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Empirical Analysis of the Relationship between Energy Consumption and Economic Growth in Sichuan Province Based On Panel Data

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Abstract: This study explores the empirical analysis of the relationship between energy consumption and economic growth in Sichuan Province through a panel data approach. The study collected data on GDP, energy consumption, labor force population and capital stock of 18 cities in Sichuan Province (Liangshan Prefecture, Ganzi Prefecture and Aba Prefecture were not counted due to the lack of corresponding data) from 2013 to 2022, constructed a panel data model, and combined with the production function to carry out a panel data unit-root test and a panel cointegration test, and the empirical study shows that there is a long-run cointegration of Sichuan's economy and energy consumption The empirical study shows that there is a long-term cointegration relationship between the Sichuan economy and energy consumption, and the relationship is significant. Specifically, for every 1% increase in energy consumption, GDP will increase by 0.38%. This indicates that energy consumption is one of the important factors driving the economic growth of Sichuan Province.

Keywords: Energy Consumption, Panel Data Model, Empirical Analysis

INTRODUCTION

The relationship between energy consumption and economic growth in Sichuan Province, one of the fast-growing economic regions in China, has been a focus of attention for academics and policymakers. In the past decades, both energy consumption and economic growth rate in Sichuan Province have increased significantly, but whether this growth relationship is stable and to what extent energy consumption contributes to economic growth still needs further research and study. This paper empirically analyzes the relationship between energy consumption and economic growth in Sichuan Province by constructing a panel data model of Sichuan Province's GDP with energy consumption, capital stock and labor force, and combining it with the Cobb-Douglas production function, with a view to providing a scientific basis for decision-making by policy makers and enterprises.

LITERATURE REVIEW

Foreign research on the relationship between energy consumption and economic growth began in the late 1970s, when the world energy crisis broke out, which made people pay attention to the role of energy.Kraft.J and Kraft.A (1978) took the lead in studying the relationship between energy consumption and economic growth. [1] Ma Hongwei et al. (2006) applied the gray correlation analysis method and the elasticity coefficient of energy consumption to analyze the relationship between China's economic growth and energy consumption, and put forward countermeasures to reduce the unit energy consumption of the secondary industry among the three major industries. [2] Hu Caimei and Wei Fulei (2010) analyzed China into three regions, namely, the north, the south and the west, and applied the production function to examine the relationship between regional energy consumption and economic growth, and came up with the result that energy consumption in the western region has the lowest contribution rate to economic growth. [3] Zeng Zhaofa, Wang Ming based on provincial panel data, applying the neoclassical economic growth model established by Solow-Swan, conducted an empirical study on the impact of economic growth, credit investment on energy consumption, and concluded that there is a significant positive correlation between economic growth and credit investment on China's energy consumption, and made the corresponding policy recommendations on the proposed research results. The results of the proposed research are given as corresponding policy recommendations. [4] Deng Wenbo, Zhuang Beni (2021) is the construction of the PVAR model of the G20 organization of 19 countries into developed industrial countries and emerging industrial countries and empirical testing, concluded that the emerging industrial countries export trade and energy consumption is a bidirectional causality, the emerging industrial countries export trade dependence on energy consumption is higher than the developed industrial countries. [5]

In summary, the current domestic and international research on the relationship between energy consumption and economic growth has the following shortcomings: first, most of the research is based on linear models. Second, due to the differences in research methods, models, sample lengths and forms, the current academic community has not yet formed a unified understanding of the relationship between the two. Thirdly, different types of regional zoning limit the development of energy consumption and economic growth in China to some extent.

EMPIRICAL ANALYSIS OF ENERGY CONSUMPTION AND ECONOMIC GROWTH IN SICHUAN

Data Sources and Descriptive Statistics

This paper collects annual data on GDP, labor force population in the three major industries, fixed capital investment and energy consumption from 2013 to 2022 from the Sichuan Statistical Yearbook and Chengdu Statistical Yearbook and other 18 municipal statistical yearbooks in Sichuan, and due to the large number of missing items in the statistics of Liangshan, Ganzi, and Aba regions in Sichuan Province, this paper only selects the 18 municipal statistical yearbooks outside of the three autonomous prefectures cities and prefectures as the research object.

In order to study the interrelationship between energy consumption and economic growth in Sichuan Province, the effects of labor force and capital stock on economic growth are considered. Among them, capital stock, the data comes from the fixed capital input of each city, and the perpetual inventory method pioneered by Goldsmith (1951) is used to measure the capital stock with the formula:

$$K_t = I_t + (1-\delta_t) * K_{t-1} \qquad (1)$$

Based on the calculation method of urban physical capital stock proposed by Zhang Jun (2004), the empirical study is carried out by utilizing the constant price capital stock data in 2013. [6] Here, Kt is the capital stock in year t, Kt-1 is the capital stock in year t-1, and the base period capital stock of each city is replaced by the total gross fixed capital formation in 2013 divided by 10%.It is based on the price index of investment in fixed assets in the years 2013-2022, and using the constant price method of gross fixed capital formation, the fixed capital formation for the years 2013-2022 is obtained. Gross. Zhang Jun set the depreciation rate of fixed assets to 9.6%, based on which, the article also set the depreciation rate of each year to 9.6%; labor input, data from the number of people employed in the three major industries in each city in Sichuan; energy consumption, using the total energy consumption in the Statistical Yearbook of 18 cities in Sichuan. The results of descriptive statistics of variables are shown in Table 3-1.

Table 3-1 Descriptive statistics of variables

Variable name	Variable	Obs	Mean	Std. dev.	Min	Max
Gross regional product	GDP	180	2128.762	3276.394	400.22	20817.5
Energy consumption	EC	180	692.6743	626.7767	30.21	3393.38
Capital stock	CS	180	11469.88	14895.7	3154.76	88815.24
Labor input	LI	180	239.2421	207.2167	63.3	1159.14

Panel Unit Root Inspection

The panel unit root test is a statistical method used to determine whether there is a unit root in the components of a time series. Unit root (unit root) means that the mean and variance of a time series are non-stationary, which makes the study of time series difficult. The purpose of panel unit root test is to determine the stability of individual time series. Based on this, we will apply five tests such as LLC, IPS,Fisher-ADF,Fisher-PP, and Breitung (all of which are originally assumed to contain unit roots) to statistically analyze the unit roots of the variables through Stata software, as shown in Table 3-2.

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Table 3-2 Panel data unit root check

	Inspection method	Statistical value (P-value)			
		lnGDP	lnCS	lnLI	lnEC
Horizontal value	LLC	-6.8916(0.0000)***	-8.4785(0.0000)***	-5.4720(0.0000)***	-13.2582(0.0000)***
	IPS	-1.1382(0.1275)	-0.3413(0.3664)	0.7261(0.7661)	-2.2400(0.0125)**
	Fisher-ADF	65.3803(0.0020)***	167.6183(0.0000)***	21.4918(0.9734)	96.3409(0.0000)***
	Fisher-PP	46.0552(0.1217)	37.4253(0.4035)	24.0028(0.9370)	37.2100(0.4131)
	Breitung	-0.3886(0.3488)	-0.5020(0.3078)	-1.1799(0.1190)	1.0858(0.8612)
First order difference	LLC	-15.1209(0.0000)***	-20.6453(0.0000)***	-22.8424(0.0000)***	-8.8821(0.0000)***
	IPS	-3.0441(0.0012)***	-4.2985(0.0000)***	-8.7393(0.0000)***	-2.8850(0.0000)***
	Fisher-ADF	139.1633(0.0000)***	141.0466(0.0000)***	297.8899(0.0000)***	70.2532(0.0005)***
	Fisher-PP	32.8600(0.6187)	38.9243(0.3395)	95.6635(0.0000)***	164.1350(0.0000)***
	Breitung	-0.1008(0.4598)	-0.2524(0.4004)	-3.2941(0.0005)***	-0.4764(0.3169)

*Note: ***, ** and * are significant at 1%, 5% and 10% levels respectively, the following are the same.*

The unit root test for the panel information shown in Table 3-2 shows that the hypotheses are rejected at 1% significant level except for lnGDP, lnCS, lnEC, lnGDP, lnCS, lnEC. The LLC method was utilized to test the lnLI level and the original hypothesis was rejected at 1% significant level and there was no unit root.The IPS, Fisher-PP, and Breitung tests showed that the series of these four indices were only 5% significant or unstable. The null hypothesis is irrefutable and it has a unit root. The unit root test was used for the first order differences of each index. However, except for lnGDP, lnCS, lnGDP, lnCS, and lnEC, which are not eliminated under Breitung's test, the first-order differences of each of the remaining variables reach the 1% significant level, which indicates that the model is stable and has no unit root. Therefore, this paper regards these series as unit roots and meets the conditions of panel cointegration test.

Panel Co-Integration Test

Panel cointegration test can be used to study the long-term equilibrium problem among multiple time series. In panel data, the development trend and fluctuation characteristics of each individual will change, and the cointegration test can determine whether there is a certain stability between the individuals. Before the panel cointegration analysis, it is generally necessary to do the unit root test to determine whether it has non-stationarity. In this paper, we use the unit root test to prove that the individual time series of the panel data are unit root, that is, over time, which requires the panel cointegration test to test the long-term equilibrium state among the variables. On this basis, we chose the seven statistics of Pedroni et al. and conducted the cointegration test on the panel data using Kao (1999). Table 3-3 shows the results of the cointegration test.

Table 3-3 Panel co-integration check

Inspection method	Statistic name		Statistical value (P-value)
Kao		ADF	2.4679(0.0068)***
Pedrni	Intra-group statistics	Panel v-statistic	-4.6619(0.0000)***
		Panel rho-statistic	3.0441(0.0012)***
		Panel PP-statistic	-10.1639(0.0000)***
		Panel ADF-statistic	-13.9045(0.0000)***
	Intergroup statistics	Group rho-statistic	5.5344(0.0000)***
		Group PP-statistic	-11.9379(0.0000)***
		Group ADF-statistic	-174.2569(0.0000)***

Under the seven statistics constructed by Pedroni and Kao test, eight statistics (P-values) are significantly negative at the 1% level of the original assumption of “no cointegration”, so the residuals of the panel data can be categorized as smooth series. The results show that China's GDP has a long-term cointegration relationship with the panel data of capital stock, labor and energy consumption, and there is no spurious regression.

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Model Construction

The many elements of economic development have become the focus of research by economists. While traditional economists viewed the accumulation of physical capital as the driving force of economic development, neoclassicism identified science and technology as its primary driver. In today's major theories of economic growth, energy economists have proposed that, along with capital and labor, they are the main production factors for economic development. With this in mind, using the classic Cobb-Douglas production function with energy consumption and capital-labor as the main factors, the following conclusions were obtained:

$$G = AC^{\alpha} L^{\beta} E^{\gamma} e^{\mu} \qquad (2)$$

Here, G is the economic aggregate, which in this article we will express in terms of gross regional product (GDP). A is the aggregate technology level, C is the capital stock (CS), L is labor input (LI), E is energy consumption (EC),α,β and γ are the coefficients of elasticity of output with respect to each of the factors, i.e., stochastic disturbances. In order to convert a nonlinear regression model into a linear regression model for parameter estimation, logarithms are applied to each side of (2), yielding the following linear model:

$$\ln G = \ln A + \alpha \ln C + \beta \ln L + \gamma \ln E + \mu \qquad (3)$$

By analyzing the ANOVA of the sample data, it can be tested to determine whether it is a constant, variable truncated tail or variable coefficient model. Based on the above analysis, this thesis takes the production function theory as an analytical tool to analyze the impact of energy consumption on regional economic growth in each region of China. On this basis, an improved variable coefficient model is proposed, i.e., the variables are assumed to be variable coefficient model, but only a variable truncated model. This paper establishes the following model through the comprehensive analysis of the production function and panel variables:

$$\ln GDP_{\mathrm{it}} = \mathrm{a} + \alpha \ln CS_{it} + \beta \ln LI_{it} + \gamma_i \ln EC_{it} + \mu_{\mathrm{it}} \qquad (4)$$

where i is 1,2,..., 18, denoting 18 cities in Sichuan Province, such as Chengdu City; where t is the time period from 2013 to 2022, where GDPit represents the total GDP of the ith city. where a is the average value of the comprehensive science and technology level of the 18 prefectural-level cities, and the elasticity coefficient of energy consumption of the ith city is gi.

Model Estimation and Result Analysis

STATA software was used to perform ordinary least square regression estimation for model (4), and the results were as follows:

$$\ln G\hat{D}P_{it} = a + 0.27 \ln CS_{it} + 24.97 \ln LI_{it} + \hat{\gamma}_{\mathrm{i}} \ln EC_{it} + \mu_{\mathrm{it}} \qquad (5)$$

On this basis, the investment elasticity of the two indicators is 0.27 and 24.97. It is found that the contribution of fixed asset investment growth to GDP in Sichuan Province is only 0.27%. In addition, the contribution of labor investment to economic growth is significant. The pulling effect of labor investment on economic growth in Sichuan province is 24.97%. According to the Sichuan Statistical Yearbook, the elasticity of energy consumption in Sichuan is 0.38, indicating that if other factors are excluded, although the growth rate of energy consumption in Sichuan is relatively slow, every 1% increase in energy consumption in Sichuan will have a pulling effect of 0.38% on the region's economic growth. However, there is a significant pull effect of energy consumption in most cities in Sichuan. The energy consumption in Sichuan varies greatly from the initial stage of dependence, and the degree of energy dependence varies greatly from region to region, due to the different levels of economic development, industry development, and the degree of marketization in the early stages of development in each region.

CONCLUSIONS AND SUGGESTIONS

The empirical analysis on the panel data of Sichuan Province from 2013 to 2022 confirms that there is a long-term equilibrium relationship between energy consumption and economic growth in Sichuan. In terms of economic growth, the labor force, capital stock and energy consumption in Sichuan Province all play a positive role in promoting economic growth

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and are positively correlated. Labor and capital stock are the main drivers of energy consumption in Sichuan Province. This suggests that population growth and higher investment in fixed assets are key to boosting energy consumption. Among them, energy consumption has a significant impact on the economic growth of Sichuan, indicating that the economic development of Sichuan depends on energy consumption to a certain extent. Secondly, by analyzing the correlation between the three major industries and energy consumption in Sichuan, we can see that there is a very significant correlation between energy consumption and the second largest industry, indicating that the energy consumption in Sichuan Province mainly promotes the economic development of Sichuan Province in the creative industry and the construction industry. Combined with the above analysis, the following suggestions suitable for the development of Sichuan are given:

First, we need to improve energy efficiency. Improving energy utilization efficiency is the key to achieve sustainable development and reduce the negative impact of energy consumption on the environment. Sichuan Province should increase investment in energy utilization efficiency and research and development efforts to promote the rationalization and efficiency of energy consumption, so as to reduce the negative impact of energy consumption on economic growth. Specific measures such as improving the production process, by improving the production process, reduce energy consumption, such as the use of efficient energy equipment, optimize the production process, reduce energy waste, etc.

Second, develop clean energy. Developing clean energy is an important way to cope with climate change, reduce environmental pollution and realize the transformation of energy structure. Sichuan Province is rich in clean energy resources, such as hydropower, wind and solar energy. Increasing the development and utilization of clean energy will help reduce dependence on traditional energy sources and reduce the impact of energy consumption on the environment.

Optimize the industrial structure. Optimization of industrial structure refers to the process of promoting industrial transformation and upgrading, improving the overall quality and competitiveness of the industry, and achieving sustainable and healthy economic development by adjusting and improving the combination, allocation and correlation of various production factors within the industry. Sichuan Province should optimize its industrial structure according to its resource advantages and develop industries with high added value and low energy consumption in order to realize the decoupling of economic growth and energy consumption.

Fourth, strengthen policy guidance. Strengthen energy policy guidance, through the formulation and implementation of energy-saving emission reduction and clean energy development policies, guide the development and reform of the energy industry, guide enterprises and individuals to change their energy consumption behavior, and promote the optimization and sustainable development of the energy structure.

Fifth, raise public awareness. Raise public awareness of energy consumption, enhance public awareness and awareness of energy consumption and energy conservation and emission reduction through strengthening energy education and publicity activities and other forms and channels, guide the public to adopt energy conservation and emission reduction behaviors, and encourage all aspects of society to participate in energy conservation and environmental protection work.

Sixth, strengthen international cooperation. Strengthening international cooperation is an important way to promote global energy security and sustainable development. Sichuan Province should actively participate in international energy cooperation and exchanges, introduce international advanced energy management experience and technology, and improve its own energy consumption management level. To promote the efficient use of energy resources and sustainable development, while addressing climate change and ensuring energy security.

Through the implementation of the above suggestions and measures, it will help promote the sustainable development of the relationship between energy consumption and economic growth in Sichuan Province, and realize the positive interaction between economic growth and energy consumption.

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