



Energy Industry Correlation Analysis Based on Input-output Table and Electricity Consumption: A Case Study of Gansu Province

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Abstract. The relationship between electricity and the economy has always been a focal point in electricity development. Based on Gansu Province's 2017 input-output table and electricity consumption data during the "14th Five-Year Plan" period, this paper analyzes the economic status and electricity consumption characteristics of the energy industry from two dimensions: industrial correlation and electricity consumption growth. The study finds that Gansu's energy industry holds a prominent position in the industrial sector but accounts for a limited share of the overall economy. The energy industry has weak backward correlations and strong forward correlations, with the electricity sector being highly sensitive to economic fluctuations. Analysis of electricity consumption growth shows that electricity consumption in the coal mining industry has rebounded significantly, the gas industry has experienced negative growth due to the impact of new energy substitution, and the growth rate of electricity and heat production is relatively low. Finally, policy recommendations are put forward to provide references for Gansu's energy planning and industrial structure optimization.

Keywords: Input-Output Table; Energy Industry; Industrial Correlation; Electricity Consumption; Gansu Province

1 Introduction

Energy industry correlation analysis is an important tool for interpreting the interaction mechanism between the energy system and the national economy. Early foreign research mainly employed the input-output analysis method to explore the pulling effect of the energy industry on economic growth and its forward and backward correlation characteristics [1]. From 2000 to 2010, research focused on the "energy-consuming resource" attribute of the production processes of traditional metals such as steel and aluminum, revealing the trend of a decline in energy consumption intensi-

ty but an increase in total consumption. After 2011, with the acceleration of low-carbon transformation, the research direction shifted to the "enabling resource" attributes of key metals such as rare earths, lithium, and cobalt, focusing on the constraint mechanism of their supply risks on the energy system, and using simulation methods such as computable general equilibrium (CGE) and system dynamics for dynamic prediction [2-3]. In terms of domestic research, scholars conduct regional and national-level analyses based on the input-output model. The research finds that the energy industry in Xinjiang has a strong backward correlation effect but a weak industrial driving capacity, presenting the characteristics of "high added value and low diffusion" [4]; At the national level, metallurgy, chemical industry and equipment manufacturing have been identified as key energy consumption sectors [5]. In recent years, methods such as grey relational analysis and complex network theory have been introduced to measure the correlation between energy consumption and economic growth and to characterize the topological structure of the energy industry network [6-7].

At present, there are few studies that take advantage of the statistical superiority of electricity consumption. The energy and power industry in Gansu Province is an important engine for economic growth. The growth potential of new energy in the future remains considerable. The energy industry correlation has obvious representativeness, but the research is also challenging. Therefore, this paper takes Gansu Province as an example to conduct research on the energy industry correlation, not only for the local economic planning of Gansu Province, At the same time, it provides important references for other regions.

2 Analysis of Industries Correlated with the Energy Industry

In this paper, the energy industry includes five sectors directly related to the production of coal, oil, gas, and electricity energy, namely coal mining and washing, oil and gas extraction, oil processing/coking and nuclear fuel processing, electricity/heat production and supply, and gas production and supply. Due to data availability constraints, the following is an analysis of the importance and influence of the energy industry based on the latest publicly available input-output table data of Gansu Province in 2017, using the complete consumption coefficient, complete distribution coefficient, influence coefficient, and sensitivity coefficient. These coefficients are all general analysis methods and do not need to be introduced further in the following text.

In terms of the proportion of industrial output value, in 2017, the proportions of the output of coal mining and washing, oil and gas extraction, oil processing/coking and nuclear fuel processing, electricity/heat production and supply, and gas production and supply in the province's total output were 1.1%, 1.5%, 4.2%, 4.7%, and 0.3% respectively. Among them, the output proportions of oil processing/coking and nuclear fuel processing, and electricity/heat production and supply were relatively high, ranking 6th and 8th respectively among the 42 major industries; the total output proportion of the energy industry was 11.8%. It can be seen that the output proportion of

the energy industry is basically close to the proportion of the energy industry's added value mentioned in the other statistical analyses (the energy industry's added value accounts for approximately 50% of the industrial added value, converted based on the industrial added value accounting for 25.4% of GDP). That is, individually, the output value of the energy industry plays a crucial role in Gansu's industrial economy, but its proportion in the overall economic output value is only slightly more than 10%.

In addition to the energy industry itself, the demand pull of the energy industry mainly comes from industries such as metal smelting and rolling processing, chemical products, transportation/storage and postal services, wholesale and retail, and finance. In 2017, the top five industries in terms of the complete consumption coefficient of coal mining and washing were coal mining and washing products (0.162), electricity and heat production and supply (0.106), finance (0.181), transportation, storage and postal services (0.096), and wholesale and retail (0.076); the top five industries for oil and gas extraction were electricity/heat production and supply (0.096), metal smelting and rolling processing products (0.094), coal mining and washing products (0.080), non-metallic mineral and other mineral mining (0.065), and wholesale and retail (0.065); the top five industries for oil processing/coking and nuclear fuel processing were oil and gas extraction products (0.536), wholesale and retail (0.121), electricity/heat production and supply (0.086), finance (0.081), and chemical products (0.076); the top five industries for electricity/heat production and supply were electricity/heat production and supply (0.491), coal mining and washing products (0.263), finance (0.214), transportation, storage and postal services (0.101), and wholesale and retail (0.085); the top five industries for gas production and supply were oil and gas extraction products (0.510), gas production and supply (0.269), electricity/heat production and supply (0.126), finance (0.068), and coal mining and washing products (0.053). As shown in Table 1 below.

Table 1. Top 5 Industries by Complete Consumption Coefficient of the Energy Industry in 2017

No.	Coal Mining and Washing	Oil and Gas Extraction	Oil Processing/Coking and Nuclear Fuel Processing	Electricity/Heat Production and Supply	Gas Production and Supply
1	Coal Mining and Washing Products (0.162)	Coal Mining and Washing Products (0.080)	Oil and Gas Extraction Products (0.536)	Coal Mining and Washing Products (0.263)	Coal Mining and Washing Products (0.053)
2	Electricity and Heat Production and Supply (0.106)	Non-Metallic Mineral and Other Mineral Mining (0.065)	Chemical Products (0.076)	Electricity and Heat Production and Supply (0.491)	Oil and Gas Extraction Products (0.510)
3	Wholesale and Retail (0.076)	Metal Smelting and Rolling Processing Products (0.094)	Electricity and Heat Production and Supply (0.086)	Wholesale and Retail (0.085)	Electricity and Heat Production and Supply (0.126)
4	Transportation, Storage and Postal Services (0.096)	Electricity and Heat Production and Supply (0.096)	Wholesale and Retail (0.121)	Transportation, Storage and Postal Services (0.101)	Gas Production and Supply (0.269)
5	Finance (0.181)	Wholesale and Retail (0.065)	Finance (0.081)	Finance (0.214)	Finance (0.068)

The main applications of the energy industry are concentrated in high-energy-consuming industries such as chemical products, non-metallic mineral products, metal smelting and rolling processing, electricity/heat production and supply, and gas production and supply, as well as the construction and transportation industries. In 2017, the top five industries in terms of the complete distribution coefficient of coal mining and washing were electricity and heat production and supply (1.189), metal smelting

and rolling processing products (1.010), construction (0.714), chemical products (0.289), and non-metallic mineral products (0.280); the top five industries for oil and gas extraction were oil processing/coking and nuclear fuel processing (1.555), construction (0.364), metal smelting and rolling processing products (0.250), chemical products (0.247), and transportation/storage and postal services (0.163); the top five industries for oil processing/coking and nuclear fuel processing were construction (0.220), metal smelting and rolling processing products (0.146), chemical products (0.144), transportation/storage and postal services (0.100), and non-metallic mineral products (0.091); the top five industries for electricity/heat production and supply were metal smelting and rolling processing products (0.610), electricity/heat production and supply (0.491), construction (0.351), chemical products (0.131), and agricultural, forestry, animal husbandry and fishery products (0.112); the top five industries for gas production and supply were gas production and supply (0.269), transportation/storage and postal services (0.225), construction (0.196), metal smelting and rolling processing products (0.118), and electricity/heat production and supply (0.073). As shown in Table 2 below.

Table 2. Top 5 Industries by Complete Distribution Coefficient of the Energy Industry in 2017

No.	Coal Mining and Washing	Oil and Gas Extraction	Oil Processing/Coking and Nuclear Fuel Processing	Electricity/Heat Production and Supply	Gas Production and Supply
1	Chemical Products (0.289)	Oil Processing/Coking and Nuclear Fuel Processing (1.555)	Chemical Products (0.144)	Agricultural, Forestry, Animal Husbandry and Fishery Products (0.112)	Metal Smelting and Rolling Processing Products (0.118)
2	Non-Metallic Mineral Products (0.280)	Chemical Products (0.247)	Non-Metallic Mineral Products (0.091)	Chemical Products (0.131)	Electricity and Heat Production and Supply (0.073)
3	Metal Smelting and Rolling Processing Products (1.010)	Metal Smelting and Rolling Processing Products (0.250)	Metal Smelting and Rolling Processing Products (0.146)	Metal Smelting and Rolling Processing Products (0.610)	Gas Production and Supply (0.269)
4	Electricity and Heat Production and Supply (1.189)	Construction (0.364)	Construction (0.220)	Electricity and Heat Production and Supply (0.491)	Construction (0.196)
5	Construction (0.714)	Transportation, Storage and Postal Services (0.163)	Transportation, Storage and Postal Services (0.100)	Construction (0.351)	Transportation, Storage and Postal Services (0.225)

The backward correlation of Gansu's energy industry is generally weak. Based on the data from Gansu Province's 2017 input-output table and the calculation of the influence coefficient mentioned earlier, the influence coefficients of all five energy industries are less than 1, indicating that the ripple effect of the energy industry's production on other sectors is lower than the average impact level of the whole society. This fully reflects the characteristic of the energy industry as an upstream link in economic production. Among them, the influence coefficients of electricity/heat production and supply, gas production and supply, and oil processing/coking and nuclear fuel processing are close to the average level (i.e., 1).

The forward correlation of most energy industries in Gansu is relatively strong. Based on the data from Gansu Province's 2017 input-output table and the calculation of the sensitivity coefficient mentioned earlier, the influence coefficients of four energy industries are greater than 1, indicating that the sensitivity of these industries' production to changes is higher than the average sensitivity level of the whole society, and they are more sensitive to changes in the overall demand of the national economy. Among them, the sensitivity coefficient of the electricity/heat production and supply

industry ranks third among the 42 industrial sectors in Gansu Province, which is 2.3 times the average level, indicating that the electricity production industry is highly responsive to fluctuations in economic activities. As shown in Figure 1 below.

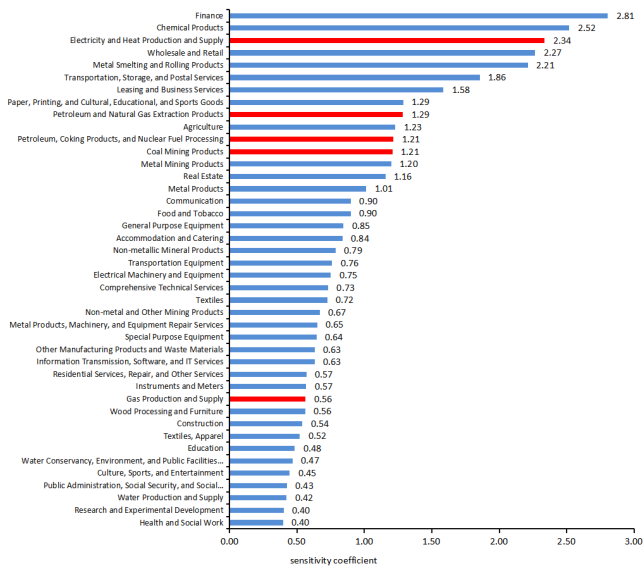


Fig. 1. Ranking of Sensitivity Coefficients of Various Industries in Gansu Province

3 Electricity Consumption Growth of Industries Correlated with the Energy Industry

3.1 Electricity Consumption Growth During the "14th Five-Year Plan" Period

The growth rate of electricity consumption in the coal mining and washing industry has rebounded, achieving high-speed growth. In the first four years of the "14th Five-Year Plan" period, after experiencing a production slump during the "13th Five-Year Plan" period, the average annual growth rate of electricity consumption in Gansu's coal mining and washing industry reached 59.7%, which was significantly higher than the national average level (only 2.5%). This is mainly because after eliminating backward production capacity during the "13th Five-Year Plan" period, Gansu Province vigorously promoted the upgrading and development of the coal industry during the "14th Five-Year Plan" period, built a number of large and medium-sized modern coal mines, released high-quality and advanced production capacity, and at the same time, the intelligent construction of coal mines and the improvement of washing and processing capacity all required a large amount of electricity support. Among them, the electricity consumption in 2024 was 85,3630,000 kWh, but there is still a gap from the peak in 2015.

Benefiting from the discovery of large oil and gas fields, the growth rate of electricity consumption in the oil and gas extraction industry is relatively fast, while the growth rate of oil, gas and coal processing industries is relatively stable. In the first four years of the "14th Five-Year Plan" period, the average annual growth rate of electricity consumption in Gansu's oil and gas extraction industry was 11.7%, a rebound of 13.8 percentage points compared with the "13th Five-Year Plan" period, and 4.4 percentage points higher than the national average. This is mainly due to the discovery of large gas fields and shale oil fields in the Longdong region, and the steady increase in oil and gas production. The average annual growth rate of crude oil production was 6.5%, 5.2 percentage points higher than that of the "13th Five-Year Plan" period. At the same time, the average annual growth rate of electricity consumption in the oil processing, coking and nuclear fuel processing industry was 6.3%, 3.4 percentage points lower than that of the "13th Five-Year Plan" period. The growth rate generally continued the rapid growth trend of the "13th Five-Year Plan" period, but the growth of energy processing capacity was still lower than the national average level.

The growth rate of electricity consumption in the electricity and heat production and supply industry is relatively low, which is not compatible with the rapid growth of the whole society's electricity consumption. In the first four years of the "14th Five-Year Plan" period, the average annual growth rate of electricity consumption in Gansu's electricity and heat production and supply industry was only 1.7%, a decrease of 5 percentage points compared with the "13th Five-Year Plan" period, and 6.1 percentage points lower than the national average level. In particular, the growth rate of electricity consumption in the industry is not compatible with the growth rate of Gansu's total social electricity consumption (6.1%).

Affected by the rapid development of new energy and the deepening of electricity substitution, the electricity consumption of the gas production and supply industry has shown negative growth. In the first four years of the "14th Five-Year Plan" period, the average annual growth rate of electricity consumption in Gansu's gas production and supply industry was -3.9%, a significant decrease of 9.3 percentage points compared with the "13th Five-Year Plan" period, and 12 percentage points lower than the national average level. The growth rate of electricity consumption has shown a downward trend since the "12th Five-Year Plan" period. The main reason is that the development of new energy in Gansu is rapid, and the substitution effect of new energy in some fields has been enhanced, reducing the demand for gas consumption. As shown in Table 3 below.

Table 3. Electricity Consumption and Average Annual Growth Rate of Gansu's Energy Industry

Sector	Electricity Consumption (10,000 kWh)			Average Annual Growth Rate (%)		
	2015	2020	2024	12th Five-Year Plan	13th Five-Year Plan	First Four Years of 14th Five-Year Plan
Coal Mining and Washing	100,625	13,115	85,363	10.8	-33.5	59.7
Oil and Gas Extraction	158,499	142,266	221,352	20.8	-2.1	11.7
Oil Processing, Coking and Nuclear Fuel Processing	149,004	236,517	302,452	0.8	9.7	6.3
Electricity and Heat Production and Supply	1,269,403	1,753,920	1,874,635	5.7	6.7	1.7
Gas Production and Supply	78,482	101,846	87,001	39.0	5.4	-3.9
Total Energy Industry	1,756,013	2,247,664	2,570,803	7.1	6.9	3.0
Total Social Electricity Consump-	10,987,197	13,756,973	17,463,248	6.4	4.6	6.1

Sector	Electricity Consumption (10,000 kWh)			Average Annual Growth Rate (%)		
	2015	2020	2024	12th Five-Year Plan"	13th Five-Year Plan	First Four Years of 14th Five-Year Plan
tion						
Growth Rate Gap	-	-	-	0.7	2.3	-3.2

3.2 Introduction to Correlation Coefficients

3.2.1 Introduction to Correlation Coefficients

The correlation coefficient is a statistical indicator used to measure the degree of linear correlation between two variables, with a value range of [-1, 1]. It is used to quantify the direction and intensity of the correlation between variables, and the common type is the Pearson correlation coefficient. The calculation formula of the Pearson correlation coefficient is:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \tag{1}$$

Among them, x_i and y_i are the observed values of the two variables respectively, and $\bar{x}$ and $\bar{y}$ are the mean values of the two variables respectively. When $|r| > 0.7$, it indicates a strong correlation between the two variables; when $0.3 < |r| < 0.5$, it indicates a moderate correlation between the two variables; when $|r| < 0.3$, it indicates a weak correlation between the two variables.

3.2.2Correlation Analysis of Industrial Electricity Consumption Growth Rates

Considering that the growth rate of electricity consumption in various industries is highly volatile and the overall correlation is not high, the moderate correlation is used here as the standard to judge the correlation between Gansu's energy industry and other industries' electricity consumption growth rates, that is, industries with a correlation coefficient greater than 0.3 with the electricity consumption growth rate of each energy industry are selected through the correlation coefficient. Specifically:

The industries with a relatively high correlation with the electricity consumption growth rate of the coal mining and washing industry are 5 industries (including both large and small sectors) such as wine/beverage and refined tea manufacturing, calcium carbide production, Chinese patent medicine production, general equipment manufacturing, and electrical machinery and equipment manufacturing; the industries with a relatively high correlation with the electricity consumption growth rate of the oil and gas extraction industry are 10 industries (including both large and small sectors) such as animal husbandry, lead-zinc smelting, instrumentation manufacturing, telecommunications/broadcasting, television and satellite transmission services, public services and management organizations, scientific research and technical services, water conservancy/environment and public facilities management, public lighting, health and social work, and public management and social organizations/international organizations, among which the number of service industries and public service industries is relatively large; the industries with a relatively high correlation with the electricity consumption growth rate of the oil/coal and other fuel processing industry

are 3 industries (including both large and small sectors) such as coal chemical industry, new energy vehicle whole-vehicle manufacturing, and geological exploration; the industries (including both large and small sectors/departments) with a relatively high correlation with the electricity consumption growth rate of the electricity and heat production and supply industry are 7 sectors such as the whole society, the secondary industry, all industries, industry, non-metallic mineral products industry, other manufacturing industries, and waste resource comprehensive utilization industry, and this industry has a relatively high correlation with the electricity consumption of the whole society and industry; the industries with a relatively high correlation with the electricity consumption growth rate of the gas production and supply industry are 15 industries (including both large and small sectors) such as the tertiary industry, mining industry, non-ferrous metal mining and dressing industry, other mining activities, leather/fur/feather and its products and footwear manufacturing, furniture manufacturing, railway/ship/aviation and aerospace and other transportation equipment manufacturing, wholesale and retail industry, accommodation and catering industry, real estate industry, leasing and business services industry, public services and management organizations, technology promotion and application services industry, water conservancy/environment and public facilities management industry, residential services/repair and other services industry, and education/culture/sports and entertainment industry, among which the number of mining and service industries is relatively large. Due to the large volume of data, the specific tables are omitted.

4 Conclusions and Policy Recommendations

Based on Gansu Province's 2017 input-output table and electricity consumption data in the first four years of the "14th Five-Year Plan" period, this paper conducts a comprehensive analysis of the economic correlation characteristics and electricity consumption dynamics of Gansu's energy industry from two dimensions: industrial correlation and electricity consumption growth. The main conclusions are as follows:

The industrial correlation analysis reveals that the energy industry plays the role of a "sensitive basic sector" in Gansu's economy. The input-output analysis shows that the energy industry has "strong forward correlations and weak backward correlations", with an influence coefficient lower than the social average level, resulting in limited direct driving effect on downstream sectors; the sensitivity coefficient is much higher than the average level, reflecting that various sectors of the national economy are highly dependent on energy, and the energy industry is sensitive to economic fluctuations. In terms of scale, it is a pillar of the industrial sector, but directly accounts for only about 10% of the province's total economic output. Its importance lies in basic input rather than scale contribution.

The analysis of electricity consumption growth reflects that Gansu's energy industry structure is undergoing profound adjustments during the "14th Five-Year Plan" period. During the "14th Five-Year Plan" period, the growth rates of electricity consumption in sub-sectors of the energy industry have shown significant differentiation: the coal mining industry has rebounded at a high speed due to production capacity

upgrading, the oil and gas extraction industry has achieved relatively fast growth due to the discovery of new resources, and the oil and gas processing industry has maintained stable growth; the growth rate of electricity consumption in the electricity and heat production industry is abnormally low, showing a significant contrast with the rapid growth of social electricity consumption, which may reflect changes in operational efficiency, plant power consumption rate, and energy structure; the gas supply industry has continued to experience negative growth due to new energy substitution, which not only reflects internal upgrading but also reflects the impact of external substitution.

The cross-analysis of industrial correlation and electricity consumption growth further describes the different interaction modes between each energy sub-sector and the economy. The electricity consumption of the electricity and heat production and supply industry has the strongest synchronization with the macro-economy and industrial production; the electricity consumption of the gas production and supply industry is closely correlated with the tertiary industry, mining industry, and service industries; the electricity consumption fluctuation of the coal mining industry is linked to that of some manufacturing industries; the growth of electricity consumption in the oil and gas extraction industry is related to the development of public services and technical fields. This shows that the growth drivers of electricity consumption in different energy sources are different, and they form a "community of shared future" with different economic sectors.

Targeted measures should be taken by industry. The coal and oil and gas industries should enhance the coordination of production capacity and resource development. The power and heat industries should optimize efficiency and energy structure. The gas industry should promote transformation and adaptation. Establish a "economy-electricity" linked monitoring mechanism, focusing on the demands of key industries. Relying on the external delivery channels, build an integrated demonstration zone, improve the local configuration of "source-grid-load-storage", and strive for national policy and financial support for cross-regional collaboration.

Acknowledgments

Thanks to the 2025 Special cost project of State Grid Gansu Electric Power Company, "Energy Industry Correlation Analysis Based on Input-Output Table and Electricity Consumption: A Case Study of Gansu Province", for its support of this article.

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