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The Impact of Energy Consumption and Industrial Value Added on Economic Growth in Central China: Dynamic Panel ARDL Analysis

Simiao Liu[1], Lee Chin[1,2], Umar Bala[1,3]*

[1]Department of Economics, School of Business and Economics, Universiti Putra Malaysia, [2]Department of Econometrics, Tashkent State University of Economics, Tashkent, Uzbekistan, [3]Department of Economics, Faculty of Social Sciences, Sa'adu Zungur University, Bauchi, Nigeria. *Email: umarbala@upm.edu.my

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ABSTRACT

Energy consumption and industry value-added are crucial to economic activities and have been a potential priority for China's domestic economic growth, especially in the resource-rich central region of the Country. The research examines the impact of energy consumption and industry value-added on economic growth in six central Chinese areas from 2000 to 2022. The study employed the PMG estimator during data estimation, along with Quantile and FMOLS regressions for robustness checks. The research utilized disaggregated data on industrial value added, specifically primary, secondary, and tertiary industry value added. The findings indicated that higher energy consumption in primary and tertiary industries significantly stimulates economic growth, while the secondary industry value-added is not significant. Furthermore, capital accumulation and urbanization significantly contributed to economic growth. The labor force indicated a negative effect on growth, possibly due to inefficiencies, low productivity, or structural imbalances in the economy. The research recommended that policymakers ought to consider different patterns of energy consumption in industrial value-added firms for greater economic growth. There is a need for labor market reforms and productivity-boosting policies. Policymakers need to consider the unique economic and energy consumption patterns of Central China when designing and implementing energy policies. A one-size-fits-all approach is ineffective due to regional disparities.

Keywords: Energy Consumption, Economic Growth, Panel ARDL, Central China
JEL Classifications: O1, Q01, Q5, Q56

1. INTRODUCTION

Energy is a basic commodity required in human societies to survive and improve human efficiency in the production process. It plays an important strategic role in national economies, contributing to economic growth. Energy plays a vital role in maintaining market and price stability, supporting industrial growth and contributing to the economic and financial progress of countries (Bala et al., 2020; Huseynli, 2024; Sobirov et al., 2024; Xu et al, 2024). Kaldor's growth law states that the manufacturing industry is an engine of growth with increasing returns and productivity spillovers. Faster manufacturing growth raises overall economic growth via Verdoorn's law of manufacturing productivity (Romero 2016; Ener and Arica 2011; Chandra and Sandilands, 2021). The link between energy use and economic growth in Central China is intricate and multidimensional. This review synthesizes findings from multiple studies to provide a comprehensive understanding of this relationship, with a focus on the region's specific characteristics and policy implications. Several studies have found a long-term equilibrium relationship between energy consumption and economic growth in China, particularly Central China (Shang, 2014; Li et al., 2019; Hu et al., 2015; Chi et al.,

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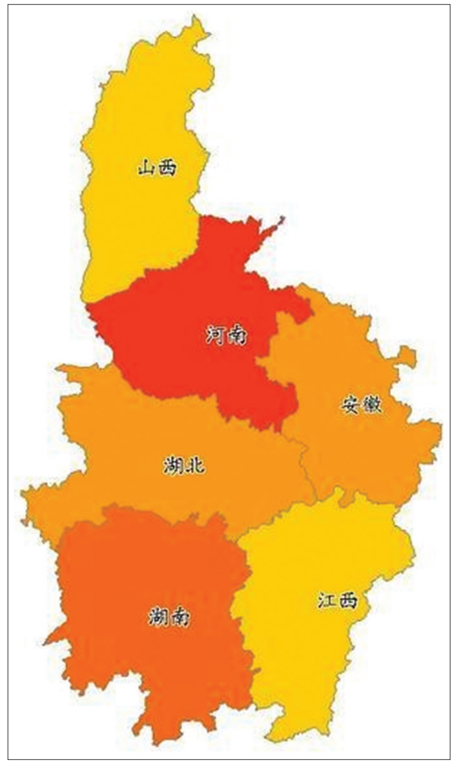
2021). This demonstrates how energy consumption and economic growth are intimately linked in the long run. The relationship between energy usage and economic growth varies. Other research reveals a unidirectional correlation between economic growth and energy consumption (Avazkhodjaev et al, 2022; Li et al., 2019; Hu et al., 2015; Xuan et al., 2018). While others report a bidirectional causality (Zhang and Broadstock, 2016; Chen, 2018; Cheng and Liu, 2019). This indicates that economic growth can influence energy consumption and vice versa; however, the direction and strength of this relationship vary by province and across time.

There are numerous cross-country and panel studies have found a positive, but not universal correlation between higher manufacturing share/growth and quicker GDP growth, particularly in the early to mid-development phases. The magnitude, however, varies with time and location (Szirmai and Verspagen, 2015). Against the backdrop of a rapidly expanding global economy, the role of energy in regional development is becoming increasingly evident. Improving energy efficiency and expanding renewable energy consumption are crucial to Central China's long-term economic prosperity. The region confronts considerable hurdles in modernizing its industrial structure and increasing energy efficiency. The use of renewable energy is critical for lowering carbon emissions and attaining sustainable growth. Central China is making progress in this area, but the rate and efficiency of these improvements differ by province (Zhao et al., 2021; Wang et al., 2024; Li et al., 2024). The relationship between energy consumption and economic growth is not uniform across China. Central China, in particular, shows distinct patterns compared to other regions (Shang, 2014; Wei et al., 2020). The decoupling of energy consumption from economic growth is more challenging in Central China due to its industrial structure and energy efficiency levels. Some Studies highlight that Central China's economic growth heavily relies on energy consumption, but there is a gradual shift towards more energy-efficient practices and renewable energy sources (Zhao et al., 2021; Wang et al., 2024).

This study focuses on the central region of China, the region precisely defined by the 2004 "The Rise of Central China,[1]" which includes Shanxi, Henan, Anhui, Hubei, Hubei, and Hunan. These provinces span a wide range of longitudes, have distinct north-south geography, and differ significantly in terms of energy production and GDP. Figure 1 presents the geographical map of the six provinces under study. Table 1 tabulates the fundamental economic differences, variations in dominant industries and their corresponding energy demands among the six provinces.

The situation varies from province to province; for example, Figure 2 shows that Shanxi is rich in coal resources and contributes significantly to the national energy supply. Shanxi's coal production has experienced fluctuations but maintains long-term growth, with the most significant output occurring in the late 2010s and early 2020s, reflecting increased demand and policy support during those years. From the perspective of energy resources and

Figure 1: The geographical distribution of six provinces



output, Shanxi is rich in coal resources and leads the country in power output. Hubei is rich in hydropower resources, with the Three Gorges Hydropower Station. Hunan relies on hydropower and has limited coal resources. Anhui lacks energy resources and relies on external supplies. From the perspective of economic structure, Henan's agriculture and manufacturing industries are developed, and its GDP is among the top ten in the country. Hubei attaches equal importance to manufacturing and service industries, with the rapid development of information technology and financial services. Hunan construction machinery and food processing as the backbone of the economy. From the perspective of energy consumption, Shanxi mainly exports electricity and is rich in coal resources. In Jiangxi, thermal power and coal are the main energy sources, and industrial consumption is the main one. Anhui is a high-carbon emitter and has a fast industrialization process. From the perspective of GDP level, Shanxi's GDP is low and mainly relies on coal resources. Henan's GDP is among the top ten in the country, and its economy is diversified. Hubei's GDP ranks first in the country, and the proportion of the service industry is gradually increasing.

There are significant differences among provinces in energy resources, economic structure and GDP level. Shanxi is famous for its rich coal resources and strong power output capacity, but its GDP level is low. Henan and Hubei have high GDP and diversified economic structures, dominated by agriculture, manufacturing and service industries respectively. The energy structure of Hunan and Jiangxi is dominated by hydropower and coal, but they depend on external energy supply. Anhui is short of energy resources, has fast industrialization and high carbon emissions. These differences reflect the different paths and challenges of the provinces in economic and energy development.

1 The Rise of Central China is a policy of the People's Republic of China aimed at promoting the common rise of the six central provinces. It was first explicitly proposed by then Premier Wen Jiabao in the government work report in March 2004.

Table 1: Tabular presentation of this information, with a brief emphasis on the most important differences

Province	Population	GDP	Industries	Source of energy	Consumption of energy	Main feature
Shanxi	About 35 million	Lower (lowest in the country except western regions)	Abundant coal resources, electricity output	Rich in coal resources, the annual power generation of 446.1 billion KWH, installed capacity of 133 million kilowatts	Power output is mainly, and 157.6 billion KWH of electricity was sent out in 2023	Coal resources are abundant, and power output is large, but GDP is low
Henan	About 98 million	About 60 trillion yuan (Top 10 in the country)	Agriculture, manufacturing, and mining	The annual coal output is about 100 million tons, and the energy consumption is about 300 million tons of standard coal	Coal dominates, and industrial consumption dominates	The province has a large population, a high GDP, developed agriculture and manufacturing industries
Anhui	About 61 million	Above average	Industry and agriculture	There are few coal and natural gas resources, and they are dependent on external energy sources	Coal and oil are the main energy sources, and industrial consumption is the main one	Energy resources are scarce, dependent on external supplies, and industrialization leads to high carbon emissions
Hubei	About 58 million	About 6.1 trillion yuan (among the top in China)	Manufacturing Services (Information technology, finance, logistics)	Hydropower, coal, oil	Industrial consumption is dominant, and electricity accounts for the largest proportion	It has abundant hydropower resources and develops manufacturing and service industries
Jiangxi	About 35 million	About 3.6 trillion yuan	Industry, agriculture (rice, tea, fruits and vegetables)	Mainly thermal power and coal, wind power and hydropower have been developed in recent years	Industrial consumption dominates, with steel and chemicals being the main energy consumers	Agriculture is important, and thermal power and coal are the main sources of energy
Hunan	About 66 million	About 5.5 trillion yuan	Engineering machinery, food processing, electronic information, and steel	Hydropower is the dominant source, while coal is dependent on external supplies	Industrial consumption dominated, and energy demand increased for buildings and transportation	Abundant hydropower resources, construction machinery and food processing developed

Despite the province's economic importance, research on the dynamics of its energy consumption and economic growth has been limited. Most of the previous studies, local and national levels, have focused mainly on the entire country. Studies in China have focused on specific regions or individual provinces. Secondly, the energy consumption patterns and economic growth dynamics in these regions are conducive to achieving the national goal of sustainable development with relevance. The six central provinces of Shanxi, Henan, Anhui, Hubei, Jiangxi and Hunan are the highest energy-consuming provinces in China. The energy consumption of the six core provinces has a significant impact on national energy policies, economic development patterns and local economic growth. Third, this paper addresses this gap by examining the interactions between energy consumption, industry value-added and economic growth, providing an empirical profile and informing energy and economic policies. The conservation theory, on the other hand, contends that rising economic growth causes an increase in energy consumption, indicating that energy efficiency measures might not be a hindrance to economic expansion. The feedback hypothesis stresses bidirectional causality and implies that energy and economic policies are interrelated. The neutral hypothesis contends that there is no causality (Lee and Chang, 2008; Eggoh et al., 2011).

The rest of this paper is organized as follows: Section 2 reviews the related literature. Section 3 explains the methodology and the data employed. Section 4 reports the empirical results and interprets the findings, while Section 5 concludes the study.

2. LITERATURE REVIEW

Theoretical anchors provide two views that shape the argument. In traditional neoclassical/endogenous growth models, energy is often a low-elasticity input that can be replaced with capital/technology; hence, growth does not have to be energy-driven unless energy is scarce. In contrast, biophysical and ecological economics suggest that usable energy (exergy) is a basic constraint on output, particularly in the early stages of development. in summary, energy matters most when it is scarce; as abundance increases, its marginal role decreases, helping to explain time and income-level variation in estimates.

Most of the research on economic growth uses the Cobb-Douglas production function because of global recognition, production efficiency and resource allocation. The relationship between factors of input and output in its production process can better fit the real economic data. Walter Trevor Shiba (2019) studied BRICS countries' economic growth, using the Cobb-Douglas production function and the Extended Stochastic Environmental Impact assessment model (STIRPAT). Agricultural growth, energy consumption (fossil fuels and electricity), the share of industry in GDP and urban population are taken as independent variables. The results indicate that Energy consumption has an important part in economic growth, both directly and indirectly, as a supplement to labor and capital in the production process. Zhuang et al. (2019) studied the relationship between economic growth and energy consumption in resource-based cities in western China. By using the Cobb-Douglas production function method and taking eight resource-based cities in the West as examples, they mainly reveal the laws of their economic development and resource consumption.

There are many perspectives and models adopted to examine the topic, tested with multivariate models in slight differences between countries. For example, 16 Asian countries have long-run unidirectional causality. Lau et al. (2011) studied 17 Asian countries that have long-run unidirectional causality and long-run equilibrium between energy consumption and GDP. Economic growth is determined by fundamental structural factors, of which energy is a key component. Chontanawat et al. (2008) studied have investigated the causality between energy consumption and economic growth, with the stronger voices in the industry focusing on four key hypotheses: growth, conservative, neutral and feedback. The growth hypothesis argues that energy consumption directly drives economic expansion, as evidenced in non-OECD countries where energy is critical for development.

Multivariate models are widely used in research and the factors that are widely considered are: economic output, energy consumption, electricity consumption, labor, capital, exports, etc. Lean and Smyth (2010) studied the Malaysian factors of total output, electricity consumption, exports, labor, and capital. Zheng et al. (2022) highlight the impact of technological advancement in economic growth and energy consumption across provincial cycles, while noting that fixed asset investment plays a moderating role to some extent. Shiba (2019), on the other hand, puts perspective in the agricultural economy and establishes that there is a long-run equilibrium relationship between economic growth, agricultural growth, energy consumption, industrial output, and urban population. Xiao et al. (2012) find that the energy-importing provinces have a long-term unidirectional causal relationship between GDP and energy consumption. With the development of the low-carbon concept, the concern of environmental quality has received more consideration from experts and scholars, and one of the main indicators of environmental quality is carbon dioxide emissions. The interaction between environmental quality and energy consumption has been shown to have a positive contribution to economic growth.

Xu et al. (2008) find a stronger energy-growth nexus in the eastern provinces compared to the western regions. Hao and Cao (2021) emphasize the reliance on energy-intensive activities in the Central Triangle region. Zhang et al. (2022) look at China's western resource-based cities, emphasizing sustainable practices for long-term growth. From an industrial perspective, studies have demonstrated the coupling between technological innovation, energy consumption and economic growth. Sun (2014) used industrial emissions as a proxy for energy use to reveal differences in energy efficiency across China's provinces. Matsumoto and Chen (2021) examined six major industries, highlighting the key role of energy in driving sectoral development.

Li and Zheng (2019) identify a stable long-term relationship between energy use and GDP in China and note that technological advances and capital investment have contributed to the relative decoupling. Yan et al. (2024) extend this analysis, emphasizing the role of innovation and policy in achieving sustainable growth. Growth. These findings emphasize the need for balanced strategies to align economic objectives with environmental priorities.

Many studies have explored the relationship between various factors and economic growth, both nationally and internationally. A wealth of empirical evidence has emerged from these investigations, revealing the complexity surrounding economic growth and its underlying relationships. Among these linkages, that between energy consumption and economic growth has attracted considerable attention. However, despite the plethora of research on broader economic relationships, there are still relatively few studies that focus specifically on the relationship between energy use and economic expansion within Chinese regions or individual provinces. This gap in the literature highlights the need for more targeted research to gain insight into how energy consumption affects local economic growth, particularly in the context of China's diverse economic landscape. Understanding these regional dynamics is crucial for developing effective policies to promote sustainable growth while managing energy resources efficiently.

3. METHODOLOGY

Energy consumption and economic growth studies mostly use the Cobb-Douglas production function. Following this trend, this study uses the Cobb-Douglas production function to explore the dynamics. The extended Douglas function, however, not only considers capital and labor but also involves energy use. This allows the study to better capture the direct impact of energy use on economic output while addressing the interconnectedness of energy consumption and industrial value added with other production inputs. The model also incorporates urbanization as a control variable, as it can improve production efficiency, thereby affecting economic growth. The integrated approach allows for a more comprehensive investigation of the impact of energy consumption and industrial value added on economic growth. The study adopted a revised model of Zhixin and Xin, (2011) on the production function model is modified as follows, modelling GDP as a function of energy consumption I, labor (L) and capital (K):

$$Y = AK^{\alpha} L^{\beta} E^{\gamma}$$

The use of the dynamic panel ARDL model to analyze the link between long-term and short-term variables allows dealing with lagged effects and is particularly suitable for assessing the relationship between energy consumption, industry value added and economic growth. The functional form of the linear model is:

$$GDP = f(Energy, Industry^{*}, Labor, Capital, Urban)$$

To express in an econometrics form is:

$$GDP_{it} = \alpha_0 + \beta_0\, GDP_{it-1} + \beta_1\, Energy_{it} + \beta_2\, Industry^*_{it} + \beta_3\, Labor_{it} + \beta_4\, Capital_{it} + \beta_5\, Urban_{it} + \mu_{it}$$

The industry value added (*Industry**) is categorized into (3) parts: primary, secondary and tertiary, which can be separated in different models for estimation purposes.

$$lGDP_{it} = c + \beta_0\, lGDP_{it-1} + \beta_1\, lEnergy_{it} + \beta_2\, lPrimary_{it} + \beta_3\, lLabor_{it} + \beta_4\, lCapital_{it} + \beta_5\, lUrban_{it} + \mu_t$$

$$lGDP_{it} = c + \beta_0\, lGDP_{it-1} + \beta_1\, lEnergy_{it} + \beta_2\, lSecondary_{it} + \beta_3\, lLabor_{it} + \beta_4\, lCapital_{it} + \beta_5\, lUrban_{it} + \mu_t$$

$$lGDP_{it} = c + \beta_0\, lGDP_{it-1} + \beta_1\, lEnergy_{it} + \beta_2\, lTertiary_{it} + \beta_3\, lLabor_{it} + \beta_4\, lCapital_{it} + \beta_5\, lUrban_{it} + \mu_t$$

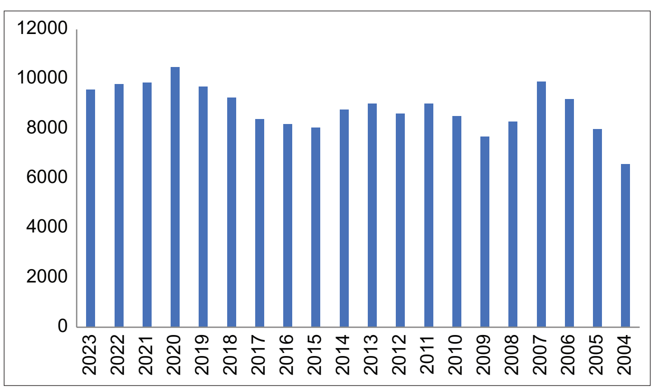
Where *GDP*, the gross domestic product per capita, represents economic growth, α_0 a constant term, GDP_{it-1} lag of the dependent variable. β_0, β_1, β_2, β_3, β_4, and β_5 are the coefficients of the independent variables, μ_t is a random error term that denotes other unexplained factors. *it* stands for a cross-section of the provinces and time. All the variables are transformed into logarithmic functions.

3.1 Data Source

The panel secondary data of six Chinese provinces, Shanxi, Henan, Anhui, Hubei, Jiangxi and Hunan between 2000-2022 are generated from different sources, as stated in Table 2. There are eight variables in the model, including: economic growth, energy consumption, labor force, capital, added value of the primary, secondary, and tertiary industries, and urbanisation.

This study employed a dynamic panel ARDL estimator, Pooled Mean Group (PMG), to examine the impact of energy consumption and industry value-added on economic growth. PMG is the most appropriate method because the nature of our data is a long panel, where T > N. The advantages of the method are that there are valid values for estimation even if the data are either integrated in level form I(0) or in first difference I(1), or even a mixture of I(0) and I(1). Generally, these are the steps to perform the Pooled Mean Group (PMG) estimations: Step 1: Panel unit root tests, to check whether the panel data variables are stationary. Step 2: Panel cointegration test; if variables are I(1), check for long-run relationships using panel cointegration tests. To confirm the existence of a long-run equilibrium relationship between dependent and independent variables. Step 3: Once cointegration is confirmed, estimate the Panel Autoregressive Distributed Lag (PARDL) Model framework using the Pooled Mean Group (PMG) estimation.

Figure 2: Coal production (million tonnes) of Shanxi



4. RESULTS AND DISCUSSION

The preliminary test of descriptive statistics was used to observe the nature of the data included in this study. Table 3 presents the results showing the statistics of each variable: mean, standard deviation, minimum and maximum value. The statistics indicate various values of 138 observations.

4.1. Unit Root Test

First, the unit root tests are performed to check the stationarity of the variables. The results in Table 4 show that the statistics, only a few variables are significant at the level, hence fail to reject the null hypothesis, indicating non-stationarity. But all the variables become significant when differenced to the first order. Therefore, we can conclude that all variables are stationary after the first difference. We conclude that the stationarity of the variables are in a mixture of I(1) and I(2) variables.

4.2. Panel Cointegration

The panel cointegration test, conducted with the Pedroni cointegration test, was used to check for long–run relationships. The results in Table 5 showed that under the null hypothesis (where there is no cointegration relationship) that means the probability is greater than 10%. But when the probability is within 1% to 10% that means cointegration exists. Based on the Pedroni cointegration test, there are 7 null hypotheses; 4 to 5 null hypotheses have been rejected in each model with trend and no trend. The null hypothesis is strongly rejected, indicating the existence of a cointegration relationship, as it is inferred that there is a long-run equilibrium connection between them.

Table 2: Data sources description

Variable	Description	Sources
GDP	Gross Domestic Product per capita (RMB/person)	National Bureau of Statistics
Energy	Energy consumption by region (tons of standard coal)	China Statistical Yearbook
Labor	All employed persons in the primary, secondary and tertiary sectors	China Statistical Yearbook
Capital	Total investment in fixed assets (billion yuan)	China Fixed Asset Investment Statistical book
Primary	The added value of the primary industry (billion yuan)	China Statistical Yearbook
Secondary	The added value of the secondary industry (billion yuan)	China Statistical Yearbook
Tertiary	The added value of the tertiary industry (billion yuan)	China Statistical Yearbook
Urban	Urbanization rate	China Statistical Yearbook

4.3. PMG Estimation Results

The PMG results in Table 6 show that energy consumption promotes economic growth in the long run, mostly from primary and tertiary industries. While primary and secondary industries value-added significantly improved economic growth, the tertiary industry is insignificant. The labor force has a negative sign and an insignificant impact on economic growth in primary and secondary industries, while negative and significant in the tertiary industry. The capital has a positive impact on economic growth in the tertiary industry; however, it is negative in the secondary industry and insignificant in the primary industry. Urbanization has positive and significant results in primary and secondary industries, while positive and insignificant results in the tertiary industry in the long run. Whereas the short-run results revealed that the impact of the dependent variables is less. The ECT of the three models are both negative, significant and less than 1% (−0.3265, −0.4406 and −0.2878, respectively). These results indicate that the economic growth is slow to respond in the short-term disequilibrium to return to the equilibrium.

To check for robustness of the PMG results, the two prominent methods, Quantile and FMOLS, were re-estimated. Table 7 provides the estimated results of the two methods; both methods' energy consumption is consistent with the previous PMG results. The three disaggregate industry value added maintain a similar sign and significance, but higher significant in secondary and tertiary industries. Labor still carries a negative sign while capital positive sign in primary and tertiary industries, but a negative and insignificant sign in the secondary value-added industry. The urbanization variable signified a positive and significant correlation to economic growth in 6 Chinese provinces.

Since energy consumption remains robust across PMG, Quantile, and FMOLS estimates, it confirms that energy is a key driver of economic growth in the provinces studied. Furthermore, the Industry value added remains the stronger significance of

Table 3: Summary statistics

VarName	Obs	Mean	SD	Min	Max
GDP	138	31313.37	21862.78	1845.7	90358
Energy	138	12975.69	5719.226	2329	24371.3
Labor	138	3381.525	1205.999	1392.4	5948.78
Capital	138	15655.66	15262.48	516.08	60414.96
Primary	138	2009.815	1364.301	171.09	5817.8
Secondary	138	8626.996	6327.979	700.76	25465
Tertiary	138	8180.232	7507.1	636.36	30062.2
Urban	138	46.35138	10.39561	23.2	64.67

Table 4: Unit roots test results

Variables	At level	LLC	IPS	ADF fisher	PP fisher
GDP	No trend	−5.5650***	−3.04248***	30.3007***	25.7720**
	Trend	−0.72248	0.87830	28.6861***	19.8495*
Energy	No trend	−6.5112***	−5.3699***	52.1972***	65.8305***
	Trend	−5.6002***	−1.1943	22.6621**	2.8649
Labor	No trend	−0.1851	0.4357	8.0161	7.4327
	Trend	3.8132	6.5218	3.7215	3.5808
Capital	No trend	−8.0595***	−5.4986***	51.9184***	37.5368***
	Trend	2.4267	4.0444	1.8630	0.1747
Primary	No trend	−2.1949**	1.1294	5.0653	6.1788
	Trend	−0.6540	0.4600	9.6748	1.8627
Secondary	No trend	−5.8921***	−2.1976**	26.1192**	20.0969*
	Trend	1.1922	2.9821	4.6872	0.9436
Tertiary	No trend	−2.9818***	0.1005	13.1372	6.2878
	Trend	5.7078	4.5295	3.4950	4.1843
Urban	No trend	−13.6051***	−8.7336***	90.4393***	77.9540***
	Trend	0.7288	3.5039	10.2317	8.6402
At First Difference					
D_GDP	No trend	−9.5889***	−5.7323***	81.1051***	84.6565***
	Trend	−10.812***	−7.4591***	74.9236***	84.4869***
D_Energy	No trend	−2.6691***	−2.9181***	30.6670***	31.3425***
	Trend	−6.7462***	−6.9976***	65.3741***	52.7009***
D_Labor	No trend	−5.5129***	−3.9465***	54.9928***	61.2005***
	Trend	−5.9759***	−4.1876***	50.1550***	65.4215***
D_Capital	No trend	−1.5535*	−1.0928	17.3281	17.3035
	Trend	−3.4252***	−2.9532***	28.0332***	38.5835***
D_Primary	No trend	−6.7282***	−5.6925***	53.7752***	63.3119***
	Trend	−5.4473***	−4.8799***	43.4478***	79.3429***
D_Secondary	No trend	−3.4340***	−2.3513***	24.4638**	25.5659**
	Trend	−4.8476***	−3.1003***	28.0584***	27.4062***
D_Tertiary	No trend	−4.5384***	−4.2744***	45.6537***	56.2035***
	Trend	−6.9082***	−5.1071***	44.5934***	49.1923***
D_Urban	No trend	0.6702	0.4809	0.4809	21.8224**
	Trend	−4.7482***	−4.6274***	41.0818***	43.5316***

*,**, and *** denote the 10%, 5%, and 1% levels of significance, respectively

Table 5: Pedroni panel cointegration results

Tests	Model 1. Primary		Model 2. Secondary		Model 3. Tertiary	
	No trend	Trend	No trend	Trend	No trend	Trend
Panel	2.1048**	1.3354*	1.3608*	0.5296	0.9334	0.1867
v-statistic	(0.0177)	(0.0909)	(0.0868)	(0.2982)	(0.1753)	(0.4259)
Panel	−1.5121*	−0.9307	−1.7653**	−1.1163	−0.6947	−0.4991
rho-statistic	(0.0652)	(0.1760)	(0.0388)	(0.1321)	(0.2436)	(0.3088)
Panel	−8.0642***	−8.4728***	−7.3727***	−7.6831***	−4.4227***	−8.0975***
PP-statistic	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel	−9.2301***	−9.7609***	−3.1534***	−3.1941***	−1.1248	−2.7407***
ADF-statistic	(0.0000)	(0.0000)	(0.0008)	(0.0007)	(0.1303)	(0.0031)
Group	2.1241	2.9914	1.3830	2.4307	1.8416	2.5326
rho-statistic	(0.9832)	(0.9986)	(0.9167)	(0.9925)	(0.9672)	(0.9943)
Group	−4.4666***	−2.5344***	−7.0206***	−6.5807***	−4.6277***	−4.7224***
PP-statistic	(0.0000)	(0.0056)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group	−4.9741***	−3.7268***	−3.9745***	−3.2321***	−4.0329***	−3.3996***
ADF-statistic	(0.0000)	(0.0001)	(0.0000)	(0.0006)	(0.0000)	(0.0003)

The figures in parentheses are the probability values. *,**, and ***denote the 10%, 5%, and 1% levels of significance, respectively

Table 6: PMG estimation results

Variables	Model 1. Primary		Model 2. Secondary		Model 3. Tertiary	
	Long run	Short run	Long run	Short run	Long run	Short run
Energy	0.3865***	−0.0019	−0.0622*	−0.1944	0.4533***	0.2844*
	(0.1261)	(0.1531)	(0.0336)	(0.2020)	(0.1228)	(0.1593)
*Industry**	0.3550***	0.0951***	0.6027***	0.3015**	0.0943	0.0850
	(0.0935)	(0.0275)	(0.0313)	(0.1249)	(0.1023)	(0.1408)
Labor	−0.0022	-	−0.0279	-	−1.1439***	-
	(0.1537)		(0.0469)		(0.1874)	
Capital	0.0658	0.0774	−0.0391**	-	0.3720***	0.0145
	(0.0514)	(0.0787)	(0.0167)		(0.0695)	(0.0847)
Urban	1.4504***	−1.7829	1.8217***	0.8210***	0.1602	−1.0741
	(0.3270)	(1.5022)	(0.0709)	(0.3062)	(0.4500)	(1.5760)
Constant	−1.7648	-	−0.9196*		10.406***	
	(1.4363)		(0.5081)	-	(1.9175)	-
COINTEQ	-	−0.3265**		−0.4406***		−0.2878***
		(0.1350)	-	(0.1555)	-	(0.0927)
Observations	132	132	132	132	132	132
No.	6	6	6	6	6	6

The figures in parentheses are the standard error values. *, **, and *** denote the 10%, 5%, and 1% levels of significance, respectively

Table 7: Regression

Variables	Model 1: Primary		Model 2: Secondary		Model 3: Tertiary	
	Quantile	FMOLS	Quantile	FMOLS	Quantile	FMOLS
Energy	0.1179***	0.1752***	−0.0709***	−0.0191	0.0970***	0.1180**
	(0.0383)	(0.0497)	(0.0263)	(0.0522)	(0.0306)	(0.0457)
*Industry**	0.1227*	0.1581**	0.5843***	0.4343***	0.1648***	0.1538**
	(0.0701)	(0.0750)	(0.0434)	(0.0984)	(0.0606)	(0.06827)
Labor	−0.1128	−0.1779***	−0.1127***	−0.0928***	−0.0475	−0.0806**
	(0.0685)	(0.0653)	(0.0124)	(0.0297)	(0.0321)	(0.0321)
Capital	0.2712***	0.2372***	−0.0201	0.0771	0.2392***	0.2355***
	(0.0525)	(0.0496)	(0.0301)	(0.0612)	(0.0501)	(0.0497)
Urban	1.7106***	1.7165***	1.7669***	1.7013***	1.5677***	1.6138***
	(0.0911)	(0.0997)	(0.0591)	(0.0837)	(0.0696)	(0.0951)
Observations	138	138	138	138	138	138
No.	6	6	6	6	6	6

The figures in parentheses are the standard error values. *, **, and *** denote the 10%, 5%, and 1% levels of significance, respectively

secondary and tertiary industries highlights their central role in structural transformation. This means industrial upgrading and expansion of services are crucial engines of growth, while the primary sector's impact is weaker. It also indicates that moving resources toward higher-value industrial and service activities can accelerate provincial growth. The negative sign of labor in most sectors may point to labor inefficiencies, skill mismatches, or surplus labor problems that hinder productivity. While capital has a positive impact on the primary and tertiary sectors, it suggests that capital deepening supports growth, but its negative role in the secondary sector implies possible overinvestment or inefficient capital allocation in manufacturing. The positive and significant link between urbanization and growth indicates that urban expansion fosters productivity gains, possibly through agglomeration effects, better infrastructure, and improved access to markets.

5. CONCLUSION

This study examines the impact of energy consumption and industry value added on economic growth in six provinces in central China from 2000 to 2022 using the PMG estimator. The study concluded that there is a different impact of energy consumption. Industry value added positively contributed to economic growth. The study concluded that there is a negative impact of the labor force on economic growth, which means the labor force negatively contributes, signifying the possibility of inefficiency, underemployment, or low productivity of workers. The capital has improved economic growth in primary and tertiary industries. The results imply that for Chinese provinces, energy security, industrial upgrading (toward secondary and tertiary sectors), efficient capital allocation, and well-managed urbanization are the main levers for boosting economic growth. At the same time, labor productivity improvements are essential to reverse the negative contribution of labor. This suggests that policies ensuring a stable and efficient energy supply are critical to sustaining long-term growth. This supports policies that guide balanced and sustainable urban development to maximize economic benefits.

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