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## Study on Relationship of Energy Consumption and Economic Growth in China

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### Abstract

Energy is one of the most basic materials of the national economy, which plays an important role in national production and life. The relationship between energy consumption and economic growth has been a fascinating question since energy crisis in 70s of last century. This paper analyzes the relationship between energy consumption and economic development based on the VAR model using temporal series of China from 1990 to 2009, then uses impulse response function and variance decomposition to portray the correlations between economic growth and energy consumption. The result shows that there exists a unidirectional causality from energy consumption to gross domestic product and energy consumption can observably promote the development of economy.

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*Keywords:* energy consumption; economic growth; VAR model; impulse response function; variance decomposition

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### 1. Introduction

The relationship between energy consumption and economic growth has been a fascinating question since energy crisis in 70s of last century. As a first priority issue, economic growth lies in a very important position both in developing and developed countries. There is no doubt that energy is one of the most basic material of the national economy, which plays an important role in national production and life. From an economic point of view, the relationship between energy consumption and economic growth lies in two aspects: the growing dependence of economic growth on energy, and on the other hand, economic growth can promote energy technology advances and large-scale development and utilization of energy.

Scholars have done a lot of research on the relationship between energy consumption and economic growth: In [5], referred that if economic growth Granger causes energy consumption, it is not a energy dependence economy, and the negative impact of energy-saving policy to economic growth may be very small or not exist. In [1], referred that if energy consumption Granger causes economic growth, it is a

energy dependence economy, and the reduction of energy consumption may affect economic growth. In [8], referred that if there is no causality between them, and there isn't a necessary link between energy policy and economic growth. In [4], referred that if there is bidirectional causality between them, that is to say economic growth and the energy consumption are interdependent. In order to keep the adaptation of the two, the best combination of policy should be used to realize the coordinate development of economic growth and energy consumption. In [1], referred that there is no causality between energy consumption and economic growth in Malaysia, Singapore and Philippines; there exists a unidirectional causality from energy consumption to gross domestic product in India; there exists a unidirectional causality from economic growth to energy consumption in India; there is bidirectional causality between them in Pakistan and Taiwan of China. In [7], comparatively analyzed cointegration of the United States and China's energy consumption and economic growth whose result shows that economic growth is the Granger cause of the energy consumption growth both in the two countries. In [9], looking at both sides of demand and production, investigated the causal relationship between energy consumption and economic growth in China during the period from 1953 to 2008, whose result shows there exists long-run equilibrium relationship between GDP and energy consumption and no causality between them in the short run, bidirectional causality in the long run. In [2], did the ADF test and Granger causality test, then used elastic analysis method to analyze the relationship between the two, whose result shows energy consumption growth promotes economic growth of China, and in turn, economic growth is not the main factor that causes the energy consumption growth. In [3], analyzed cointegration and Granger causality between energy consumption and economic growth based on the data of China from 1978 to 2008, whose result shows that there is bidirectional causality between them, but doesn't have long-term cointegration. In [6], referred that economic growth and energy consumption is long-term equilibrium through cointegration analysis and Granger causality test based on the data of China from 1980 to 2006, energy consumption is an important impetus of the stably growing economy, and economic growth in the past is energy needed economy, the current data doesn't show the constraint of energy consumption to economic growth.

Studies suggest that the relationship between energy consumption and economic growth is different in different countries, and even if in the same country the relationship is different at different times.

## 2. The VAR Model

Using economic theory to describe the relation between the variables couldn't offer the strict definition for dynamic relation between the variables frequently, besides endogenous variables may also appear on both sides of an equation, which make the estimation and inference complicated. And nonstructural approach of multi-variable modeling is used to solve these problems. And the vector autoregression model is one of nonstructural approach of multi-variable modeling.

A vector autoregression(VAR) is a set of  $k$  time series regressions, in which the regressors are lagged values of all  $k$  series. A VAR extends the univariate autoregression to a list, or "vector," of time series variables. When the number of lags in each of the equations is the same and is equal to  $p$ , the system of equations is called a VAR ( $p$ ).

In the case of two time series variables,  $Y_t$  and  $X_t$ , the VAR( $p$ ) consists of the two equations

$$\begin{aligned} Y_t &= \beta_0 + \beta_1 Y_{t-1} + \dots + \beta_p Y_{t-p} + \gamma_1 X_{t-1} + \dots + \gamma_p X_{t-p} + u_{1t} \\ X_t &= \beta_{20} + \beta_{21} Y_{t-1} + \dots + \beta_{2p} Y_{t-p} + \gamma_{21} X_{t-1} + \dots + \gamma_{2p} X_{t-p} + u_{2t} \end{aligned} \quad (1)$$

where the  $\beta$ 's and the  $\gamma$ 's are unknown coefficients and  $u_{1t}$  and  $u_{2t}$  are error terms. In practical, we hope that lag  $p$  is large enough to reflect dynamic characteristic of model, On the other hand, the longer lag length is, the more unknown coefficients are, and the less degree of freedom is. So, there need to find a balance between lag length and degree of freedom. And lag length can be determined using either F-tests or information criteria, such as Akaike information criterion, Schwarz criterion.

### 3. Positive Analysis

#### *The Choosing of Indexes and Data*

Taking into account availability and reliability of data, this paper selects the gross domestic product (GDP) of China as indicator which measures the total of economic growth, uses total consumption of energy (EC) as indicator which measures the consumption of energy. These two groups of indicator data all comes from the Statistical Yearbook of China from 1991 to 2010, GDP is adjusted at 1990's constant price according to the indices of gross domestic product, total consumption of energy (EC) is calculated on the basic of heat value equivalent, and all data are processed by logarithm in order to maintain the stability of data using Eviews 5.0.

TABLE 1 THE DATA OF ENERGY CONSUMPTION AND GDP

YEAR	EC	GDP	ADJUSTID GDP
1990	98703	18667.8	18667.8
1991	103783	21781.5	19950.3
1992	109170	26923.5	21586.0
1993	115993	35333.9	24857.8
1994	122737	48197.9	29985.5
1995	131176	60793.7	34096.7
1996	135192	71176.6	36288.1
1997	135909	78973.0	36838.1
1998	136184	84402.3	36510.7
1999	140569	89677.1	36045.8
2000	145531	99214.6	36778.5
2001	150406	109655.2	37533.4
2002	159431	120332.7	37758.9
2003	183792	135822.8	38736.1
2004	213456	159878.3	41419.4
2005	235997	184937.4	43043.2
2006	258676	216314.4	44682.0
2007	280508	265810.3	48094.5
2008	291448	314045.4	51828.5
2009	306647	340506.9	51502.1

#### *Granger Causality*

To assert a causal relationship between EC and GDP, we could analyze the relationship between LEC and LGDP by using Granger causality tests.

TABLE 2 GRANGER CAUSALITY TEST

Null Hypothesis:	lag	F-Statistic	Probability	Conclusion
<i>LGDP does not Granger</i>	1	1.281	0.274	Accept

<i>Cause LEC</i>		3.403	0.084***	Reject
<i>LEC does not Granger Cause LGDP</i>	2	0.962	0.408	Accept
		3.917	0.047**	Reject
	3	0.306	0.821	Accept
		5.442	0.018**	Reject
	4	0.769	0.578	Accept
		12.167	0.003*	Reject
	5	0.343	0.865	Accept
		4.882	0.075***	Reject

Notes: “\*”, “\*\*”, “\*\*\*” indicates significance under 1%, 5%, 10% of the levels respectively.

According to Table 2, we can draw the conclusion: LEC Granger-causes LGDP at the 1%, 5% or 10% significant level, and LGDP does not Granger cause LEC when lag length is from one to five.

This is true according to the status of China: energy is the bridge of other industries in national economy, its consumption will condition production scale of national economy to some extent; national economy can not be sustained growth without consumption of energy. Energy consumption stimulates the economic growth of the entire society while economic growth doesn't stimulate energy consumption. That may be caused by the non-renewable of some energy resources, imbalance between energy supply and demand and inefficiency of energy consumption.

*Establish of VAR Models*

1) *VAR Lag Order Selection*

The results provide VAR models of value of LR , FPE ,AIC, SC and HQ from 0 to the 3rd lags in Table 3 and \* indicates lag order selected by the criterion which shows that most criterion select the lag order of VAR models is 2.

TABLE 3 VAR LAG ORDER SELECTION CRITERIA

Lag	LogL	LR	FPE	AIC	SC	HQ
0	15.52	NA	0.000699	-1.59	-1.49	-1.59
1	69.69	89.21	1.92e-06	-7.49	-7.20	-7.46
2	82.07	17.48*	7.38e-07*	-8.48	-7.99*	-8.43
3	86.44	5.14	7.57e-07	-8.52*	-7.84	-8.45*

Notes: “\*”: lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

2) *VAR Model*

$$\begin{pmatrix} Lec \\ Lgdp \end{pmatrix} = \begin{pmatrix} 1.81 & -0.23 \\ 0.36 & 1.29 \end{pmatrix} * \begin{pmatrix} Lec_{-1} \\ Lgdp_{-1} \end{pmatrix} + \begin{pmatrix} -0.81 & 0.21 \\ 0.29 & -0.48 \end{pmatrix} * \begin{pmatrix} Lec_{-2} \\ Lgdp_{-2} \end{pmatrix} + \begin{pmatrix} 0.27 \\ 1.11 \end{pmatrix}$$

AIC=-3.96, SC=-3.71

According to equation, we could conclude that LEC has a positive effect on LGDP; and LGDP may have a little negative effect on LEC. That means the relationship between them is unidirectional. So the VAR matrix performs Granger causality tests to a certain degree.

## Impulse Responses

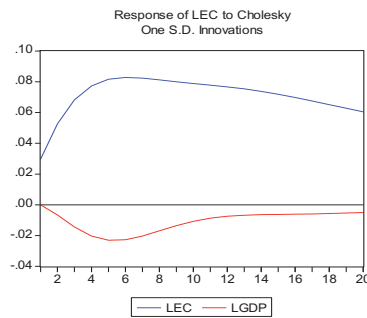


Figure 1. Response of LEC to One S.D. Innovations

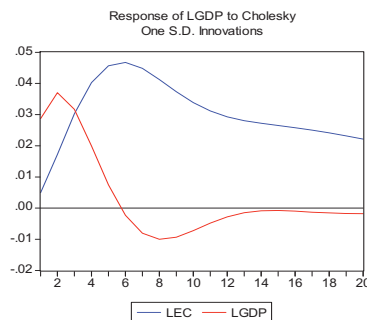


Figure 2. Response of LGDP to One S.D. Innovations

As seen in Figure 1, LEC to one S.D. innovations of itself makes an immediate response, the first phase is positive and about 0.03, then the response extent increases till the sixth phase, which reaches the maximum, then decreases but stays positive. That means the consumption of energy is accelerated by itself, and on short term, the promoter action increases. The response of LEC to one S.D. innovations of LGDP does not presented immediately, the first period response is 0, after that, the response extent decreases till minimum of the fifth period, then it increases, and keeps a stable status from the twelfth period but stays negative. That means with the development of economy, the consumption of energy maybe decrease which may be caused by the increasing of energy efficiency, imbalance between energy supply and demand and so on.

As seen in Figure 2, LGDP to one S.D. innovations of LEC makes an immediate response, at about the sixth period reaches to the maximum, after that, the response extent decreases gradually but keeps positive for a long run. That means consumption of energy has significant positive effects on economic growth in the long term; LGDP to one S.D. innovations of itself makes an immediate response, at the second phase reaches the maximum, then the response extent decreases till the eighth phase, which reaches to the minimum, then increases to constringency. That means the stimulating effect of LGDP to itself decreases and comes to a negative influence, but finally approach to zero.

## Variance Decompositions

It is defined as variance decomposition to separate the variation in an endogenous variable into the component shocks to the VAR for finding out information about the relative importance of each random innovation in affecting the variables in the VAR. And Figure 3, Figure 4 are variance decomposition charts of LQCZL and LGDP.

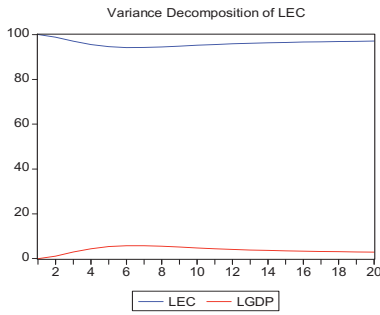


Figure 3. Variance Decomposition of LEC

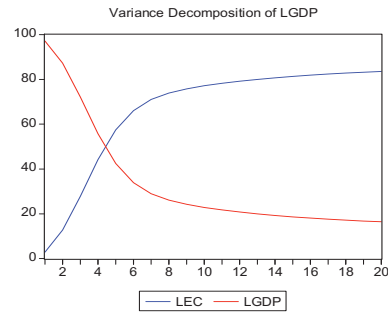


Figure 4. Variance Decomposition of LGDP

As seen in Figure 3, the contribution to LEC is mainly from itself, and the contribution from LGDP increases rapidly from the first to sixth period response, then stays a relatively stable status but in general the contribution is small. That means GDP is not the granger cause to energy consumption.

As seen in Figure 4, the contribution from LEC to LGDP increases observably, and exceeds the contribution of LGDP to itself after the fourth period, and finally comes to a stable status from the twelfth period, which means the economic growth comes from the stimulating effect of itself at first, but as time goes on, the stimulating effect of energy consumption to economic growth is very more significant than that economic to itself. That is to say economic growth is mainly stimulated by the consumption of energy.

#### 4. Conclusions

The empirical study of energy consumption and economic growth in China has shown that: the role of energy consumption in promoting economic growth is obvious and as time goes on, the role of energy consumption in promoting economic growth would be enhanced and finally to a stable level. In turn, economic growth is not the factor to promote energy consumption.

These may be caused by the raising desire for the energy supply and the limited energy producing with the rapid development of our economy. Meanwhile, there is a big gap of energy efficiency between China and the developed countries. So we can not simply increase the total consumption of energy to promote economic growth, but enhance the efficiency of energy consumption and develop the new energy to realize a green, sustainable development of economy.

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