An Empirical Study on the Deviation between Electricity Consumption and GDP Growth in Anhui Provinc

Lizhao

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Abstract

Today, energy use is closely related to economic development, and electricity is an important engine driving economic development for cities that rely on traditional industries. Combining the data of electricity consumption and total output value, through the *Logarithmic Mean Divisia Index Method (LMDI)*, we can decompose the growth rate of power consumption into intensity effect, structure effect, and output effect. These effects will reflect the phenomena that appear in industrial development, and for regions that are preparing to carry out industrial reform, they can provide valuable suggestions for the overall economic development in the future.

Anhui, an inland province in China. Due to its large coal and ore reserves, it has several industrial cities, mainly engaged in thermal power generation and metal manufacturing. With the reduction of mineral reserves, the internal cycle of the previous high-yield power (coal power generation) and high power consumption (metal processing) is no longer stable, and it is imperative to adjust the original industrial structure. Since 2019, the economic growth rate of Anhui Province has slowed down, and the use of electricity has also reflected the deviation from the growth rate of GDP. The study of electricity consumption has positive significance for future economic development.

Chapter1 Research background and the current research status

(I) Background Since the last century, the relationship between energy consumption and industrial development has become extremely close. For some industrialized regions in China, the most important energy source is electricity. Because of its connection with industrial production, electricity use also has an important relationship with economic development. Previously, experts and scholars from various countries have conducted long-term and in-depth studies on the correlation between power consumption and economic growth. Hwang(1984)[1], Gum(1992)[2] and Mashi(1997)[3] were among the earliest scholars to study this subject. They used Granger Causality Test(1969)[4] to test the level value of the time series according to the sample data of different countries, or the same series of the same country but different sample intervals, got different conclusions. With the deepening of research, the research methods between power consumption and economy are constantly improved, mainly econometric analysis and decomposition analysis.

(II) Analysis of Econometric Methods In recent years, more and more various econometric methods have been widely used in related research. Soytas(2003)[5] used 16 countries as the research object to analyze the relationship between energy consumption and economic growth. The results of cointegration analysis showed that the two-time series values in all countries are first-order single-integration, and there is a co-integration relationship. In addition to economic growth, more and more factors have been proved to be explanatory variables of electricity growth. Lariviere(1999)[6] found that population, temperature, and other factors have important influences on the electricity consumption of major cities in Canada. Steenhof(2006)[7] analyzed the power consumption of China's industrial sector from 1998 to 2002 and believed that technological progress was an important influencing factor. Cui(2013)[8] used the principal component analysis method to quantitatively analyze that Chongqing is the main influencing factor of electricity consumption as macroeconomic factors, residents' demand, and climate. Yu, Lin(2015)[9] used partial least squares regression to predict the electricity demand in Shandong Province. After taking into account socio-economic development, industrial structure adjustment, urbanization, and consumer prices, the results showed that the most important factor for the increase in electricity demand is the development of the secondary industry, the increase of the total population, and the growth of GDP.

(III) Decomposition Analysis In the process of the research department on power consumption, scholars have developed various structural decomposition analysis methods to decompose the impact of each element on power demand. When Steenhof(2006)[7] decomposed and analyzed the electricity consumption of China's industrial sectors, it was confirmed that changes in the industrial structure, energy transfer, and improvement in electricity efficiency are the main factors that cause changes in electricity consumption per unit of output. Ma, Shen(2007)[10] used the factor decomposition method to quantitatively study the impact of economic growth, structural changes, and changes in power consumption coefficients on China's power consumption. In addition, Ang$ (2004)^{[11]}$ proposed the specific decomposition step of the logarithmic average Dirichlet index method (LMDI), which decomposes multiple factors at the same time without generating residuals, and is not restricted by zero and negative values. It can be applied to any case, and it is currently a relatively good structural decomposition analysis method.

Chapter2 Analysis of Characteristics of Economic Growth and Electricity Consumption in Anhui Province

(I) Anhui Province Background Information Anhui is a inland province of the People's Republic of China, part of the East China region. Natural resources of Anhui include iron in Ma'anshan, coal in Huainan, and copper in Tongling. There are industries related to these natural resources (e.g. steel industry at Ma'anshan)[11]. Compared to its more prosperous neighbours to the east, Zhejiang Province and Jiangsu Province, Anhui has lagged markedly behind in economic development, with a GDP per capita around half of those two provinces in 2017 rapidly improved from 1/3 of those two provinces in 2010[12]. Anhui Province has a relatively complete variety of minerals and abundant reserves. Over the past few years, coal mines in Anhui have been mainly used for thermal power generation and to send electricity to industrial cities such as Ma'anshan.

(II) Anhui Economic Development This article uses real GDP to measure the annual economic development of Anhui province, and GDP index to calculate real GDP. We use the data of 1990 as the base year, and its GDP Index is 100. The real GDP is calculated as follows:

$$RealGDP_t = NominalGDP_{1990} * \prod_{t=1991}^{T} GDPIndex_t$$

While calculating the GDP of the whole society, I introduced the GDP of each (subdivided) industry, so as to see the contribution of each industry to economic development and energy consumption more clearly. According to the **Classification of China's National Economic Industries**, the Chinese three major industries are classified as follows: The primary industry refers to agriculture, forestry, animal husbandry, and fishery (excluding agriculture, forestry, animal husbandry, and fishery service industries). The secondary industry refers to the mining industry (excluding mining auxiliary activities), manufacturing industry (excluding metal products, machinery and equipment repair industry), electricity, heat, gas and water production and supply industry, and construction industry. The tertiary industry is the service industry, which refers to industries other than the primary industry and the secondary industry.

In general, the main industries in Anhui Province in the past, such as mineral mining, thermal power generation, metal smelting, etc., belonged to the secondary industry, and we will see this situation in the follow-up.

(1) GDP and its composition At first, I plot the real GDP of Anhui Province,

Figure 2_1: Anhui Province Real GDP from 1990−2018

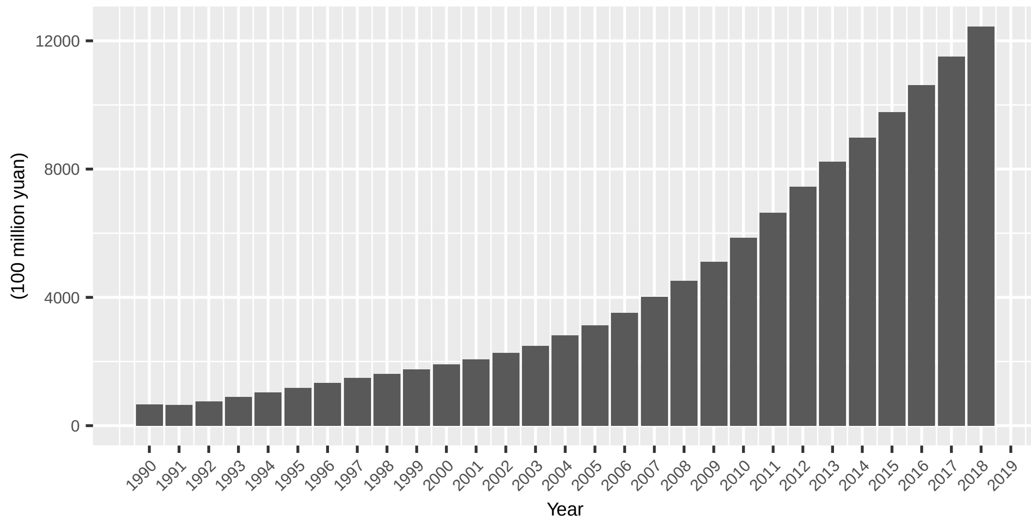
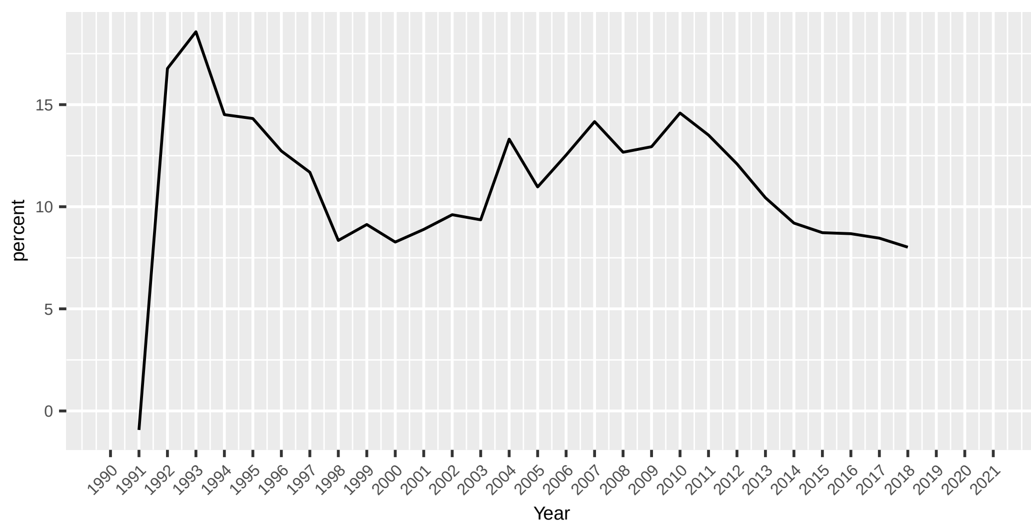


Figure 2_2: Anhui Province Real GDP Growth Rate from 1991−2018



From Figure 2-1 and Figure 2-2, we can be sure that the GDP of Anhui Province has increased several times within 30 years, and at the same time, the economic growth rate has been maintained at around 10% all year round. But compared with the huge population base of Anhui Province and the low GDP level in the past, this is not very rare. On the other hand, we can see that before the 21st century, the GDP of Anhui Province experienced a huge growth (1992-1993), and then its growth rate has been declining. Then from 2000 to 2008, the growth rate returned to the previous high speed state, but after 2010, we can clearly see that the growth rate continued to slow down.

Figure 2_3: Anhui Province Major Industry GDP Value from 1991−2018

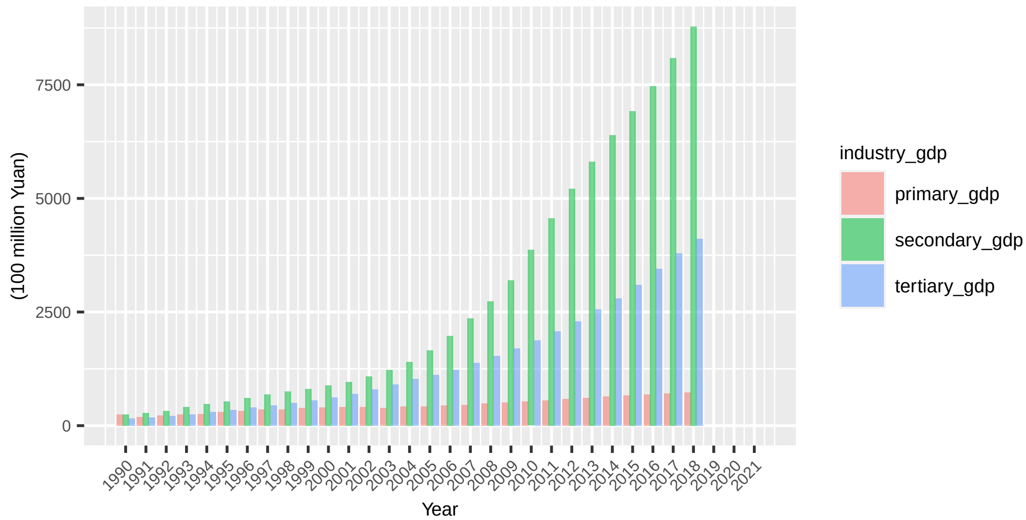
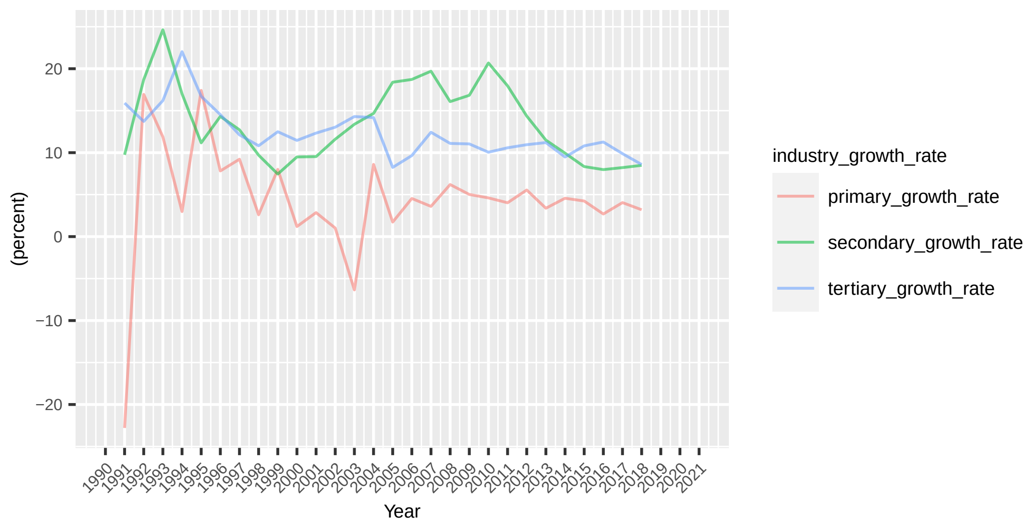


Figure 2_4: Anhui Province Major Industry GDP Growth Rate from 1991−2018



From Figures 2-3 and 2-4, we can see that the main driving force for Anhui's GDP growth is the rapid development of the secondary industry. After 2000, the GDP output value of the secondary industry doubled several times within ten years, and continued to account for the vast majority of GDP. In contrast, the GDP of the primary industry has been maintained at a relatively low range, and the tertiary industry has maintained a stable growth rate until around 2008, but then its growth rate began to accelerate and its output value gradually increased.

At the same time, the GDP growth rate of the secondary industry began to slow down after 2010, which coincided with the previous slowdown in the GDP growth rate of Anhui Province, which shows that Anhui's GDP still relies on the secondary industry. Although the growth rate of the tertiary industry is accelerating, difficulties are still encountered in the process of industrial transformation, and it is impossible to completely get rid of the past economic development model.

(2) Why Electricity? The main research core of this article is the problem of the deviation between electricity use and economic growth. Many readers will wonder why other energy sources, such as natural gas and coal, are not considered. This chapter will try to explain as much as possible that electricity, as an energy source for the development of major industries in Anhui Province, has an important relationship with economic growth.

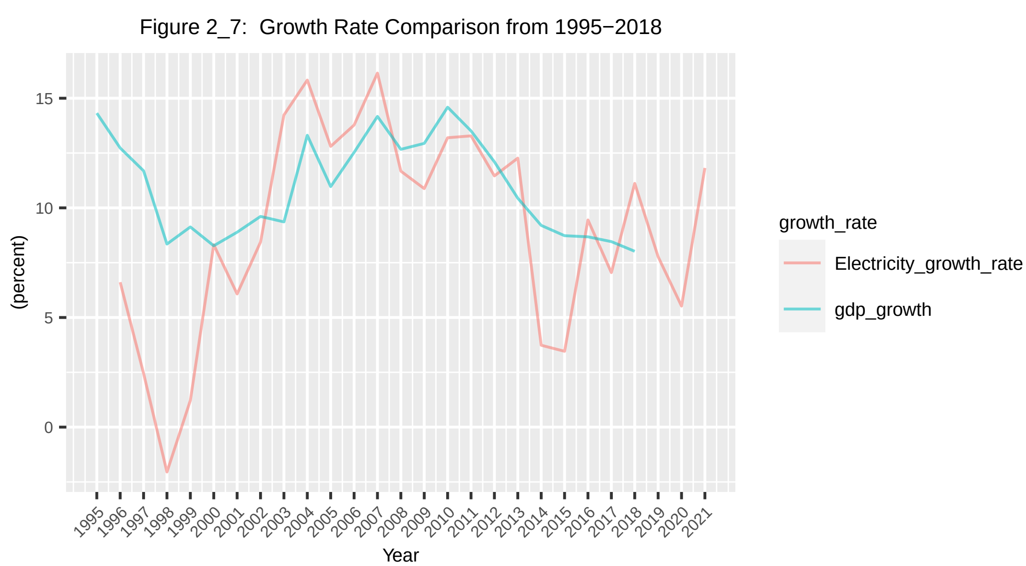
In Table 2-1, I listed the types and quantities of major energy consumption in Anhui Province in recent years. In this table, except natural gas is measured by 100 million cubic meters and electricity is measured by 100 million kilowatt-hours, the remaining fuels are measured by 10,000 tons. This is just a part of the data, the full data is here:

Table 1: Part of Main Energy Consumption in Anhui

	year	Coal	Coke	Crude	Gasoline	Kerosene	Diesel	Fuel_oil	Natural_gas	Electricity
1	1995	4964.57	440.72	277.04	58.38	5.36	108.06	47.02	NA	289
6	2000	5909.39	533.27	345.06	68.54	2.56	142.12	46.91	NA	339
11	2005	8339.64	538.39	414.49	86.41	10.52	210.07	23.88	0.85	582
16	2010	13375.70	910.17	477.57	157.40	8.41	365.75	11.73	12.48	1078
21	2015	15671.32	1164.77	690.59	456.60	13.94	611.80	13.44	34.83	1640
25	2019	16699.74	1161.43	658.92	655.95	16.59	689.10	21.49	59.64	2301

We can see from the table that the main forms of energy consumption in Anhui Province are mainly coal and electricity. As Anhui is a major coal-producing area, Anhui's coal consumption has always been at the forefront of the country. However, the consumption structure of coal has remained stable. According to statistics from the Anhui Provincial Energy Bureau in 2019, more than 60% of coal consumption in the province is used for thermal power generation all year round. This figure will be higher in the past due to energy structure reform measures over the years According to statistics from the Anhui Provincial Energy Bureau in 2019, more than 60% of coal consumption in the province is used for thermal power generation all year round, and directly converted into electricity through pithead power plant and used again. This figure will be higher in the past due to energy structure reform measures over the years[12]. On the other hand, in addition to the fact that the consumption of coal mines has always been higher than that of other fossil fuels, the energy consumption structure of Anhui Province has also been continuously upgraded in recent years, which is confirmed by the rapid growth of natural gas use. In general, we have reasons to believe that the main energy consumption in Anhui Province is electricity, because it occupies an important proportion of the main energy consumption, which is also in line with the consumption characteristics of traditional industries such as metallurgy in Anhui Province.

(3) Electricity Usage



In order to facilitate the comparison of the relationship between electricity consumption and economic development, we use the growth rate of the two to measure. Figure 2-5 clearly shows the relationship between electricity use and GDP growth since 1996. As can be seen from the figure, before 2002, there was a certain deviation between the growth rate of electricity consumption and the growth rate of GDP, but the growth rates of the two have been close to each other. After 2002, the values and trends of the two started to be very similar until 2012. After 2012, we can clearly find that there is a relatively obvious deviation between the two. From 2012 to 2015, the GDP growth rate continued to decline, but the electricity usage increased first and then declined rapidly. After 2017, electricity usage began to fluctuate continuously, while GDP growth rate declined slowly.

(III)The relationship between electricity use and GDP growth From the previous chart analysis, the author wondered why the growth rate of electricity consumption in Anhui Province no longer continued to slow down with the growth rate of GDP? Since 2010, the growth rate of GDP has slowed down, and the growth rate of the advantageous industries (secondary industry) in Anhui Province has also slowed down (see Figure 2-4). But what are the reasons for this deviation in growth rate after 2017? Is it due to the industrial transformation of Anhui Province? After the industrial transformation, the electric power can no longer reflect the development status of the leading industry at this stage? In the context of slowing GDP growth, is economic development and energy demand no longer as closely linked as before?

In the following sections, this paper will conduct characteristic analysis and quantitative analysis of economic growth and electricity consumption in an attempt to explain these raised questions.

Chapter3 Research on the Mechanism of Electricity Consumption Deviation from Economic Growth

(I)Indicator introduction We first introduce some variables, they are Electricity consumption elasticity coefficient (denoted by E), Electricity consumption per unit output value, They will be used multiple times later.

(1) Electricity consumption elasticity coefficient

The electricity consumption elasticity coefficient (denoted by E) is the ratio of the growth rate of electricity usage to that of GDP in a certain period, which can be used to measure the relationship between power consumption and economic development. It is defined in Equation 3.1, where Y represents GDP in year t and EC represents electricity consumption in year t

$$E_t = \frac{(\Delta EC_t/EC_t)}{(\Delta Y_t/Y_t)} \qquad \text{(eq 3.1)}$$

Its economic meaning is that when E is less than 1, equal to 1, or greater than 1, it reflects that the growth rate of power consumption is less than, equal to, and greater than the regional economic growth rate, respectively.

(2) Electricity consumption per unit output value Electricity consumption per unit of output value (denoted by EP) refers to the electric energy consumed per unit of real GDP(denoted by Y). It reflects the power utilization efficiency of a region, and the unit is kWh/yuan. The lower the electricity consumption per unit of output value, the higher the electricity efficiency. It is defined by Equation 3.2

$$EP_t = \frac{EC_t}{Y_t} \qquad \text{(eq 3.2)}$$

(II) Factors affecting the growth rate of electricity consumption

(1) The growth rate of electricity consumption In Equation 3.3, we introduce the growth rate of electricity consumption (denoted as g_t^{EC}), and the growth rate of GDP (denoted as g_t^{y} for year t)to illustrate the relationship between the growth rate of electricity consumption, the growth rate of electricity consumption per unit of output value(denoted as g_t^{EP}), and the growth rate of GDP. Equation 3.3 shows that the GDP growth rate and the growth rate of electricity consumption per unit of output value jointly determine the size of the growth rate of electricity consumption.

$$\begin{aligned} g_t^{EC} &= \frac{EC_t - EC_{t-1}}{EC_{t-1}} = \frac{Y_t * EP_t - Y_{t-1} * EP_{t-1}}{Y_{t-1} * EP_{t-1}} \\ &= \frac{Y_{t-1} * (1 + g_t^y) * EP_{t-1} * (1 + g_t^{EP}) - Y_{t-1} * EP_{t-1}}{Y_{t-1} * EP_{t-1}} \\ &= (1 + g_t^y) * (1 + g_t^{EP}) - 1 \\ &= g_t^y + g_t^{EP} + g_t^y * g_t^{EP} \end{aligned} \tag{eq 3.3}$$

Combine equation 3.1, We can derive equation 3.4 that:

$$\begin{aligned} E_t &= \frac{(\Delta EC_t/EC_t)}{(\Delta Y_t/Y_t)} = \frac{g_t^{EC}}{g_t^y} \\ &= 1 + g_t^{EP} + \frac{g_t^{EP}}{g_t^y} \end{aligned} \tag{eq 3.4}$$

Equation 3.4 describes the quantity relationship between the elasticity coefficient of electricity consumption (E_t), the growth rate of electricity consumption (g_t^{EP}), and the growth rate of GDP (g_t^Y). If the electricity consumption per unit of output value remains unchanged ($\Delta EP_t = 0$) and the rate of increase in electricity consumption per unit of output value is zero ($g_t^{EP} = 0$), then the rate of increase in electricity consumption is equal to the rate of increase in GDP ($g_t^{EC} = g_t^y$), and the elasticity coefficient is 1 ($E_t = 1$).

Under normal circumstances, when g_t^Y is greater than 0, real GDP keeps increasing, but as g_t^{EP} decreases to a negative number, g_t^{EC} will appear to be less than g_t^Y. When g_t^{EP} is negative and very small, g_t^{EC} will deviate downward from g_t^Y. When enough deviation occurs, the two may have opposite trends, as shown in Figure 2-7. This explanation is of great significance to our subsequent research, and it is the core content of subsequent research.

(2) Electricity consumption per unit output value The electricity consumption per unit of output value is a measure of the intensity of electricity consumption, which reflects the efficiency of electricity utilization in the process of economic growth. The lower the electricity consumption per unit of output value, the higher the electricity usage efficiency, and vice versa, the lower the electricity usage efficiency. When the electricity consumption per unit of output value shows a downward trend, the electricity elasticity coefficient is less than 1, otherwise it is greater than 1.

Regarding the factors that affect the change of electricity consumption per unit of output value, Steenhof (2006)[12] used the structural decomposition method to analyze the electricity consumption of China's industrial sector and found that, changes in industrial structure, energy transfer and the improvement of electricity efficiency are the main factors that change the electricity consumption per unit of output value.

Let EC_i represent the electricity consumption of the ith industry sector, and Y_i represent the output value of the ith industry sector, then the electricity consumption per unit output value of the tth year EP_t can be expressed as:

$$EP_t = \frac{EC_t}{Y_t} = \frac{\sum_{i=1}^{n} EC_{it}}{Y_t} = \frac{\sum_{i=1}^{n} Y_{it} * EP_{it}}{Y_t} = \sum_{i=1}^{n} EP_{it} * S_{it} \tag{eq 3.5}$$

S_{it} represents the proportion of the output value of the ith industrial sector in the ith year, which is a variable to measure the industrial structure; EP_{it} represents the electricity consumption per unit output value of the ith industrial sector in the tth year.

Equation (3.5) shows that the electricity consumption per unit output value is the weighted average of the electricity consumption per unit output value of the industrial sector, and the weight is the proportion of the output value of the industrial sector. Therefore, the electricity consumption per unit output value is jointly affected by the electricity consumption per unit output value of the industrial sector and the output value of the industrial sector, that is, the industrial structure. The author refers to the influence of electricity consumption per unit output value of industrial sectors as efficiency factors, and the proportion of industrial sector output value as structural factors.

Changes in the industrial structure affect the electricity consumption per unit of output value and change the growth rate of electricity consumption, thereby causing the growth rate of electricity consumption to deviate from the GDP growth rate. On the other hand, the size of the electricity consumption per unit output value of the industrial sector directly affects the size of the electricity consumption per unit output value of the whole industry.

Chapter4 Econometric Model Method Analysis

In this chapter, I analyze the relationship between the output value of each industry and electricity consumption. Then, according to its connection, the time series data is used to build a model to estimate the specific influence degree of electricity consumption growth rate deviating from GDP growth rate caused by changes in industrial structure.

(I) The relationship between GDP and energy

(1) GDP and various energy sources relation First of all, this paper analyzes the correlation between GDP and various energy sources. For the convenience of comparison, this paper focuses on analyzing the relationship between their respective growth rates. Although some values are missing, it does not affect the final comparison result.

Table 2: energy growth rate correlation with gdp growth rate

	year	Coal	Coke	Crude	Gasoline	Kerosene	Diesel	Fuel_oil	Natural_gas	Electricity	gdp_growth
year	1.00	-0.22	-0.07	0.03	0.50	-0.11	-0.04	0.22	-0.65	0.22	-0.20
Coal	-0.22	1.00	0.22	0.03	-0.12	0.14	0.33	-0.27	0.27	0.50	0.34
Coke	-0.07	0.22	1.00	-0.31	0.26	0.06	0.15	-0.09	0.02	0.18	0.30
Crude	0.03	0.03	-0.31	1.00	-0.11	-0.12	-0.13	-0.40	-0.10	0.09	-0.01
Gasoline	0.50	-0.12	0.26	-0.11	1.00	-0.01	0.40	0.08	-0.19	0.16	0.07
Kerosene	-0.11	0.14	0.06	-0.12	-0.01	1.00	0.05	0.17	0.25	-0.12	-0.28
Diesel	-0.04	0.33	0.15	-0.13	0.40	0.05	1.00	-0.23	0.14	0.41	0.47
Fuel_oil	0.22	-0.27	-0.09	-0.40	0.08	0.17	-0.23	1.00	-0.16	-0.41	-0.51
Natural_gas	-0.65	0.27	0.02	-0.10	-0.19	0.25	0.14	-0.16	1.00	0.37	0.17
Electricity	0.22	0.50	0.18	0.09	0.16	-0.12	0.41	-0.41	0.37	1.00	0.58
gdp_growth	-0.20	0.34	0.30	-0.01	0.07	-0.28	0.47	-0.51	0.17	0.58	1.00

Table 2 shows the correlation matrix between various energy sources and GDP growth rates. From this, we can see that in terms of growth rate, electricity, GDP and coal growth have a very large positive correlation coefficient (0.58, 0.5 respectively), which is also in line with the previous discussion, 60% of coal is used for thermal power generation. On the other hand, as we can see from the last column, in terms of growth rate, GDP has the highest correlation coefficient with electricity use (0.58), followed by Diesel, coal (0.47, 0.34 respectively), and Fuel_oil has the highest correlation coefficient (0.58) Large negative correlation (-0.51). It is worth mentioning that, as can be seen from Table 1, the consumption of coal is several times that of other fossil fuels calculated in tons. Therefore, we have reason to believe that electricity still has a great correlation with GDP. On the other hand, other energy sources are gradually replacing coal as the driving force for GDP growth.

(2) Industrial and residential electricity. Figure 4-1 illustrates the proportion of industrial electricity and residential electricity in total electricity consumption since records began. Industry includes primary, secondary, and tertiary industries. It can be seen that industrial electricity has always accounted for the vast majority of all electricity consumption. Combined with Table 3, in terms of growth rate, we have listed the correlation matrix of electricity consumption in the whole society, industrial electricity consumption, and GDP.

It can be seen that the correlation coefficient between the growth rate of gdp and the growth rate of overall electricity use is the highest (0.58), and the correlation coefficient with the growth rate of industrial electricity consumption is slightly lower (0.56). In contrast, the correlation coefficient of the growth rate of residential electricity consumption is only (0.36)

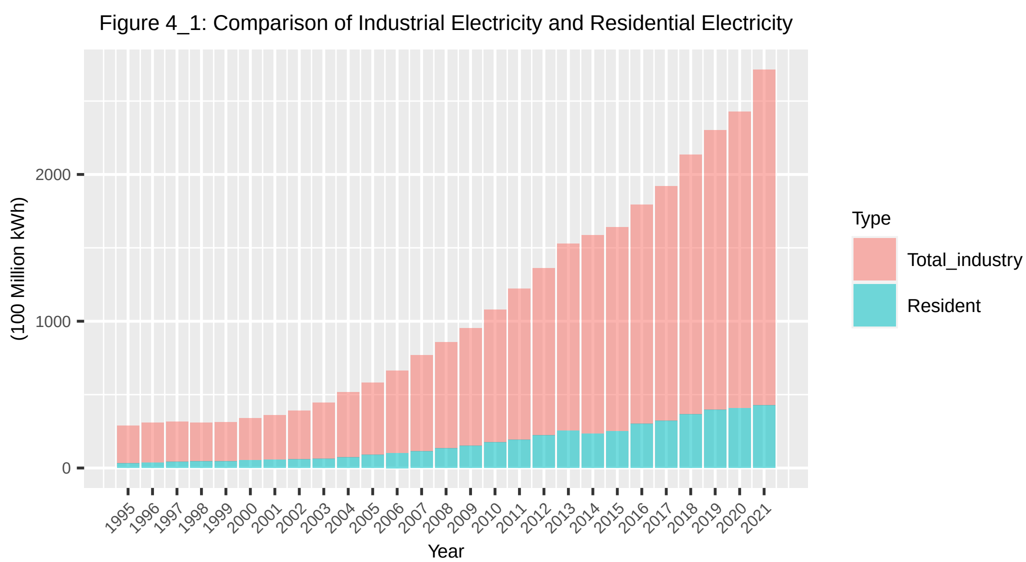


Table 3: electricity growth rate correlation with gdp growth rate

	year	Total	Total_industry	Resident	gdp_growth
year	1.00	0.22	0.26	-0.14	-0.20
Total	0.22	1.00	0.98	0.47	0.58
Total_industry	0.26	0.98	1.00	0.28	0.56
Resident	-0.14	0.47	0.28	1.00	0.36
gdp_growth	-0.20	0.58	0.56	0.36	1.00

Because the growth rate of industrial electricity consumption is more relevant to GDP growth, we will mainly use the data of the growth rate of industrial electricity consumption, supplemented by the data of the overall electricity consumption growth rate.

(II) Econometric Model Analysis This section will test the relationship between the following variables and the growth rate of electricity consumption. g_t^{EC} represents the growth rate of electricity consumption in the whole industry, which is used to represent the change in electricity consumption for industry; g_t^y represents the increase in GDP Growth rate, which represents changes in economic growth. K_{it} represents the ratio of the output value of the i industry to the increase in GDP of the year, which is used to measure the changes in the industrial structure. EP_i represents the Electricity consumption per unit output value of the ith industry, $g_t^{EP_i}$ represents its rate, which reflects the change of electric energy utilization efficiency.

From this we can know that, $K_{1t} + K_{2t} + K_{3_t} = 1$, in order to avoid perfect collinearity in the regression, we only list the proportion of the secondary industry K_{2t} and the tertiary industry K_{3t}, because it can be seen from Figure 2-3 that the proportion of the primary industry is less and slower than other two industries.

Since the above variables are time series data, in order to avoid problems such as pseudo-regression, OLS cannot be used directly for regression. In order to avoid the pseudo-regression problem, this paper uses the cointegration test method to test the unit root of the residual of the regression equation, also known as the Engle-Granger test method. This method requires that each variable is integrated of order 1 (also be written as $I(1)$), and then performs regression based on OLS. After the regression, the residual sequence estimated by the model is obtained, and then use unit root test on the residual sequence to determine whether the residual sequence is stable or integrated of order 0. If the residual sequence is stable (also be written as $I(0)$), each variable in the regression equation has a co-integration relationship, the equation setting is reasonable. Then the estimated of independent variables' coefficients under OLS are "super-consistent" estimator, converge to true result much faster than usual asymptotics.

(1) Stationarity Test In this paper, We first perform a stationarity test on the previously mentioned variables (g_t^{EC}, g_t^y, K_{it}). Since many economic and financial time series have a more complicated dynamiv structure than is captured by a simple AR(1) model, so we choose *Augmented Dickey-Fuller (ADF)Test*, which is invented by Said and Dickey (1894)[14], they augment the basic autoregressive unit root test to accommodate general ARMA models, with a wider applicability.

It is further worth noting that the critical value table for judging whether the residual series is stationary is different from the ADF critical value table. This is because the basic principle of using the ordinary least squares method is to minimize the residual sum of squares, so the residual sequence generated by the regression equation is small. If the ADF critical value table is still used for judgment, it will lead to the probability ratio of rejecting the null hypothesis. The real situation is large, so the AEG critical value table smaller than the ADF threshold value should be used for judgment. The AEG critical value table was derived by Mackinnon in 1991 through simulation experiments[16].

Table 4: ADF test report (null hypothesis: not stationary)

variable	ADF_statistics	P_value
industrial_electricity_growth_rate	-2.3058	0.4559
gdp_growth_rate	-1.3832	0.8073
K_2	-1.1795	0.8849
K_3	-2.2549	0.4753
EP_1	-1.5255	0.7532
EP_2	-5.7295	0.0100
EP_3	-1.1139	0.9038

Table 5: First Difference ADF test report (null hypothesis: not stationary)

variable	ADF_statistics_diff	P_value_diff
industrial_electricity_growth_rate	-5.7200	0.01000

variable	ADF_statistics_diff	P_value_diff
gdp_growth_rate	-2.8486	0.24910
K_2	-3.7493	0.03934
K_3	-2.2549	0.08979
EP_1	-4.2262	0.01537
EP_2	-3.3373	0.08648
EP_3	-2.7046	0.30400

Table 4 and Table 5 show the ADF statistics of the variables. where **K_2** and **K_3** represent K_{2t} and K_{3t} respectively, where **EP_1** , **EP_2**, **EP_3** represent EP_{1t}, EP_{2t}, EP_{3t} respectively. As can be seen from the table, the first-order difference sequence of almost all variables rejects the null hypothesis that there is a unit root at the 10% significance level, except for gdp Growth rate, which is also the focus of our later research. At the same time, we can also show that these three sequences are all first-order single integer sequences. Therefore, an EG cointegration test can be performed based on OLS regression.

(2) Model building After confirming that the above variables are first-order single integration, the regression equation of the growth rate of electricity consumption in the whole industry, the growth rate of GDP and the proportion of industrial added value to GDP added value is established. It is used to estimate the specific impact degree of electricity consumption growth rate deviating from GDP growth rate caused by changes in industrial structure.

The result I get is as table 6.

Before testing the regression results, we first need to perform a unit root test on the residuals to judge whether our cointegration regression is credible.

Table 6: ADF test for linear regression's residuals

variable	ADF_statistics_residual	P_value_residual
linear_result$residuals	-3.4003	0.078

Table 7: model regression result (Adjusted R-squared: 0.7164)

Predictor	B	SE	t	p
Intercept	-65.43	19.957	-3.28	0.005
gdp_growth_rate	2.02	0.534	3.78	0.002
K_2	0.24	0.098	2.46	0.026
K_3	0.72	0.163	4.42	<0.001
EP_1	-168.24	158.058	-1.06	0.303
EP_2	46.36	53.065	0.87	0.395
EP_3	120.63	121.180	1.00	0.334

Table 6 shows the results of the unit root test of the residuals of the regression results. The results show that the residuals are stationary series, which shows that we can believe that independent variables and the dependent variable are cointegrated.

According to the results in Table 7, the growth rate of industrial electricity consumption (g_t^{EC}) has a positive correlation with the growth rate of gdp (g_t^y). When GDP growth rate increase by 1 percent, the growth rate of electricity consumption will increase by 2.02 percent.

On the other hand, g_t^{EC} is indeed affected by changes in the industrial structure. When the proportion of the increase in the secondary industry' value to the increase in total GDP(K_{2t}) increases by one percent, g_t^{EC}

will increase by 0.24 percent. In addition, for tertiary industry, that ratio(K_{3t}) increases by 1 percent will lead to an increase of 0.72 percent in g_t^{EC}. It can be seen from this that with the development of the tertiary industry, although the secondary industry still occupies a large proportion in GDP, its role in promoting the growth rate of industrial electricity consumption is not as good as that of the tertiary industry. After the transformation of the industrial structure, the proportion of the tertiary industry in the increased GDP(K_{2t}) in Anhui Province has increased (Figure 2_3), and the tertiary industry has become the driving force for the growth rate of electricity consumption. This is also in line with the previous inference that the reduction of the secondary industry is an important reason for the change in the growth rate of industrial electricity consumption.

In the regression, except for the electricity consumption per unit output value of the primary industry, the electricity consumption coefficient per unit output value of other industries is not significant. In addition, adjusted R-Squared is only 0.72, indicating that our model still needs to be improved.

(3) Adjust the model In order to improve the goodness of fit of the model and enhance the explanatory power of the model, according to the previous analysis of the factors affecting the growth rate of electricity consumption, I choose to use the growth rate of electricity consumption per unit output value to replace the electricity consumption per unit output value in the original model. , we repeat the same steps as before and get the result as follows.

Table 8: ADF test report (null hypothesis: not stationary)

variable_2	ADF_statistics_2	P_value_2
EP_1_growth	-1.5255	0.7532
EP_2_growth	-5.7295	0.0100
EP_3_growth	-1.1139	0.9038

Table 9: First Difference ADF test report (null hypothesis: not stationary)

variable_2	ADF_statistics_diff_2	P_value_diff_2
EP_1_growth	-4.2262	0.01537
EP_2_growth	-3.3373	0.08648
EP_3_growth	-2.7046	0.30400

In tables 7 and 8, **EP_1_growth**, **EP_2_growth**, **EP_3_growth** represent $g_t^{EP_1}$, $g_t^{EP_2}$, $g_t^{EP_3}$ respectively. Tables 7 and 8 show that except for the growth rate of electricity consumption per unit of output in the tertiary industry, these variables are stable (within the conventional confidence interval) after the first-order difference.

From Table 9, it can be seen that the residuals are stationary, which means that we can trust the results of the cointegration model. According to the results in Table 10, it is not difficult to see that the parameters of each part have significantly improved, and the Adjusted R-squared has increased to 0.9683, which indicates that the model can better describe the explained variables.

Table 10: ADF test for adjusted model's residuals

variable_3	ADF_statistics_residual_3	P_value_residual_3
Adjusted_linear_result$residuals	-3.5705	0.05409

Table 11: adjusted model regression result (Adjusted R-squared: 0.9683)

Predictor	B	SE	t	p
Intercept	-17.79	5.263	-3.38	0.004
gdp_growth_rate	1.41	0.140	10.07	<0.001
secondary_growth_percent	0.14	0.027	5.20	<0.001
tertiary_growth_percent	0.15	0.071	2.08	0.054
EP_primary_rate	-0.02	0.018	-1.22	0.240
EP_secondary_rate	0.87	0.083	10.42	<0.001
EP_tertiary_rate	0.08	0.038	2.03	0.060

From the results, we can derive the equation of the regression model:

$$\hat{g}_t^{EC} = 1.41g_t^y + 0.14K_{2t} + 0.15K_{3t} - 0.02g_t^{EP_1} + 0.87g_t^{EP_2} + 0.08g_t^{EP_3} - 17.79 \qquad \text{(eq 4.1)}$$

The adjusted model still shows that changes in GDP growth rate have a significant impact on the growth rate of electricity consumption, Whenever g_t^y increases by 1 percent, g_t^{EC} increases by 1.4 percent. Especially for the secondary industry, when the proportion of the increase in the output value of the secondary industry to the increase in total GDP increases by one percentage point, the growth rate of industrial electricity consumption will increase by 1.41 percent. However, in the adjusted model, K_{2t} and K_{3t} have similar effects on g_t^{EC} with coefficients of 0.14 and 0.15, respectively. This shows that under the adjusted model, changes in industrial structure have a similar impact on the growth rate of industrial electricity consumption, in terms of secondary and tertiary industry.

In terms of industrial electricity efficiency, $g_t^{EP_2}$ has the largest coefficient (0.86), far exceeding $g_t^{EP_3}$ (0.08). On the one hand, this shows that the improvement of the electricity efficiency of the secondary industry will greatly increase the growth rate of electricity consumption and stimulate the growth of electricity consumption. On the other hand, the electricity consumption efficiency of the growth rate of the tertiary industry has a limited impact on the growth rate of electricity consumption, indicating that the increase in the output value of the tertiary industry will not use more electricity.

It is worth mentioning that the coefficient of $g_t^{EP_1}$ is negative. This shows that when the electricity efficiency of the primary industry is improved, it can delay the growth rate of electricity consumption and save more energy.

(III) Conclusion According to the econometric method, this chapter establishes a linear regression model by proving that the growth rate of electricity consumption has a cointegration relationship with other variables.

Through the linear model, we can know that the growth rate of gdp still has a significant positive effect on the growth rate of electricity consumption, which is also the core issue we have been discussing, the relationship between g_t^{EC} and g_t^y deviation. We will continue the analysis in the next chapter.

The change of industrial structure has a positive effect on the growth rate of electricity consumption. In the increased GDP, with the increase in the proportion of the secondary industry (K_{2t}) and the tertiary industry (K_{3t}) , g_t^{EC} is also increasing. Overall, K_{3t} will lead to a larger impact on g_t^{EC} than K_{2t}, when the proportion of the tertiary industry increases, it will cause the industrial electricity consumption to grow faster than other industries. Combined with the proportion of tertiary industry output value in recent years (K_{3t}) increases, we can predict that the industrial structure will have a lasting impact on g_t^{EC}

In terms of electricity consumption per unit of output value, the secondary industry has a great impact on g_t^{EC}, which shows that the secondary industry is the main driving force for the growth of electricity, and it also shows that: as the proportion of the secondary industry in GDP declines , the connection between g_t^{EC}

and g_t^y will not be very close. Conversely, $g_t^{EP_1}$, $g_t^{EP_1}$ have less impact on g_t^{EC}. Although the output value of the tertiary industry is increasing, the improvement of their power utilization efficiency has a relatively limited impact on power consumption.

Overall, according to our regression model, the growth rate of gdp has a strong relationship with the growth rate of electricity use. In terms of the impact of changes in industrial structure K_{it}, the increase in the proportion of the tertiary industry has a greater impact on electricity consumption than the secondary industry. In terms of electricity consumption per unit output value EP_{it}, the increase in the secondary industry will greatly increase the electricity consumption, which is far greater than that of the tertiary and primary industries. GDP growth rate, changes in industrial structure, and electricity consumption per unit of output value jointly determine the growth rate of electricity consumption. The secondary and tertiary industries, which account for the vast majority of GDP, have a greater impact in different aspects (EP and industry structure change respectively). In order to see more clearly what causes the deviation of g_t^{EC} and g_t^y, we will use the *Logarithmic Mean Divisia Index Method (LMDI)* to decompose the electricity consumption, which will be covered in the next chapter.

Chapter5 Research on the deviation of Anhui's power consumption from economic growth based on the LMDI method

In order to quantify the relationship between electricity consumption and economic growth more accurately, and to better explain the deviation of electricity consumption from economic growth, I use *Logarithmic Mean Divisia Index Method (LMDI)* to analyze the electricity consumption of the whole industry in Anhui Province. By decomposing industrial electricity consumption, the reader can see how much the output effect, intensity effect, and structural change effect contribute to the deviation.

(I) Logarithmic Mean Divisia Index Method (LMDI)

(1) Introduction of LMDI The LMDI method was proposed by Ang.B.W et al. in 2004, and is the mainstream analysis method in the field of exponential decomposition in recent years. This method decomposes the change of the explained variable into the sum of the changes of the independent explanatory variables that cause its change by differentiating the time (t), so as to calculate the contribution of the change of the explanatory variable to the change of the explained variable. The biggest advantage of this method is that the influence of cross terms can be completely decomposed, and there will be no unexplained residual terms, and the solution to the problem of zero and negative values in the decomposition process is given. This allows the LMDI method to be used in a variety of situations.

(2) LMDI decomposition mechanism First, we use the method of the KAYA identity (1993)[17] to decompose the overall electricity consumption, and the result is as shown in equation 5.1. Here EC_t, EC_{it} represent the electricity consumption of the whole industry in the year, and the electricity consumption of the i industry respectively, Y_t and Y_it represent the total GDP and the i industry GDP respectively.

$$EC_t = \sum_{i=1}^{n} EC_{it} = \sum_{i=1}^{n} \frac{EC_{it}}{Y_{it}} * \frac{Y_{it}}{Y_t} * Y_t \qquad \text{(eq 5.1)}$$

From equation 5.1 we can derive equation 5.2 with EP_{it}, K_{it}, from Equation 5.1, we can deduce Equation 5.2 with EP_{it}, S_{it}, EP_{it} measures the electricity efficiency of the i-th industry, S_{it} represents the proportion of the output value of the i-th industry in GDP,measures the change of the industrial structure, Y measures the state of economic development.

$$EC_t = \sum_{i=1}^{n} EP_{it} * S_{it} * Y_t \qquad \text{(eq 5.2)}$$

According to the method proposed by Ang B. W, the change in power consumption in the base period and the current period is:

$$\Delta EC_t = EC_t - EC_0 = \Delta EC_t^{EP} + \Delta EC_t^{S} + \Delta EC_t^{Y} \qquad \text{(eq 5.3)}$$

ΔEC_t is the amount of change in power consumption, based on the comparison between the base period and the t period. ΔEC_t^{Ep} is the amount of in electricity consumption per unit output value of the i industry, also known as **intensity effect**.When it is negative, it means that the industry can save electricity after the efficiency of electricity consumption is improved, and it is the opposite when it is positive. ΔEC_t^S is the amount of change in the proportion of the ith industry in the total GDP, also known as **structure effect**. When it is negative, it means that the proportion of the industry GDP to total GDP increases can save electricity, and it is the opposite when it is positive. ΔEC_t^Y is the amount of change in GDP, also known as **output effect**. Typically, it is a positive number because as GDP grows, electricity use will inevitably grow. It is also a major source of growth in electricity use.

(3) Derivation of the effect formula Since that there are several forms of LMDI, the decomposition method I chose here is as follows:

Given an economic variable y_t, y_t can be represented by the product of n factors x_1 $x_2 \ldots x_n$

$$y_t = \prod_{i=1}^{n} x_{i,t} \tag{eq 5.4}$$

Among them, $X_{i,0}$, $X_{i,1}$ represent the value of the base period and the current period of the explanatory variable X_i, respectively. According to the LMDI method proposed by Ang et al., the change in y can be decomposed into:

$$\Delta y = \sum_{i=1}^{n} \frac{\Delta y}{\Delta(\ln y)} \ln \frac{x_{i,1}}{x_{i,0}} \tag{eq 5.5}$$

According to Equation 5.5, we can derive ΔEC_t^{Ep}, ΔEC_t^S, ΔEC_t^Y as follow:

$$\Delta EC_t^{EP} = \sum_{i=1}^{n} W_i * \ln \frac{EP_{i,t}}{EP_{i,0}} \tag{eq 5.6}$$

$$\Delta EC_t^S = \sum_{i=1}^{n} W_i * \ln \frac{S_{i,t}}{S_{i,0}} \tag{eq 5.7}$$

$$\Delta EC_t^Y = \sum_{i=1}^{n} W_i * \ln \frac{Y_t}{Y_0} \tag{eq 5.8}$$

$$W_i = \frac{EP_{i,t} * S_{i,t} * Y_t - EP_{i,0} * S_{i,0} * Y_0}{\ln(EP_{i,t} * S_{i,t} * Y_t) - \ln(EP_{i,0} * S_{i,0} * Y_0)} \tag{eq 5.9}$$

This article uses these symbols to represent the degree of contribution of different effects:

$$C_{EP_t} = \frac{\Delta EC_t^{EP}}{\Delta EC_t} \tag{eq 5.10}$$

$$C_{S_t} = \frac{\Delta EC_t^S}{\Delta EC_t} \tag{eq 5.11}$$

$$C_{Y_t} = \frac{\Delta EC_t^Y}{\Delta EC_t} \tag{eq 5.12}$$

It can be seen from above equations that $C_{EP_{i,t}} + C_{S_{i,t}} + C_{Y_t} = 1$. Later, we will use the last year as the base year to calculate the indicators listed above. In order to facilitate the reader to compare the multiple relationship, the percentage is not used for $C_{EP_{i,t}}$ $C_{S_{i,t}}$, C_{Y_t}, but the ratio is directly displayed.

(II) Results of Decomposition Based on LMDI Method In this chapter, in order to reflect the impact of economic scale and output on electricity consumption, the whole industrial electricity consumption is used as the explained variable. Because residential electricity consumption is far less than industrial electricity consumption, and residential electricity consumption generally has no economic output, only the electricity consumption of the whole industry is considered.

This chapter analyzes the electricity consumption of the whole industry, the primary industry, the secondary industry, and the tertiary industry successively, and draws the statistical results into a table for readers to view.

(1) Decomposition of industrial electricity consumption in Anhui Province

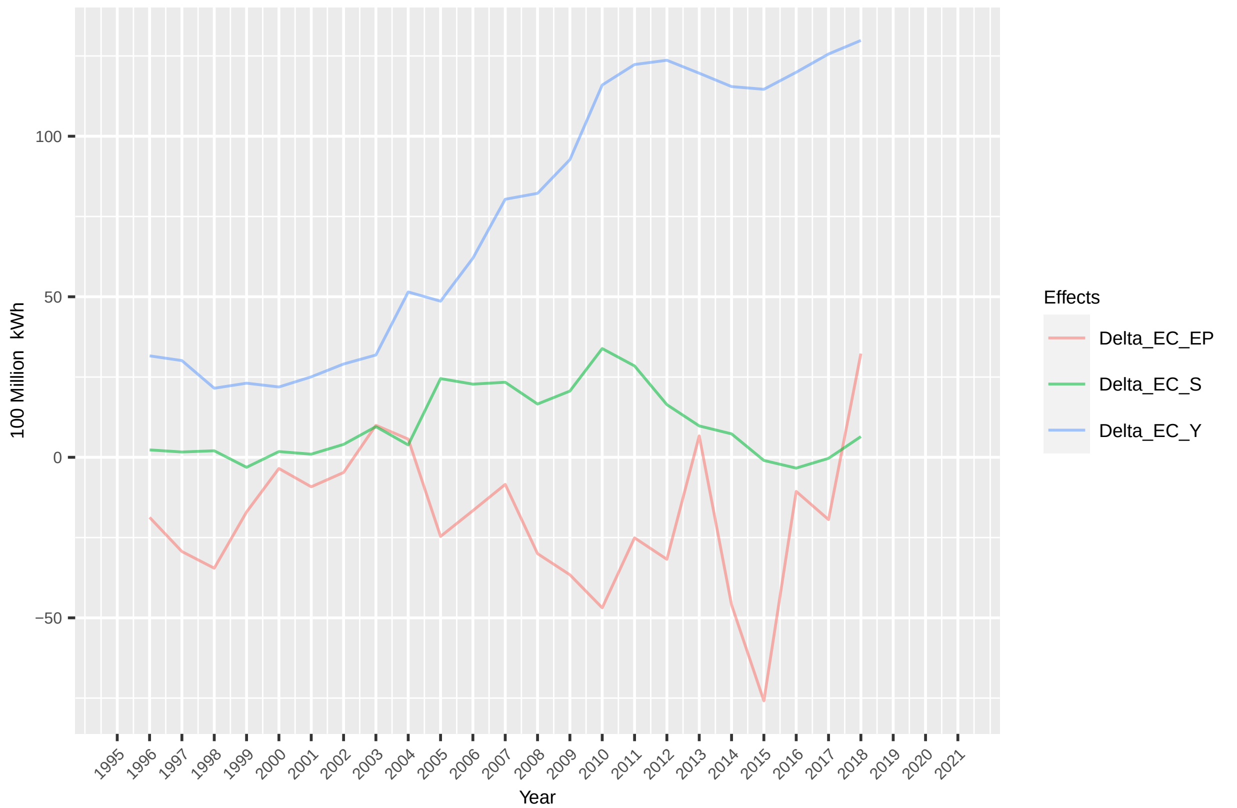
Table 12: LMDI decomposition analysis result

year	Total_EC	real_diff	Delta_EC_EP	C_EP	Delta_EC_S	C_S	Delta_EC_Y	C_Y
1995	NA	NA	NA	NA	NA	NA	NA	NA
1996	15.18	15.18	-18.71	-1.23	2.30	0.15	31.59	2.08
1997	2.44	2.44	-29.34	-12.03	1.66	0.68	30.12	12.34
1998	-11.00	-10.70	-34.55	3.14	2.04	-0.19	21.51	-1.96
1999	2.94	2.75	-17.03	-5.79	-3.12	-1.06	23.08	7.85
2000	20.20	20.09	-3.49	-0.17	1.79	0.09	21.90	1.08
2001	16.85	16.69	-9.18	-0.55	0.98	0.06	25.06	1.49
2002	28.34	29.30	-4.73	-0.17	4.02	0.14	29.05	1.03
2003	51.37	50.57	9.96	0.19	9.55	0.19	31.86	0.62
2004	61.01	61.01	5.67	0.09	3.85	0.06	51.49	0.84
2005	48.49	48.49	-24.64	-0.51	24.51	0.51	48.62	1.00
2006	68.19	68.19	-16.61	-0.24	22.79	0.33	62.01	0.91
2007	95.30	95.30	-8.44	-0.09	23.37	0.25	80.38	0.84
2008	68.81	68.81	-30.01	-0.44	16.60	0.24	82.22	1.19
2009	76.75	76.75	-36.60	-0.48	20.63	0.27	92.71	1.21
2010	102.94	102.94	-46.88	-0.46	33.87	0.33	115.96	1.13
2011	125.70	125.70	-25.09	-0.20	28.45	0.23	122.34	0.97
2012	108.29	108.28	-31.78	-0.29	16.40	0.15	123.67	1.14
2013	136.07	136.08	6.67	0.05	9.77	0.07	119.63	0.88
2014	76.83	76.83	-45.94	-0.60	7.30	0.10	115.47	1.50
2015	37.78	37.78	-75.86	-2.01	-0.98	-0.03	114.62	3.03
2016	105.92	105.92	-10.64	-0.10	-3.37	-0.03	119.92	1.13
2017	105.89	105.89	-19.40	-0.18	-0.32	0.00	125.62	1.19
2018	168.58	168.58	32.30	0.19	6.45	0.04	129.83	0.77
2019	NA	135.90	NA	NA	NA	NA	NA	NA
2020	NA	114.86	NA	NA	NA	NA	NA	NA
2021	NA	268.79	NA	NA	NA	NA	NA	NA

Table 12 shows the results obtained after LMDI decomposition. **Total_EC** is the estimated total power added value under the LMDI method, **real_diff** is the real power added value. Comparing these two columns, we can see that the gap between the overall predicted value and the true value is small, and we can believe the results of the LMDI decomposition. **Delta_EC_EP**, **Delta_EC_S**, **Delta_EC_Y** represent ΔEC_t^{EP}, ΔEC_t^{S}, ΔEC_t^{Y} respectively, **C_EP**, **C_S**, **C_Y** represent C_{EP_t}, C_{S_t} and C_{Y_t}.

As can be seen from Table 12, the industrial electricity consumption in Anhui Province has shown a rapid upward trend. After 2000, the annual increase has generally increased, but this number has decreased a lot from 2013 to 2017, and then it has increased rapidly. It was from 2013 that the growth rate of GDP in Anhui Province began to decline, the proportion of the secondary industry in the output value decreased, and the proportion of the output value of the tertiary industry increased. At the same time, the growth rate of GDP and the growth rate of electricity consumption began to deviate greatly.

Figure 5_1: different effects on industrial electricity consumption

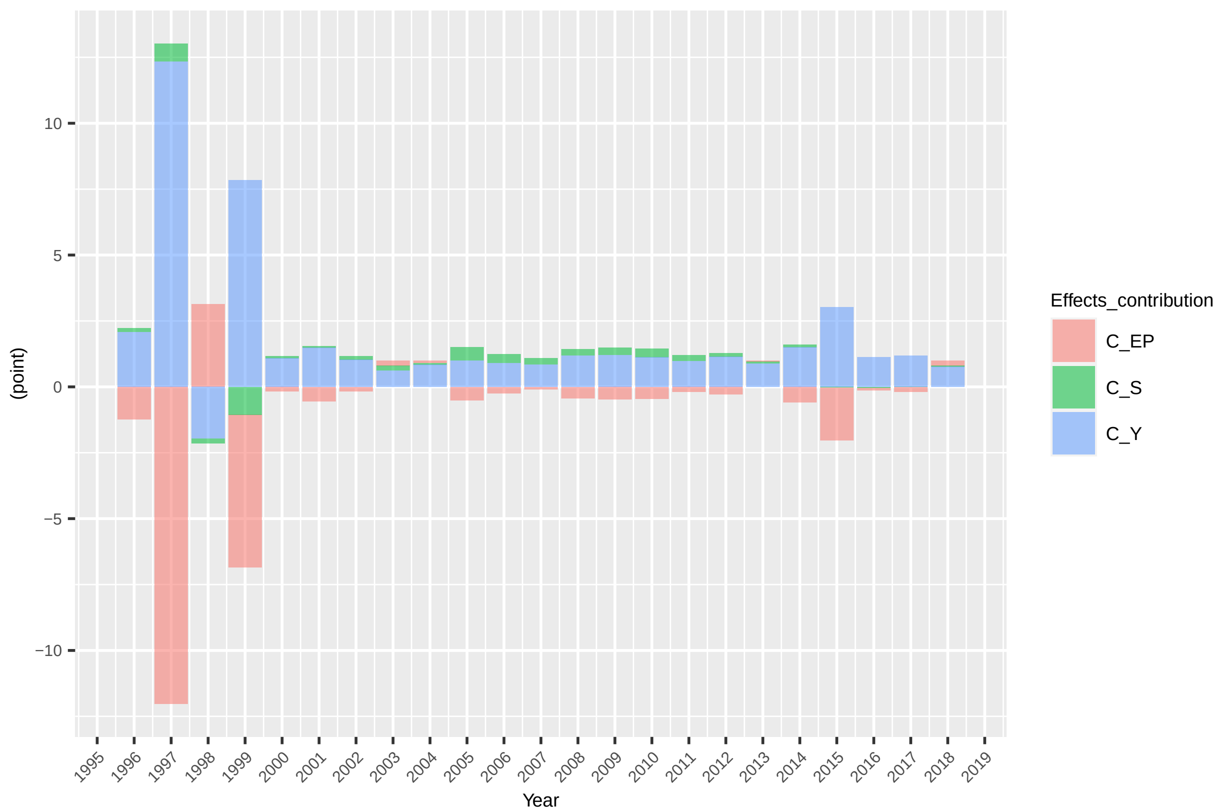


As can be seen in Figure 5_1, the output effect has been the main driver of electricity consumption growth, and in recent years, it has contributed to more than 1.2 billion kWh of electricity consumption per year. Structure effect contributed to a significant amount of positive electricity consumption from 2004 to 2012. This is because during this period of time, the mining and metallurgical industries in Anhui Province developed rapidly, which on the one hand increased the GDP, and on the other hand led to a large amount of electricity consumption. In the past five years, the contribution of the structure effect to the increase in power consumption first decreased and then increased, but remained at a low level overall speaking, which shows that the industrial structure change in Anhui Province is successful in terms of energy saving, and it also confirms that after the change of the industrial structure, the current economic structure is more green, environmentally friendly and energy-saving. Intensity effect is the main force in reducing power consumption. Since 2004, it has saved a lot of energy consumption for Anhui Province every year until 2017, of which 2015 saved the largest amount of energy consumption, about 7.6 billion kWh. But in recent years, the intensity effect has instead started to increase electricity consumption. This is also in full compliance with the hypothesis that the effect of technology that Wang W (2010) et al[17] obtained through research and analysis shows an inverted U shape.

There are many possible reasons. The author believes that with the slowdown of technological development, traditional industries have limited technologies that can improve electricity efficiency, and the marginal cost is high, which makes enterprises lack the will to improve electricity efficiency and reduce costs.

Figure 5_2 illustrates the impact of various effecs on power growth over the years. Here, instead of using percentages, decimals are used directly for the convenience of readers. Figure 5_2 shows that, in recent years, the output effect and the intensity effect have been the main driving forces for the growth and decline of electricity use, respectively, they are often multiples of the overall effect (which should be 1). The low proportion of structure effect makes the author realize that the industrial transformation of Anhui Province still has a long way to go, because the general trend of society is the continuous growth of GDP, and the output effect will definitely bring about an increase in electricity consumption. However, with the deceleration of technological development, it is difficult for the energy utilization efficiency to increase rapidly in the short term, and the intensity effect will not be able to offset the increase in power consumption caused by the output effect. The transformation of industrial structure has become the focus of low-energy consumption and high-efficiency development.

Figure 5_2: Effects' contribution to electricity usage



(2) Three effects of each industry Here, this paper lists the contributions of the primary industry, the secondary industry, and the tertiary industry to different effects, and the results are shown in tables 13, 14, and 15.

Table 13: Intensity effect for all industry

year	Delta_EC_EP_1	C_EP_1	Delta_EC_EP_2	C_EP_2	Delta_EC_EP_3	C_EP_3
1995	NA	NA	NA	NA	NA	NA
1996	-1.11	-0.07	-15.99	-1.05	-1.61	-0.11
1997	-3.55	-1.46	-27.99	-11.47	2.20	0.90
1998	-2.88	0.26	-29.50	2.68	-2.16	0.20
1999	-0.95	-0.32	-16.15	-5.49	0.07	0.02
2000	-0.42	-0.02	-3.14	-0.16	0.06	0.00
2001	-0.38	-0.02	-8.21	-0.49	-0.59	-0.03
2002	-2.83	-0.10	-1.90	-0.07	0.00	0.00
2003	0.57	0.01	9.24	0.18	0.15	0.00
2004	-4.04	-0.07	8.86	0.15	0.85	0.01
2005	-4.08	-0.08	-24.09	-0.50	3.53	0.07
2006	-0.48	-0.01	-19.88	-0.29	3.76	0.06

year	Delta_EC_EP_1	C_EP_1	Delta_EC_EP_2	C_EP_2	Delta_EC_EP_3	C_EP_3
2007	-0.20	0.00	-11.69	-0.12	3.44	0.04
2008	-1.63	-0.02	-29.59	-0.43	1.21	0.02
2009	-0.34	0.00	-43.11	-0.56	6.85	0.09
2010	0.11	0.00	-52.19	-0.51	5.20	0.05
2011	0.54	0.00	-35.16	-0.28	9.54	0.08
2012	1.41	0.01	-48.96	-0.45	15.78	0.15
2013	1.19	0.01	-2.07	-0.02	7.56	0.06
2014	-2.63	-0.03	-41.64	-0.54	-1.68	-0.02
2015	1.28	0.03	-79.99	-2.12	2.85	0.08
2016	4.55	0.04	-24.42	-0.23	9.23	0.09
2017	1.15	0.01	-27.25	-0.26	6.70	0.06
2018	-2.96	-0.02	-1.17	-0.01	36.43	0.22
2019	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA
2021	NA	NA	NA	NA	NA	NA

Table 14: structure effect for all industry

year	Delta_EC_S_1	C_S_1	Delta_EC_S_2	C_S_2	Delta_EC_S_3	C_S_3
1995	NA	NA	NA	NA	NA	NA
1996	-1.08	-0.07	3.16	0.21	0.22	0.01
1997	-0.53	-0.22	2.13	0.87	0.06	0.03
1998	-1.20	0.11	2.83	-0.26	0.41	-0.04
1999	-0.22	-0.07	-3.48	-1.18	0.58	0.20
2000	-1.44	-0.07	2.61	0.13	0.62	0.03
2001	-1.22	-0.07	1.46	0.09	0.74	0.04
2002	-1.65	-0.06	4.86	0.17	0.81	0.03
2003	-2.88	-0.06	11.10	0.22	1.32	0.03
2004	-0.72	-0.01	4.30	0.07	0.27	0.00
2005	-1.18	-0.02	26.71	0.55	-1.02	-0.02
2006	-0.87	-0.01	24.91	0.37	-1.25	-0.02
2007	-1.16	-0.01	25.41	0.27	-0.88	-0.01
2008	-0.68	-0.01	18.22	0.26	-0.94	-0.01
2009	-0.81	-0.01	22.77	0.30	-1.33	-0.02
2010	-1.06	-0.01	38.68	0.38	-3.75	-0.04
2011	-1.08	-0.01	32.41	0.26	-2.88	-0.02
2012	-0.84	-0.01	18.64	0.17	-1.39	-0.01
2013	-1.05	-0.01	9.71	0.07	1.12	0.01
2014	-0.69	-0.01	7.52	0.10	0.47	0.01
2015	-0.67	-0.02	-4.14	-0.11	3.82	0.10
2016	-1.09	-0.01	-7.70	-0.07	5.42	0.05
2017	-0.95	-0.01	-2.79	-0.03	3.42	0.03
2018	-1.04	-0.01	5.87	0.03	1.63	0.01
2019	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA
2021	NA	NA	NA	NA	NA	NA

Table 15: output effect for all industry

year	Delta_EC_Y_1	C_Y_1	Delta_EC_Y_2	C_Y_2	Delta_EC_Y_3	C_Y_3
1995	NA	NA	NA	NA	NA	NA
1996	2.90	0.19	27.01	1.78	1.68	0.11
1997	2.63	1.08	25.71	10.54	1.78	0.73
1998	1.76	-0.16	18.30	-1.66	1.45	-0.13
1999	1.85	0.63	19.58	6.66	1.66	0.56
2000	1.70	0.08	18.51	0.92	1.70	0.08
2001	1.82	0.11	21.22	1.26	2.01	0.12
2002	1.85	0.07	24.79	0.87	2.41	0.09
2003	1.66	0.03	27.52	0.54	2.68	0.05
2004	2.11	0.03	45.04	0.74	4.34	0.07
2005	1.41	0.03	42.95	0.89	4.25	0.09
2006	1.39	0.02	54.92	0.81	5.71	0.08
2007	1.58	0.02	71.18	0.75	7.62	0.08
2008	1.38	0.02	72.88	1.06	7.96	0.12
2009	1.36	0.02	81.83	1.07	9.52	0.12
2010	1.58	0.02	101.73	0.99	12.65	0.12
2011	1.57	0.01	106.81	0.85	13.95	0.11
2012	1.60	0.01	106.64	0.98	15.43	0.14
2013	1.58	0.01	101.89	0.75	16.15	0.12
2014	1.40	0.02	98.00	1.28	16.08	0.21
2015	1.33	0.04	96.41	2.55	16.89	0.45
2016	1.60	0.02	99.15	0.94	19.17	0.18
2017	1.86	0.02	102.40	0.97	21.36	0.20
2018	1.76	0.01	104.23	0.62	23.84	0.14
2019	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	NA	NA	NA
2021	NA	NA	NA	NA	NA	NA

It can be seen from Table 13 that the intensity effect of the secondary industry is very small (negative number) for a long period of time, which shows that the improvement of the power utilization efficiency of the secondary industry has made a huge contribution to reducing power consumption. The secondary industry is also a major contributor to the intensity effect. The value of the primary industry was first negative, then continued to rise to positive, and then fluctuated up and down, maintaining a low level. This shows that the improvement of the power utilization efficiency of the primary industry has a relatively stable impact on the total power consumption. The intensity effect of the tertiary industry has maintained a low level until 2018, but it has reached a large value in 2012 and 2018.

Table 14 shows the impact of structure effects for three industries. The structure effect of the secondary industry on the growth of electricity consumption accounts for a large part of the three industries. The structure effect of the primary industry is always negative, this shows that when the proportion of the secondary industry in the overall GDP increases, electricity consumption will increase rapidly, but if it is the primary industry, the increase in electricity consumption will decrease. It is worth mentioning that the structure effect of the tertiary industry is not obvious, it maintains a low level all year round, and its proportion is also very small.

Table 15 shows the impact of output effect for three industries. The increase in the output value of the secondary industry has a very large impact on the increase in electricity consumption, exceeding the sum of other industries. In terms of time period, its value decreased slightly from 1997 to 2001, and then rose rapidly until 2011. Since 2012, its value has fluctuated around 100. For the tertiary industry, its value has increased since 2004 and has accelerated in recent years. In contrast, the output effect of the primary industry is much smaller than the other two.

Chapter 6 Explanation for the divergence between GDP growth and electricity use growth

(I) Summary of Analysis Results This part combines the analysis results of previous chapters to explain the deviation phenomenon.

In chapter 2 figure 2_5, we see that g_t^{EC} and g_t^{y} were close to each other before 2002, and maintained the same trend and close relationship from 2002 to 2013. After 2013, there has been a significant deviation between g_t^{EC} and g_t^{y}, not only in value, but also in trend. At the same time, in 2012, overall GDP growth began to slow, and this phenomenon is still ongoing. The original industrial structure began to accelerate its transformation, the proportion of the output value of the secondary industry both in the increased GDP (K_{2t}) and in the overall GDP (S_{2t}) began to decline. The proportion of the tertiary industry began to increase (K_{3t}, S_{3t}).

In Chapter 4, by proving that g_t^{EC} has a cointegration relationship with the explained variable, we construct a time series model with a high degree of explanation (equation 4.1). In the equation, the growth rate of electricity consumption per unit output value of the secondary industry ($g_t^{EP_2}$) has the greatest impact on g_t^{EC}. An increase in the proportion of tertiary and secondary industries in GDP (K_{3t}, K_{2t}) will also lead to an increase in electricity consumption.

In Chapter 5, the output effect is the main driving force of the main power growth, among which the secondary industry is the most obvious, and the tertiary industry is also growing. The intensity effect is the main driving force for delaying the growth of electricity consumption, and the secondary industry accounts for the vast majority, indicating that the improvement of electricity efficiency in the secondary industry is crucial to saving electricity. The intensity effect of the tertiary industry has become more volatile after 2012. On the whole, the effect of structural effects on power growth is not obvious, mainly in the secondary industry.

(II) Explanation of the deviation between the growth rate of electricity use and the growth rate of GDP. This part mainly uses the previous analysis results such as (eq 4.1, eq 5.3, etc.) and data (table 12, etc.) to analyze the reasons for the deviation before and after (figure 2_5).

(1) Before 2002: Began close together Before 2002, the growth rate of GDP slowed down for a period of time (1993-2001) during which the industrial structure was relatively stable (see Figure 2-3). Although the output value of the secondary industry is larger than that of the industry, the growth rate of each industry is stable. Before 2002, the growth rate of GDP slowed down for a period of time (1993-2001). During this period, the base of output value was small and the industrial structure was relatively stable (see Figure 2_3). Although the output value of the secondary industry is more than that of the industry, the growth rate of each industry is similar (see figure 2-4).

While the output effect is mainly concentrated in the secondary industry, the intensity effect is also mainly concentrated in the secondary industry (shown in tables 15 and 13). This means that when the electricity efficiency of the secondary industry is improved, the output effect and the intensity effect will be patrially offset, and the remaining structural effect is not obvious because the economic structure is relatively stable.

Combined with Equation 4.1, $g_E P_{it}$ is partial offset by g_t^{y}, K_{it} is not obvious because the structure is relatively stable, the remaining dominant explanatory variable is g_t^{y}, and its coefficient is very large , so make g_t^{EC} close to g_t^{y} gradually. Equation 5.3 and its results also show that in this period, $DeltaEC_t$ is mainly composed of ΔEC_t^{EP} (negative) and $Delta EC_t^{Y} $ (positive), $DeltaEC_t$ is relative stable.

(2) 2002 – 2012: Similar stage It can be seen from figure 2_5 that in this period g_t^{EC} fluctuates up and down around g_t^{y}, the trends and values of the two are very similar, and the connection is very close. During this period, the GDP growth rate began to increase, mainly due to the output value of the secondary industry. The most obvious feature of the entire economic structure is that the proportion of the secondary industry in GDP has increased rapidly, far exceeding that of the primary and tertiary industries.

During this period, the growth rate of electricity consumption was huge. Although the intensity effect was still negative (Table 12), the output effect was too large to be offset, and the structural effect also contributed to a large increase in electricity consumption. Since the secondary industry has both the main intensity effect and the output effect, and the secondary industry also occupies a dominant position in GDP, the growth rate of GDP is highly correlated with the growth rate of the secondary industry. The growth rate of the secondary industry is also related to the high growth rate of electricity consumption, so g_t^{EC} is highly correlated with g_t^y.

Combining eq 4.1 and table 12, we can see that during 2002-2007, the structure effect was positive, and the intensity effect was offset by the structure effect or also positive, causing g_t^{EC} to be greater than g_t^y. But from 2008 to 2012, $/DeltaEC_t^{EP}$ suddenly decreased to about -30, in which $/DeltaEC_t^{EP_2}$ also went through this process, making $g_t^{EP_2}$ rapidly decrease, its relatively high coefficient (0.87 in eq 4.1) has a strong weakening effect on g_t^{EC}, so g_t^y is greater than g_t^{EC} in this period.

(3) 2012 – now: Deviation Since 2012, the deviation between g_t^{EC} and g_t^y has become more and more obvious, and sometimes even the opposite trend has appeared. Overall, GDP growth slowed down, but the growth rate of electricity consumption began to fluctuate greatly.

2013 - 2015

From 2013-2015, g_t^{EC} decrease more significantly than g_t^Y. In terms of industry's GDP, the growth rate of the secondary industry slows down the most. Since 2010, its growth rate has dropped from 20% to 8% in 2018. In contrast, the growth rates of the primary and tertiary industries are relatively stable, remaining at around 4% and 10% respectively.

As far as the total output effect is concerned, table 12 shows that ΔEC_t^Y exprience its first numerical decline. In terms of different industries, the secondary industry has the largest decline. In addition, the intensity effect of the secondary industry also reached a trough during this period (-79.99 kWh in 2015), and the total intensity effect also seriously weakened the added value of electricity. Finally, the overall structural effect is also negative during this time period, although the primary and tertiary industries are increasing and the secondary industry is trending downward. According to equation 5.3, we can predict ΔEC_t is smaller as $\Delta EC_t^{EP} < 0$, $\Delta EC_t^S < 0$, ΔEC_t^Y smaller. Combined with eq 4.1, we can reason that $g_t^{EC} < g_t^y$ because the explanatory variables in the model are all decreasing or negative.

2015 - 2018

During this period, the overall trend of g_t^{EC} is to rise and exceed g_t^y. In terms of industry's GDP, the growth rate of the secondary industry has stabilized at 8% after several years of decline, the primary industry has been fluctuating around 3%, and the tertiary industry has declined slightly.

The aggregate output effect returned to a growing trend. In terms of sub-sectors, the secondary industry has begun to increase, but the growth rate has slowed down. The primary industry floated slightly, and the tertiary industry increased steadily. In terms of output effects, the output effects of the three industries are all positive, and the second industry has the largest increase. In terms of the intensity effect, the secondary industry weakens and its ability to reduce electricity consumption becomes weaker. The value of the tertiary industry is on the rise, reaching a historical high of 3.643 billion kwh, which shows that the electricity efficiency of the tertiary industry is very low. The electricity efficiency of the primary industry has been slightly improved, and the value has been reduced to -296 million kWh. The structural effect shows that the secondary industry has the largest value, followed by the tertiary industry (all positive numbers), and the primary industry is negative.

In general, during this period, the values of the three effects of the secondary industry rebounded, and the intensity effect of the primary industry increased. Although the three effects of the primary industry are reduced, because of its small proportion in GDP, it can be predicted according to eq 5.3: ΔEC_t is larger as $\Delta EC_t^{EP} > 0$, $\Delta EC_t^S > 0$, ΔEC_t^Y larger. Combined with eq 4.1, we can reason that $g_t^{EC} > g_t^y$ because the explanatory variables in the model are increaing.

(III) In-depth analysis of deviations Based on the previous summary, this part further analyzes the deviation problem. In the previous analysis, eq 4.1 explains the relationship between $g_t^{EC}$and g_t^y, and also shows the reasons for their deviation through explanatory variables. The decomposition based on LMDI also concretely shows that the power growth is the result of the combined action of three kinds of influences.

In terms of secondary industries, in the two deviations, the change in output effect contributes a large proportion of deviations, which is also in line with the trend of the secondary industry development, its rate has decreasing significantly and then maintain stable. At the same time, the improvement of electricity efficiency in 2015 reach its record. The structural effect increases electricity consumption most of the time, was negative in 2013-2015. The output effect and intensity effect of the secondary industry together contribute a lot for $g_t^{EC} < g_t^y$ during 2013-2015. When they started to rise in 201, g_t^{EC} quickly exceeded g_t^y.

The tertiary industry has been growing rapidly in recent years. Its output effect has shown steady growth in the two deviations, but the increase is not very obvious. In contrast, its intensity effect on energy consumption in recent years continued to increase, in 2018 reached 3.643 billion KWH, prompting g_t^{EC} increase rapidly. The structural effect of the tertiary industry was negative from 2005 to 2012, but then rose to a positive value and fluctuated up and down. It also increases power consumption during two deviations

The output effect of the primary industry has been limited due to its small output value and low growth rate. Due to the small output value and low growth rate of the primary industry, its output effect has been limited and fluctuates up and down during the deviation period. Its intensity effect experienced a decrease first and then an increase, which also contributed to the deviation of g_t^{EC}. It is worth mentioning its structural effect, whose value always fluctuates up and down at - 1 million kwh.

In general, the reason for the deviation from 2013 to 2015 is that the slowdown of GDP growth has weakened the output effect. Among them, the output value of the secondary industry declined the most and experience a strong intensity effect, which offset other effects. During 2015-2018, the output effect of the secondary industry recovered and the intensity effect increased, while the intensity effect of the tertiary industry increased rapidly, making the growth rate of electricity consumption rapidly exceed the GDP growth rate.

Chapter 7 Enlightenment of this devision

At present, on a global scale, the three major issues of tight energy demand, industrial restructuring and slowing economic growth combine to test the economic development of various countries. Taking Anhui Province as an example, this paper starts with the deviation between the growth rate of electricity consumption and the growth rate of GDP, and analyzes the reasons for this phenomenon based on the changes in industrial structure and electricity efficiency, hoping to help the future economic development. This chapter divides the author's inspiration into two aspects: industrial structure and power efficiency.

(1) Industrial structure The changes in the industrial structure of Anhui Province over the years are: at the beginning, three industries developed in a balanced way. Subsequently, the proportion of the secondary industry expanded and developed rapidly, while other industries grew steadily. In recent years, the development of the secondary industry has slowed down, the growth of the tertiary industry has accelerated, and the growth of the primary industry has been stable.

The structural transformation has a obvious effect on the use of electricity. The overall structural effect began to soar in 2005 (the proportion of the secondary industry has increased rapidly since 2003), weakened in 2012, and rebounded in 2016. When the proportion of the secondary industry increases, structural changes will bring huge power consumption. Since 2012, the proportion of the tertiary industry has increased, and the growth rate of the secondary industry has slowed down. This change in the industrial structure has delayed power consumption.

Does this mean that increasing the proportion of the tertiary industry can reduce energy consumption? The answer is **no**. In our analysis, in 2010-2012, the structural effect of the tertiary industry was negative, but after 2016, this value rose to positive. This means that the increase in the proportion of the tertiary industry also consumes more electricity. In 2016, the main driving force really makes the structural effect optimal(-3.37 million kwh) is the secondary industry (-7.70 million kwh). On the contrary, the tertiary industry consumes more electricity (5.42 million kwh). In contrast, the ratio of the primary industry to GDP is stable and provides a stable structural effect, saving 1 million kwh per year.

(2) Electricity utilization efficiency In this paper, electricity utilization efficiency is measured by electricity consumption per unit output value (structural effect). The higher the efficiency, the less electricity consumption per unit output value, and the structural effect can save more energy consumption. Intensity effect has always been the main force of power saving.

The intensity effect has experienced many significant rises and falls, all of which are related to the secondary industry. Before 2000, the intensity effect of the secondary industry had reached a peak. During the period of rapid development of the industry from 2002 to 2012, its intensity effect dominated the main electric energy saving effect, in 2015, it reached the lowest level in history, saving about 8 billion kwh of electric energy for Anhui Province. This also partly explains why the structural change of the secondary industry in 2016 is negative: with the improvement of the secondary industry's electricity efficiency, when the ratio of the secondary industry to GDP increases, more electricity can be used more efficiently.

Is the power utilization efficiency of the secondary industry always the most important part of power saving? The answer is **no**. Although the secondary industry has a large power consumption and has been improving the efficiency of use, the problem has emerged. The electricity utilization efficiency of the tertiary industry is decreasing, and its intensity effect in 2018 even wasted 3.643 billion kwh. Under the background of accelerated growth of the tertiary industry and increased proportion of the whole industry, this will largely offset the electricity saved by the secondary industry. The improvement of power efficiency in the secondary industry comes from the continuous development of its production technology. However, as the technology encounters a bottleneck, its intensity effect will only save 1.17 million kwh in 2018, lower than primary industry.

(3) Future development mode In the short term, the current economic structure of Anhui Province will still be dominated by the secondary industry, tertiary industry grow faster. In the context of slowing economic growth, the secondary industry still needs a lot of power. In addition to continuing to develop the technology needed to improve efficiency, it is urgent to develop the technology of the tertiary industry to reduce power consumption.

In the long run, the author believes that the industrial structure of Anhui Province needs to be changed slowly. In addition to the development of the tertiary industry, attention should also be paid to the development of the primary industry. The direction of industrial transformation is to establish an environmental economic structure with high output value and low energy consumption. In the future, the power utilization efficiency of the tertiary industry will be the focus, and its development should be vigorously promoted.