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Retraction

Retracted: Analysis of Dynamic Relationship between Energy Consumption and Economic Growth Based on PVAR Model

International Transactions on Electrical Energy Systems

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] J. Han, "Analysis of Dynamic Relationship between Energy Consumption and Economic Growth Based on PVAR Model," *International Transactions on Electrical Energy Systems*, vol. 2022, Article ID 3945522, 7 pages, 2022.

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Research Article

Analysis of Dynamic Relationship between Energy Consumption and Economic Growth Based on PVAR Model

Junyan Han

Department of Legal Technology, Hainan Vocational College of Political Science and Law, Haikou 570100, Hainan, China

Correspondence should be addressed to Junyan Han; 20141128@stu.sicau.edu.cn

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In order to analyze the relationship between energy consumption and economic growth dynamics, the author proposes a dynamic analysis technology of energy consumption and economic growth based on the PVAR model. This technology uses the PVAR method to compare and quantitatively describe the relationship between economic growth and energy consumption in developed and developing countries from 1990 to 2009, using impulse response functions and variance decomposition analysis methods; study the similarities and differences between total energy consumption and various fossil energy consumption and the dynamic impact of economic development, and finally establish a PVAR model for analysis. Experimental results show that: in the forecast of variance analysis, the impact explanatory power of the total energy consumption of developing countries on the fluctuation of economic growth reaches 8.85070. However, the contribution of total energy consumption in developed countries to economic growth is insufficient. The explanatory power of economic growth in developed countries to total energy consumption is 15.58070, while that in developing country is 29.28070, both of which are greater than the explanatory power of their respective total energy consumption on economic growth. *Conclusion*. The technology based on the PVAR model can effectively meet the needs of analyzing the dynamic relationship between energy consumption and economic growth.

1. Introduction

With the rapid development of the global economy, energy and economic issues have gradually become a hot issue of general concern in the international community. Since human beings entered the industrial age, energy, especially fossil energy, has become one of the important factors related to the future development direction and development level of the entire world economy.

Energy is an indispensable material resource for the survival and development of human society and an important strategic material related to a country's economic lifeline. The healthy development of the energy system has become an important material basis for sustainable social and economic development. However, problems such as insufficient supply of energy, especially fossil energy, deviation of energy structure, and low energy efficiency have become the bottleneck of the economic development of all countries in the world. Energy consumption promotes economic growth, and economic growth promotes the large-scale development and utilization of energy, at the same time, energy is also a restrictive factor, with the rapid development of the economy, it is bound to face the contradiction between increasing energy demand and energy scarcity. Since the oil crisis in the 1970s, the causal relationship between energy consumption and economic growth has been studied, and whether economic development is ahead of energy consumption or whether energy consumption promotes economic growth, it has always been an issue of interest to economists and policy analysts. As their relationship directly affects the formulation of government energy policy. If energy consumption is the cause of economic growth, then energy shortages will hinder economic growth; if economic growth is the cause of energy consumption growth, it means that economic growth is not strongly dependent on energy, and the implementation of energy reserve policies will have little effect on the economy. However, the relationship between energy consumption and economic growth has long been a contentious issue. At different times and in different countries, different testing methods often lead to different conclusions.

Correctly handling and understanding the relationship between energy consumption and economic growth is very important for long-term social and economic planning, energy development strategies, and the formulation of relevant laws and regulations, and can provide some help for building a safe and sustainable energy future [1].

2. Literature Review

Over the past half-century, the panel data model (PVAR model) has made great progress. The PVAR model has become an important branch of econometrics, related theories such as panel data unit root test theory, panel data cointegration theory, panel data causality test, mixed panel data model, static panel data model, dynamic panel data model, spatial panel data model, panel data error correction model, panel data vector autoregressive model, rotating panel data model, and so on are becoming more and more mature. It has become a common research direction for scholars to discuss macro and microeconomic issues of various countries with panel data. With the maturity of the PVAR model, a lot of achievements have been made in the application of the model. The research results in the last three years abroad include Khalid applies the PVAR model to study which factors affect the growth process of French manufacturing enterprises [2]. Yurtkuran used the PVAR model to study the effect of rising house prices on household consumption in South Africa [3]. Xu using the PVAR model to study the impact of renewable and nonrenewable energy sources on economic growth and carbon dioxide emissions in Europe and Eurasian countries [4]. Panwar discussed the relationship between terrorist attacks and public spending in Europe using the PVAR model [5]. Kuang used the PVAR model to analyze the loan supply of euro area countries during the global financial crisis [6]. Moldovan Used the PVAR model to study the relationship between the threat of terrorism and economic growth in developing countries [7]. Emir used the PVAR model to analyze the relationship between income growth and energy consumption [8]. Horobet used the PVAR model to discuss the relationship between monetary policy, asset prices, and the macroeconomic environment in 17 OECD countries [9]. Popa used the PVAR model to study the output relationship between the global oil sector and the nonoil sector [10]. Sun used the PVAR model to study the dynamic relationship between the income gap between the eastern and western regions of Germany and the regional labor market and labor transfer [11]. Shabani used the PVAR model to study the labor income problem of US residents [12]. Umarov applyies the PVAR model to the problem of bank risk in EU countries [13].

In response to the above problems, the author uses the panel data vector autoregression (PVAR) method, where all variables are assumed to be endogenous, which shows the interaction between the variables; analyze the relationship between oil, natural gas, and coal individual energy consumption and economic growth, and the relationship between total energy consumption and economic growth; At the same time, the impact of each shock can be differentiated to obtain the impact of the impulse response excluding the impact of other factors, and to better analyze the relationship between energy consumption and economic growth variable decomposition. A PVAR model is used to further determine the magnitude of the effect and to measure the contribution of each effect to the variation in the endogenous variables. As shown in Figure 1.

3. Research Methods

3.1. Energy Consumption Theory. Energy consumption refers to the energy used for production and living. Per capita energy consumption is an important indicator for measuring the economic development of a country and the standard of living of the people. The higher the consumption of energy per person, the greater the product of the country and the rich. In developing countries, changes in energy consumption are closely related to the process of industrialization. With the development of the economy, the energy consumption in the early and middle industrialization period will generally increase slowly, and the economic development will move to the postindustrial stage, there have been major changes in business development, and efforts. Electricity consumption has started to decrease.

3.2. Economic Growth Theory. Economic growth is a term used by economists and journalists and refers to the growth of a country's GDP in a year compared to previous years. Broadly speaking, the meaning of economic growth is the expansion of the productive resources of the economy in the production of goods and services necessary for the survival of its members in a period (for example, the expansion of the supply curve outside). Productivity growth is determined by the country's natural resources, real capital formation, efficiency, human capital formation, skill level, and development of the organizational environment. Therefore, the growth of the economy determines the expansion and improvement of the range of production.

3.3. Analysis of Correlation Changes between Economic Growth and Energy Consumption. Generally speaking, energy consumption will promote economic development, the greater the energy consumption, the higher the labor productivity, with the improvement of labor productivity, the total social wealth is also increasing, the economy is developing rapidly, and the amount of energy required for production and life will also increase accordingly, therefore, there is a spiral upward momentum between energy and the economy. As can be seen from Figure 2, from 1971 to 2010, GDP increased from 3.20024 E+12 USD to 6.31952 E+13 USD. Correspondingly, the total energy consumption has also grown steadily, from 5500032.48 kilotons of oil equivalent to 12324301.2 kilotons of oil equivalent. In general, energy consumption growth is slower than GDP growth, but GDP is more volatile.

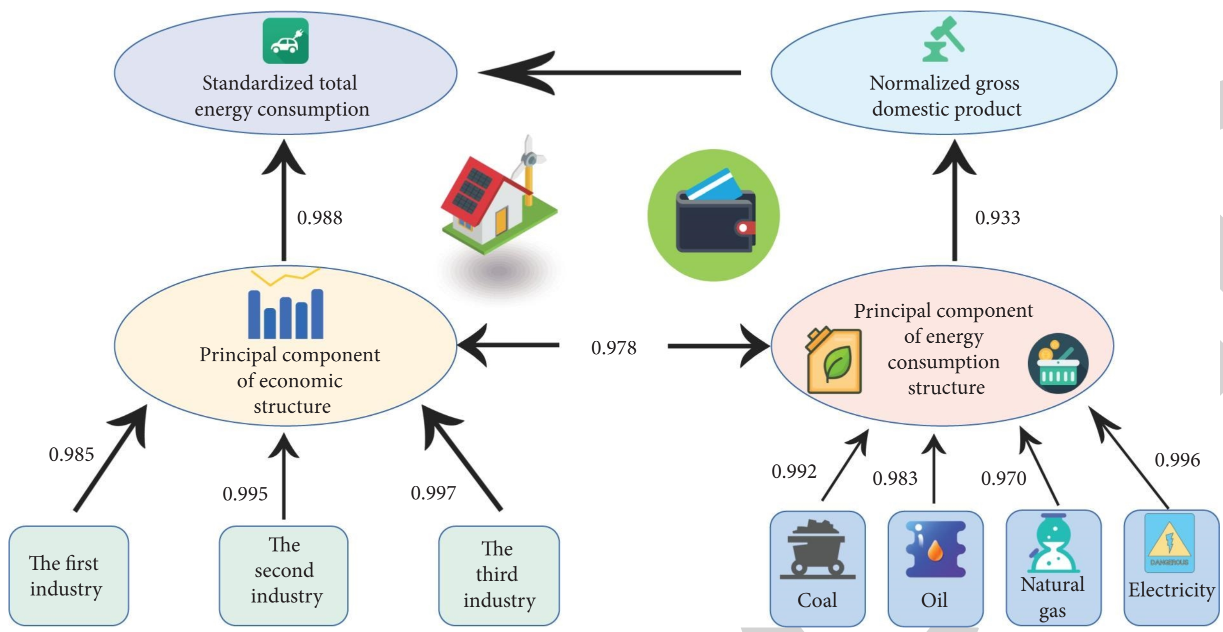

Figure 1: Relationship between energy consumption and economic growth based on the PVAR model.

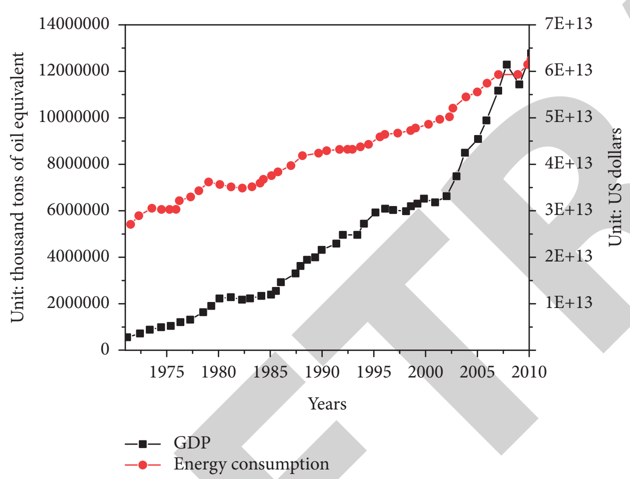

Figure 2: Trend chart of world GDP and total energy consumption from 1971 to 2007.

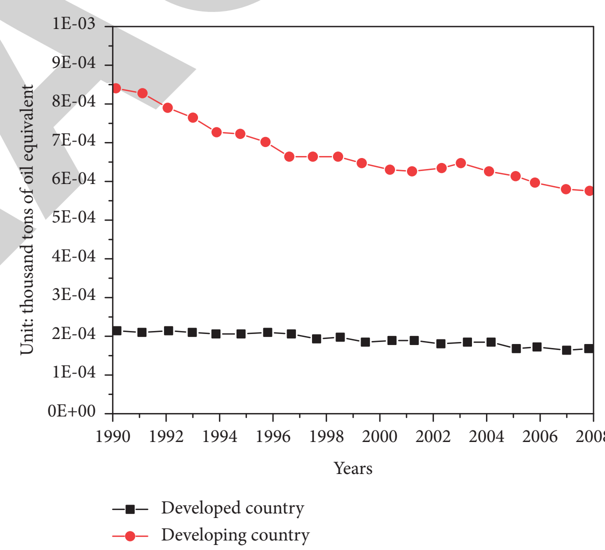

Figure 3: Trend chart of energy consumption intensity from 1990 to 2008.

The change in energy consumption intensity can be seen from Figure 3, both developed and developing countries show a downward trend year by year. The energy consumption intensity of developed countries was at a relatively low level in 1990, it can be seen that the energy utilization efficiency is relatively high, so the energy consumption intensity declines relatively slowly. In developing countries, the energy consumption intensity is relatively high, and the lowest value from 1990 to 2008 was much higher than the highest value in developed countries.

The change of the elastic coefficient of energy consumption can be seen from Figure 4 that the elastic coefficient of energy consumption fluctuates up and down, which is very unstable and does not show an obvious change law, among them, the fluctuation range of the energy consumption elasticity coefficient of developed countries is larger than that of developing countries, and the energy consumption elasticity coefficients of the two are high and low. In 2008, energy consumption in developed countries experienced a large negative growth relative to the economy, and the energy consumption elasticity coefficient was large.

3.4. Theoretical Basis of PVAR Model

3.4.1. Introduction to PVAR Model. The characteristics of the PVAR model are that it combines the characteristics of the traditional time series VAR model and the panel data model. A multivariate dynamic system model is established, which provides a flexible analysis framework for the analysis of multivariate system dynamics, more and more problems

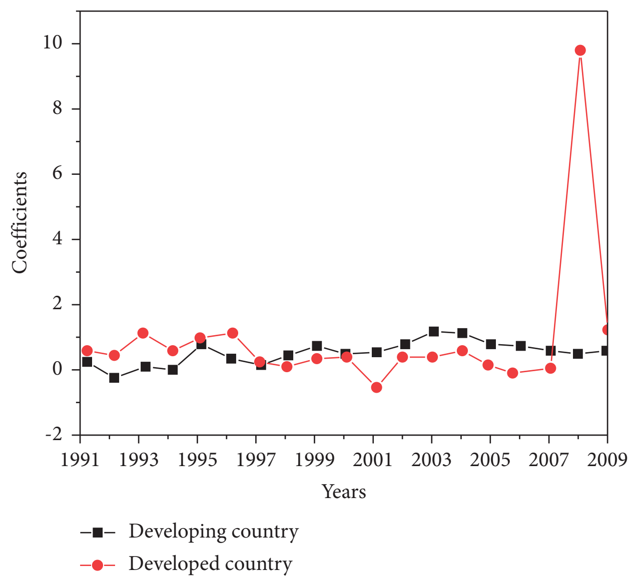

Figure 4: Trend chart of energy consumption elasticity coefficient from 1991 to 2009.

in reality can be discussed by establishing panel vector autoregressive models.

Zhang did pioneering work on the study of the PVAR model and proposed the problem of building a vector autoregressive model on panel data, but in the equation model, he makes a very strong assumption: by making the observation in the first period equal to the life of the individual unit in the first period, the restriction on the length of the lag is avoided, that is, there is a correspondence such as $m(t) = t - 1$ between the length of the lag period m and the period t, but in fact, it is often difficult to observe the entire lifespan of each economic unit, which requires some assumptions to be made based on the existing observation data to determine the relationship between the time series X and Y [14, 15].

Ameen analyzed that when N is relatively large and T is small in panel data, and the time series has a unit root and cointegration relationship, how to effectively estimate the parameters of random effects and fixed effects in panel vector autoregressive models, here, Liu given that the individuals in the panel data are independent, the analysis shows that generalized distance estimation (GMM) and quasi-maximum likelihood estimation QML() will fail, extended generalized distance estimation (extended GMM) and QML estimation can avoid this situation, and QML estimation shows better characteristics [16, 17].

The constructed model is shown in the following formula:

$$w_{i,t} = (I_m - \Phi)u_i + \Phi w_{i,t-1} + \varepsilon_{i,t}. \qquad (1)$$

$w_{i,t}$ is a $m \times 1$-dimensional random variable, $i = 1, 2, \ldots, N$; $t = 1, 2, \ldots, T$; Φ is the $m \times m$-dimensional cross-sectional coefficient matrix; u_i is the $m \times 1$-dimensional vector individual fixed effects; $\varepsilon_{i,t}$ is a random interference term, and several assumptions are given in the paper [18].

The general model of the panel vector autoregressive model can be expressed as follows:

$$Y_{i,t} = \gamma_0 + \sum_{k=1}^{m} \Phi_{t,k} Y_{i,t-k} + \sum_{j=1}^{m} \Psi_{t,j} X_{i,t-j} + \gamma_i + u_{i,t}. \qquad (2)$$

$i = 1, 2, \ldots, N$; $t = 1, 2, \ldots, T$; $Y_{i,t}$ is the $M \times 1$ vector of the M observable variables of the cross-section individual i at time t, $X_{i,t}$ is the $M \times 1$ vector of the observable deterministic strict exogenous variable, $\Psi_{i,j}$ is the coefficient matrix to be estimated for $M \times M$, γ_i is the M unobservable individual fixed effect matrix of individual i, and $u_{i,t}$ is the random error term [19].

In practical use, there are situations where the coefficient matrix of lagged endogenous and exogenous variables is time invariant, as shown in the following formula:

$$Y_{i,t} = \gamma_0 + \sum_{k=1}^{m} \Phi_k Y_{i,t-k} + \sum_{j=1}^{m} \Psi_j X_{i,t-j} + \gamma_i + u_{i,t}. \qquad (3)$$

$i = 1, 2, \ldots, N$; $t = 1, 2, \ldots, T$; Moreover, the estimation method and assumption of equation (3) can be easily extended to equation (2), therefore, for the convenience of discussion, the following analysis is aimed at equation (3).

3.4.2. Assumptions of the PVAR Model

Assumption 1. For any number of individuals N and epoch length T, $Y_{1,t}, Y_{2,t}, \ldots, Y_{NT}$ are both observable variables.

Assumption 2. For arbitrary $i = 1, \ldots, N$; $t = 1, \ldots, T$, $u_{i,t}$ is an independent and identically distributed random variable whose random error term satisfies zero expectation and whose covariance matrix is Ω, namely, $u_{i,t} \sim i.i.d(0, \Omega)$.

Assumption 3. When $s < t$, Y_i, X_i and γ_i are orthogonal to the random error term, as shown in equation:

$$E\left[Y_{i,s}u_{i,t}\right] = E\left[X_{i,s}u_{i,t}\right] = E\left[\gamma_i u_{i,t}\right] = 0, \quad (s < t). \qquad (4)$$

3.4.3. Identification of PVAR Model. The so-called model validation includes estimates and parameters in the model, such as coefficients and lags. The first difference can be obtained, as shown in the following equation:

$$\Delta Y_{i,t} = \Delta \sum_{k=1}^{m} \Phi_k Y_{i,t-k} + \Delta \sum_{j=1}^{m} \Psi_j X_{i,t-j} + \Delta u_{i,t}. \qquad (5)$$

From assumption 3, when $s < t - 1$, it is shown in the following formula:

$$E\left[\Delta Y_{i,s}u_{i,t}\right] = E\left[\Delta X_{i,s}u_{i,t}\right] = 0, \quad (s < t - 1). \qquad (6)$$

Suppose ${y_{i,t}}^j$ is the jth variable in the economic variable vector $Y_{i,t}$, then the first-order difference model of ${y_{i,t}}^j$ is a vector, as shown in the following formula:

$$\Delta y_{i,t}^{j} = \sum_{k=1}^{m} \phi_k^j \Delta Y_{i,t-k} + \sum_{l=1}^{m} \psi_l^j \Delta X_{i,t-l} + v_{i,t}^{j}. \quad (7)$$

Among them, $v_{i,t}{}^{j}$ is the random error term of the single-equation first-order difference model whose endogenous variable is $y_{i,t}{}^{j}$, namely $v_{i,t}{}^{j} = \Delta u_{i,t}{}^{j}$; vectors $\phi_l^j = (\phi_{1,l}{}^{j}, \phi_{2,l}{}^{j}, \ldots, \phi_{m,l}{}^{j})$ and $\psi_l^j = (\psi_{1,l}{}^{j}, \psi_{2,l}{}^{j}, \ldots, \psi_{m,l}{}^{j}) (l = 1, 2, \ldots, p)$.

Therefore, by the orthogonal condition of hypothesis 3, model (7) has an instrumental variable vector as shown in the following formula:

$$Z_{i,j} = \left[1, \Delta Y_{i,t-2}', \Delta Y_{i,t-3}', \ldots, \Delta Y_{i,2}', \Delta X_{i,t-2}', X_{i,t-3}', \ldots, \Delta X_{i,2}'\right]. \quad (8)$$

That is, the number of instrumental variables in equation (7) is 2t − 3.

Since the identifiable condition of equation (7) is that the number of instrumental variables is at least the number of variables on the right side of equation (8), therefore, equation (8) is recognizable when $2t - 3 \geq 2m + 3$, that is, when $t \geq m + 3$. Therefore, the identifiable condition of the panel vector autoregressive model (3) is $T \geq m + 3$ [20].

But for equation (5), due to differential transformation, there will be $(T - m - 2)2(m + 1)$ parameters to be estimated in the model, and $(\mathrm{T} - \mathrm{m} - 2)2(\mathrm{m} + 1) + 1$ parameters to be estimated if the constant term is included. Therefore, when considering the constant term, it is necessary to satisfy $(T - m - 2)2(m + 1) + 1 \geq 2(m + 3)$, among them, $2(m + 3)$ is the number of variables in formula (5), that is, if the $T \geq 2m + 3$ rule is satisfied, formula (5) can be fully identified, and m all represent the number of lag periods.

4. Analysis of Results

4.1. Impulse Response Analysis. The impulse response function describes the influence of the orthogonal innovation of a variable in the model on each variable in the system, through the dynamic response of each variable to the shock; the impact of each shock factor on other factors can be specifically analyzed [21].

The author gave the variables a shock with a standard deviation size and obtained the relevant impulse response function graph. The 5% confidence interval was obtained from 500 Monte Carlo simulations. In the figure, the horizontal axis represents the time of response to the shock, and the vertical axis represents the degree of response of each variable to the shock of the endogenous variable. Ignoring personal responses turns into shock. The middle curve represents the response curve, and the two side curves represent the reliability of the two different models [3].

Figure 5 clearly shows the dynamic impact of the GDP and total energy consumption of developed and developing countries. It can be seen that in developed countries, with an orthogonal innovation of GDP, the total energy consumption increased slightly in the first period, decreased rapidly in the second period, and then gradually returned to a balanced state. Conversely, in the face of an orthogonal innovation in total energy consumption, the response of GDP is positive in

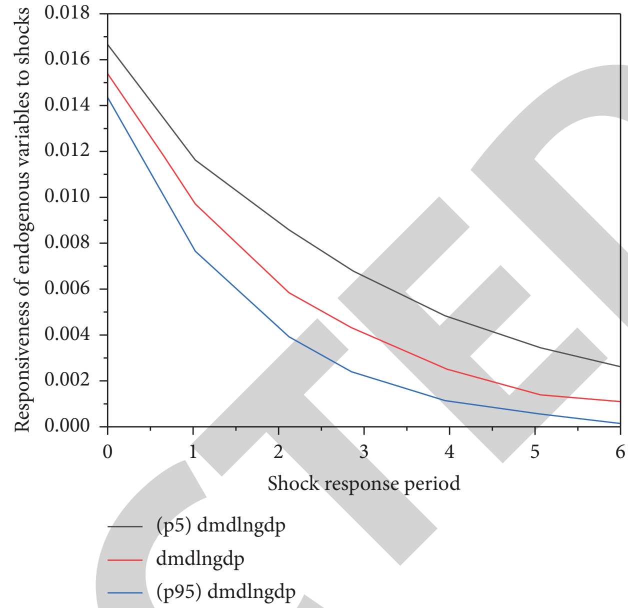

Figure 5: Impulse response plot of total energy consumption and real GDP.

the six lag periods, however, the effect is small, first increasing significantly, then, decreasing significantly, and then, gradually returning to the equilibrium state [22].

For developed countries, with an orthogonal innovation of oil and coal consumption, the GDP first rises and then falls and tends to converge, the impact caused by oil consumption fluctuates more, and the impact of natural gas consumption on GDP is small, the impact is not significant [23]. Generally speaking, the consumption of the three types of fossil energy in developed countries has a positive impact on the GDP, but the effect is small. The above results combined with the basic regression results show that, the total energy consumption of developed countries has a positive effect on economic growth and this effect is delayed, economic development generally depends on the total energy consumption for a long time, energy, as a necessary factor of production, has a nonnegligible impact on economic development. However, economic growth has a positive effect on total energy consumption, and this effect is lagged, indicating that economic growth has a greater effect. The long-term effects and relationship between total energy consumption and economic changes on total energy consumption. Overall, energy consumption and business growth are strengthening but not equal.

4.2. Variance Decomposition. Variance decomposition provides information about the significance of each negative effect that contributes to the sample variance. The panel model variance decomposition is used to describe the magnitude of the effect, thereby measuring the contribution of each shock to the change in the endogenous variable [24].

The results of variance analysis are shown in Tables 1 and 2, the fluctuation of each variable mainly comes from itself. The equation analysis results of oil, natural gas, coal

Table 1: Variance decomposition results of total energy consumption and real GDP.

Period		Developed countries			Developing country	
S		Dmdlngdp	Dmdlnetc		Dmlngdp2	Dmdlnetc2
10	Dmdlngdp	0.96513	0.03487	Dmdlngdp2	0.91146	0.08854
10	Dmdlnetc	0.15581	0.84419	Dmdlnetc2	0.29281	0.70719
20	Dmdlngdp	0.96513	0.03487	Dmdlngdp2	0.90759	0.09241
20	Dmdlnetc	0.15583	0.84417	Dmdlnetc2	0.29285	0.70715
30	Dmdlngdp	0.96513	0.03487	Dmdlngdp2	0.90655	0.09345
30	Dmdlnetc	0.15583	0.84417	Dmdlnetc2	0.29288	0.70712

Table 2: Variance decomposition results of oil, natural gas, coal consumption, and real GDP.

Period		Developed countries					Developing country			
S		Dmdlngdp	Dmlncc	Dmdlnoc	Dmdlngc		Dmdlngdp2	Dmlncc2	Dmdlnoc2	Dmdlngc2
10	Dmdlngdp	0.9769	0.0085	0.0113	0.0031	Dmdlngdp2	0.9161	0.0175	0.0588	0.007
10	Dmlncc	0.0865	0.9110	0.0006	0.0017	Dmlncc2	0.0837	0.8822	0.0300	0.0039
10	Dmdlnoc	0.1230	0.0101	0.8662	0.0006	Dmdlnoc2	0.4329	0.0012	0.5646	0.0011
10	Dmdlngc	0.0349	0.0145	0.0127	0.9378	Dmdlngc2	0.0410	0.0013	0.0342	0.9233
20	Dmdlngdp	0.9764	0.0081	0.0114	0.0040	Dmdlngdp2	0.9115	0.0183	0.0615	0.0085
20	Dmlncc	0.0879	0.9096	0.0006	0.0017	Dmlncc2	0.1119	0.8169	0.0666	0.0043
20	Dmdlnoc	0.1231	0.0102	0.8659	0.0006	Dmdlnoc2	0.4925	0.0047	0.4979	0.0047
20	Dmdlngc	0.0349	0.0145	0.0127	0.9377	Dmdlngc2	0.0575	0.0016	0.0549	0.8858
30	Dmdlngdp	0.9764	0.0081	0.0114	0.0040	Dmdlngdp2	0.9072	0.0185	0.0652	0.0088
30	Dmlncc	0.0880	0.9096	0.0006	0.0017	Dmlncc2	0.1510	0.7280	0.1160	0.0048
30	Dmdlnoc	0.1231	0.0102	0.8659	0.0006	Dmdlnoc2	0.4849	0.0066	0.5016	0.0067
30	Dmdlngc	0.0349	0.0145	0.0127	0.9377	Dmdlngc2	0.0827	0.0020	0.0835	0.8316

consumption, and real GDP in developing countries have great changes in different forecast periods, the explanatory power of oil, natural gas and coal on economic growth has gradually increased, indicating that the influence of these variables in developing countries has a lag. However, the variables of other systems have little effect on the results of equation analysis in different forecast periods, indicating that after 10 forecast periods, the system has been basically stable.

In the 10th forecast, fluctuations in energy consumption and economic growth are explained as follows: the explanatory power of the total energy consumption of developing countries to the fluctuation of economic growth reaches 8.85%, while the contribution of total energy consumption of developed countries to economic growth is insufficient; the explanatory power of economic growth in developed countries to total energy consumption is 15.58%, and that in developing countries is 29.28%, both of which are greater than the explanatory power of their respective total energy consumption to economic growth, there is also a similar relationship between the three fossil energy sources and economic growth, indicating that the interaction between economic fluctuations and energy consumption is unequal; the explanatory power of oil consumption for economic growth in developing countries is relatively high, while the explanatory power of natural gas consumption for economic growth is relatively low.

5. Conclusions

The author proposes technical research on the dynamic relationship analysis between energy consumption and economic growth based on the PVAR model. This technology uses the PVAR method to compare and quantitatively describe the relationship between economic growth and energy consumption in developed and developing countries from 1990 to 2009, using impulse response functions and variance decomposition analysis methods; study the similarities and differences between total energy consumption and various fossil energy consumption and the dynamic impact of economic development, and finally, establish a PVAR model for analysis. It is proved that the technology based on the PVAR model can effectively meet the needs of analyzing the dynamic relationship between energy consumption and economic growth.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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