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# Factors that affect energy consumption: An empirical study of Liaoning province in China

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**ABSTRACT**

*This paper examines the factors that affect energy consumption in Liaoning Province, China. Based on a vector autoregression (VAR) model and an empirical test application of time series data between 1978 and 2010, we show a stable long-run equilibrium relationship between energy consumption and the four identified influencing factors (i.e., GDP, population size and the proportion of service/heavy industries). Specifically, the proportion of heavy industries has the most significant influence on energy consumption in the long-term, while the proportion of service industries has a significant influence in the short-term. Finally, the disturbance of demographic factors on energy consumption is the least significant determinant according to the results of the impulse response function and variance decomposition.*

**Key words:** Energy Consumption, Vector Autoregression Mode, Vector Error Correction Model

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## INTRODUCTION

Continued economic growth in most countries relies on energy consumption, which still tends to be driven by the consumption of fossil fuels. Therefore, energy issues must be addressed in order to solve the contradiction between rapid economic development and environmental deterioration. In this regard, exploring the factors that affect energy consumption is beneficial to governments for them to better grasp energy consumption characteristics, formulate feasible energy-saving policies, and promote the development of energy and related industries in order to improve energy efficiency and reduce environmental pollution.

As a traditional industrial base that has a high proportion of heavy industry relative to the rest of China, Liaoning Province is one of the largest producers and consumers of energy in the country. In 2012, the total energy production in Liaoning Province was 67.70 million tons of standard coal and the total energy consumption was 198.56 million tons of standard coal. Given this large degree of energy usage, this paper uses time series data for the years 1978–2010 to establish an unrestricted vector autoregression (VAR) model in order to investigate the factors that affect energy consumption in Liaoning Province.

The study conducted by Kraft and Kraft of the energy consumption–income relationship in the U.S. triggered subsequent studies dedicated to this topic. In 1978, these authors tested for causality between energy consumption and GNP for the years 1947–1974 and concluded unidirectional causality running from GNP to energy consumption [1]. Other studies, however, have since found mixed results due to the utilization of different timeframes, datasets, and methodologies. For example, Cheng and Lai demonstrated that both Singapore and Korea have one-way relationships from GDP to energy consumption [2], while Aguirre found that economic growth positive affects energy consumption [3] and Stern carried out the Granger test to find a one-way causal relation between GDP and energy consumption [4]. In subsequent research, Stern obtained the same result by applying a Johansen–Juselius (JJ) co-integration test to U.S. data from 1948 to 1994 and CIS data from 1991 to 2005 [5]. Finally, Apergis and Payne found a positive relationship among real GDP, energy consumption, fixedasset investment, and labor, while their error correction model showed a one-way causal relation between GDP and energy consumption in the short-term and a two-way causal relation in the long-term [6].

Given the foregoing, it is clear that energy consumption is influenced not only by GDP but also by demographic factors, economic structure, industry-level policy, energy price, and energy efficiency. in the Chinese context, Shi found that the national economic reforms have had more of an effect on energy consumption than has economic growth [7]. However, Wang and Shen tested the spatial correlation between energy consumption and economic growth by using a space propinquity matrix and spatial autocorrelation coefficient and found a significant spatial correlation between GDP and energy consumption in China [8].

Lin and colleagues analyzed the influence of GDP, coal price, economic structure, and transportation cost on coal consumption [9,10]; later, the same research team used input-output decomposition to analyze the influence of energy consumption, international trade, and technological progress on the electricity consumption of energy and non-energy departments [11]. Finally, Zhou built a VAR model and impulse response function to show that among the numerous influencing factors, the transformation of economic growth and the change in the proportion of heavy industry play a decisive role in energy consumption [12].

Based on these previous studies, the present paper investigated how GDP, population size, the proportion of service industries, and the proportion of heavy industries affect energy consumption in Liaoning Province. We applied a VAR model and demonstrated that heavy industries are the most significant energy consumers in the long-term.

The remainder of the paper is organized as follows. Section 2 presents the variables and data. Section 3 establishes the VAR model and provides an empirical test application of time series data between 1978 and 2010. Section 4 draws conclusions based on the presented analysis of the relationships between energy consumption in Liaoning Province and the main influencing factors.

## VARIABLES AND DATA

### 2.1 Economic aggregate (*GDP*)

Several papers report that an economic aggregate such as GDP has a significant positive effect on energy consumption. The GDP value used in this paper has eliminated the effect of inflation and used 1978 as the base year.

### 2.2 Population size (*pop*)

Energy consumption can be divided into household use and industrial use. Population size is the main factor that determines household energy consumption. Quality of life improvements and the ageing population have led to increased household energy consumption. Therefore, in this paper we considered the influence of population size on household energy consumption.

### 2.3 Proportion of service industries (*stru*) and heavy industries (*ind*)

As different industries have different levels of energy consumption, industry structure is an important determinant of energy consumption. Because service industries have low energy consumption levels compared with heavy industries, an increase in the proportion of service industries reduces aggregate energy consumption and vice versa. In this paper, we proposed that the proportion of service (heavy) industries has a negative (positive) relation with energy consumption.

### 2.4 Data

Data were derived from the statistical yearbook of Liaoning Province. According to the previous article, we defined the energy consumption function as follows:

$$ener = GDP^{\beta_1} pop^{\beta_2} e^{(\beta_0+\beta_3 stru+\beta_4 ind+\varepsilon)}$$

In order to eliminate intensive variation in the data as well as heteroscedasticity, we took the logarithm of both sides of the function:

$$\ln ener = \beta_0 + \beta_1 \ln GDP + \beta_2 \ln pop + \beta_3 stru + \beta_4 ind + \varepsilon$$

where $\beta_1$ and $\beta_2$ represent the elasticity of energy consumption to economic growth and population, respectively, and $\beta_3$ and $\beta_4$ mean the average change in energy consumption when a unit changes in the proportion of the added benefit of the service industries and heavy industries, respectively.

## Model and empirical analysis

### 3.1 The establishment of the VAR model

The application of VAR in empirical economics was first introduced by Sims [13]. Compared with other economic models, the VAR model is more concerned about the random disturbance term when assessing the dynamic effect of multivariate time series. Under normal circumstances, the variables in the VAR model must be smooth, and thus we first test the stationarity of the variables.

### 3.1.1. Unit root test

The standard method for the examination of series stationarity is the unit root test. There are six kinds of commonly used methods of inspection in this regard: the ADF test, DF-GLS test, PP test, KPSS test, ERS test, and NP test. In the case of small samples, the ADF test cannot test detrended stationary series that contain a time trend. This paper thus uses the modified DF-GLS test to ascertain whether the time series of the null hypothesis is non-stationary and the alternative hypothesis is stationary. The experimental process is:

The test results are shown in Table 1. Any original time series that is not significant at the 10% level fails the DF-GLS test. On this basis, we find that all five series contain a unit root (i.e., they are non-stationary), whereas the first-differenced series do not, which suggests that Δln*ener*, Δln*GDP*, Δln*pop*, Δ*stru*, and Δ*ind* series are stationary with a single whole I (1).

**Table 1. Unit Root Test**

| Variable | Type of test (c, T, d) | DF-GLS value | The results of inspection level | | | Conclusion |
|---|---|---|---|---|---|---|
| | | | 1% | 5% | 10% | |
| **ln*ener*** | (c,0,0) | 1.28 | -2.64 | -1.95 | -1.61 | Non-stationary |
| **Δln*ener*** | (c,0,0) | -6.11 | -2.64 | -1.95 | -1.61 | Stationary |
| **ln*GDP*** | (c,0,1) | -0.41 | -2.64 | -1.95 | -1.61 | Non-stationary |
| **Δln*GDP*** | (c,0,0) | -2.63 | -2.64 | -1.95 | -1.61 | Stationary |
| **ln*pop*** | (c,0,1) | -0.59 | -2.64 | -1.95 | -1.61 | Non-stationary |
| **Δln*pop*** | (c,T,1) | -3.96 | -3.77 | -3.19 | -2.89 | Stationary |
| ***stru*** | (c,0,1) | -0.78 | -2.64 | -1.95 | -1.61 | Non-stationary |
| **Δ*stru*** | (c,0,0) | -3.84 | -2.64 | -1.95 | -1.61 | Stationary |
| ***ind*** | (c,0,0) | -0.92 | -2.64 | -1.95 | -1.61 | Non-stationary |
| **Δ*ind*** | (c,0,0) | -5.58 | -2.64 | -1.95 | -1.61 | Stationary |

*Note: (C, T, d) represent the test equation that contains the intercept, trend item, and lag order, where the lag order is determined according to the AIC and SC.*

### 3.1.2. Determining the optimal lag period

Before the co-integration test of the variables, we need to determine the optimal lag order for the VAR model. On one hand, we want to ensure that the lag order is large enough in order to reflect the dynamic features of the VAR model; on the other hand, if the lag order is large, we need to estimate the parameters more, and this results in the model having fewer degrees of freedom. In this paper, we use the LR test, AIC, and SC criterion to determine the lag order. The results are presented in Table 2. The observed results of the five evaluation indexes show that the optimal lag order is of order 1.

**Table 2. Lag Period of the VAR Model**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| **0** | 243.415 | NA | 8.61E-14 | -15.894 | -15.661 | -15.820 |
| **1** | 428.325 | 295.856* | 2.07E-1* | -26.555* | -25.1538* | -26.107* |
| **2** | 451.204 | 28.980 | 2.78E-18 | -26.411 | -23.845 | -25.592 |
| **3** | 475.011 | 22.220 | 4.65E-18 | -26.334 | -22.598 | -25.139 |

*Note: * indicates the number of lag order determination criteria*

### 3.1.3 VAR model and stability test

Based on the selected variables, this paper constructs the following unrestricted VAR model without exogenous variables:

$$Y_t = \phi_1 Y_{t-1} + \cdots + \phi_p Y_{t-p} + \varepsilon_t, \qquad t = 1,2,\cdots T$$

where $Y_t = (\ln ener, \ln GDP, \ln pop, stru, ind)'$;
$\varepsilon_t$ is the disturbance column vector;
$\Phi$ is the coefficient matrix; and
$t$ is the lag order.
Therefore, we can build the first-order VAR model, namely VAR (1), according to Eviews in order to estimate its parameters. We ascertain the following five equations:

$$\ln ener = 0.503 \ln ener(-1) - 0.0533 \ln GDP(-1) + 6.543 \ln pop(-1) - 2.991 stru(-1) + 1.806 ind(-1) - 49.576$$
$$\ln ener = 0.120 \ln ener(-1) - 0.760 \ln GDP(-1) + 5.451 \ln pop(-1) - 1.550 stru(-1) + 0.944 ind(-1) - 44.453$$
$$\ln ener = 0.007 \ln ener(-1) - 0.003 \ln GDP(-1) + 0.941 \ln pop(-1) + 0.019 stru(-1) - 0.005 ind(-1) + 0.454$$
$$stru = -0.004 \ln ener(-1) - 0.021 \ln GDP(-1) + 0.647 \ln pop(-1) + 0.764 stru(-1) + 0.006 ind(-1) - 5.079$$
$$ind = -0.006 \ln ener(-1) - 0.062 \ln GDP(-1) - 1.498 \ln pop(-1) + 0.710 stru(-1) + 0.302 ind(-1) + 12.268$$

**3.2 Co-integration test and vector error correction model (VECM)**

The co-integration test for co-integration variables must have the same number of single integers. From the result of the unit root test, it can be seen that the multivariate VAR model satisfies the conditions for co-integration. There are two main kinds of co-integration test methods: (i) the co-integration regression known as the JJ test and (ii) the co-integration regression based on residual error, such as the E-G two-step method. As we adopt more than two variables in this study, the JJ test is preferred.

The JJ test is then divided into the eigenvalue trace test (Trace test) and the maximum eigenvalue test (Max-Eigen test). The primary hypothesis of the characteristic roots trace test is at least an r co-integration relationship; the alternative hypothesis is the m (full rank) test statistic for a co-integration relationship:

$$\eta_r = -T \sum_{i=r+1}^{k} \ln(1-\lambda_i) \qquad r = 0,1,\cdots,k-1$$

The largest eigenvalue of the null hypothesis testing is a co-integration relationship; the alternative hypothesis is at least an r+1 co-integration relationship. The test statistic is:

$$\xi_r = -T \ln(1-\lambda_{r+1}) \qquad r = 0,1,\cdots,k-1$$

**Table 3. JJ Test**

| Null Hypothesis | Trace Statistic | 5% Critical Value | Max-Eigen Statistic | 5% Critical Value |
|---|---|---|---|---|
| **None** | 69.4886* | 60.0614 | 42.5951* | 30.4396 |
| **At most 1** | 26.8935 | 40.1749 | 16.0056 | 24.1592 |
| **At most 2** | 10.8879 | 24.2760 | 7.2666 | 17.7973 |
| **At most 3** | 3.6213 | 12.3209 | 3.3437 | 11.2248 |
| **At most 4** | 0.2776 | 4.1299 | 0.2776 | 4.1299 |

*Note: We rejected the null hypothesis at the 5% significance level; the lag order is of order 1.*

The co-integration test results are shown in Table 3. It can be seen from the Trace and Max-Eigen statistic test results that there is one co-integration relationship at the 5% significance level. The co-integration equation is thus:

$$\ln ener = 0.184 \ln GDP + 0.389 \ln pop - 2.374 stru + 6.534 ind + ecm$$
$$(0.05438) \qquad (0.05010) \qquad (0.58743) \quad (0.70970)$$

The results of the VECM show that in the period 1978–2010 there are long-term equilibrium co-integration relations between all four explanatory variables and energy consumption in Liaoning Province. In the long run, economic growth (energy consumption elasticity of GDP = 0.1837) and population size (population elasticity = 0.3893) positively affect energy consumption in Liaoning Province. Further, the proportion of service industries has a negative effect on energy consumption; a 1% increase in the proportion of service industries reduces energy consumption by 2.37%. By contrast, as expected, the proportion of heavy industries has a positive impact on energy consumption. Indeed, this variable is shown to be the most important factor that affects energy consumption in Liaoning Province.

Because there is a co-integration relationship between the studied variables, we can use the regression distribution error correction model (VEC). The VEC can show the short-term dynamic adjustment process between energy consumption and its influencing factors in order to demonstrate when variables deviate from the long-term equilibrium owing to external shocks and how the variables can return to the long-run equilibrium state in the next stage.

The VEC model's results are shown in Table 4. The coefficients for energy consumption rate, economic growth rate, and population growth rate on the short-term effect on the energy consumption coefficient are -0.42, 0.658, and

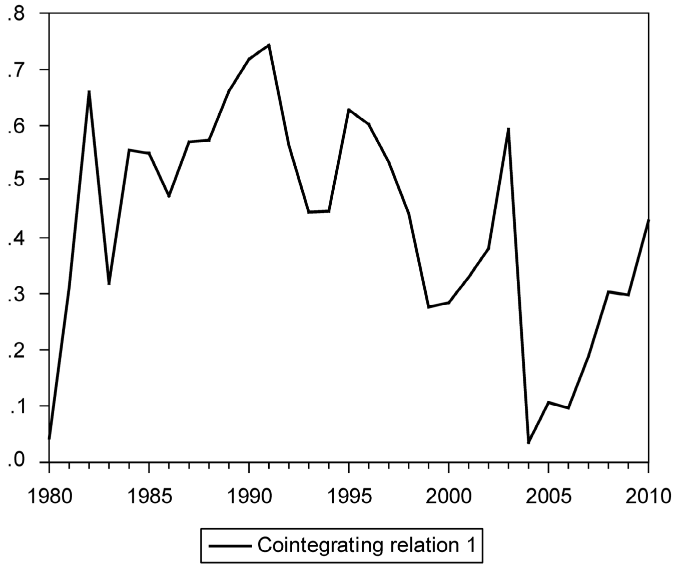
0.936, respectively. Moreover, the coefficients of the proportion of service industries and the proportion of heavy industries to changes in the short-term energy consumption coefficient are -1.54 and 1.088. Thus, the factors that influence the short-term fluctuations in energy consumption also have a corresponding impact on the other determinants.

**Table 4. Estimated Results of the VECM**

| Error Correction | D(ln*ener*) | D(ln*GDP*) | D(ln*pop*) | D(*stru*) | D(*ind*) |
|---|---|---|---|---|---|
| **CointEq1** | -0.067884 | 0.047883 | -0.003997 | 0.038234 | 0.119099 |
| | -0.0939 | -0.06541 | -0.0032 | -0.01485 | -0.02572 |
| | [-0.72294] | [ 0.73210] | [-1.24718] | [ 2.57453] | [ 4.62973] |
| **D(ln*ener*(-1))** | -0.420139 | 0.009918 | 0.001847 | 0.019296 | -0.073239 |
| | -0.18089 | -0.126 | -0.00617 | -0.02861 | -0.04956 |
| | [-2.32265] | [ 0.07872] | [ 0.29915] | [ 0.67450] | [-1.47792] |
| **D(ln*GDP*(-1))** | 0.658411 | 0.656903 | 0.01091 | -0.114759 | -0.150698 |
| | -0.25282 | -0.1761 | -0.00863 | -0.03998 | -0.06926 |
| | [ 2.60431] | [ 3.73037] | [ 1.26448] | [-2.87013] | [-2.17580] |
| **D(ln*pop*(-1))** | 0.935957 | 3.962927 | 0.850027 | 1.135592 | -3.07515 |
| | -3.02011 | -2.10362 | -0.10307 | -0.47764 | -0.82738 |
| | [ 0.30991] | [ 1.88386] | [ 8.24679] | [ 2.37750] | [-3.71672] |
| **D(*stru*(-1))** | -1.539892 | -0.867663 | 0.0907 | -0.308481 | -0.39564 |
| | -1.47527 | -1.02758 | -0.05035 | -0.23332 | -0.40416 |
| | [-1.04380] | [-0.84437] | [ 1.80139] | [-1.32214] | [-0.97891] |
| **D(*ind*(-1))** | 1.088461 | 0.66863 | -0.019403 | 0.143706 | 0.116931 |
| | -0.52791 | -0.36771 | -0.01802 | -0.08349 | -0.14463 |
| | [ 2.06182] | [ 1.81836] | [-1.07694] | [ 1.72121] | [ 0.80851] |
| **R-squared** | 0.383739 | 0.249274 | 0.751764 | 0.438553 | 0.558862 |
| **Adj. R-squared** | 0.260486 | 0.099129 | 0.702117 | 0.326263 | 0.470634 |
| **Sum sq. resides** | 0.120246 | 0.058339 | 0.00014 | 0.003008 | 0.009025 |
| **S.E. equation** | 0.069353 | 0.048307 | 0.002367 | 0.010968 | 0.019 |
| **F-statistic** | 3.11344 | 1.660221 | 15.1421 | 3.905555 | 6.33431 |
| **Log likelihood** | 42.07211 | 53.28273 | 146.7779 | 99.24192 | 82.21027 |
| **AIC** | -2.327233 | -3.050499 | -9.082442 | -6.015608 | -4.916791 |
| **SC** | -2.049687 | -2.772953 | -8.804896 | -5.738062 | -4.639245 |
| **Mean dependent** | 0.042579 | 0.138072 | 0.006809 | 0.006968 | 0.002655 |
| **S.D. dependent** | 0.080648 | 0.050895 | 0.004337 | 0.013363 | 0.026114 |

In Figure 1, the zero mean line represents the long-term stable equilibrium relationship between the investigated variables. Around 1991, the error correction term is at its maximum, implying that the period of the short-term fluctuation deviates from the long-term equilibrium relationship between the magnitudes of the maximum. After about 13 years of adjustment, in 2004, it returned to the long-term steady-state equilibrium. Thereafter, the error in correction term curve rose, indicating that short-term volatility began to deviate from the long-run equilibrium state again.

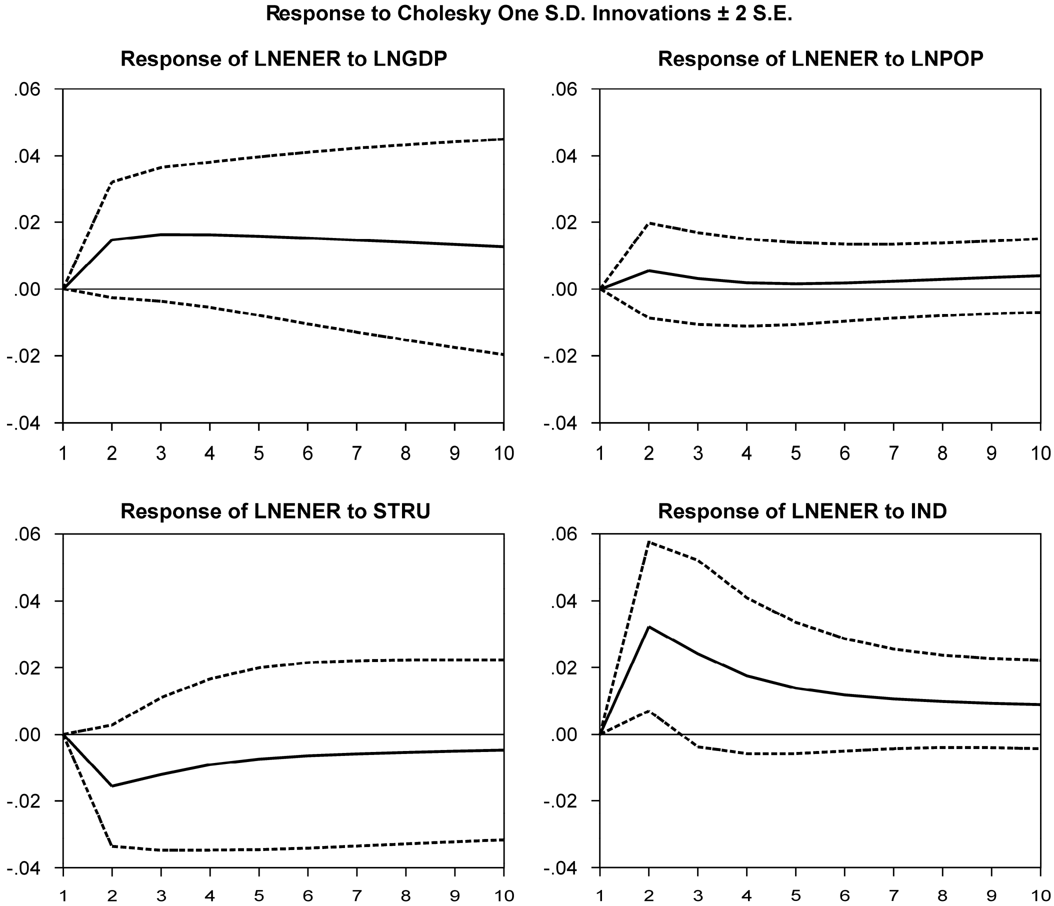
**Figure 1. The VEC Model's Co-integration Relationship**



### 3.3 Impulse response function

The impulse response function can be used to analyze the influence of each endogenous variable on random disturbance in the VAR model. We can thus assess whether ln*ener*, ln*GDP*, ln*pop*, *stru*, and *ind* have a positive impact on the impulse response functions of energy consumption in Liaoning Province (see Figure 2). In these figures, the horizontal axis represents the lag period of impact (unit: number of years), while the vertical axis represents the total energy consumption in Liaoning Province (unit: millions of tons of standard coal). Further, the solid line represents the impulse response function, while the dotted line represents the standard deviation zone (i.e., ± 2 × SD).

**Figure 2. Response of Total Energy Consumption to Each Variable**




As can be seen, after giving a positive impact in the current period, in response to third to the disturbance of the maximum (about 0.0163), suggesting that when subjected to external impact to economic growth, the market effect of transfer to the energy industry, and for the energy industry bring positive impact. After giving the ln*pop* a positive impact, the ln*ener* has not made a greater response; its value has been less than 0.006, in periods 4–8 tends towards 0, suggesting that population size does not significantly affect energy consumption. Although with the improvement of quality of life, demand for cars, home appliances, etc. increases, but compared with other factors, on the influence of energy consumption is still low consume life energy.

After giving *stru* a positive impact, ln*ener* showed a negative effect in the second period of negative effect on energy consumption; it began to gradually weaken from the seventh period that started at -0.005, and its effect has always been negative. When *ind* was given a positive impact, in response to the ln*ener*, *ind* perturbation increased rapidly in the second period to 0.0323 and gradually decreased in the tenth period to 0.0089. Thus, the proportion of service industries and heavy industries, and their impact on energy consumption and energy situation in Liaoning Province could be evaluated. In order to save energy, industrial structure adjustment should be focus on the development of tertiary industries to reduce secondary industries, especially the proportion of heavy industries.

### 3.4 Variance decomposition

The impulse response function describes the effect of VAR model of endogenous variables impact to other variables brings, variance decomposition is by contribution analysis variable changes to the internal structural shocks, the importance of further evaluation of the different impact.

This paper considers only how the variables affect energy consumption; thus, the variance decomposition model is as follows:

$$RVC_{1j}(S)=\frac{\sum_{q=0}^{\infty}(\theta_{1j}^{(q)})^2\sigma_{jj}}{\text{var}(y_1)}=\frac{\sum_{q=0}^{\infty}(\theta_{1j}^{(q)})^2}{\sum_{j=1}^{k}\left\{\sum_{q=0}^{\infty}(\theta_{1j}^{(q)})^2\sigma_{jj}\right\}}\quad j=1,2,\cdots k$$
,

When $RVC_{1j}(S)$ is large, *j* variables affect the energy consumption to a large degree, whereas when $RVC_{1j}(S)$ is small, the effect of *j* variables is small.

Table 5 presents the contribution of each variable to the energy consumption results. As can be seen, the proportion of heavy industries makes the largest contribution to energy consumption, showing that the variance of 13.18% can be composed of heavy industry-level changes to explain energy consumption in Liaoning Province. This reflects the prevailing industry characteristics, such as the old industrial base of Liaoning Province in addition to the Shenyang-Fushun-Anshan-Benxi Industrial Zone, Luda Industrial Zone, and West Liaoning corridor. The contribution to energy consumption of GDP is next followed by the proportion of service industries. However, the contribution of population size is very small.

**Table 5. ln*ener* variance decomposition results**

| **Period** | **S.E.** | **ln*ener*** | **ln*GDP*** | **ln*pop*** | ***stru*** | ***ind*** |
|---|---|---|---|---|---|---|
| **1** | 0.070 | 100 | 0 | 0 | 0 | 0 |
| **2** | 0.102 | 85.34 | 2.075 | 0.287 | 2.310 | 9.986 |
| **3** | 0.116 | 81.06 | 3.611 | 0.298 | 2.889 | 12.142 |
| **4** | 0.123 | 78.85 | 4.954 | 0.288 | 3.114 | 12.795 |
| **5** | 0.128 | 77.33 | 6.135 | 0.283 | 3.226 | 13.028 |
| **6** | 0.131 | 76.14 | 7.157 | 0.287 | 3.293 | 13.119 |
| **7** | 0.134 | 75.17 | 8.032 | 0.305 | 3.337 | 13.156 |
| **8** | 0.137 | 74.35 | 8.774 | 0.337 | 3.367 | 13.171 |
| **9** | 0.139 | 73.65 | 9.399 | 0.388 | 3.387 | 13.178 |
| **10** | 0.141 | 73.04 | 9.922 | 0.456 | 3.401 | 13.181 |

*Note: The first column is for the forecast period and the second column is for the standard error of the predicted LENER. The other columns represent contributions to the prediction error (%)*

## CONCLUSION

Based on the presented analysis of the relationships between energy consumption in Liaoning Province and the main influencing factors, this paper concludes that, in the long term, there is a stable equilibrium relation between GDP, population size, the proportion of service industries, and the proportion of heavy industries and energy consumption. Of these determinants, the proportion of heavy industries has the most significant effect on energy consumption. According to the short-term fluctuations, when the system is subjected to external shocks, the change in the proportion of service industries is a powerful factor, too; however, household energy use has a less positive influence on energy consumption compared with industrial energy use.

In recent years, there seems to be an imbalance in energy supply and demand in Liaoning Province. In 2010, the net amount of energy imported from outside Liaoning Province reached 132 million tons of standard coal, which accounted for 66.7% of the total energy consumption in that year. Thus, energy consumption in this province has long depended on external resources. As a result, renewable energy sources should be developed by increasing subsidies for hydro energy, wind energy, and solar energy. This could not only solve future energy shortages in Liaoning Province, but also reduce environmental pollution at the same time.

The dominance of secondary industries in Liaoning Province has long determined its characteristics of energy consumption. In 2010, the growth rate of energy consumption in industrial use was 12.97%. The advantage of service industries is that they consume less energy and positively influence the sustainable growth of industry and agriculture. Compared with the average national level, the proportion of service industries in Liaoning Province is low. Industries that have high levels of energy consumption and high emissions should thus be limited in order to promote the growth of service industries.

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