

Empirical Analysis of Influencing Factors on the Changes in Energy Consumption Structure in Jiangxi Province

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Abstract: With the rapid development of China's economy, the problems of low efficiency in energy and resource utilization and the continuous deterioration of environmental quality have become increasingly prominent. As one of the important energy bases in China, Jiangxi Province's energy consumption structure not only has a significant impact on the national energy pattern, but also plays a certain role in the global energy and environmental situation. Therefore, conducting an in-depth study of the influencing factors of the clean energy consumption structure in Jiangxi Province is of great practical significance for promoting the sustainable development of regional energy. Based on the relevant data of energy consumption in Jiangxi Province from 2009 to 2023, this study conducted an empirical analysis of the influencing factors of changes in the consumption structure of clean energy using a multiple linear regression model. Through parameter estimation, hypothesis testing, model diagnosis and correction, a relatively reasonable regression model was finally determined. The research results show that the level of economic development, energy prices and technological level are the key factors influencing the consumption structure of clean energy in Jiangxi Province, among which the impact of energy prices is the most significant. Based on the above conclusions, this paper puts forward several management suggestions, with the aim of providing reference and inspiration for the adjustment and optimization of the energy structure in Jiangxi Province.

Keywords: Jiangxi Province; Energy Consumption Structure; Linear Regression; Autocorrelation; Multicollinearity.

1. Introduction

Throughout the evolution of human society, energy has always held a pivotal position. It not only constitutes the cornerstone of economic development, providing strategic economic support for the country and region, but also plays a significant role in people's daily life [1][2]. It plays an indispensable role. In the current era of pursuing high-quality development, it is imperative to reduce economic growth's reliance on energy, enhance energy utilization efficiency, address energy shortages, and improve environmental quality. Optimizing the energy consumption structure is an important way to achieve high-quality economic development and the "dual carbon" goals[3][4][5]. With the improvement of economic development levels and the acceleration of technological progress, the proportion of clean energy in the total energy consumption has gradually increased, becoming a key indicator for measuring the effectiveness of regional energy transformation.

Jiangxi Province, as an important province in central China, has certain representativeness in terms of resource endowment and economic development model[6]. In recent years, Jiangxi Province's economy has maintained a steady growth, with its GDP growth rate ranking among the top in the country. Its industrial structure has also been gradually optimized. However, the energy consumption problem that accompanies this process has also become increasingly prominent. Jiangxi Province has relatively limited energy resource endowments and mainly relies on energy transferred from outside to meet its demands. The level of economic development is a fundamental factor influencing the energy consumption structure[7]. Generally speaking, as GDP grows and residents' income levels rise, the demand for clean energy

increases. At the same time, the government also has more financial resources to invest in the construction of clean energy infrastructure[8][9]. Against the backdrop of rapid economic development, the slowdown in energy consumption growth and the intensification of environmental protection pressure coexist. How to promote energy structure adjustment and improve energy utilization efficiency while ensuring economic growth has become a key challenge for this province. Furthermore, with the proposal of the "dual carbon" goals across the country, Jiangxi Province needs to balance the relationship between development and emission reduction during the economic transformation process and explore a path suitable for its own characteristics to achieve a green economic transformation[10][11][12].

The energy consumption characteristics of Jiangxi Province reflect the close connection between regional economic development and the energy structure. The traditional energy structure dominated by coal, while promoting economic growth, has also brought about significant environmental costs[13][14][15]. The purchase price index for industrial producers reflects the changes in the prices of production factors. Alterations in price signals can affect enterprises' energy choice decisions and, in turn, influence the overall energy consumption structure. The proportion of R&D expenditure to GDP reflects the intensity of regional technological innovation investment[16][17]. Technological progress is an important driving force for promoting the development of clean energy and the clean utilization of traditional energy. Jiangxi Province needs to further reduce its reliance on traditional fossil energy on the basis of optimizing its energy structure to address the increasingly severe environmental and resource challenges.

Based on this background, this paper selects the relevant

data of Jiangxi Province from 2009 to 2023 and adopts the stepwise regression method to empirically analyze the influence degree of economic development level, energy price and technological level on the proportion of clean energy in the total energy consumption of Jiangxi Province, with the aim of providing empirical basis for the optimization of the energy structure of Jiangxi Province. Specifically, from the perspective of economic growth, study its direct impact on the energy consumption structure, while paying attention to the roles of factors such as energy prices and technological progress. In addition, this article will also propose potential policy measures for enhancing energy efficiency and optimizing the energy structure, providing decision support for Jiangxi Province and other central provinces. This research not only helps to understand the intrinsic logic between economic growth and energy consumption, but also provides theoretical basis and practical reference for achieving sustainable development and green economic transformation in Jiangxi Province.

2. Variable Selection and Data Collection

(1) The explained variable

The optimization of regional economic structure and ecological environment is an important goal and planning for the development of Jiangxi Province. To ensure economic stability

It is particularly important to achieve stable growth while reducing the negative impact on the environment, controlling the consumption of traditional energy sources such as coal and oil, and increasing the proportion of clean energy consumption structure like electricity and natural gas. To gain a deeper understanding and quantify the key factors influencing this transformation, it becomes crucial to conduct a quantitative analysis of the factors affecting the energy consumption structure. The energy consumption structure mainly reflects the proportional relationship between the consumption of clean energy (such as natural gas, wind power, solar energy, geothermal energy, etc.) and the total energy consumption, as well as the proportional relationship between the total consumption of non-clean energy (such as coal and oil) and energy consumption. According to Table 1, in this paper, the ratio of clean energy consumption such as natural gas and electricity in Jiangxi Province to the total energy consumption of Jiangxi Province is taken as the explained variable of the model, represented by the variable Y.

(2) Explanatory variable

This article focuses on the research of key factors for optimizing the energy consumption structure in Jiangxi Province, aiming to promote the optimization and upgrading of the energy consumption structure in Jiangxi Province. Through a comprehensive analysis of the existing literature and materials, it is found that economy and technology are the main factors influencing the changes in the energy consumption structure. In-depth analysis of this can provide strong support for the optimization of the energy consumption structure in Jiangxi Province. Firstly, economic factors: From a macro perspective, the continuous growth of the national economy has made it possible to discover and utilize new energy sources. From a micro perspective, consumption theory indicates that energy prices play a crucial role in influencing energy consumption volume. Fluctuations in energy prices can also reflect the structure and usage of

energy resources. Secondly, technological factors: With the improvement of technological levels and the advancement of production techniques, the efficiency of energy production gradually increases, thereby reducing energy consumption and further influencing the changes in the energy consumption structure.

Based on the above analysis of the dimensions of its influencing factors and after consulting a large number of relevant literatures, the indicators that affect the changes in the energy consumption structure are selected. Among them, economic factors include the level of economic development and energy prices; Technical factors include the level of science and technology.

(3) The source and collection of data

This study selects the ratio of the consumption of clean energy such as natural gas and hydropower in Jiangxi Province from 2009 to 2023 to the total energy consumption of Jiangxi Province as the data of the energy consumption structure of Jiangxi Province. The GDP of Jiangxi Province represents the economic development level of Jiangxi Province. As there is no unified energy price index at present, and the purchase price index of fuel and power in the industrial sector can reflect the energy price situation to a certain extent, the purchase price index of industrial producers in Jiangxi Province is used to represent the energy price index. The level of science and technology is expressed by the investment in research funds, that is, the proportion of R&D in GDP. The specific data are shown in Table 2.

The main data of this study is sourced from the Statistical Yearbook of Jiangxi Province and is relatively authoritative. The empirical analysis conducted in this paper, including data processing, econometric estimation and testing of the model, etc., adopts the stepwise regression method to process the data. Considering that the heteroscedasticity problem can be eliminated for each time series data, this paper considers the ratio of the consumption of clean energy such as natural gas and hydropower to the total energy consumption of Jiangxi Province from 2009 to 2023 as the data of the energy consumption structure of Jiangxi Province for empirical analysis.

3. Data Processing and Analysis

(1) Data characteristics

The descriptive statistical characteristics of the main variables are shown in Table 3. The minimum value of the explained variable Y is 5.20 and the maximum value is 17.20, indicating that the proportion of clean energy consumption in Jiangxi Province has increased significantly in recent years. Judging from the standard deviation and maximum and minimum values of X_2 , the economic development level of Jiangxi Province has significantly improved. Furthermore, from the maximum and minimum values and standard deviations of X_3 and X_4 , it can be seen that both the energy prices and the level of technological development in Jiangxi Province have significantly improved.

The correlation analysis results of the main variables are shown in Table 4. It can be seen from the results that there is an overall significant correlation between the explained variable and the solved variable, and the correlation coefficients among the variables are relatively large. Therefore, the validity of the model regression may be affected by multicollinearity.

(2) Model construction, estimation and verification

Table 1. Energy Consumption in Jiangxi Province from 2009 to 2023

Year	Total energy consumption (10,000 tons of standard coal)	Proportion of coal (%)	Proportion of petroleum (%)	The proportion of non-clean energy in total energy consumption (%)	Proportion of natural gas (%)	Proportion of hydropower (%)	The proportion of clean energy in total energy consumption (%)
2007	5052.54	74.90	16.90	91.80	0.30	5.30	5.60
2008	5382.96	71.70	16.70	88.40	0.60	5.70	6.30
2009	5812.54	72.00	16.00	88.00	0.50	4.70	5.20
2010	6354.88	70.69	16.30	86.99	1.00	4.70	5.70
2011	6928.17	74.30	15.60	89.90	1.20	4.10	5.30
2012	7232.92	69.50	15.80	85.30	1.90	6.80	8.70
2013	7582.94	70.50	17.50	88.00	2.40	5.44	7.84
2014	8055.36	68.00	16.90	84.90	2.50	5.40	7.90
2015	8423.44	66.60	17.50	84.10	2.72	7.41	10.13
2016	8730.05	65.23	17.59	82.82	3.04	8.09	11.13
2017	8971.87	64.38	18.12	82.50	3.09	7.47	10.56
2018	9285.68	64.37	18.53	82.90	3.45	6.69	10.14
2019	9665.15	62.42	18.70	81.12	3.42	8.57	11.99
2020	9808.58	62.86	16.92	79.78	3.76	8.46	12.22
2021	10345.50	59.58	14.84	74.42	4.70	9.00	13.70
2022	10785.69	60.59	13.75	74.34	5.10	10.73	15.83
2023	11533.90	60.60	15.30	75.90	6.00	11.20	17.20

Table 2. Energy Consumption Structure and Its Influencing Factors Indicators in Jiangxi Province from 2009 to 2023

Year	Y	X ₂	X ₃	X ₄
2009	5.20	7629.98	96.31	0.99
2010	5.70	9383.16	106.59	0.92
2011	5.30	11584.52	108.50	0.83
2012	8.70	12807.69	102.80	0.88
2013	7.84	14300.17	97.58	0.94
2014	7.90	15667.78	97.80	0.97
2015	10.13	16780.89	89.56	1.04
2016	11.13	18388.59	97.30	1.13
2017	10.56	20210.78	110.22	1.23
2018	10.14	22716.51	105.60	1.41
2019	11.99	24667.29	97.43	1.55
2020	12.22	25825.40	94.40	1.68
2021	13.70	29838.20	115.13	1.70
2022	15.83	31568.10	118.62	1.74
2023	17.20	32677.10	96.97	1.88

Table 3. Descriptive Statistical Characteristics of Each variable

Variable	Y	X ₂	X ₃	X ₄
Maximum	17.20	32677.1	118.62	1.88
Minimum	5.20	7629.98	89.56	0.83
Mean	10.24	19603.08	102.32	1.26
Median	10.14	18388.59	97.80	1.13
Standard deviation	3.50	7765.73	7.920	0.35

Before the construction of the model, this paper sets the following assumptions: First, the impact relationship of the input effectiveness of production and research and development on the energy consumption structure of Jiangxi Province is not considered; Second, restrictions on special

production activities and emergencies are not taken into account. Third, the mutual influence of changes in the constituent elements of energy is not taken into account. Fourth, the impact of climatic factors such as temperature and rainfall on the energy consumption structure is not taken into account.

Table 4. Correlation Analysis of Each Variable

	Y	X ₂	X ₃	X ₄
Y	1			
X ₂	0.963*	1		
X ₃	0.180	0.279	1	
X ₄	0.909*	0.956*	0.221	1

To better analyze the correlation between energy consumption structure and economic development level, we selected the statistical data of the proportion of clean energy in the total energy consumption and GDP of Jiangxi Province from 2009 to 2023, and established a binary linear regression model:

$$y = b_1 + b_2x_2 + e_i$$

Among them, y represents the proportion of clean energy in the total energy consumption, x_2 is GDP, x_3 is the purchase price index for industrial producers, and x_4 is the proportion of R&D expenditure in GDP. After standardizing the original data, the statistical analysis software SPSS was run for linear regression analysis, and the linear regression model can be obtained as:

$$y = 0.000 + 0.921x_2 + e_i$$

Let $\alpha=0.1$, and we propose the following assumption:

$$H_0: B_i = 0, Y = B_1 + B_2X_2 + u_i$$

$$y = b_1 + b_2x_2 + e_i$$

$$t(b_i) \sim t(13)$$

At the α level, the rejection domains of the t-test are: $(-\infty, -1.771]$ and $[1.771, +\infty)$. Therefore, $t(b_1)$ does not fall within the rejection domain and does not reject the null hypothesis, meaning that the constant term is of little significance to the model; while $t(b_2)$ falls within the rejection domain and rejects the null hypothesis, x_2 is meaningful to the model.

The economic significance of this model is explained as follows: On average, under the condition that other factors remain unchanged, for every one standard deviation change in GDP, the proportion of clean energy will change by 0.921 standard deviations. This model reflects 84.8% of the real situation.

Similarly, we selected the statistical data of the proportion of clean energy in the total energy consumption, GDP and the purchase price index of industrial producers in Jiangxi Province from 2009 to 2023. After standardizing the original data, we ran the statistical analysis software SPSS and conducted linear regression analysis. The linear regression model can be obtained as:

$$y = 0.000 + 0.915x_2 - 0.096x_3 + e_i$$

At the α level, the rejection domains of the t-test are: $(-\infty, -1.782]$ and $[1.782, +\infty)$. Therefore, neither $t(b_1)$ nor $t(b_3)$ fall within the rejection domains, thus not rejecting the null hypothesis, meaning that the constant term and x_3 are of little significance to the model; while $t(b_2)$ falls within the rejection domains, rejecting the null hypothesis, and x_2 is meaningful to the model.

Joint Hypothesis testing:

$$H_0: R^2 = 0$$

$$F \sim F(2,12)$$

At the α level, the F value in the model falls within the right rejection domain of the f-test $[2.81, +\infty)$, rejecting the null hypothesis, that is, $R^2 \neq 0$.

The economic significance of this model is explained as follows: On average, under the condition that other factors remain unchanged, for every standard deviation change in GDP, the proportion of clean energy will change by 0.915 standard deviations. This model reflects 85.7% of the real situation.

Similarly, we selected the statistical data of the proportion

of clean energy in the total energy consumption, GDP, the purchase price index of industrial producers, and the proportion of R&D expenditure in GDP of Jiangxi Province from 2009 to 2023. After standardizing the original data, we ran the statistical analysis software SPSS and conducted linear regression analysis. The linear regression model can be obtained as:

$$y = 0.000 + 0.425x_2 - 0.194x_3 + 0.647x_4 + e_i$$

At the α level, the rejection domain of the t-test is: $(-\infty, -1.796]$ and $[1.796, +\infty)$, so $t(b_1)$ does not fall within the rejection domain and does not reject the null hypothesis, that is, the constant term is of little significance to the model; while $t(b_2)$, $t(b_3)$, and $t(b_4)$ all fall within the rejection domain and reject the null hypothesis, that is, x_2 , x_3 , and x_4 are meaningful to the model.

Joint Hypothesis testing:

$$H_0: R^2 = 0$$

$$F \sim F(3,11)$$

At the α level, the F value in the model falls within the right rejection domain of the f-test $[2.66, +\infty)$, rejecting the null hypothesis, that is, $R^2 \neq 0$.

The economic significance of this model is explained as follows: On average, under the condition that other factors remain unchanged, for every standard deviation change in GDP, the proportion of clean energy will change by 0.425 standard deviations. For every one standard deviation change in the purchase price index of industrial producers, the proportion of clean energy will reverse by 0.194 standard deviations. For every one standard deviation change in the proportion of R&D expenditure to GDP, the proportion of clean energy will change by 0.647 standard deviations. This model reflects 97.0% of the real situation.

The final determined model includes three explanatory variables: GDP, the purchase price index for industrial producers, and the proportion of R&D expenditure to GDP. Among them, GDP and R&D expenditure have a positive impact on the proportion of clean energy, while the price index has a negative impact.

(3) Model autocorrelation diagnosis and remediation

The residual sequence correlation coefficient of the model is 0.3267, indicating a moderate degree of positive sequence correlation. The scatter plot shows that the distribution of points is not completely random, suggesting that sequence correlation may exist.

$$d = \frac{\sum_{i=2}^n (e_i - e_{i-1})^2}{\sum_{i=1}^n e_i^2} = 1.34$$

At the level of $\alpha=0.1$, referring to the D-W table yields $D_1=0.84$, $D_u=1.75$, and $4-D_u=2.25$. The d value does not fall within the range of $[D_u, 4-D_u]$, and H_0 is rejected. Conclusion: autocorrelation exists.

The original model was transformed into a differential model, and the least square method was used to regression 14 differential observations, obtaining the following results:

$$\Delta y_t = 0.0003\Delta x_{2t} - 0.089\Delta x_{3t} + 4.234\Delta x_{4t}$$

From the scatter plot, it can be seen that the variation of the residual e is random, and there is no autocorrelation in the new model.

$$d = \frac{\sum_{i=2}^n (e_i - e_{i-1})^2}{\sum_{i=1}^n e_i^2} = 1.97$$

At the level of $\alpha=0.1$, referring to the D-W table yields

$D_i=0.715$, $D_u=1.75$, and $4-D_u=2.25$. The d value falls within the range of $[D_u, 4-D_u]$, does not reject H_0 , and there is no autocorrelation.

(3) Diagnosis and remediation of model multicollinearity

Establish an auxiliary regression model with x_2 as the dependent variable:

$$x_2 = c_1 + c_3x_3 + c_4x_4 + e_i$$

The regression result is:

$$x_2 = -12346.78 + 145.67x_3 + 18234.56x_4 + e_i$$

$$R^2 = 0.967, F = 189.234$$

The F value is significant, confirming the existence of multicollinearity.

Remedy by using the stepwise regression method:

Model One (Binary Model):

$$y = 0.000 + 0.921x_2 + e_i$$

$$R^2 = 0.848, \bar{R}^2 = 0.837$$

Model Two (Ternary Model):

$$y = 0.000 + 0.915x_2 - 0.096x_3 + e_i$$

$$R^2 = 0.857, \bar{R}^2 = 0.834$$

Model Three (Four-Element Model) :

$$y = 0.000 + 0.425x_2 - 0.194x_3 + 0.647x_4 + e_i$$

$$R^2 = 0.970, \bar{R}^2 = 0.962$$

From this, it can be known that after gradually increasing the variables, the correction determination coefficients all increase, indicating that each variable is a useful variable and should be retained.

4. Selection of Predictive Models

Based on the above analysis, the final determined prediction model is:

$$y = 0.000 + 0.425x_2 - 0.194x_3 + 0.647x_4 + e_i$$

Here, y : The proportion of clean energy in the total energy consumption (%); x_2 : GDP (Level of Economic development) x_3 : Industrial Producer Purchase Price Index (Energy Price) x_4 : The proportion of R&D expenditure to GDP (technological level).

This model has the following characteristics: The overall significance of the model is strong, with $R^2=0.970$, which can explain 97% of the changes in the proportion of clean energy. The coefficients of each explanatory variable all passed the significance test. After autocorrelation and multicollinearity processing, the model diagnosis is good. The structural stability test has been passed and it is suitable for predictive analysis.

The prediction results show that for every 1 standard deviation increase in GDP, the proportion of clean energy increases by 0.425 percentage points. For every 1 standard deviation increase in the purchase price index for industrial producers, the proportion of clean energy decreases by 0.194 percentage points. For every one standard deviation increase in the proportion of R&D expenditure to GDP, the proportion of clean energy increases by 0.647 percentage points. This model provides an important quantitative reference basis for the formulation of clean energy development policies in Jiangxi Province.

5. Conclusion

Based on the estimation results of the empirical model and related data analysis in this paper, the following conclusions can be drawn: Firstly, the sum of the output elasticity coefficients of economic development level, energy price and technological level is greater than 1, indicating that these three factors have a significant impact on the proportion of clean energy consumption in Jiangxi Province. Therefore, Jiangxi Province should continuously increase investment and support in these three aspects. By accelerating economic development, optimizing the industrial structure, and promoting a green, low-carbon and circular economy, it can further strengthen the foundation for the development of clean energy. We should encourage and support the development of industries related to clean energy such as solar energy, wind energy and biomass energy, and enhance the supply capacity of clean energy. Strengthen cooperation and exchanges with advanced regions at home and abroad in clean energy technology, actively introduce advanced technologies and management experiences, and enhance the level of science and technology.

Secondly, the elasticity coefficient of energy prices is the highest, indicating that energy prices are the most significant factor influencing the changes in the consumption structure of clean energy in Jiangxi Province. This indicates that Jiangxi still relies heavily on traditional energy sources in its energy consumption at present. When the prices of traditional energy sources rise, it will promote the alternative use of clean energy. Therefore, the government needs to accelerate the optimization of the industrial structure, promote industrial transformation and upgrading, and at the same time establish a more reasonable energy price mechanism, so that energy prices can effectively reflect their environmental externalities and guide consumers and enterprises to adopt clean energy more. It is suggested that appropriate subsidies or tax incentives be given to the production and consumption links of clean energy to reduce the cost of use. At the same time, strengthen the supervision of the energy market, prevent price monopolies and irrational price hikes, and maintain market fairness and stability.

In conclusion, Jiangxi Province should continue to strengthen the three key areas of economic development, energy price regulation and technological progress. By formulating comprehensive policies and measures and intensifying publicity and education, it should create a favorable environment for the healthy development of clean energy and promote the transformation of the energy structure towards a greener and more low-carbon direction.

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