Research on energy problem based on cointegration test

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Abstract. In this paper, the VAR model is used to determine the optimal lag order, and the dynamic relationship of each endogenous variable in the time series is predicted and analyzed, so as to effectively predict the interrelated time series variables. On the basis of the stationarity of the test variable series, this paper uses co-integration test and Granger causality test to conduct dynamic empirical analysis on the total energy amount and related variables in Shaanxi Province from 2000 to 2019. The research shows that there is a long-term stable equilibrium relationship between total energy and other variables.

Key words: Energy; Energy consumption; Co-integration test.

Energy resources are the power center of economic development and the material basis for human production and development. In the context of the energy revolution and the new normal of China's economy, energy occupies an important strategic position in various fields in Shaanxi. Energy development is inseparable from social progress and economic development. Similarly, economic development takes energy as the core, and energy is also a material guarantee for economic development. Shaanxi Province advocates the strategy of energy green, healthy and sustainable development, adheres to energy conservation and emission reduction, comprehensively promotes the transformation of energy use mode, implements the energy consumption revolution, and implements total energy consumption control constraints on industries with high energy consumption and overcapacity to reduce The proportion of coal in energy consumption has accelerated the transformation of urban and rural energy use patterns. Studying the relationship between energy consumption and economic growth in Shaanxi Province has become a more meaningful research topic.

1. Literature review
The research of foreign scholars in this field mainly includes: M Bhattacharya et al. (2016) confirmed the evidence of long-term dynamics between economic growth and traditional energy-related inputs through panel estimation technology. Simplice Asongu et al. (2016) used the ARDL method to study the relationship between energy consumption, carbon dioxide emissions and economic growth in 24 African countries. Wen-Cheng Lu (2017) used the ARDL method to study the relationship between electricity consumption and economic growth in Taiwan’s 17 industries. SU Yun-Shan (2018) empirically analyzed the relationship between China's energy consumption structure and economic growth from 1980 to 2016.
Domestic scholars' related research mainly includes bivariate framework and multivariate framework. The idea of bivariate framework modeling is that only two variables, economic growth and energy consumption, are considered in the research design, so as to examine the causal relationship between the two. The multivariate research framework incorporates energy consumption into the macro production function, and regards energy as an input of the same important factor as capital and labor. The reason for this is that the bivariate framework may omit important explanatory variables in econometric empirical terms, and therefore cannot draw rigorous causal conclusions.

Based on the theoretical basis of econometrics, this paper uses co-integration test and Granger causality test to analyze the causal relationship between economic growth and energy consumption in Shaanxi Province.

2. Data variable selection
This article combines the empirical analysis in the vector regression model (VAR) with time data, and compares the total energy consumption (EC), energy industry investment (K), and secondary industry research in the time series data from 2000 to 2019. The total labor input (L), the contribution rate of the secondary industry to GDP (CS), and the provincial GDP (GDP) are required to establish a VAR model and analyze the impact of energy consumption on each variable. The basic data tables in recent years are as follows:

| years | Total energy consumption (10,000 tons of standard coal) | Energy industry investment (100 million yuan) | Total labor input in the secondary industry (10,000 people) | The contribution rate of the secondary industry to GDP | GDP (100 million yuan) |
|-------|--------------------------------------------------------|---------------------------------------------|----------------------------------------------------------|----------------------------------------------------|-----------------------|
| 2000  | 2616.8                                                 | 105.84                                      | 1727.61853                                               | 0.433803                                           | 1804.00               |
| 2001  | 3034.3                                                 | 94.48                                       | 1662.383285                                              | 0.437089                                           | 2010.62               |
| 2002  | 3447.9                                                 | 106.53                                      | 1463.992271                                              | 0.447131                                           | 2253.39               |
| 2003  | 3919                                                   | 152.77                                      | 1341.731418                                              | 0.47191                                            | 2587.72               |
| 2004  | 4692.7                                                 | 234.24                                      | 1227.782694                                              | 0.489076                                           | 3175.58               |
| 2005  | 5557.77                                                | 300.75                                      | 1003.915908                                              | 0.49606                                            | 3933.72               |
| 2006  | 6170.39                                                | 383.63                                      | 1134.342927                                              | 0.516999                                           | 4743.61               |
| 2007  | 7008.14                                                | 576.85                                      | 1196.104515                                              | 0.518727                                           | 5757.29               |
| 2008  | 7638.56                                                | 705.19                                      | 1199.768595                                              | 0.527866                                           | 7314.58               |
| 2009  | 8254.59                                                | 923.75                                      | 1112.48295                                               | 0.518546                                           | 8169.8                |
| 2010  | 8287.63                                                | 1043.2                                      | 1187.399686                                              | 0.537967                                           | 10123.48              |
| 2011  | 9107.48                                                | 1234.77                                     | 1282.952804                                              | 0.554302                                           | 12512.3               |
| 2012  | 9914.53                                                | 1343.19                                     | 1317.660118                                              | 0.558603                                           | 14453.68              |
| 2013  | 10610.48                                               | 1786.46                                     | 1372.744448                                              | 0.54959                                           | 16205.45              |
| 2014  | 11222.46                                               | 1676.09                                     | 1421.434844                                              | 0.541395                                           | 17689.94              |
| 2015  | 11746.93                                               | 1696.64                                     | 1409.62723                                               | 0.50395                                           | 18021.86              |
| 2016  | 12146.47                                               | 1802.65                                     | 1589.07034                                               | 0.489223                                           | 19399.59              |
| 2017  | 12549.52                                               | 1799.47                                     | 1629.573621                                              | 0.496962                                           | 21898.81              |
| 2018  | 12900.38                                               | 1804.87                                     | 1640.686825                                              | 0.468437                                           | 23941.88              |
| 2019  | 13478.06                                               | 2055.75                                     | 1760.759348                                              | 0.464493                                           | 25793.17              |

Data source: Shaanxi Provincial Statistical Yearbook

3. Empirical analysis

3.1. ADF inspection and VAR model establishment
The premise of establishing a VAR model is to judge whether each variable is stable. According to the stationarity, each variable of the time series needs to be tested for unit root, and each variable is inferred whether it is stable or not, so as to avoid some erroneous results caused by pseudo-regression. The ADF
test shows that the time series after the first-order difference is stable under the critical value of 5% significance level.

Based on the theory of econometrics and statistics, the VAR model predicts and analyzes the dynamic relationship of each endogenous variable in the time series without any constraints. Establish a VAR model for the time series LNEC, LNGDP, LNK, LNL and LNCS variables. The general VAR(P) model is:

\[ y_t = c + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots + \beta_p y_{t-p} + \epsilon_t \]  

Formula (1) can be sorted out:

\[ \beta(L) = \alpha - \beta_1 L - \beta_2 L^2 - \ldots - \beta_p L^p \]  

The optimal lag period of the model is determined by comparing the endogenous variables of the model with other lags, AIC and SC. So the VAR model estimation equation is as follows:

\[
\begin{bmatrix}
\text{LnEC}_t \\
\text{LnCS}_t \\
\text{LnGDP}_t \\
\text{LnK}_t \\
\text{LnL}_t
\end{bmatrix} = 
\begin{bmatrix}
1.32 \\
4.66 \\
5.06 \\
-4.22 \\
9.23
\end{bmatrix}
\begin{bmatrix}
0.83 & 0.12 & 0.41 & -0.05 & 0.05 \\
-0.56 & 0.17 & 0.20 & 0.18 & -0.20 \\
-0.27 & -0.33 & 0.84 & 0.39 & -0.18 \\
-1.11 & 0.83 & 1.03 & 0.07 & -0.13 \\
-0.65 & -1.22 & 0.15 & -0.23 & 0.22
\end{bmatrix}
\begin{bmatrix}
\text{LnEC}_{t-1} \\
\text{LnCS}_{t-1} \\
\text{LnGDP}_{t-1} \\
\text{LnK}_{t-1} \\
\text{LnL}_{t-1}
\end{bmatrix}
\]

\[ R^2 \approx 0.99 \quad AIC \approx -19.00 \quad SC \approx -16.28 \]  

It can be seen from formula 3 that with energy consumption (LNEC) as the dependent variable, a time series VAR model is constructed to analyze and test the variables such as LNGDP, LNK, LNL, and LNCS. It can be seen that the fit of the VAR model reaches 99%. Since the values of AIC and SC are relatively small (AIC = -19.00, SC = -16.28), the constructed model is relatively stable.

### 3.2. Cointegration test

The cointegration test is to use the estimation and the cointegration test of multiple cointegration relationship variables to test whether there is a stable relationship and cointegration equation between the variables, so as to analyze a certain linear relationship between the variables. From the results of statistics and the maximum eigenvalue statistics, it can be seen that there are at most two cointegration equations in the rejection of the null hypothesis at the 5% significance level, that is, the cointegration equation is as follows:

\[ LNEC = 0.53 \times LNGDP + 0.65 \times LNCS + 4.56 \]  

Formula (4) is a mathematical description of this long-term stable equilibrium relationship. In this model, since the total energy consumption and GDP of Shaanxi are both logarithmic, the regression coefficient 0.53 is the elasticity coefficient of energy consumption with respect to GDP, indicating Shaanxi's energy consumption and GDP growth are closely related.
3.3. Granger causality test

In order to judge whether there is a causal relationship between the variables in a statistical sense, a Granger causality test is performed on LNEC, LNCS, and LNGDP. The test results are shown in the following table:

| Null hypothesis                      | F statistic | Probability P | in conclusion |
|--------------------------------------|-------------|---------------|---------------|
| LNGDP is not a Granger of LNEC       | 1.72320     | 0.2169        | accept        |
| LNEC is not a Granger of LNGDP       | 3.29649     | 0.0695        | accept        |
| LNK is not a Granger of LNEC         | 0.88240     | 0.4372        | accept        |
| LNEC is not a Granger of LNK         | 1.36515     | 0.2896        | accept        |
| LNGD is not a Granger of LNC         | 7.11079     | 0.0082        | refused       |
| LNL is not a Granger of LNGD         | 0.97324     | 0.4038        | accept        |
| LNEC is not a Granger of LNC         | 1.82975     | 0.1994        | accept        |
| LNCS is not a Granger of LNEC        | 2.78164     | 0.0987        | refused       |

It can be seen from Table 2 that in the time series from 2000 to 2019, there is Granger causality among variables such as total energy consumption to GDP, labor input in the secondary industry, and the contribution rate of the secondary industry to GDP. Total consumption and GDP are Granger causality tests for each other. Therefore, when implementing energy-saving and emission-reduction policies, Shaanxi Province should pay attention to the relationship between energy and economy. It should focus on improving energy efficiency instead of relying solely on extensive policy models such as reducing energy input to achieve the balance between economic growth and energy consumption. Sustainable low-carbon economy.

4. Conclusion

The energy industry occupies a leading position in the secondary industry and economic development of Shaanxi Province, and is the focus of future industrial economic development. Regarding the issue of energy consumption, it is necessary to improve energy utilization, adjust the energy industry structure and industrial transformation. At present, in the energy consumption of Shaanxi Province, fossil energy consumption accounts for the vast majority of the total. This is inseparable from the endowment characteristics of natural resources in Shaanxi Province. The endowment and output characteristics of energy resources have a significant impact on energy consumption and consumption structure. Big impact. The long-term impact of the energy consumption structure dominated by coal and oil, the energy revolution in Shaanxi Province is far from enough, and the energy structure needs to be further adjusted in the future. Therefore, in the future, it is necessary to vigorously develop low-carbon sustainable clean energy to replace the new industrial chain based on coal, petroleum and other mineral energy sources, to achieve industrial substitution, and to ensure the green, healthy and sustainable development of the social economy in Shaanxi Province.

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