Empirical Analysis on the Impact of Energy Output and Industrial Structure Adjustment on Economic Growth in Shanxi Province, China: from the Perspective of SVAR

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Abstract: Based on the time series data of Shanxi Province from 1989 to 2018, this paper constructs the SVAR model (structural Vector autoregression). Using impulse response function, variance decomposition and other tools, this paper makes an empirical study on the relationship between economic growth, industrial structure adjustment and energy output in Shanxi Province. The correlation and contribution rate among energy output, industrial structure adjustment and economic growth are evaluated dynamically. The main conclusions of this paper are as follows: there is a long-term stable relationship among the economic growth, the proportion of the gross output of the secondary industry and the output of the primary energy; when the proportion of the Gross Domestic Product of the secondary industry and the output of the primary energy have a dynamic impact on economic growth, their responses are not the same; by comparison, the impact of industrial restructuring on the economic growth of primary energy is greater than the pulling effect of output.

1. Introduction
Shanxi province is an important energy base in China. It promotes national and local economic development with abundant coal resources. Resource-based economy has become the essential feature of regional economic development in recent years. However, while Shanxi Province has received huge economic dividends from coal during the stage of heavy industrialization in China’s economic development, it has also brought about problems such as industrial simplification, lack of human capital, destruction of ecological environment, and serious power rent-seeking phenomenon, in part because of the “Resource Curse” trap.

Under the double pressure of the economic slowdown and the economic development pattern of “Coal occupies a major position in economic development” for many years, Shanxi province, due to its excessive reliance on coal and extensive mining, it has caused the unbalance of industrial structure, economic precipitous decline and serious ecological damage, and brought the people of Shanxi personal pain. Since the 18th National Congress of the CPC, General Secretary Xi Jinping has made a series of important statements in promoting energy reform and development and building solid foundations for energy security, creatively pointing out the strategic theory of “Four Revolutions and one cooperation,” It points out the direction for the future energy work of Shanxi Province. In this context, the study of the relationship between economic growth, industrial restructuring and energy production is of great importance to the formulation of effective industrial policies, the transformation
of economic development patterns, and the implementation of the no-coal policy, it is of great significance to make the strategic choice of being the vanguard of the Energy Revolution.

Therefore, this paper chooses Shanxi province as the empirical research object, based on the related indexes of Shanxi Province from 1989 to 2018, establishes the structural Vector autoregression, uses the tools of impulse response function, variance decomposition, etc. This paper analyzes the equilibrium relationship among economic growth, industrial structure adjustment and energy production in Shanxi province. In order to explore the road of sustainable development of Economy and Environment in Shanxi province, the relationship between energy, especially the production of primary energy, industrial structure and economic growth was studied.

2. Literature Review

Domestic scholars have studied economic growth in many ways, from index analysis, simple regression model analysis to VAR model and SVAR model analysis. Using VAR or SVAR models to quantitative analysis economic growth problems is more useful than traditional analysis methods.

Many domestic scholars have made a qualitative analysis of the factors affecting the economic growth of Shanxi Province. Zhang Weiqin[1] selected typical Shanxi Province, which is a big resource province, a small economy province and a big pollution province, to study the causes of slow economic growth and environmental deterioration in the areas with good resource endowment. Yan Erwang, Jiang Wei and Zhang Yu[2] analyze the factors affecting the economic growth of Shanxi province by using the regression model of the contribution rate of traditional factor inputs. The model uses the cobb-Douglas production function to analyze the economic performance of Shanxi Province from 2000 to 2017. The conclusion shows that the production function presents the characteristic of increasing returns to scale. Zhang Jinjuan[3] based on the data collected from 1978 to 2011 in Shanxi Province, studied the relationship between economic growth and coal consumption by analyzing the two indexes of coal consumption elasticity and intensity.

Zhang Jianying[4], Wang Xing and Fan Zhongqi[5], Zhang Zirong [6], Jiang Xinying and Zhao Shuang [7], Zhao Fangfei and Qin Ying [8], Wang Xiao and Wang Fayuan [9] used VAR models to study the influencing factors of macroeconomic growth and economic growth in developed regions.

Different from the above, Qin Nan[10] constructs the SVAR model by using the time series data of industrial structure, energy structure and energy intensity of Shaanxi Province from 1990 to 2012 when studying the problems between energy intensity, industrial structure and energy structure, the impulse response function (IRF) and variance decomposition are used to study the dynamic effect of energy intensity change in Shaanxi Province, and the correlation and contribution of industrial structure, energy structure and energy intensity are evaluated.

Domestic scholars study the relationship between the national economic growth and its influencing factors from the theoretical level of environment, resources, development and regional economics. At present, for the empirical research on the impact of energy output or economic structure on economic growth, more domestic scholars focus on the macroeconomy as a whole, or on regions with higher economic development level, but to the small area or the area with the low level of economic development research are relatively few. In addition, domestic scholars choose VAR model to analyze the relationship between economic variables, and make effective analysis and research from different angles, and put forward macro-policy recommendations for enterprises and Government Departments.

Foreign scholars use SVAR model to analyze the relationship between economic variables mainly in currency market and financial market, such as Futures Price, stock market and so on. Elif Akay Toparli, Abdurrahman Nazif Catik, et al.[11] set up a Vector autoregression to analyse the impact of oil price shocks and various macroeconomic variables on the Turkish stock market by using monthly data from February 1988 to March 2017. Yang Lu[12] combined the data from 2005 to 2015 to establish a panel data VAR model, and empirically compared the data of real estate prices, economic factors and non-economic factors in 31 provinces and cities, and the panel VAR model is used to empirically study the relevant factors that affect the housing prices. Using the SVAR model for empirical analysis in real economy has fewer research results.
Energy production, industrial structure and economic growth pattern are regional issues, especially the economic growth pattern. Each region has its own characteristics and endowments, which cannot be generalized. This paper analyzes the relationship between energy production, industrial structure, and economic growth of Shanxi province based on its development situation and characteristics. In this paper, the Economic Growth Index of Shanxi Province is expressed by GDP index, which is a relative index, from two angles: eliminating the influence of price on the gross domestic product (GDP) and reflecting the trend and degree of change in the gross domestic product (GDP) of Shanxi province in a certain period, from the actual situation of Shanxi province, this paper selects the proportion of the gross output value of the secondary industry to express the change of the economic structure of Shanxi Province. Since the province’s energy production is dominated by primary energy, especially raw coal, energy production is expressed in terms of primary energy.

3. Selection, treatment and descriptive statistics of variables

3.1. Variable selection, processing and data source

Based on the annual data of Shanxi Province from 1989 to 2018, this paper analyzes the dynamic relationship among economic growth, industrial structure adjustment, and energy output. From two angles, excluding the effect of prices on the gross domestic product and reflecting the trend and degree of changes in the Gross Domestic Product of Shanxi Province in a certain period, in this paper, the Economic Growth Index of Shanxi Province is expressed by GDP index, which is a relative index of GDP, that is, the GDP is adjusted from 1952 as the base period, in this paper, the change of the economic structure of Shanxi province is expressed by the proportion of the gross output of the secondary industry, and the energy output of Shanxi province is expressed by the output of the primary energy, especially the raw coal, which is mainly produced by the primary energy. The related data in this paper are from Shanxi Province Statistical Annual Inspection and China Statistical Yearbook. Table 1 shows the main statistical indicators for the variables. Among them, DECYSZCBZ (DE) means the proportion of secondary industry gross output, QNSCZZZS (QN) means the annual Gross Output Index, YCNYCL (YC) means the output of primary energy. Specifically, in the 30 years from 1989 to 2018, the annual GDP Index of Shanxi Province (1952 GDP index = 100) has a maximum value of 18,412.8, a minimum value of 1,174.5 and an average value of 7,119.92; the maximum yield of primary energy is 78,182.9, the minimum yield is 21,220.76, and the average yield is 44,387.93; the proportion of the gross output value of the secondary industry is 59.3 at the maximum, 38.7 at the minimum and 50.12 at the average. The distribution trends of DE, QN, and YC are shown in charts 1, 2, and 3. In order to avoid heteroscedasticity, natural logarithms are taken for three variables respectively, which increases the validity of data.

3.2. Descriptive statistics of variables

Descriptive statistics of the three variables are shown in Table 1:

| Sequence name | Sample size | mean | median | maximum | minimum | Standard deviation |
|---------------|-------------|------|--------|---------|---------|--------------------|
| DE            | 30          | 50.1 | 49.1   | 59.3    | 38.7    | 5.3                |
| QN            | 30          | 7119.9 | 5058.7 | 18412.8 | 1174.5  | 5617.2             |
| YC            | 30          | 44387.9 | 41222. | 78182.9 | 21220.8 | 19543.4            |

The trends for DE, QN, and YC are as follows:
Fig. 1. The proportion of the gross output value of the secondary industry of Shanxi Province from 1989 to 2018 (unit: %)

Fig. 2. Annual GDP Index of Shanxi Province from 1989-2018 (year of 1952 = 100)

Fig. 3. Primary Energy Production of Shanxi Province from 1989-2018 (unit: 10,000 tons standard coal)
4. Model setting and empirical analysis

4.1. Model setting

Firstly, establish the VAR model with three-dimensional structure between annual GDP index, primary energy output and secondary sector of the economy proportion of Shanxi province:

\[ C_0X_t = \Gamma_1 X_{t-1} + \Gamma_2 X_{t-2} + \mu_t \]  

(1)

The variable and parameter matrices are:

\[ X_0 = \begin{bmatrix} QN_t \\ YC_t \\ DE_t \end{bmatrix} \]

\[ C_0 = \begin{bmatrix} 1 & C_{12} & C_{13} \\ C_{21} & 1 & C_{23} \\ C_{31} & C_{32} & 1 \end{bmatrix} \]

\[ \Gamma_1 = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \]

\[ \mu_t = \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \end{bmatrix} \]

QNT, YCT and DEt respectively correspond to annual GDP index, primary energy and secondary sector of the economy. The number of variables \( n = 3 \), \( \mu_{1t}, \mu_{2t} \) and \( \mu_{3t} \) are the structural residuals on these three sequences, respectively, that is, structural shock, \( \mu_t \sim VMN (0, In) \), that is, \( \mu_t \) is a white noise vector, its covariance is a unit matrix. If the matrix \( C_0 \) is invertible, then the equation (1) can be transformed into a simplified equation:

\[ X_t = C_0^{-1} \Gamma_1 X_{t-1} + C_0^{-1} \Gamma_2 X_{t-2} + \varepsilon_t \]  

(2)

Let \( A_1 = C_0^{-1} \Gamma_1, A_2 = C_0^{-1} \Gamma_2, \varepsilon_t = C_0^{-1} \mu_t \), then a simplified structural equation can be obtained:

\[ X_t = A_1 X_{t-1} + A_2 X_{t-2} + \varepsilon_t \]  

(3)

In this equation \( \varepsilon_t \) is a linear combination of \( \mu_t \) and is essentially a compound shock. In this paper, a three-dimensional SVAR model is established to identify structural shocks, so it is necessary to apply \( n(n-1)/2 = 3(n = 3) \) constraints to the model in order to identify structural shocks. According to the actual situation of economic operation and energy output of Shanxi province at the present stage, the following three assumptions are put forward: ① the output of primary energy affects the current GDP index of Shanxi Province, but the GDP index does not affect the current primary energy output, that is, \( C_{12} = 0 \) in the matrix \( C_0 \); ② the proportion of the secondary industry’s GDP affects the current GDP index, however, the GDP index does not affect the proportion of secondary industry output in the current period, i.e. \( C_{31} = 0 \) in the matrix \( C_0 \); ③ the proportion of secondary industry output in the current period affects the primary energy output, however, the output of the primary energy does not affect the proportion of the current secondary industry output, that is, \( C_{32} = 0 \) in the matrix \( C_0 \).

4.2. Testing the stationarity of variables

The classical econometrics theory is based on a stationary time series, in which the correlation coefficients between the initial assumed variables follow a normal distribution, while experience shows that most economic variables are nonstationary, which reduces the effectiveness of the test, increases the likelihood of forgery. In order to avoid pseudo-regression, ADF unit root test is used to test the stationarity of three time series, and the results are shown in Table 2:
Table.2.Test results for the stationarity of a variable

| Variable name | ADF value | Type of test (C,T,K) | Critical value (1%) | Critical value (5%) | Critical value (10%) | P     | conclusion |
|---------------|-----------|----------------------|---------------------|--------------------|----------------------|-------|------------|
| L NYC         | -0.8782   | (C, 0, 0)           | -3.6891             | -2.9718            | -2.6251              | 0.7801| unsteady   |
| D(LNYC)      | -3.1937   | (C, 0, 1)           | -3.6998             | -2.9762            | -2.6274              | 0.0315| steady     |
| L NDY         | -1.3591   | (C, 0, 0)           | -3.6891             | -2.9718            | -2.6251              | 0.5807| unsteady   |
| D(LNDY)      | -3.4793   | (C, 0, 1)           | -3.6998             | -2.9762            | -2.6274              | 0.0167| steady     |
| L DE          | -1.4551   | (C, 0, 0)           | -3.6891             | -2.9718            | -2.6251              | 0.5401| unsteady   |
| D(LNQN)      | -2.9763   | (C, 0, 1)           | -3.6998             | -2.9620            | -2.6274              | 0.0415| steady     |

Note: D is the first order difference; (C, T, K) is the constant, time trend and lag in the ADF test; 5% critical value is used as the comparison criterion.

The table shows that under the 5% significance level, the three sequences of LNQN (annual Gross Domestic Product Index), LNYC (output of primary energy) and LNDY (proportion of gross domestic product of secondary industry) have not passed the stationarity test, which indicates that there are unit roots in the sequences concerned, is a non-stationary time series. After performing the ADF test on the three time series, we can see that at the 5% significance level, there is a unit root after the logarithm of the three original time series, and the three first-order difference time series have passed the stationarity test, that is, all three sequences are single integral sequences of first order.

4.3. Lag of Choice Model and Johansen Cointegration Test

In order to avoid false regression, three variables are tested by cointegration test. Engle-granger two-step Method and Johansen co-integration test are two common methods for co-integration test. Generally speaking, EG test is used to test the co-integration relationship between two variables, but Johansen test is more suitable to test the co-integration relationship between two or more variables. In this paper, Johansen test is used to examine whether there is a long-term stable relationship among the three sequences. It is necessary to determine the order of the lag period of the model before doing the Johansen Test. The main principle of determining the lag period is to ensure not only sufficient degree of freedom, but also sufficient lag period, the lag time of the model chosen in this paper is of order 2. The Johansen Cointegration test results are shown in Table 3:

Table.3.The results of the Johansen Cointegration Test

| The assumption with cointegration relationship | Characteristic root | trace statistic | 5% critical value | associated probability P |
|-----------------------------------------------|---------------------|-----------------|-------------------|--------------------------|
| No existence*                                  | 0.7929              | 59.540          | 24.2760           | 0.0000                   |
| One at the most*                               | 0.4530              | 17.022          | 12.3209           | 0.0076                   |
| Two at the most                                | 0.0268              | 0.7328          | 4.1299            | 0.4502                   |

| The assumption without cointegration relationship | Characteristic root | λ−max Statistic | 5% critical value | associated probability P |
|---------------------------------------------------|---------------------|-----------------|-------------------|--------------------------|
| No existence *                                    | 0.7929              | 42.5184         | 17.7973           | 0.0000                   |
| One at the most *                                 | 0.4530              | 16.2890         | 11.2248           | 0.0060                   |
| Two at the most                                   | 0.0268              | 0.7328          | 4.1299            | 0.4502                   |
From the Johansen Test in Table 3, it can be seen that the trace statistic value of 59.54033 is greater than the critical value of 5% significance level of 24.27596, and the $\lambda$-max statistic value of 42.51849 is greater than the critical value of 5% significance level of 17.79730. Therefore, under the 95% confidence level, there is at least one cointegration relationship between the three variables, that is, between 1989 and 2018, there is a long-term stable relationship between the economic growth level, primary energy and secondary sector of the economy. In addition, as shown in Figure 4 and Table 4, according to the test results of the global stationarity of the model, it can be seen that the reciprocal of the root of the characteristic equation is all inside the unit circle, which shows that the model is stable.

### 4.4. Impulse Response Function

In order to make the relationship between variables more clear, this paper analyzes the impulse response function on the basis of constructing SVAR model. The impulse response function mainly analyzes the impact on the other variables and its present and future, that is, the dynamic influence on the whole system, if one variable is given a unit variance change in SVAR model.

In figures 5 and 6, the horizontal axis represents the lag time of the impact, the vertical axis represents the value of the actual impact on the explained variable, and the Blue Solid Line in the middle is the impulse response function, the red dotted lines on the upper and lower sides represent the plus-minus double standard deviation (confidence band).

Figure 5 shows the impact of a shock to the secondary industry’s gross domestic product (GDP) on the annual GDP index. When the first period gives a shock to the proportion of the gross output value of the secondary industry, it will have a positive effect on the annual Gross Output Value Index, leading to an increase in the annual Gross Output Value Index, and the positive effect has been on the rise until the third period. After the 3rd period, this positive effect appears a downward trend, that is, the utility of the increase of the proportion of the gross product of the secondary industry to the
increase of the Gross Product Index of the whole year decreases gradually. This trend is consistent with the upward trend of economic growth in Shanxi over the past 30 years.

Figure 6 shows the effect of a shock to primary energy output on the annual GDP index. As the chart shows, the impact of primary energy on the annual GDP index has always been positive, but this positive effect has been steadily declining. This result may be due to the fact that the increase in primary energy output has played an important role in promoting economic growth in Shanxi province, and can not fundamentally improve its economic growth pattern.

Overall, Figures 5 and 6 show that the impact of primary energy on GDP is greater than that of secondary industry on GDP.
4.5. Variance Decomposition
According to Sims, the variance decomposition “takes into account the economic significance of the relationship between economic variables” and can explain how much a unit variance shock affects each endogenous variable. In order to make the degree of interaction between the variables more clear, this paper also makes the variance decomposition of the annual GDP index. The results are shown in Table 5. First, the main source of the mean square error of the annual GDP index is its own impact, and this relative importance decreases with the increase of the lag period, from 74% in the first period to 52%, second, the impact of the proportion of the secondary industry’s GDP on the mean square error of the annual GDP index cannot be ignored. Overall, its importance is first to rise and then to decline, finally, from the point of view of primary energy production, although its impact on the annual mean square error of the Gross Domestic Product Index has shown a growing trend, reaching the contribution level of about 10% in the 10th period, but the overall impact is still small. It is clear that the contribution of the secondary sector to the GDP shock is much greater than that of the primary energy.

| Lag Period | Variance | LNQN     | LNDE     | LNYC     |
|------------|----------|----------|----------|----------|
| 1          | 0.055504 | 73.85092 | 26.14908 | 0.000000 |
| 2          | 0.080391 | 61.28813 | 38.17897 | 0.532903 |
| 3          | 0.097786 | 56.41762 | 43.21881 | 0.363571 |
| 4          | 0.108954 | 54.35832 | 45.23719 | 0.404485 |
| 5          | 0.116000 | 53.39927 | 45.26783 | 1.332896 |
| 6          | 0.120518 | 52.83388 | 44.10224 | 3.063881 |
| 7          | 0.123428 | 52.45598 | 42.42680 | 5.117221 |
| 8          | 0.125230 | 52.23462 | 40.70468 | 7.060701 |
| 9          | 0.126259 | 52.15959 | 39.16412 | 8.676294 |
| 10         | 0.126785 | 52.20343 | 37.87409 | 9.922480 |

5. Conclusion
5.1. Empirical Results
Based on the SVAR model of the related annual time series data of Shanxi Province from 1989 to 2018, this paper empirically studies the dynamic relationships among economic growth, the proportion of the gross output of the secondary industry and the output of the primary energy. The conclusions of this paper are as follows:

Firstly, there is a long-term stable relationship among the economic growth, the proportion of secondary industry and the output of primary energy in Shanxi province through Johansen cointegration test. Secondly, when the proportion of the gross domestic product of the secondary industry and the output of the primary energy have a dynamic impact on the economic growth, the reaction degree is not the same. The impact of the proportion of the output of the primary energy and the gross output of the secondary industry on the GDP index is both positive, but the positive effect of the secondary sector of the economy impact shows an upward trend at first and then a downward trend, and reaches its maximum value in the third period, and the impact of primary energy production has been a steady decline. In comparison, the impact of industrial restructuring on the economic growth of primary energy is greater than the pull effect of output. Thirdly, the variance decomposition results show that the main source of the mean square error of the annual GDP index is its own impact, and this relative importance decreases with the increase of the lag. The impact of the proportion of the gross output of the secondary industry on the mean square error of the annual Gross Output Index can
not be ignored. The effect of primary energy on the mean square error of the annual GDP index is increasing. The contribution of the secondary industry to GDP shocks is far greater than that of the primary energy.

5.2. Policy Recommendations
Firstly, in order to maintain the sustainable development of Shanxi GDP, people need to strengthen the GDP to a deeper level, which requires deepening the reform of Shanxi GDP itself. In the area of investment, people will resolutely implement the policies of the central government and vigorously carry out the Macroeconomic regulation and control construction activities, with a view to improving the investment structure and thus increasing the effectiveness of investment. In the area of consumption, it is imperative to continuously expand consumption demand, which requires the government to actively adjust various consumption escalation action plans in light of the economic situation, such as promoting the quality and expansion of Business Services, promoting the construction of Consumer Service Centers for the convenience of urban and rural residents, accelerating the innovation of business models and promoting the development of new retail enterprises, and vigorously developing the Export-oriented industrialization in import and export, people will take solid steps to promote foreign trade and economic cooperation, increase efforts to cultivate foreign trade entities, promote new forms of foreign trade, and actively respond to the impact of economic and trade frictions between China and the United States. In addition, people should strengthen the pre-judgment, monitoring and dispatching of the economic situation, and solve the problems of the first sign and tendency of the economic operation in time.

Secondly, the contribution of the proportion of the gross output value of the secondary industry to the GDP growth of Shanxi province is second only to its own deepening, so the mode of economic development is constantly changing, developing from extensive economy to intensive economy and constantly adjusting industrial structure is the inevitable path of Shanxi’s economic development. People will adhere to the principle of putting the basic point of transformation and development on innovation, and promote the cultivation and expansion of emerging industries and the upgrading of traditional industries. The key to vigorously cultivating emerging industries is to maintain rapid growth in strategic emerging industries such as New Generation Information Technology, high-end equipment manufacturing, new energy vehicles, and speed up the high-end, green and intelligent transformation of traditional industries, people will actively promote industrial restructuring. The most important thing to accelerate the development of the modern service industry is to speed up the construction of the three major tourism sectors of the Yellow River, the Great Wall and Taihang Mountains, so as to gather great strength for the transformation and development.

Thirdly, energy production has been a positive force for the economic development of Shanxi province, but Shanxi’s energy production is dominated by primary energy, especially raw coal, and its impact on the environment can not be underestimated. The key to solve this problem is to effectively improve the quality of supply, withdraw excess coal production capacity, and promote the coal industry to “reduce, excellent, Green” development path. Only by vigorously developing new energy sources such as hydropower, Nuclear Power and wind power, as well as large-scale promotion of many high-quality and clean energy sources, including coal gas beds, coal-to-methanol, dimethyl ether and coke-oven gas, can people promote better and sustainable economic development, break the “Resource Curse” of the argument to the Energy Revolution in the vanguard of a solid step.

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