Measurement and Influencing Factors Research of the Energy and Power Efficiency in China: Based on the Supply-Side Structural Reform Perspective

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Abstract: China’s supply-side structural reforms are facing bottlenecks in the energy and power sector, and improving energy and power efficiency and advancing reforms are urgent. To promote sustainable development, based on panel data from 30 provinces and cities in China from 2009 to 2017, this paper uses the super-efficiency DEA method to measure energy and power efficiency; explores the trend of energy and power efficiency changes before and after reform; uses the Tobit model to identify key efficiency factors; and provides policy recommendations to achieve reform goals. The research shows that China’s efficiency level takes the supply-side structural reform as the turning point and presents a volatile upward trend; from the situation of the country, technological progress, the economic development level, and the opening up level are positively correlated with the energy and power efficiency, among which the correlation coefficient between technological progress and efficiency is the highest. The study can offer a reference for the sustainable comprehensive utilization of China’s energy and power, and provide empirical evidence for other countries to improve the energy and power efficiency from the perspectives of theory and policies.

Keywords: the supply-side structural reform; energy and power efficiency; super-efficiency DEA; Tobit model; influencing factors

1. Introduction

Since the reform and opening-up, China’s economy has achieved rapid growth, but the unreasonable industrial structure, environmental pollution, and other development bottlenecks caused by the rapid growth mode have become increasingly prominent. To transform the economic development mode and improve the quality of development, the Chinese government launched a major strategic deployment of “supply-side structural reform” in early 2015, proposing reforms to promote structural adjustment, reduce ineffective and low-end supply, expand effective and high-end supply, and enhance the adaptability and flexibility of the supply structure to changes in demand. Among them, energy and power are important inputs of basic industrial products and living means, and improving the energy and power efficiency is not only a key area for enhancing the sustainability of economic development but also important part of promoting reform.

Since the beginning of the supply-side structural reform, several supportive policies have been promulgated, such as the Guidance Catalogue for Industrial Structure Adjustment, Several Opinions...
of the CPC Central Committee and the State Council on Further Deepening the Reform of the Electric Power System, Opinions on Promoting the Supply-Side Structural Reform and Resolve the Risk of Overcapacity in Coal Power, etc. With the implementation of policy measures, China’s energy and power efficiency has achieved a certain degree of improvement, but the electricity generation surplus is always at a low level. As shown in Figure 1, as of 2018, the electricity consumption has reached 6.74 trillion kWh, and the ratio of electricity generation to electricity consumption has dropped to the lowest in recent years, only 100.2%. However, the electricity consumption per unit of GDP is about 759.74 kWh per 10,000 yuan in 2018, which is 4.3 times that of the United States and 11.5 times that of Japan. Thus, there are still certain efficiency problems in energy and power utilization in China.

![Figure 1](image_url)

**Figure 1.** Full caliber electricity consumption and electricity generation in China from 2013 to 2018. (Source: Statistical Communique of China’s National Economic and Social Development from 2013 to 2018 [1]).

The key objective of supply-side structural reform in the energy and power sector is to improve the energy and power efficiency and achieve sustainable development. However, statistics show that the current reform faces the following three major problems:

- **“Structural excess” problem.** On the one hand, the low consumption rate of clean energy is not conducive to solving the problem of power supply pressure. In 2018, the wind attenuation rate was 7%, the light rejection rate was 3%, and the water disposal rate was 5%. On the other hand, the utilization hours of power generation equipment in China are low. The cumulative average utilization hours of power generation equipment of 6000 kW and above nationwide continued to fall from 2013 to 2017, and the cumulative average utilization hours of 2018 were only 3862 h.

- **“Structural deficiency” problem.** China’s energy and power resources have structural contradictions in the reverse distribution of demand and supply. The western provinces of Southwest China, Gansu, and Xinjiang are rich in renewable energy resources, but the demand for electricity is small and the level of development and utilization technology is limited, which cause serious waste of energy resources. The energy resources in the eastern part of China are scarce, and the scale of flexible power supply is small, but the demand for power is large, and the market supply and demand are seriously out of balance.

- **Environmental pollution.** Coal combustion emits 1.7 times more pollutants than clean energy such as natural gas, and it is responsible for 74% of sulfur dioxide emissions, 60% of nitrogen oxides, and 70% of soot in air pollutants. Due to the high coal consumption characteristics of China’s energy consumption structure, the problem of environmental pollution is significant.

Due to the constraints of “structural excess”, “structural deficiency”, and “environmental pollution”, China’s overall energy and power utilization is not sustainable enough, and there is still a gap between the status quo of the supply-side structural reform and the ideal goals. Therefore, it is necessary to study the results of reforms in improving energy and power efficiency, provide
recommendations for improving energy and power efficiency based on key influencing factors’ analysis, deepen the energy and power supply-side structural reform, and enhance the sustainability of comprehensive utilization of energy and power.

Based on this, in Section 1, the paper analyzes the bottlenecks in the supply-side structural reform of China’s energy and power sector, and puts forward the significance of studying the factors affecting the energy and power efficiency. Section 2 combs scholars’ research status of the energy and power efficiency. Section 3 builds the input–output index based on the comprehensive consideration of the supply-side structural reform status and the characteristics of the energy and power, and then measures and analyzes the energy and power efficiency in China from 2009 to 2017 based on SE-DEA model. Section 4 introduces the selected explanatory variables, using the Tobit model for quantitative regression analysis. Section 5 proposes an optimization strategy for improving the energy and power efficiency. Section 6 is the conclusion.

The research method adopted and research problems solved by each module in this paper is shown in Figure 2.

Figure 2. Research content and method diagram.

2. Literature Review

Energy efficiency is closely related to the economic development quality [2]. With the increase in fossil energy consumption and changes in the ecological environment, meeting the energy demands of economic and social development through clean and efficient power generation has become one of the major challenges facing by the energy and power industry [3]. However, Zhang (2011) [4] sampled the data of thermal power generation panels in 30 provinces and cities in China to measure the technical efficiency of the power generation industry. The study found that the overall efficiency level of the power generation industry in China is relatively low. This article expands the literature review from four perspectives: efficiency measurement methods, China’s energy efficiency measurement, the impact of reform on energy efficiency, and efficiency influencing factors.

Energy efficiency measurement usually uses two methods: the parametric method represented by Stochastic Frontier Analysis and the non-parametric method represented by Data Envelopment Analysis. Among them, DEA is a data-oriented method proposed by Charnes that can evaluate the efficiency of decision-making units with multiple input and output elements [5], and has been widely used in industry efficiency evaluation [6]. Since multiple evaluation units may be valid at the same time under the traditional DEA method, Anderson et al. (1993) proposed the SE-DEA method to rank homogeneous decision units to effectively solve the problem [7]. Färe and Grosskopf (2000) proposed the network DEA model, which is used to calculate the overall efficiency and zoning efficiency of decision-making units under the same framework [8]. To deal with the problems caused by the slack
of input factors, output factors, and intermediate product, Tone and Tsutsui (2009) introduced the network SBM-DEA method based on slack [9].

As an effective way to measure energy efficiency, the DEA method has been widely used in China’s industrial sector and provincial energy efficiency measurement. Zhao et al. (2014) used the DEA method to calculate the energy efficiency of China’s inter-provincial industrial sector, and compared the efficiency values of different regions [10]. Wang et al. (2014) applied the extended DEA method to evaluate the energy efficiency and energy saving and emission reduction potential of China’s inter-provincial industrial sector, revealing the current situation of unbalanced industrial development across the country [11]. Liu et al. (2015) analyzed the energy efficiency of China’s industrial sector using the network DEA model and proposed energy efficiency improvement methods [12]. Jiang (2014), Xie (2016), and Wang (2017) used the Malmquist index decomposition method based on the SBM-DEA model considering relaxation variables, using labor, capital, and energy consumption as input indicators to measure energy efficiency of China or individual provinces and cities [13–15]. Zhang et al. (2017) used super-efficiency DEA method to evaluate China’s low-carbon energy efficiency [16]. To better reflect the sustainable development ability of the research object, Zhu et al. (2019) fully considered the undesired output factors, and provided appropriate efficiency evaluation standards for the provinces and cities in the central region to evaluate the effectiveness of emission reduction [17].

In terms of the relationship between reform and efficiency, Fisher-Vander Karen et al. (2004) used 2500 high-energy-consuming large and medium-sized enterprises in China as a sample to measure the efficiency, and analyzed the driving effect of ownership reform on energy efficiency [18]. Fan et al. (2007) studied the relationship between market-oriented economic reforms and changes in energy efficiency, revealing the contribution of accelerated reforms to energy efficiency improvement [19]. To promote the development of the electricity trading market, She et al. (2020) compared and analyzed the power system production efficiency with and without market reform and pointed out that complete market reform will help improve production efficiency and shrink differences among regions [20].

The generation of reactive power in the energy and power industry will lead to an increase in energy consumption costs and environmental costs [21], and improving the comprehensive utilization of energy and power has become the only way to improve the sustainability of production activities [22]. Therefore, based on the measurement of energy efficiency, scholars have conducted a lot of research on the factors affecting efficiency. Hu et al. (2006) conducted energy efficiency calculations under the context of resource constraints and analyzed the factors influencing energy efficiency from the perspectives of technical efficiency, scale efficiency, and overall efficiency [23]. Flavia de Castro (2016) and Yi et al. (2019) used the Tobit model to analyze the influencing factors based on the efficiency measurement results under the DEA method [3,24]. Huang et al. (1993) believed that technological progress is the most important influencing factor and the actual effect of industrial structure changes is small [25]. Karen Fisher et al. (2006) studied the relationship between energy consumption and economic growth, employment, and other factors [26]. Sun et al. (2011), Miao et al. (2018), and Liu et al. (2018) found that technological progress is the key driving force for improving energy efficiency in empirical research [27–29]. Apriani et al. (2018) conducted research on energy efficiency data of the steel industry and found that government policies and management organizational factors have the greatest direct impact on energy efficiency improvement [30]. However, the concentration of key factors in energy-intensive industries does not mean that the final efficiency is improved. Only when all problems within the system are solved can the sustainable development of the power industry be achieved [31].

The above research shows that scholars have conducted in-depth research in the field of efficiency measurement and influencing factors, applied various model methods to empirical research, and comprehensively considered factors such as unintended output, technological level, economic status, and government intervention. However, from a macro perspective, the existing research rarely involves the interactive relationship between the efficiency of energy and power and supply-side structural reforms; the input–output indicator system has not been consistent with the reform goals; and the influencing factors analysis process failed to reflect the impact of reforms on changes in energy
efficiency, which have limited effect on effectively solving the problem of structural imbalance in energy power supply and demand. Therefore, this paper focuses on solving this problem during the research process and studies the measurement of China’s energy and power efficiency and influencing factors in combination with the target and current situation of the supply-side structural reform to clarify the specific direction of improving energy and power efficiency and provide references for other countries to formulate the efficiency improvement strategy.

3. Evaluation of the Energy and Power Efficiency Based on Super-Efficiency DEA Method

3.1. Conceptual Definition of the Energy and Power Efficiency

Energy efficiency reflects the level of energy consumption and the efficiency of energy utilization and is a comprehensive factor for measuring the level of energy utilization technology and economic benefits [32]. Based on energy efficiency, this paper comprehensively considers the status of energy and power supply and demand and environmental issues, and joins the power factor to derive the index of energy and power efficiency. Energy and power efficiency is a comprehensive measurement of the economic and environmental benefits obtained by decision-making units under certain input or output conditions. Combining the research background, research methods, and selected indicators of the paper, the energy and power efficiency refers to, in the case of ensuring a certain output level, the proportion of human, financial, and material resources invested by Chinese provinces increase or decrease proportionally to achieve the structural balance of energy and power supply and demand and the optimization of environmental quality. Thus, the indicator can be used as a reference basis for evaluating the effectiveness of the energy and power supply-side structural reform.

3.2. Super-Efficiency DEA Method

3.2.1. Selection of the Energy and Power Efficiency Measurement Method

Based on the literature review, the DEA method is an effective method for energy efficiency evaluation and has been widely used. Therefore, this paper makes a method selection based on the analysis of the applicability of specific methods under the DEA method. The DEA method, first proposed by the famous American operations researcher Charnes et al. in 1978, is a method for evaluating the efficiency of decision-making units, which can be used to evaluate the performance and efficiency of industries and organizations [33]. However, the evaluation system based on the CCR and BCC models under the traditional DEA efficiency evaluation method cannot completely order all homogeneous decision-making units, that is, the efficiency values of the effective decision-making units are uniformly defined as 1, and the pros and cons of different effective decision-making units cannot be identified [34]. The input-oriented super-efficiency DEA model, proposed by Anderson et al. in 1993, effectively solves this problem by comparing the evaluated decision-making unit with other decision-making units to obtain the super-efficiency value when the decision-making unit is effective so as to sort the effective decision-making units [7].

Because the purpose of this paper is to mine the degree of influence of key factors based on the energy and power efficiency in 30 provinces and cities in China from 2009 to 2017, it is required to obtain the specific efficiency value of effective decision-making units to ensure the accuracy of subsequent quantitative regression analysis results. Therefore, this section selects the super-efficient DEA method to measure the energy and power efficiency.

3.2.2. Introduction of the Super-Efficiency DEA Method

When evaluating the efficiency of the jth decision unit, the super-efficient DEA method replaces the input factor and output factor of the jth decision unit with the linear combination of the input factors and output factors of all other decision-making units, thereby eliminating the jth decision-making unit. An effective decision-making unit is that its input increases or decreases proportionally, but the
efficiency remains unchanged, and the proportion of its input increase or decrease is the super-efficiency evaluation value of the decision-making unit; while the inefficient decision-making unit, its efficiency is consistent with the results of the CCR-DEA model. The super-efficiency DEA method realizes the effective ranking of the evaluated decision units by distinguishing the efficiency differences of the effective decision-making units [7]. The mathematical model of the super-efficiency DEA method is as follows.

Suppose there are \( n \) decision units and each of them has \( m \) inputs and outputs, where \( x_j = (x_{j1}, x_{j2}, \ldots, x_{jm})^T > 0, y_j = (y_{j1}, y_{j2}, \ldots, y_{js})^T > 0 \), \( x_{ij} \) is the \( i \)th input of the \( j \)th decision-making unit, and \( y_{rj} \) is the \( r \)th output of the \( j \)th decision-making unit. Then, the calculation of the super efficiency value of the \( k \)th decision unit is as shown in Equation (1):

\[
h_k = \max \sum_{r=1}^{s} U_r y_{rk} \left\{ \begin{array}{l}
\sum_{i=1}^{m} V_i X_{ri} - \sum_{r=1}^{s} U_r y_{rj} \geq 0, j = 1, \ldots, n, j \neq k \\
\sum_{i=1}^{m} V_i X_{ik} = 1 \\
U_r \geq \epsilon, r = 1, \ldots, S \\
V_i \geq \epsilon, i = 1, \ldots, m
\end{array} \right. \tag{1}
\]

The dual problem of the above problem is shown in Equation (2):

\[
\min \theta_k \left\{ \begin{array}{l}
\sum_{j=1, j \neq k}^{n} \lambda_j x_{ij} + s_j^- = \theta x_k, i = 1, \ldots, m \\
\sum_{j=1, j \neq k}^{n} \lambda_j y_{ij} - s_r^+ = y_k, r = 1, \ldots, s \\
\lambda_j, s_j^- \geq 0, j = 1, \ldots, n
\end{array} \right. \tag{2}
\]

In the equation, \( \theta \) is the super efficiency value of the \( j \)th decision-making unit, and \( n \) is the number of decision-making units.

The results calculated by the super-efficient DEA model can be divided into three categories [35]:

- If the efficiency value is greater than 1, it indicates that the DMU is highly efficient or insoluble.
- If the efficiency value is less than 1, it indicates that the DMU is not efficient.
- If the efficiency value is equal to 1, it indicates that the DMU is weakly efficient or efficient but not extremely efficient.

### 3.3. Determination of Input–Output Factor System and Data Sources

A reasonable input–output index system is related to the effectiveness and accuracy of the energy and power efficiency evaluation, and it is also the premise and basis for quantifying the extent that the reform goals have been achieved. This paper takes the panel data of 30 provinces and cities in China from 2009 to 2017 as a sample, considering the three factors of human, financial, and material resources, taking labor, capital investment, and total energy consumption as input factors, and divides output into expected output and unexpected output according to the economic goals, which are expressed by the economic output factor GDP and the environmental output factor sulfur dioxide emissions, respectively. The results of the factor selection are shown in Table 1, and the reasons for the selection are as follows.

- Labor. Human resources are one of the most important input resources for economic and social development. As a unit that engages in a series of activities such as power generation, transmission, substation, and power distribution, to give full play to the value of human resources and strengthen the management of labor force deployment is an inevitable requirement for the energy and power sector to improve the internal management level and external competitiveness and get rid of the insufficient operation of traditional electric power enterprises.
- Capital investment. To realize the effective supply of energy and power resources, improving power facilities and increasing investment in fixed assets are inevitable measures for the industry. The amount of fixed asset investment in power facilities can effectively measure the capital investment in the power industry to promote efficient development, and can also respond to the demand of “improving the quality of supply system” in the supply-side structural reform of energy and power.

- Total electricity consumption. To promote economic development and improve development quality, in recent years, the scale of electricity consumption in the whole society continues to expand. On the one hand, the total electricity consumption can be used to measure the material resources invested by various provinces in China for economic and social development. On the other hand, in response to the requirements of the “transformation of economic development mode” for energy and power supply-side structural reform, provinces tend to use electrical energy instead of coal and other pollutant-emitting energy sources to reduce total amount of pollution emissions by strictly implementing China’s current power plant air pollutant emission standards. Therefore, this paper takes total electricity consumption as one of the key input factors.

- GDP. GDP refers to the value of all final products and services produced in the economy of a country or region within a certain period. Due to the close correlation between energy and power and economic development, this paper uses GDP as the expected output factor according to the economic purpose of the multi-factor input of energy and power.

- Sulfur dioxide emissions. In the process of economic and social operation, energy consumption emits many pollutants such as carbon dioxide, sulfur dioxide, nitrogen oxides, and soot, among which sulfur dioxide has the most serious negative impact on the atmospheric environment. Considering the impact of the energy consumption structure adjustment on the green index of comprehensive utilization of energy and power in various provinces, the paper selects sulfur dioxide emissions as one of the output indicators, which reflects the impact of changes in the proportion of total electrical energy consumption on energy efficiency through changes in undesired output indicators.

Table 1. The input–output factors of the energy and power efficiency.

| Factors                  | Measurement Standard |
|--------------------------|----------------------|
| Input factors            |                      |
| Labor                   | Number of permanent residents at the end of the year (unit: 10,000) |
| Capital investment      | The investment amount of fixed assets for power facilities in the energy and power industry (unit: 100 million yuan) |
| Total electricity consumption | Annual total electricity consumption (unit: 100 kWh) |
| Output factors          |                      |
| GDP                     | Annual gross domestic product (unit: 100 million yuan) |
| Sulfur dioxide emissions| Annual sulfur dioxide emissions in the power industry (unit: ton) |

According to the traditional geographical location, this paper divides the 29 provinces and cities except for Guangxi and divides Guangxi from the central area into the western area according to the definition of Western Development Strategy. For the sake of data availability, the research sample does not include data on Tibet, Hong Kong, Macau, and Taiwan, thus Tibet, Hong Kong, Macao and Taiwan are not included in the four areas. The details of the four regional divisions are shown in Table 2.

This part of the data comes from the 2009-2017 China Statistical Yearbook, China Energy Statistics Yearbook and the National Bureau of Statistics website. Among them, due to the lack of data on the labor in individual provinces, the paper selects the number of permanent residents at the end of the year to measure the human resources input and the data were obtained from China Statistical Yearbook in each year.
### Table 2. Details of the four regional divisions in China.

| Region          | Provinces and Cities                                      |
|-----------------|----------------------------------------------------------|
| Coastal area    | Beijing, Shanghai, Tianjin, Hebei, Shandong, Jiangsu, Zhejiang, Guangdong, Fujian, Hainan |
| Northeast area  | Liaoning, Jilin, Heilongjiang                            |
| Central area    | Henan, Anhui, Hunan, Hubei, Jiangxi, Inner Mongolia     |
| Western area    | Xinjiang, Qinghai, Gansu, Ningxia, Shaanxi, Shanxi, Guizhou, Sichuan, Chongqing, Yunnan, Guangxi |

### 3.4. Empirical Results and Analysis

Based on the index selection and data collection work, the MaxDea software is used to calculate the comprehensive efficiency with the SE-DEA method to obtain the energy and power efficiency in 30 provinces and cities in China and the measurement results are shown in Table 3.

### Table 3. The energy and power efficiency in 30 provinces and cities in China.

| Region          | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Mean  |
|-----------------|------|------|------|------|------|------|------|------|------|-------|
| Beijing         | 1.00 | 1.00 | 1.05 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.03 | 1.00  |
| Tianjin         | 0.90 | 0.95 | 1.00 | 1.01 | 1.01 | 1.12 | 1.23 | 1.27 | 1.25 | 0.94  |
| Shanghai        | 1.00 | 1.00 | 1.01 | 1.02 | 1.06 | 1.14 | 1.16 | 1.24 | 1.07 | 0.72  |
| Hebei           | 0.36 | 0.37 | 0.42 | 0.38 | 0.42 | 0.39 | 0.42 | 0.44 | 0.43 | 0.40  |
| Shandong        | 0.61 | 0.53 | 0.65 | 0.59 | 0.54 | 0.61 | 0.70 | 0.85 | 0.72 | 0.65  |
| Jiangsu         | 0.77 | 0.76 | 0.75 | 0.72 | 0.73 | 0.69 | 0.80 | 0.74 | 0.78 | 0.75  |
| Zhejiang        | 0.66 | 0.69 | 0.71 | 0.66 | 0.66 | 0.71 | 0.66 | 0.69 | 0.69 | 0.67  |
| Guangdong       | 0.66 | 0.64 | 0.62 | 0.64 | 0.66 | 0.63 | 0.63 | 0.62 | 0.67 | 0.64  |
| Fujian          | 0.63 | 0.62 | 0.57 | 0.56 | 0.57 | 0.53 | 0.62 | 0.58 | 0.63 | 0.59  |
| Hainan          | 0.54 | 0.52 | 0.66 | 0.54 | 0.53 | 0.46 | 0.59 | 0.72 | 0.71 | 0.58  |
| Liaoning        | 0.60 | 0.60 | 0.61 | 0.60 | 0.60 | 0.60 | 0.51 | 0.47 | 0.58 | 0.58  |
| Jilin           | 0.81 | 0.81 | 0.81 | 0.72 | 0.72 | 0.62 | 0.85 | 0.76 | 0.75 | 0.76  |
| Heilongjiang    | 0.72 | 0.75 | 0.76 | 0.63 | 0.63 | 0.56 | 0.69 | 0.61 | 0.62 | 0.66  |
| Henan           | 0.55 | 0.55 | 0.54 | 0.57 | 0.53 | 0.53 | 0.52 | 0.48 | 0.51 | 0.53  |
| Anhui           | 0.62 | 0.63 | 0.61 | 0.54 | 0.52 | 0.50 | 0.53 | 0.48 | 0.51 | 0.55  |
| Hunan           | 0.75 | 0.75 | 0.74 | 0.69 | 0.69 | 0.65 | 0.79 | 0.74 | 0.77 | 0.73  |
| Hubei           | 0.66 | 0.66 | 0.66 | 0.67 | 0.67 | 0.66 | 0.71 | 0.66 | 0.69 | 0.67  |
| Jiangxi         | 0.73 | 0.74 | 0.68 | 0.64 | 0.63 | 0.57 | 0.61 | 0.54 | 0.56 | 0.63  |
| Inner Mongolia  | 0.56 | 0.61 | 0.66 | 0.56 | 0.55 | 0.46 | 0.63 | 0.51 | 0.44 | 0.55  |
| Xinjiang        | 0.45 | 0.45 | 0.38 | 0.32 | 0.31 | 0.27 | 0.35 | 0.29 | 0.32 | 0.35  |
| Qinghai         | 0.28 | 0.31 | 0.34 | 0.28 | 0.28 | 0.25 | 0.36 | 0.30 | 0.30 | 0.30  |
| Gansu           | 0.28 | 0.28 | 0.27 | 0.23 | 0.23 | 0.22 | 0.25 | 0.25 | 0.25 | 0.25  |
| Ningxia         | 0.31 | 0.34 | 0.37 | 0.31 | 0.31 | 0.26 | 0.38 | 0.32 | 0.35 | 0.33  |
| Shaanxi         | 0.64 | 0.62 | 0.62 | 0.58 | 0.55 | 0.49 | 0.59 | 0.50 | 0.53 | 0.57  |
| Shanxi          | 0.34 | 0.35 | 0.38 | 0.34 | 0.33 | 0.28 | 0.32 | 0.27 | 0.32 | 0.33  |
| Guizhou         | 0.30 | 0.30 | 0.29 | 0.30 | 0.31 | 0.30 | 0.36 | 0.36 | 0.42 | 0.33  |
| Sichuan         | 0.62 | 0.60 | 0.58 | 0.50 | 0.49 | 0.35 | 0.59 | 0.54 | 0.60 | 0.54  |
| Chongqing       | 0.71 | 0.69 | 0.68 | 0.63 | 0.60 | 0.58 | 0.72 | 0.69 | 0.76 | 0.67  |
| Yunnan          | 0.40 | 0.39 | 0.36 | 0.30 | 0.30 | 0.28 | 0.37 | 0.37 | 0.41 | 0.35  |
| Guangxi         | 0.47 | 0.46 | 0.42 | 0.50 | 0.46 | 0.46 | 0.53 | 0.53 | 0.51 | 0.48  |
| Coastal area    | 0.71 | 0.71 | 0.74 | 0.71 | 0.72 | 0.71 | 0.78 | 0.80 | 0.81 | 0.73  |
| Northeast area  | 0.71 | 0.72 | 0.73 | 0.65 | 0.65 | 0.59 | 0.72 | 0.63 | 0.61 | 0.67  |
| Central area    | 0.65 | 0.66 | 0.65 | 0.61 | 0.60 | 0.56 | 0.63 | 0.57 | 0.58 | 0.61  |
| Western area    | 0.44 | 0.44 | 0.43 | 0.39 | 0.38 | 0.34 | 0.44 | 0.40 | 0.43 | 0.41  |
| National area   | 0.62 | 0.62 | 0.61 | 0.58 | 0.57 | 0.54 | 0.59 | 0.56 | 0.58 | 0.58  |

### 3.4.1. Analysis of the Energy and Power Efficiency Level

As shown in Figure 3, there are significant regional differences in the energy and power efficiency level, showing a decreasing trend from the coastal area and the northeast area to the central area and western area. During the study period, Beijing and Shanghai have the highest efficiency values, always
greater than 1. Gansu has the lowest, with an average efficiency of only 0.2521 and energy-saving potential of more than 70%; therefore, it is an area that China should focus on in energy conservation and consumption reduction work. The specific analysis is as follows.

Figure 3. Mean value distribution map of the energy and power efficiency level in various provinces and cities in China.

- Provinces and cities in the coastal area have higher efficiency levels, but the average efficiency of Hebei is relatively low. In the coastal areas, the high level of economic development provides material security for the energy conservation and emission reduction technology research and development and environmental pollution control. However, due to the dominant position of the secondary industry and the long-term transfer of heavy industry enterprises in the Beijing-Tianjin region, the economic benefits of Hebei Province are low, and the pollutant emissions problem is serious. Therefore, the efficiency level of energy and power in Hebei is lower than that in the coastal areas.

- The average efficiency of energy and power in the northeast area is at a medium level, and regional differences are small. Benefiting from the traditional old industrial bases, the northeast area has a good economic development foundation, but it is dependent on the development of high-energy-consumption and high-pollution industries. The large-scale discharge of pollutants has led to stagnant progress in efficiency improvement, that is, considering the unexpected output, there is a certain potential for energy conservation in the energy and power industry of the northeast area.

- The energy and power efficiency in the central area is between 0.5 and 0.7 except for Hunan, and the overall efficiency level is slightly lower than that in the northeast area. Because the economic development mode has not been significantly changed, the industrial structure of the provinces in the central area has heavy industry characteristics only after the eastern area. Against the background of supply-side structural reforms, the provinces in the central area cannot balance GDP growth and environmental protection, which leads to the bottleneck in improving energy and power efficiency.

- The energy and power efficiency level of provinces and cities in the western area is at the bottom, with the average efficiency from 2009 to 2017 less than 0.5, except for Chongqing, Shaanxi, and Inner Mongolia. Located in the interior of China, the western area is in a disadvantaged economic environment in terms of historical development basis, ecological stability, labor, etc. The lack of technical support for the development and utilization of renewable energy resources ultimately leads to a low level of energy and power efficiency.
3.4.2. The Trend Analysis of the Energy and Power Efficiency

From 2009 to 2013, Chinese economic development has one-sided pursuit of development speed; seriously wasted energy resources; neglected environmental pollution supervision and other issues; and improved the overall level of GDP at the expense of environmental quality and waste of natural resources. This has led to the consequence that the energy and power efficiency in the four areas showed a slow downward trend and fell to the lowest level during the study period in 2014. At the beginning of 2015, the relevant policies for the supply-side structural reform were initially launched. The government’s intervention in market-based behaviors has an impact on the energy and power efficiency in various areas. The resulting trend change analysis is shown in Figure 4.

Figure 4. Principle of overall efficiency level change before and after the supply-side structural reform.

However, historical development foundations and natural environmental reasons have led to regional differences in secondary industry dependency, technological level and resource reserves, and there are regional differences in the effectiveness of the energy and power supply-side structural reforms. As shown in Figure 5, the average energy and power efficiency in China as a whole and various areas generally changed significantly in 2014 as a turning point, and the energy efficiency average value in coastal areas is the highest, followed by the northeast and central areas. The western area had the lowest energy efficiency average value, which was always below the national average.

The interpretation and cause analysis of the changes in the average efficiency of each area are as follows:

- After the implementation of structural reforms in coastal areas from 2015 to 2017, the average efficiency showed a rising trend. The high-quality human resources and solid capital foundation attracted by the transformation of the economic development mode provide the human and material resources for the R&D and promotion of new technology of resource utilization in the coastal areas and eventually help solve the problem of structural excess and environmental pollution. The cross-regional consumption strategy has effectively alleviated the problem of the
structural shortage of regional energy and power supply. To sum up, policy and economic factors have jointly promoted the improvement of energy and power efficiency in the coastal area.

- The average value of energy and power efficiency in the northeast area showed a continuous decline before the supply-side structural reform and experienced a change from rising to falling after the reform. Since the supply-side structural reforms place high requirements on the quality of economic development, provinces in the northeast area improve the efficiency by optimizing the industrial structure and mitigating environmental pollution early in the reform. However, since the economic development of northeast China is highly dependent on the secondary industry, the positive impact of the decline in undesired output levels such as sulfur dioxide is not enough to make up for the negative impact of the slowdown in GDP growth on the trend of changes in energy efficiency values. Therefore, the efficiency level of northeast China shows a downward trend after the deepening of the supply-side structural reform.

- After a small improvement in 2015, the energy and power efficiency in the central area fell to the efficiency level before the supply-side structural reform. Problems such as a single energy utilization structure and backward energy conservation and emission reduction technology have existed for a long time in the central area, so it is difficult for short-term supply-side structural reforms to play a stable role in solving the problems, leading to great resistance in improving the energy and power efficiency, and the efficiency value dropped to the initial level after a slight increase.

- The efficiency level in the western area changed from a downward trend to an upward trend with 2014 as the turning point. To solve the problems of “structural insufficiency” and “structural excess” during the energy and power supply-side structural reform, the Chinese government has put forward a series of energy resource development and cross-regional consumption measures and policies. The western provinces and cities seized the opportunity to realize the improvement of the economic development level, reduce the cost of energy and power by making full use of renewable resources such as wind and solar energy, further meeting the energy and power needs of other areas, and ultimately promoting the improvement of regional efficiency level.

![Figure 5. China’s sub-regional efficiency average trend from 2009 to 2017.](image)

4. Analysis of Factors Influencing the Energy and Power Efficiency Based on Tobit Model

4.1. Tobit Model

4.1.1. Selection of the Correlation Analysis Method

After using the SE-DEA method to measure the energy and power efficiency in various provinces, this paper needs to choose a correlation analysis method to further explore its influencing factors and the degree of influence of each factor. Commonly used correlation analysis methods include visual
chart processing, covariance and covariance matrix, correlation coefficient calculation, information entropy and mutual information and univariate regression analysis and multiple regression analysis methods. In view of the characteristics of the large sample size of the research data in this paper, multiple regression analysis can achieve accurate measurement of the correlation of the analyzed objects, and is a more applicable correlation analysis method.

Among multiple regression analysis methods, the Tobit model is an econometric model first proposed by the Nobel Laureate in Economics James Tobin when he was studying the demand for durable consumer goods in 1958, mainly used to study the regression problem of observation data or the value of the dependent variable being truncated or restricted [36]. The applicability of the model in this paper is reflected in two perspectives. From the perspective of data dimensions, the model can reduce the correlation between explanatory variables as the sample size increases and eliminate multicollinearity to the greatest extent, so as to identify the relationship between observed values and explanatory variables, which is consistent with the goal of this article to accurately measure the correlation between the energy power efficiency and various influencing factors. From the perspective of observation range, the model can study all the values including different observation objects and the same observation object at different times, and its parameter estimation results can reflect the relationship between the observed objects and the explanatory variables within a certain period; thus, its dynamic advantages apply to this article’s requirement to observe all data of 30 provinces in China from 2009 to 2017. Therefore, the Tobit model is selected to study the factors influencing the energy and power efficiency and the degree of correlation between the energy and power efficiency and various influencing factors.

4.1.2. Introduction of the Tobit Model

Due to the particularity of the Tobit model, the coefficient deviation is high when the traditional least square method is used to solve the model. Therefore, the model estimates the parameters through the maximum likelihood function and requires the variables to follow a normal distribution. The expressions of the observed variables are shown in Equation (3):

\[ y_i^* = X_i \beta + \epsilon_i \]  \hspace{1cm} (3)

The form of data obtained in this article can be expressed as Equation (4):

\[ y_i = \begin{cases} y_i^*, & \text{if } y_i^* > c \\ c, & \text{if } y_i^* \leq c \end{cases} \]  \hspace{1cm} (4)

In this paper, a regression model of Equation (3) is established based on Equation (4) to estimate the parameters. Since the truncation limit c is known and the parameters are assumed to meet a certain distribution condition, the complete expression of the Tobit model obtained by normalizing and deforming is shown in Equation (5):

\[
\begin{cases}
    y_i = \begin{cases} X_i \beta + \epsilon_i, & X_i \beta + \epsilon_i > 0 \\ 0, & X_i \beta + \epsilon_i \leq 0 \end{cases} \\
    \epsilon_i = \text{Normal}(0, \sigma^2)
\end{cases}
\]  \hspace{1cm} (5)

That is, when yi is greater than zero, the value is not restricted. When yi is less than or equal to zero, the value is restricted, and all of them are zero. In the formula, X is the explanatory variable and \( \epsilon \) is the random error term.
4.2. Selection of Explanatory Variables Based on the Supply-Side Structural Reform and Data Sources

4.2.1. Selection of Explanatory Variables Based on the Supply-Side Structural Reform

With the reform philosophy of “de-capacity, de-stocking, deleveraging, cost reduction, and make up for the shortcomings”, China’s energy and power supply-side structural reform involves industrial structure, regional structure, emission structure, and other aspects, and is committed to improving the quality of supply and improve the structural contradiction of the supply and demand of energy and power resources. As the fundamental guarantee for improving economic benefits, promoting the optimization and upgrading of industrial structure and enhancing technological advantages will help promote the transformation of economic development methods, which will have a positive impact on the efficient use of energy and power resources and the increase in the effective supply, reduce undesired production to achieve efficiency improvement goals, and improve the sustainability of the energy and power industry. As an important way to make up for the shortage of market, the energy and power supply-side structural reform makes the government artificially adjust the fiscal expenditure to indirectly affect the energy and power efficiency level.

Based on the above analysis, this paper combines the current status and goals of the supply-side structural reform and uses the measurement results of the energy and power efficiency as the explanatory variables to select efficiency influencing factors that are in line with the reform goals and reflect the characteristics of energy and power industry. The final factor selection result is shown in Table 4, and the specific reasons for selecting are as follows.

Table 4. The selection result of factors influencing the energy and power efficiency.

| Influencing Factors               | Measurement Standard                                      |
|----------------------------------|----------------------------------------------------------|
| Industrial structure             | The proportion of output value of the secondary industry to GDP (unit: %) |
| Technological progress           | R&D expenditure as a percentage of GDP (unit: %)          |
| The economic development level   | GDP per capita (unit: ten thousand yuan per person)       |
| The opening up level             | Foreign direct investment as a percentage of GDP (unit: %) |
| Energy consumption structure     | Proportion of coal consumption in total energy consumption (unit: %) |
| Government intervention degree   | General public budget expenditure as a percentage of GDP (unit: %) |

- **Industrial structure.** Industrial structure is an important factor that affects the intensity of resource consumption. Its adjustment can promote the flow of resource elements from low-productivity industries to high-productivity industries, reduce resource waste, and increase the proportion of clean energy power consumption and reduce pollutants emission level by improving the energy and power resource demand structure [37]. Due to the high output value of the secondary industry and the large electrical energy demand, this paper selects the proportion of the output value of the secondary industry to GDP to represent the industrial structure.

- **Technological progress.** On the one hand, technological progress can push the market to eliminate backward-developed enterprises with low energy and power efficiency, promote effective resource allocation, and reduce low-end demand. On the other hand, the development of new technologies can realize the further development and utilization of clean energy, improve the clean energy consumption rate, and reduce pollutant emissions. Since adequate funding is the key to achieving technological progress, the proportion of research and development expenditure in GDP is selected to indicate technological progress.

- **The economic development level.** The extensive economic growth mode of economically backward regions is strongly dependent on thermal power generation, and the problems of environmental pollution and resource waste are serious. However, economically developed regions tend to be in a sustainable development mode, and the comprehensive utilization efficiency of energy and power is high. Because the demand for the supply-side structural reform to transform the economic development mode will directly impact the extensive economic growth mode in
backward areas and improve the efficiency level, and then affect the pollutant emissions and energy and power resource consumption, the economic development level is taken as an important explanatory variable.

- The opening up level. Firstly, foreign direct investment brings advanced technology, equipment, R&D capabilities, and management experience that can have a direct impact on the quality of energy supply and environmental pollution. Secondly, by increasing market vitality, foreign direct investment has forced similar Chinese enterprises to adopt more efficient and advanced production and management methods, which has caused resource flows to be reset and enter more energy-efficient companies. That is, foreign direct investment can improve the energy and power supply and demand structure by affecting the internal and external environment of the enterprise, thereby improving energy efficiency. Therefore, the opening up level is taken as an explanatory variable for energy and power efficiency.

- Energy consumption structure. Because China’s energy resource stocks are characterized by a large amount of coal, lack of oil, and low gas, coal consumption accounts for a high proportion of total energy consumption, resulting in high emissions of pollutants [38]. Industrial structure adjustment, as an important part of the supply-side structural reform, has a driving role in optimizing the traditional energy consumption structure and increasing the proportion of electricity consumption, thereby contributing to efficiency improvement. Therefore, in this paper, the proportion of coal consumption in total energy consumption is used as an explanatory variable for energy and power efficiency.

- Government intervention degree. There is a relationship between government intervention and market regulation, that is, excessive government intervention can easily weaken the role of market regulation and lead to inefficient investment, which influences the energy and power efficiency by reducing energy allocation efficiency. Fiscal expenditure refers to the actual use and control scale of GDP by the government to perform its functions. Therefore, this article uses the proportion of general public budget expenditure to GDP to measure the degree of government intervention.

4.2.2. Data Sources

Data come from the Statistical Yearbook of China, Statistical Yearbook of Provinces and Cities, Statistical Bulletin of National Scientific Research Expenditure, and Annual Statistical Reports of China from 2009 to 2017. GDP per capita selects the actual value of each province; for foreign direct investment, the actual amount of foreign capital utilized in the current year is selected and converted at the average annual exchange rate level for subsequent calculation in renminbi; public budget expenditure is selected from the local general public budget expenditure.

4.3. Empirical Results and Analysis

In this paper, Eviews8.0 software is used to perform Tobit quantitative regression analysis from five angles: national, coastal, northeast, central, and western. The correlation coefficient analysis results of each explanatory variable are shown in Table 5.

| Factor                        | National Area | Coastal Area | Northeast Area | Central Area | Western Area |
|-------------------------------|---------------|--------------|----------------|--------------|--------------|
| Industrial structure          | -0.002612     | -0.005513    | -0.008971      | -0.010489    | -0.005412    |
| Technological progress        | 0.107729      | 0.089272     | -0.129793      | 0.359626     | 0.060308     |
| The economic development level| 0.023724      | 0.015878     | 0.007513       | 0.005535     | 0.016737     |
| The opening up level          | 0.033048      | 0.040972     | -0.001627      | -0.155270    | 0.044070     |
| Energy consumption structure  | -0.016220     | -0.001144    | -0.002448      | -0.430776    | 0.001234     |
| Government intervention degree| -0.000271     | 0.006008     | 0.013180       | -0.001015    | -0.002618    |
As shown in Table 5, from the overall situation of the country, technological progress, the economic development level, and the opening up level have a positive correlation with the energy and power efficiency, while the industrial structure, energy consumption structure, and government intervention degree have a negative correlation, which is the same as the assumptions when interpreting the variables. From the perspective of the four areas, technological progress is an important influencing factor for the energy and power efficiency in each area to change from a downward trend to an upward trend taking the supply-side structural reform as a turning point. There are regional differences in the influence and degree of various influencing factors on the energy and power efficiency. The specific analysis is as follows.

4.3.1. Industrial Structure

As shown in Table 5, the industrial structure and the efficiency values of the four areas have a negative correlation, that is, the lower is the proportion of the output value of the secondary industry in GDP, the higher is the energy efficiency value. The correlation between industrial structure and efficiency levels before and after the supply-side structural reform is shown in Figure 6.

![Figure 6. Influence mechanism of industrial structure on the efficiency level.](image)

For a long time, the secondary industry, as a basis for promoting economic growth and increasing government taxation, has led to the obvious industrialization characteristics of China’s industrial structure. Its high energy consumption and high pollution emission characteristics make China’s energy and power efficiency level have large room for improvement. Since the supply-side structural reform in 2015, the Chinese government has set the goal of establishing a new modern industry system of “optimized structure, advanced technology, clean and safe, high added value and strong employability” to provide an impetus for the upgrading of industrial structure through policy guidance. With the implementation of various policies and measures for reform, the problems of backward development and low quality of the overall industrial structure caused by the extensive development mode have been alleviated and the proportion of the secondary industry in GDP in all provinces and cities has declined. The flow of the resources from the secondary industry to the tertiary industry and emerging industries has promoted the improvement of the energy and power efficiency in various regions.

4.3.2. Technological Progress

Technological progress has the strongest correlation with the overall energy and power efficiency of the country, about 0.107279, but shows a weak negative correlation in the northeast area. The government regards technological progress as an important support for the supply-side structural reform, deepening the implementation of the innovation-driven development strategy, and accelerating the conversion of new and old kinetic energy to address major development issues in the energy and
power industry. The relationship between technological progress and efficiency levels before and after the supply-side structural reform is shown in Figure 7.

![Figure 7. Influence mechanism of technological progress on the efficiency level.](image)

The improvement effect of technological progress on the energy and power efficiency in the coastal area, central area, and western area can be analyzed from three aspects. On the demand side, technological progress is conducive to the comprehensive utilization of resources, prompting the market to eliminate low-tech enterprises or industries and reduce waste of energy and power resources. On the supply side, technological progress is closely related to the development and utilization of renewable energy, which can effectively alleviate the “structural insufficiency” problem by increasing the renewable energy consumption rate. In terms of energy conservation and emission reduction, technological progress means improving the ability to control environmental pollution, reducing unexpected output, and then improving the energy and power efficiency.

However, technological progress has negatively affected the improvement of energy and power efficiency in the northeast area, which is caused by the dependence on traditional industries. Technological progress has promoted increased emissions reduction of pollutants in the northeast area, but the economic losses caused by the decline in the proportion of the output value of the secondary industry in GDP are too high, resulting in a negative correlation between technological progress and the energy and power efficiency.

4.3.3. The Economic Development Level

The level of economic development in four areas has a positive correlation with energy and power efficiency. In 2015, the State Council put forward the green development strategy, which aims to strengthen the regional economic strength while implementing policies related to energy conservation and emission reduction and promoting the improvement of the economic development quality. With the gradual deepening of supply-side structural reform, the economic development level and the energy and power efficiency in the four areas have achieved simultaneous growth. The correlation between the two is shown in Figure 8.

On the one hand, economic development lays a material foundation for the widespread application of advanced technologies and equipment, which contributes to improving the technique level of comprehensive energy utilization and developing the clean energy power, and directly promotes the improvement of the energy and power efficiency. On the other hand, economic development makes people demand a higher level of quality of life, which requires individuals to increase environmental awareness and relevant departments to improve their pollution control capabilities. It can be seen that economic development echoes the supply-side structural reform’s major development requirements of “expand effective supply” and “improve the adaptability of supply and demand structure” in the aspects of consolidating the material basis for the development and utilization of energy and power.
resources and enhancing the environmental protection awareness of the whole society. Therefore, economic development is the inherent driving force behind the improvement of energy and power efficiency levels in various regions after the reform.

![Figure 8. Influence mechanism of economic development level on the efficiency level.](image)

4.3.4. The Opening Up Level

The relationship between the opening up level and the energy and power efficiency is positively correlated in coastal and western provinces and cities, and negatively correlated in the central and northeast provinces and cities. The correlation between the opening up level and the efficiency level in each area is shown in Figure 9.

![Figure 9. Influence mechanism of the opening up level on the efficiency level.](image)

In terms of coastal areas, the actual use of foreign capital can not only bring advanced technology, equipment, and management experience to provinces and cities to improve energy and power efficiency directly but also play an incentive role in market regulation, prompting companies to adopt more efficient production and management methods and improve efficiency level by increasing the efficiency of resource allocation. As far as the western area is concerned, as the provinces and cities have long been rarely open to the outside world, the growth of the actual use of foreign capital has a significant positive impact on economic development and the use of clean energy sources such as wind energy and solar energy, and then indirectly promotes the improvement of the energy and power efficiency by reducing undesired output level.

During the process of opening up to the outside world, the northeast and central area introduced more resource-intensive products such as steel, automobiles, machinery, and equipment, which resulted
in high production energy consumption and serious environmental pollution, reducing the energy and power efficiency. Some provinces and cities aim to increase the economic development level by increasing energy and power resources input to conduct primary processing of products, which ultimately leads to a reduction in economies of scale and a negative impact on the energy and power efficiency level.

To sum up, the impact of opening up on the efficiency level is two-sided. Different areas or enterprises should combine the actual situation and make reasonable use of foreign capital.

4.3.5. Energy Consumption Structure

The relationship between the proportion of coal consumption and the energy and power efficiency level is negatively correlated in the coastal, northeast, and central areas and positively correlated in the western area. China’s energy consumption structure is dominated by coal, which has low heat production efficiency and a higher pollution emission coefficient than other energy sources; thus, high pollution emissions hinder the improvement of energy power efficiency.

In response to the above problems, the Chinese government issued Action Plan for the Upgrade and Reconstruction of Energy Saving and Emission Reduction of Coal Power (2014–2020), Opinions on Promoting Safe and Green Development and Clean and Efficient Utilization of Coal, and About Opinions on Promoting the Supply-Side Structural Reforms to Prevent and Eliminate the Risk of Coal Power Overcapacity as well as other documents committed to strictly controlling pollutant emissions from thermal power generation enterprises, encouraging enterprises in various industries to directly use power resources to carry out production and operation activities, and promoting the energy and power supply-side structural reform. As shown in Figure 10, the total energy and power consumption in the coastal, northeast, and central areas is high, much of which flows to resource-intensive industries; thus, optimizing the energy consumption structure can promote the energy and power efficiency has an upward trend after 2014 by increasing the proportion of clean energy consumption and reducing pollutant emissions. Since the economic development level and total energy and power consumption is relatively low in the western area, increasing coal consumption has a driving effect on GDP growth. Therefore, the proportion of coal consumption has a weak positive correlation with the efficiency in the western area.

![Figure 10. Influence mechanism of energy consumption structure on the efficiency level.](image)

4.3.6. Government Intervention Degree

Among the six explanatory variables, government intervention degree has the weakest correlation with the energy and power efficiency, which has a positive correlation in coastal and northeast areas and a negative correlation in central and western areas. Since the supply-side structural reform, the government has continued to increase fiscal expenditures to support technological research and development, promote regional economic development, and attract investment, committing to improving the quality of energy and power supply in various areas. The mechanism analysis of the effect of technological progress on the efficiency level is shown in Figure 11.
Due to the developed economy and relatively high levels of marketization, strengthening government intervention can help complementary advantages of market adjustment and government adjustment, then improve the energy and power efficiency by encouraging enterprises to reform their development mode and reduce the risk of development quality caused by blind pursuit of economic growth. Relatively speaking, the central and western areas have a limited degree of marketization, so it is easy for the government to intervene excessively in the process of economic intervention, which weakens the market's ability to effectively allocate resources and leads to severe redundancy of labor, energy and power, capital, and other resource factors. In places where the original policy occupied some energy resources but did not achieve the expected results, the improvement of the efficiency level in the central and western areas was hindered. To sum up, the impact of government intervention on energy and power efficiency is two-sided.

5. Optimization Strategy on the Energy and Power Efficiency

The above analysis shows that industrial structure, technological progress, the economic development level, the opening up level, energy consumption structure, and government intervention degree can all have different degrees of influence on the energy and power efficiency, and different areas are affected differently. Thus, formulating efficiency optimization strategies can provide guarantee for the improvement of the energy and power efficiency based on the correct understanding of the domestic situation. According to the efficiency trends from 2009 to 2017 and the correlation of various influencing factors, this article proposes policy suggestions for improving China’s energy and power efficiency in the aspects of structural adjustment, technological research and development, the transformation of development methods, and government regulations.

- Speed up industrial structure adjustment and optimize energy consumption structure. The transformation of the industrial structure will directly promote the changes in the regional energy and power utilization through “energy conservation, consumption reduction, pollution reduction and efficiency enhancement” by enterprises, thus improving the efficiency level [39,40]. The coastal area should continue to vigorously develop modern service industries such as health industry and tourism and deepen the ecological capital operation. The correlation between industrial structure and efficiency in the northeast and central areas is higher than that in the coastal and western areas, which are ~0.008971 and ~0.010489, respectively. Therefore, great efforts should be made to finally reduce the dependence of economic development on the energy and power through reforming or eliminating resource-intensive industries. The correlation coefficient between the efficiency level and coal consumption in the western area is 0.001234, but it should...
also coordinate with China’s energy and power supply-side structural reform to improve the energy and power efficiency from the perspective of sustainable development.

- Increase support for R&D funding and encourage technological innovation and promotion. Technological progress is positively correlated with the national energy and power efficiency, and the correlation coefficient is as high as 0.107279, which is the key influencing factor for the continuous improvement of efficiency. The coastal and northeast areas focus on research and development of energy-saving and emission-reduction technologies and promote the development of innovative and environmentally-friendly technology application industries, thereby boosting the simultaneous improvement of economic development and environmental quality. The central and western areas should deepen the impact of technological innovation on energy development and utilization methods and make full use of clean energy. All areas should build a regional technology exchange platform to promote extensive communication of comprehensive energy utilization technologies.

- Promote the transformation of development mode and improve the quality of economic development. The northeast area can make full use of the policy opportunities to expand domestic demand to cultivate emerging industries and accelerate the formation of a pillar industry diversification pattern, so as to reduce the dependency of economic development on the secondary industry. The central area should pay attention to extending the industrial chain of coal conversion, build a circular economy system, and take a new road to green industrialization. The western area can take advantage of the Western Development Strategy to give play to the role of support funds in guiding industrial development and encourage provinces and cities to fully develop and utilize regional clean energy resources on the premise of sustainable development.

- Formulate policies according to local conditions and improve the level of government regulation. Since there is a regional difference in the correlation between government intervention and the energy and power efficiency, the government should tailor measures to suit the goals of energy and power supply-side structural reform according to local conditions and rationally use the market mechanism and government intervention to improve efficiency. Among them, the efficiency levels of the northeast and central areas are negatively related to the degree of government intervention, with correlation coefficients of \(-0.001015\) and \(-0.002618\), respectively. The local government should strengthen the supervision of pollutant discharge, rationally plan the pollution control investment, and reduce the undesired output level through government regulations.

6. Conclusions

Based on the analysis of the current energy use situation in China and revealing the development problems of the energy and power industry, this paper uses the SE-DEA model and the Tobit model to conduct efficiency measurement and analyzes of the impact mechanism of energy development quality in 30 provinces and cities in China from 2009 to 2017. The following conclusions are drawn:

- The measurement results of the energy and power efficiency show that China’s supply-side structural reform has achieved results in the field of energy and power, and the overall energy and power efficiency level in China has achieved improvement with the reform as the turning point. However, different actual conditions lead to different trends in the efficiency level after the reform. Among them, the effectiveness of reform in the northeast and central areas is slightly lower than that in the coastal and western areas, thus further reform measures should be taken to improve the energy and power efficiency.

- According to the research results of the influencing factors of efficiency based on the supply-side structural reform, from the overall situation in the country, technological progress, economic development level, and the opening up level are positively related to the energy and power efficiency, while industrial structure, energy consumption structure, and government intervention degree are negatively correlated. Among them, the correlation between technological progress
and the efficiency level is as high as 0.107279, which can be used as a key starting point for improving energy and power efficiency.

- Combining the measurement results of China’s energy and power efficiency with influencing factors research results, it can be seen that the improvement of China’s energy and power efficiency depends on structural adjustment, technology research and development, the transformation of development modes, and government regulations. Therefore, this paper formulates the optimization strategy to improve the energy and power efficiency based on the above factors, which can provide an important basis for deepening the energy and power supply-side structural reform.

According to the World Energy Outlook of 2018 released by the International Energy Agency, global demand for electricity will increase by 90% by 2040 from the current level. Data show that, in 2018, global investment in renewable energy accounted for more than 60%; electrification and green power have become the focus of green investment in energy and power; and improving energy and power efficiency is the common goal of the current international community. Therefore, this paper proposes strategies to improve the energy and power efficiency by studying actual panel data of Chinese provinces, which will not only help deepen China’s energy and power supply-side structural reform but also provide a clear reference for the improvement of the energy and power efficiency in the international community, so as to offer impetus to the global energy and power supply–demand balance and environmental pollution issues.

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