure of energy consumption and raising the level of labor force. In view of the fact that the Chinese economy has now entered the new normal stage, the economic growth has shifted from pursuing of the expansion of the economic scale and the increase of GDP to focusing on the sustainable development that pays more attention to the quality of economic growth. Therefore, we believe that as China's economy will shift from high-speed development to more efficient and sustainable medium-to-high-speed growth, the pace of economic expansion will also decline. Because the economic scale is

the first driving factor for China's electricity consumption, the deceleration of its growth will inevitably lead to a direct slowdown in the growth of electricity consumption; on the other hand, the contribution rate of economic scale effect to changes in electricity consumption throughout the sample period is 7.99 times, which shows from the side that in the process of economic development, matched power supply is the basis. However, China's current electricity is still facing a structural shortage [36], which requires the Chinese government not only to optimize the existing power supply structure, but also to reasonably forecast the power consumption and to lay out the power capacity in advance.

(2) In most periods, the reduction of electricity consumption intensity has effectively inhibited the rapid growth of China's electricity consumption. However, the data shows that from 2000 to 2007, due to the mass production of energy-dependent manufacturing projects, the power consumption intensity did not fall but rose, showing a phased pulling effect on China's electricity consumption. This indicates that the fundamental way to curb the excessive growth of electricity consumption is to reduce the intensity of electricity consumption. Based on the empirical results of industrial decomposition, although the industrial added value only accounts for about 40% of GDP, it consumes more than 75% of the electricity. This shows that the core of reducing the electricity consumption intensity is the upgrading of the industry. According to the expression of energy consumption intensity, on the one hand we need to raise the level of industrial manufacturing and improve the efficiency of industrial energy use, on the other hand to develop high value-added processing and manufacturing industries through research and development of products. The Chinese government should strengthen independent technological innovation and introduce foreign advanced technology, reduce the consumption of electricity through technological progress, promote economic growth, and thus eliminate the excessive reliance on electricity for economic development.

(3) The effect of industrial power consumption structure on China's power consumption is limited, but due to its gradual performance of "optimization", its potential to reduce power consumption remains to be further excavated. At present, the development of various industries in China is not mature enough or complete, large room for them still left. Meanwhile, in order to meet various social needs and maintain national stability, China needs to ensure that all industries are involved. This determines in the short term, China will not be able to achieve the improvement of industrial power consumption structure through the adjustment of industrial structure. But in the long run, because the secondary industries in China accounts for a too high proportion, and it belongs to industries of high power consumption intensity. Through the adjustment of industrial structure, China can not only achieve the goal of reducing energy consumption, but also realize the adjustment of industrial structure. Therefore, it is an inevitable choice to more develop the tertiary industries with low power consumption intensity and promote the optimization of industrial power consumption structure for reducing energy consumption in China after the proper distribution of industrial structure.

(4) In general, the economically geographical structure has a certain inhibition effect on the growth of China's electricity consumption, but it is relatively small in current stage. The implementation of the "Rise of Central China" and "Western Development" strategy has promoted the economic development of the central and western regions, but it has not really changed the spatial pattern of the Chinese economy. However, the analysis of regional power consumption shows that the power consumption intensity in the western region is still much higher than that of the eastern and central regions. The eastern power consumption also shows that improving energy efficiency can effectively decouple power consumption from economic development. Therefore, further improving the electricity utilization efficiency of various industries in the western region and promoting the reasonable distribute industries among different regions will not only benefit the development of the western economy, but also help to optimize the economic geographical structure of electricity consumption and reduce the consumption of electricity resources as well.

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