A Study on the Shandong Utilized Industrial Solid Waste Based on VAR Model

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Abstract. This study is aiming at analysing the relationship among the utilized fixed industrial solid waste, GDP growth and the R&D expenditure in Shandong. The results show that Shandong GDP growth will have a positive influence upon utilized fixed industrial solid waste and Shandong enterprises’ R&D expenditure growth will have positive influences too. Granger Causality tests indicate that Shandong's utilized industrial solid waste helped push the GDP development and Shandong enterprises R&D expenditure also helped push the Shandong GDP development. We can also see that government policies concerning encouraging the enterprises investment in R&D are also good for the sustainable development.

1 Introduction

Shandong is developing very fast in those past 40 years since China’s opening up and reform. Pollution is also a very serious problem in Shandong province in its process of development. The volume of Industrial solid waste had reached to 239 million tons in 2017 and became very serious problem in Shandong. However, with the technology progress and innovation, industrial solid waste is treated and utilized back in the production process and gradually benefit the economy of Shandong. This paper will explore the relationship between the volume of utilized industrial solid waste and the GDP growth in Shandong with R&D expenditure of enterprises as the necessary variable in the analysis.

2 Literature review

In the many developing countries, the inadequacy of basic waste data is a significant obstacle for solid waste management so the identification of influencing socio-economic factors is very important in the study. [1] In some studies, multiple regression analysis are used to identify the various socioeconomic parameters, such as population, GDP, literacy rate, income per capita, human development index (HDI) etc. Independent variables have been recommended and forecasted values of solid waste generation rate are in a good agreement with the actual values thus validating the model [2].

In other studies, the model applies statistical tools to select suitable function and most relevant explanatory variables that have strong relationship with solid waste generation.
The results indicate that the number of employees, population, household income, and temperature are significant variables of waste generation [3]. Other studies used the statistical data of the old industrial bases in northeast China and nationwide from 1993 to 2012 to study the performance and gap of implementing the strategy of rejuvenating the old industrial bases in northeast China for ten years by using before- and- after analysis and computing performance increment value [4].

Because the industrial solid waste is so important component of solid waste, statistical data in recent 10 years in China showed that generating status and characteristics of industrial solid waste such as the generated quantities utilized quantities and disposed quantities of industrial solid waste, etc. [5]. Some studies explored the correlations between industrial solid waste management policy and other influencing factors by using system dynamics methods, thus the causal relationship diagrams and flow charts were studied. The research results have an important theoretical and empirical significance for devising management policy, and improving the level of research on the industrial solid waste management [6].

In this paper, we first make a description of the model and data; then test variable unit root, perform the cointegration test and Granger causality test to estimate the long-run relationship among utilized industrial solid waste, GDP growth and the R&D expenditure in Shandong.

3 Model and data

The VAR model is mainly used for the relevant time series prediction system and the dynamic impact of random disturbance on variables system. The VAR model with only one lag can be written as:

\[ Y_t = \alpha + \Phi Y_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim IID(0, \Omega) \]  \hspace{1cm} (1)

This model can be expressed in a Vector Moving Average (VMA) form:

\[ Y_t = (I - \Phi)^{-1} \alpha + \sum_{i=0}^{\infty} \Phi^i \varepsilon_{t-i} \]  \hspace{1cm} (2)

or in the matrix form as:

\[
\begin{pmatrix}
  x_t \\
  y_t \\
\end{pmatrix} = \begin{pmatrix}
  1 - \phi_{22} & \phi_{21} \\
  \phi_{12} & 1 - \phi_{11} \\
\end{pmatrix} \begin{pmatrix}
  \alpha_1 \\
  \alpha_2 \\
\end{pmatrix} + \sum_{i=0}^{\infty} \begin{pmatrix}
  \varphi_{11}(i) & \varphi_{12}(i) \\
  \varphi_{21}(i) & \varphi_{22}(i) \\
\end{pmatrix} \begin{pmatrix}
  \varepsilon_{x_{t-i}} \\
  \varepsilon_{y_{t-i}} \\
\end{pmatrix} \hspace{1cm} (3)
\]

In this paper, Granger causality test method as a common approach is used to test the causal link between the two variables. The Granger causality test is using the following two equations:

\[ y_t = \sum_{i=1}^{q} \delta_i x_{t-i} + \sum_{j=1}^{q} \beta_j y_{t-j} + u_{1t} \]  \hspace{1cm} (4)

\[ x_t = \sum_{i=1}^{q} \lambda_i x_{t-i} + \sum_{j=1}^{q} \beta_j y_{t-j} + u_{2t} \]  \hspace{1cm} (5)

In doing Granger causality test, it is necessary to test the stationarity of the variable series to determine whether they are stationary sequences. A difference stationary series is said to be integrated and is denoted as \( l(d) \) where \( d \) is the order of integration. Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is important to check whether a series is stationary or not before using it in a regression.

In this study, data are taken from "Shandong Statistical Yearbook" and "China Energy Statistical Yearbook". Sample period is selected from 1995 to 2018. Model variables are including the Industrial solid waste utilized (WUD), Gross domestic product (GDP) and R&D expenditure (RDE). Variables are in the form of the natural logarithm, that is, LNWUD, LNGDP and LNRDE.
4 Tests results and discussion

4.1 Unit root test

The Augmented Dickey and Fuller (ADF) test method is used in this paper to test the variable’s unit root. Unit root test is essential in the empirical analysis. As test results in Table 1 indicate that the ADF values of all the three series of LNMUD, LNGDP and LNRDE are more than the critical value at 1 per cent Mackinnon critical level. This actually indicates that those three variables are not stationary. We take these three variables to be the 1st order differential as DLNMUD, DLNGDP and DLNRDE, ADF tests show that values of those three variables are less than the corresponding critical value at 1 percent Mackinnon critical value. So that DLNMUD, DLNGDP and DLNRDE do not have unit roots and they are stationary. We can say hereby that these three variables under ADF test are the first-order difference stationary series I(1) and we can continue the following research.

Table 1. ADF test results for each variable.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Selection(c, t, p)</th>
<th>ADF Value</th>
<th>Probability</th>
<th>Critical Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNMUD</td>
<td>(c, 0, 1)</td>
<td>-1.681327</td>
<td>0.4270</td>
<td>-3.752946*</td>
<td>Non-stationary</td>
</tr>
<tr>
<td>LNGDP</td>
<td>(c, 0, 1)</td>
<td>-0.832285</td>
<td>0.7898</td>
<td>-3.769597*</td>
<td>Non-stationary</td>
</tr>
<tr>
<td>LNRDE</td>
<td>(c, 0, 1)</td>
<td>1.464336</td>
<td>0.9600</td>
<td>-2.669359*</td>
<td>Non-stationary</td>
</tr>
<tr>
<td>DLNMUD</td>
<td>(c, 0, 1)</td>
<td>-4.061997</td>
<td>0.0052</td>
<td>-3.769597*</td>
<td>Stationary</td>
</tr>
<tr>
<td>DLNGDP</td>
<td>(c, 0, 1)</td>
<td>-10.79627</td>
<td>0.0000</td>
<td>-3.788030*</td>
<td>Stationary</td>
</tr>
<tr>
<td>DLNRDE</td>
<td>(0, 0, 1)</td>
<td>-19.20901</td>
<td>0.0001</td>
<td>-2.674290*</td>
<td>Stationary</td>
</tr>
</tbody>
</table>

Note: Among Selection(c, t, p), c means constant, t means trends, p means difference lagging order; D indicates difference; * represent the Mackinnon critical value at 1% significant level.

4.2 Cointegration test

From the above analysis, we can say that the stationary test indicates that each variable of LNMUD LNGDP LNRDE meets the I(1) 1st order stationary conditions. In this section, the cointegration method is carried out to form a VAR model equation. The VARD model is proposed by Johansen and Juselius (1990) to test a possible long-run relationship that may exists among the variables under study. We use the Trace statistics test and the test results indicate that there is 1 cointegration equation exiting at the 0.05 significant level. Cointegration test results are as shown in table 2.

Table 2. VAR model variables cointegration test.

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Hypothesized Trace</th>
<th>0.05 Critical Value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>0.947609</td>
<td>73.27799</td>
<td>24.27596</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.407400</td>
<td>11.34845</td>
<td>12.32090</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.017020</td>
<td>0.360499</td>
<td>4.129906</td>
</tr>
</tbody>
</table>

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
So the coefficients of VAR model are estimated on EViews with a lag number $p = 1$ as shown in Equation (6). The equation shows that a 1 per cent increase of the LNGDP will lead to a 0.028 per cent increase in LNWUD and that a 1 per cent increase of the LNRDE will to a 0.037 per cent of LNWUD. This means that Shandong GDP grow will have a positive influence upon fixed industrial waste utilized and Shandong enterprises’ R&D expenditure growth will a positive influences too.

$$\text{LNWUD} = 0.83^{*}\text{LNWUD(-1)} + 0.028^{*}\text{LNGDP(-1)} + 0.037^{*}\text{LNRDE(-1)} + 0.80$$  

(6)

4.3 Granger causality tests

We performed the Granger Causality test and the results as shown in Table 3. At lagging order of 3 and 5% significant level tests results indicate that we have to accept the null hypothesis that LNGDP doesn’t Granger cause LNWUD, but reject the null hypothesis that LNWUD does not Granger cause LNGDP, that is to say, LNWUD does Granger cause LNGDP. Results also indicate that LNRDE does not Granger cause LNWUD and LNWUD does Granger cause LNRDE. LNRDE does Granger cause LNGDP, and LNGDP does Granger cause LNRDE. These test results mean there are a two-way Granger cause of LNRDE and LNGDP, but only a one-way Granger cause of LNWUD to LNGDP and GNWUD to LNRDE. This indicates that Shandong's fixed industrial solid waste utilized helped push the GDP development and Shandong enterprises R&D expenditure also helped push the GDP development in Shandong province.

### Table 3. Pairwise Granger causality tests.

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Obs</th>
<th>F-Statistic</th>
<th>Prob.</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNGDP does not Granger Cause LNWUD</td>
<td>21</td>
<td>1.41828</td>
<td>0.2791</td>
<td>Accept</td>
</tr>
<tr>
<td>LNWUD does not Granger Cause LNGDP</td>
<td>13</td>
<td>4.069</td>
<td>0.0002</td>
<td>Reject</td>
</tr>
<tr>
<td>LNRDE does not Granger Cause LNWUD</td>
<td>21</td>
<td>2.39714</td>
<td>0.1117</td>
<td>Accept</td>
</tr>
<tr>
<td>LNWUD does not Granger Cause LNRDE</td>
<td>7</td>
<td>3.6069</td>
<td>0.0034</td>
<td>Reject</td>
</tr>
<tr>
<td>LNRDE does not Granger Cause LNGDP</td>
<td>21</td>
<td>8.14455</td>
<td>0.0022</td>
<td>Reject</td>
</tr>
<tr>
<td>LNGDP does not Granger Cause LNRDE</td>
<td>22</td>
<td>0.0022</td>
<td>1.E-05</td>
<td>Reject</td>
</tr>
</tbody>
</table>

5 Conclusion

This study is aiming at analysing the relationship among the industrial solid waste utilized, GDP growth and the R&D expenditure in Shandong. After the unit root is tested we know that 1st order differential of the variables are stationary. The VAR model coefficients are estimated and the results are that a 1% increase of the LNGDP will lead to a 0.028% increase in LNWUD and that a 1% increase of the LNRDE will lead to a 0.037% of LNWUD. This means that Shandong GDP growth will have a positive influence upon industrial solid waste utilized and Shandong enterprises’ R&D expenditure growth will a positive influences too.

Granger Causality tests indicate that LNWUD does Granger cause LNGDP and LNRDE does Granger cause LNGDP, too. These test results mean there are a two-way Granger cause of LNRDE and LNGDP, but only a one-way Granger cause of LNWUD to LNGDP and GNWUD to LNRDE. This indicates that Shandong's industrial solid waste utilized helped push the GDP development and Shandong enterprises R&D expenditure also helped
push the GDP development in Shandong province. Shandong industrial solid waste utilized helped explain the increase of enterprises R&D expenditure.

This study could help the decision makers of Shandong government and to guide decisions making process. From the study we know that it is good for government to issue policies to accelerate the application of utilizing industrial solid waste which is good for the environment protection and is essential for the sustainable development in Shandong province. We can also see that policies concerning encouraging the enterprises investment in R&D are also good for the sustainable development.

Shandong social science planning research project: Research on dynamic collaborative development of Shandong manufacturing industry and producer services industry (19CDNJ31).

References