Research on the dynamic relationship between environmental growth and economic quality based on VAR model

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Abstract. In the last few years, there has been a rapidly growth in the china of economic, especially from 2010 to 2017. However, environmental quality paid a heavy price. This article established the VAR model of economy environment in China and we used the methods of generalized impulse response and Variance decomposition to carry out an empirical analysis of the dynamic correlations among economic evolution and environmental quality based on the annual data which is during the years of 2000-2016 in China. The results point out GDP shows a positive response to Solid waste emission in generally, and it picks up a significant part (71.1%) of the variations in GDP. However, there is negative impulse response of Exhaust gas emission to GDP in the whole process. Finally, it is worth noting that one standard deviation shock to Wastewater emission, the positive and negative impulse response of Wastewater emission on the GDP appear alternately.

1. Introduction

In the last few years, the urbanization level and economic level of the China is developed rapidly. In 2016, the total population of China is 1382.71 million, the macroeconomic indicators of GDP in the China during the period 2016 was 74412.7 billion, far higher than those in the period 2015(68905.2 billion), 2014(64397.4billion), the data in the China Statistical Yearbook. However, the heavy price has also been paid for China: the deterioration of environmental quality. According to Bulletin on environmental conditions in China, there are only 99 cities with ambient air quality reaching the standard, accounting for 29.3% of all cities, and 239 cities (70.7%) have exceed the air quality. During the 6124 water quality monitoring station, the water quality of the poor and bad levels was 45.4% and 14.7% respectively. In the assessment of surface water quality, the possession of grade I, II, III, IV, and V water was 2.4%, 37.5%, 27.9%, 16.8% and 6.9% respectively at 2016. Therefore, the association in environmental quality and economic expansion is significance to be explored.

The issue of environmental pollution and economic progress has become research hotspots in the China and even the world. By international scholars all the time, In 1995, The Kuznets Curve of environment was first proposed by Grossman in 1995. And subsequently, The Kuznets Curve of China's environment was proved to be real by Zhang Juan[2], that is, the “inverted U shape”. What’s more, The Kuznets Curve is not recognized by some scholars. Stern D.I. and Common M.S.[3] and Harbaugh et al.[4] have proved that the estimation of parameters is biased due to the sample addition and different measuring methods. Zhang Tianrong[5] et al. Concluded that different levels of economic growth and industrial structures are the notable factors for the different contacts between economic development and environmental quality by analyzing the Yangtze River Delta Region.
Although the contact in the economic evolution and the environmental quality has been extensively researched by many scholars, there are still some aspects that are not considered in the existing exploration. Firstly, most scholars explore the influences of the lag phase of the explanatory variables on its private and the explanatory variables[6]. And find that it is hard to explain the dynamic effects using the Time series analysis[7] and linear regression methods[8]. Secondly, it is essential that the establishment of traditional models needs to be based on economic theory between variables. But, it is difficult to find an ideal model that works for us.

Vector auto regression (VAR) model will be used in this article to weakened the absences in the existing study. The VAR methods not only has the capacity to describe the dynamic structure of the model, but also beyond the limitations based on financial and commercial theories and enhances any other explanatory variables of the model. The most critical thing is that the short-term relationship and long-term trend between economic variables will be revealed by the VAR model[9].

The remaining parts of the article are planned as follows. Section 2 describes the applies method and sample data. Section 3 presents and discusses the empirical results, and Conclusion analysis is provided in Section 4.

2. Methodology and model specification

2.1. Vector auto regression

The vector auto regression model was firstly proposed by Sims in 1980 and then introduced into the macroeconomic research, making it one of the main models of modern time series analysis. The variables that we chose are not based on financial and economic theories when the model has been established. The VAR model can be thought as a system of equations with several endogenous variables and the dynamic relationship between these endogenous variables will be reflected by the regression of itself and other lagged values. An n variable VAR (P) system can be printed as

\[ Y_t = \mu + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \epsilon_t, t = 1, 2, \ldots, T \]

And

\[ Y_{t-i} = \begin{bmatrix} Y_{1t-i} \\ Y_{2t-i} \\ \vdots \\ Y_{nt-i} \end{bmatrix}, \quad i = 1, 2, \ldots, p \]

\[ A_j = \begin{bmatrix} a_{11j} & a_{12j} & a_{13j} & \ldots & a_{1kj} \\ a_{21j} & a_{22j} & a_{23j} & \ldots & a_{2kj} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1j} & a_{n2j} & \ldots & a_{nkJ} \end{bmatrix}, \quad j = 1, 2, \ldots, p \]

\[ \mu = (\mu_1, \mu_2, \ldots, \mu_k)^\prime \]

\[ \epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, \ldots, \epsilon_{kt})^\prime \]

Where the p endogenous variables of [GDPt, SOLIDt, GAS t, WATERt] are defined as Yt which is the (5×1) vector, the intercept terms of model is denoted as \( \mu \) which is a (5×1) vector. The matrix of autoregressive coefficients (5×5) and the vector of random disturbances are represented by \( A_j \) and \( \epsilon_t \) respectively.

In the process of establishing a VAR model, it is necessary to specify the number of variables contained, that is, there are several variables in the VAR model. Second, the reasonable lag length in the model equation is a key factor which is able to reflect the relationship between variables to the maximum extent.
2.2. Impulse response function

Although there are many methods to analyze the VAR model, the impulse response function is considered to be the most appropriate function, because the impact of shocks on all current and future endogenous variables in VAR models can be easily examined by the impulse response function.

Consider the following form of VAR (P) model:

\[ Y_t = \mu + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_P Y_{t-P} + \varepsilon_t, t = 1, 2, \ldots, T \]

Where \( \varepsilon_t \) is the vector of random disturbances, the formula can be written as follows when the lag operator (\( L \)) is introduced:

\[ (I - A_1 L - \ldots - A_P L^P) \varepsilon_t = (I + C_1 L + C_2 L^2 + \ldots + C_i L^i + \ldots) \varepsilon_t = \varepsilon_t + C_1 \varepsilon_{t-1} + C_2 \varepsilon_{t-2} + \ldots + C_i \varepsilon_{t-i} + \ldots, t = 1, 2, \ldots, T \]

The impulse of \( Y_t \) is expressed as follows:

\[ y_{it} = \sum_{j=1}^{k} (c_{ij}^{(0)} u_{jt} + c_{ij}^{(1)} u_{jt-1} + c_{ij}^{(2)} u_{jt-2} + \ldots + c_{ij}^{(q)} u_{jt-q} + \ldots) \]

The response function produced by the impulse of \( Y_t \) is expressed as follows:

\[ c_{ij}^{(0)}, c_{ij}^{(1)}, c_{ij}^{(2)}, c_{ij}^{(3)}, \ldots \]

Or

\[ c_{ij}^{(s)} = \partial r_{it,s} / \partial u_{jt} (i = t = s = 0, 1, 2, \ldots, n) \]

And the cumulative response function can be expressed as:

\[ \sum_{q=0}^{\infty} c_{ij}^{(q)} \]

2.3. Data source and description

The sample data adopted in this paper is composed of Chinese time series data. The 2000-2016 time series data of Gross Domestic Product (GDP), Wastewater emission (WATER), Solid waste emissions (SOLID), Exhaust gas emissions (GAS)[10] are obtained from National Bureau of Statistics of China and Ministry of Ecology and Environment of China to reflect the quality of China.

We surveyed the annual data of the selected variables from 2000-2016. As shown in Fig.1, GDP grows at an average annual growth rate of 10.6%, which means that the speed of China's economy growth is fast. But Wastewater emission and Solid waste emissions increased to 7110.95 million tons and 327.079 million tons on an annual growth rate of 3.26% and 8.5% respectively. Exhaust gas emissions displayed an “inverter U-shaped” shape, and reaches the peak point (25888 million tons) in 2006, This is because the level of industrialization has grown relatively fast in the initial stage, and then with the enlargement of the tertiary industry it has gradually decreased.

Fig.1. the trends of GDP, WATER, SOLID, GAS during 2000-2016

3. The empirical results

3.1. Variables verification

Generally speaking, economic variables are complex dynamic and are non-stationary[11]. Therefore, trying to convert a non-stationary sequence into a stationary sequence is a key step to prevent pseudo-regression, and the difference method is one of the methods that can be adapted. Then the ADF unit
root assessment method is implemented to examine the stability of economic variable sequence in this study, and the results are shown as Table 1.

| Variable | ADF value | Test critical values | P value |
|----------|-----------|----------------------|---------|
| GDP      | 3.386     | -3.921               | -3.066  | -2.673  | 1.000 |
| WATER    | -0.883    | -3.920               | -3.066  | -2.674  | 0.766 |
| SOLID    | -0.230    | -3.960               | -3.081  | -2.681  | 0.904 |
| GAS      | 0.795     | -3.920               | -3.066  | -2.673  | 0.990 |
| GDP      | -1.867    | -3.959               | -3.081  | -2.681  | 0.337 |
| WATER    | -3.936    | -3.959               | -3.081  | -2.681  | 0.012 |
| SOLID    | -2.687    | -4.004               | -3.099  | -2.690  | 0.101 |
| GAS      | -0.474    | -3.959               | -3.081  | -2.681  | 0.871 |
| GDP      | -4.689    | -4.058               | -3.119  | -2.701  | 0.003 |
| WATER    | -4.005    | -4.058               | -3.120  | -2.701  | 0.009 |
| SOLID    | -4.291    | -4.058               | -3.119  | -2.701  | 0.007 |
| GAS      | -3.987    | -4.004               | -3.099  | -2.691  | 0.021 |

As can be seen from Table 1 that not all economic variable sequences have passed the significance test, that is, these variables are non-stationary. However Engle and Granger[12] believes that it is rare for economic variables to be stationary sequences, but their linear group may be works, that is, the famous cointegration theory[13], which providing a new way to achieve regression. So the co-integration relationship between the variables is shown as Table 2.

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| ADF test statistic | T value | P value |
|--------------------|---------|---------|
| 1% Level           | -3.9591 | 0.012   |
| 5% Level           | -3.0810 |         |
| 10% Level          | -2.6813 |         |

The test result shown it is feasible to analyze and explore the interaction between environmental quality and economic evolution through impulse response, that is, there is a cointegration connection between them.

### 3.2. VAR model

The acquisition of the optimal time lag is one of the important prerequisites for making the estimation of the VAR model reliable, that is, the weight among the lag period and the degree of freedom is maintained. In the general case, the article uses Log likelihood ratio, Akaike information criterion, Hannan-Quinn information criterion, Likelihood Ratio, Schwarz information criterion, and Final prediction error to determine the appropriate lag period. The FPE, AIC and HQ test results are publicized in table 3, and 2 is the most appropriate lag term.

| Lag | LogL     | LR       | FPE      | AIC      | SC       | HQ       |
|-----|----------|----------|----------|----------|----------|----------|
| 0   | -657.808 | NA*      | 1.95e+39 | 101.816  | 101.990* | 101.780  |
| 1   | -642.755 | 18.525   | 2.66e+39 | 101.962  | 102.831  | 101.783  |
| 2   | -617.321 | 15.651   | 1.90e+39*| 100.511* | 102.075  | 100.189* |
Therefore, the VAR model of this study can be written as

$$Y_t = A \cdot Y_{t-1} + B \cdot Y_{t-2} + C$$

(11)

And

$$Y_{t+1} = \begin{bmatrix} GDP \\ GAS \\ WATER \\ SOLID \end{bmatrix}, \quad C = \begin{bmatrix} 410604.9 \\ 31293.0 \\ 36832.8 \\ 1574105.0 \end{bmatrix}$$

(12)

$$A \cdot Y_{t-1} = \begin{bmatrix} -0.087 & 0.046 & 0.781 & 0.004 \\ 3.945 & 7.790 & -43.585 & -0.209 \\ -0.914 & 3.564 & 2.604 & -0.015 \\ -0.038 & 0.667 & 0.850 & -0.209 \end{bmatrix}$$

(13)

$$B \cdot Y_{t-2} = \begin{bmatrix} -0.079 & 0.369 & 0.089 & -0.001 \\ 3.675 & -3.104 & -41.450 & -0.138 \\ -0.326 & 0.495 & -2.399 & 0.014 \\ 0.002 & 0.365 & -2.265 & -0.107 \end{bmatrix}$$

(14)

In this paper, the Pesaran and Pesaran procedure[14] methods are adapted to detect the correctness and robustness of the model, and the results are shown in Fig. 2. The unit circle contains all the characteristic roots of the model, which shows the rationality of our measures.

Fig. 2 The distribution of characteristic roots

3.3. Impulse response analysis based on VAR

The influence of a dependent variable on the remaining variables in var model is generally described by the impulse response function. In this part, the paper analyzes the response of GDP to its driving force from a long-term and short-term perspective, only 15 time periods are reported. The abscissa and ordinate in the figure represent the lag order and response value respectively.

Fig. 3 Response of the GDP to GAS, WATER, SOLID

Through analyzing the response graph, the GDP only has a small response when Wastewater emission increase, and reach the negative maximum (-5434.883) in the fifth phase, and almost disappears in the ninth period. During the whole study, the GDP shows a negative response to exhaust gas emissions in all time.

One standard deviation shock to Wastewater emission, the positive and negative impulse response of Wastewater emission on the GDP appear alternately. Rising in Wastewater emission initially increases GDP in the short run, But from the second to third period, the GDP produce a negative response. From the fourth period, the GDP improved slightly, and finally, the GDP does not have great amplitude, and progressively return to calm.
The GDP shows a positive response to Solid waste emissions in all period. The GDP is improved rapidly in the first period and then this increase gradually tapers off over the successive quarters. A long response cycle exists between GDP and solid waste emissions, as well as a large response to economic growth, which indicates that the relationship between GDP and Solid waste emissions closer and more sensitive.

3.4. Variance decompose

After deriving the impulse response of each variable, the variance decomposition method in this paper to describe the contribution of each variable to the influence of the VAR model. Following results can be concluded base on the time series between GDP and Wastewater emission, Solid waste emissions and Exhaust gas emissions. The abscissa and ordinate in the figure represent the lagged periods and the contribution rate.

![Fig. 4 Analysis of variance decompose](image)

Fig. 4 presents the variance decomposition for the 15-quarters forecasts. In the variation of GDP index, the GDP contribution rate has little to do with its own, the Exhaust gas emissions has very low contribution rate(1.71%) on the GDP at all stages, which signifies that the Exhaust gas emissions is not the focal motivation causing a fluctuation of GDP. The Wastewater emission has a 16.56% of contribution rate at the peak point on GDP with an average contribution rate at 14.85%. On the other hand, the GDP explained about 8.61% of its own variations at first quarter, and about 10.73% at the fifth quarter, to a certain extent, it echoes the results of Zhang Jinfeng's study on the Yangtze river delta. Finally, it is worth noting that the other element that also obtains a significant part of the variations in GDP is the value of Solid waste emissions, it counts for about 71.1%.

4. The empirical results

4.1. The empirical results

The primary desire of this document was to explore how Gross Domestic Product reacts to fluctuations in the macroeconomic variables with the annual data in 2000-2016. Than the VAR model is employed to running the co-integration test, impulse study, variance report and other dynamic studies between the GDP and Wastewater emission, Solid waste emissions and Exhaust gas emissions. The result shows that the GDP presents a steady rising style with an average annual progress rate of 10.6 percent. The Wastewater emission shows a circuitous and winding rising trend in general. The Solid waste emissions had a steady evolution, as it grew at an annual rate of 8.5% during the stage 2000-2010, and it stabilizes around 327.079 million tons during the period 2011-2016. The increase in exhaust emissions first increases and then is gradually weakened, which showed an “inverter U-shaped” shape, and reaches the highest point (25888 million tons) in 2006.

Co-integration analysis appears that there is a cointegration relationship in economic growth and environmental quality; the increase of Solid waste emissions plays a facilitating role on the economic evolution, furthermore the economic evolution has positive effect in general. In addition to this, The solid waste emissions not only has a high contribution rate (71.1%) on the spread of economic growth but also has a robust and long-time force on economic growth. This is mainly due to the rise in per capita income is accompanied by the construction of urbanization, which increases residents’ demand for housing and automobiles, thereby housing investment and the automobile industry obtains rapid growth. So it will inevitably produce solid waste and we also have reason to believe that rising in Solid waste emissions plays a facilitating part on the economic evolution.
At the same time, one standard deviation shock to Wastewater emission, the positive and negative impulse response of Wastewater emission on the GDP appear alternately. This is because of the rapid expansion of industry, the increase of the tertiary industry and the increase of urban residents, which has led to the improvement of GDP. On the other hand, it also increases the funds spent on the treatment of wastewater.

Much more interesting, the impulse response of GDP on Exhaust gas emissions increase has small spread and short time, that is to say, Exhaust gas emissions has a little donation proportion on the variation of environmental quality. This is dependence on fixed asset financing and export trade have long been relied which has led to mass of energy expenditure and CO2 etc. emissions; it has enlarged the expense of economic progress and threatened sustainable economic progress.

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