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EMPIRICAL RESEARCH ON ECONOMIC GROWTH AND ENVIRONMENTAL POLLUTION BASED ON VAR MODEL

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Introduction. The relationship between environmental pollution and economic development has been a hot issue to environmental economics and ecological economics research. In recent years, as the growth of the economy, many provinces and cities in China are facing increasingly serious environmental pollution problems. In this article, we mainly make a discussion about the problems of environmental pollution and economic of Hubei Province in China during 1999–2009.

Hubei Province is located in center of China, the total area is 186000 square kilometers, and the total population is about 57 million. The transportation and communication are very convenient here. It is rich in natural resources, Changjiang River which is the world's third largest river is through here. Hubei Province is one of China's important industrial and agricultural base.

In recent years, It has a very good development opportunity. The province's GDP was 3229.29 billion yuan in 1999 and 12961.10 billion yuan in 2009. The per capita GDP was 3857.99 yuan in 1999 and 22677 yuan in 2009. During this period, the industrial structure changed a lot. Proportion of three industrial structure was 20.3: 40.7: 39.0 in 1999, and it became to 13.8: 46.6: 39.6 in 2009. Due to historical reasons, the industrial structure of Hubei was major heavy industry at long time. Since the reform and opening up, structure of light and heavy industrial has adjusted, but the heavy industrial characteristics are still evident [1].

At the beginning of industrialization, the industrial model of economic development were basically based on the resource–based, high material consumption, high energy consumption, heavy pollution and heavy chemical industry in Hubei Province. The rapid economic growth of Hubei Province in China has led to increase pressure on resources and environment. Industrial waste water emissions were respectively 1159.85 million tons in 1999 and 913.24 million tons in 2009. The industrial waste gas emissions were 556.60 billion cubic meters in 1999 and 1125.30 billion cubic meters in 2009. The amount of industrial solid waste production achieved 25.11 million tons in 1999 and 55.61 million tons in 2009. Look at the situation from 1999 to 2009, the amount of industrial waste gas emissions and solid waste were in rapid growth to the emissions of industrial waste water. Meanwhile, as a water–rich province, Hubei is also inevitably facing a serious problem of water pollution [1].

It is necessary to research the relationship between environmental pollution and economic growth. In this paper, we mainly use the VAR model, and apply the method of impulse response function and variance decomposition to make up long–term dynamic characteristics between per capita GDP and three kinds of pollution indicator of Hubei Province.

Research method.

Vector Autoregressive (VAR) Model.

The VAR model is an unstructured modeling method to study the relationship among each variable which was first use by Sims. The expression of the model is:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t \quad t = 1,2\cdots T$$

There y_t is a dimension variable dimension vector, x_t is a exogenous variable vector, p is the number of lags, T is the number of samples. $A_1 \cdots A_p$ are $k \times k$ dimensional matrix and B is $k \times d$ dimensional matrix which will be estimated. ε_t is a k–dimensional matrix of error terms.

We analyze dynamic impact to VAR model when an error term changes, this method is called Impulse Response Function (IRF) method [2]. We analyze the contribution of each structure shock to endogenous

variables, and further evaluate the importance of different structural shocks, this method is known as Variance Decomposition [2].

Index selection and data source. In order to build the model, we select the data of industrial waste water, waste gas and solid waste of Hubei Province as environmental pollution indicators. Real GDP per capita is selected as the economic indicator. All the data is from Hubei Statistical Yearbook during 1999 to 2009 [1]. In this paper, x:GDP per captia; y_1:the emissions of waste water; y_2:the emissions of waste gas; y_3:the emissions of solid waste. In order to removal the heteroscedasticity of the data, we use lnx, ln y_1, ln y_2, ln y_3 to model and Eviews 5.0 as a mathematical tool.

Modeling and analysis.

Unit Root Test and Co–Integration Test.

Many real time series of economic variables are non–stationary. In order to prevent spurious regression, we conduct Unit Root Test by ADF (Augmented Dickey–Fuller) method to see if the time series are stationary. The test results show $\ln x, \ln y_1, \ln y_2, \ln y_3$ are non–stationary time sequence ,but all the first–order differential series are stationary at the 5% significance level. We can see the results in table 1.

Table 1 – The unit root test of all the variables

Variables	ADF test statistic	Test critical values:	Inspection form (C,T,K)	Results
$\Delta \ln x$	–9.059207	–3.320969**	(C,0,2)	stationary
$\Delta \ln y_1$	–4.566553	–3.320969**	(C,0,2)	stationary
$\Delta \ln y_2$	–7.977313	–3.320969**	(C,0,2)	stationary
$\Delta \ln y_3$	–6.189583	–3.320969**	(C,0,2)	stationary

(C: containing a constant term in ADF test statistic; T: containing a trend term;K: the number of lag; Δ: first–order differential series. **:5% significance level).

So the original sequences satisfy the integrated of 1, and there may be a co–integration relationship. Thus our use Johansen co–integration to test, and the results in table 2 show that: $\ln x$ and $\ln y_1$, $\ln x$ and $\ln y_2$, $\ln x$ and $\ln y_3$ are through the 5% critical test. So there exists long–term stable relationship (co–integration relationship) between the variables in each group.

Table 2 – Johansen co–integration test

Variables	Eigenvalue	Trace Statistic	5% Critical Value	Hypothesized No. of CE(s)
$\ln x$	0.889975	21.65312	15.49471	None *
$\ln y_1$	0.180332	1.789706	3.841466	At most 1
$\ln x$	0.710653	11.49520	15.49471	None
$\ln y_2$	0.036436	0.334050	3.841466	At most 1
$\ln x$	0.759816	16.10931	15.49471	None *
$\ln y_3$	0.304812	3.272163	3.841466	At most 1

VAR Model and Impulse Response Function method.

We respectively build corresponding VAR models for $\ln x$ and $\ln y_1$, $\ln x$ and $\ln y_2$, $\ln x$ and $\ln y_3$. The number of lags of model are choose as AIC(Akaike Information Criterion). After several tests, all the number of lags for three VAR models are 2, these show there are remarkable influence of two variables in each group. Then we see all the reciprocals of root modulus for VAR models are less than 1 by using AR root test, which show that the VAR models are stable. we further get Figure 1 and Figure 2 by impulse

response function analysis[3][4], and try to find the long–term response of single variable pulse disturbance.

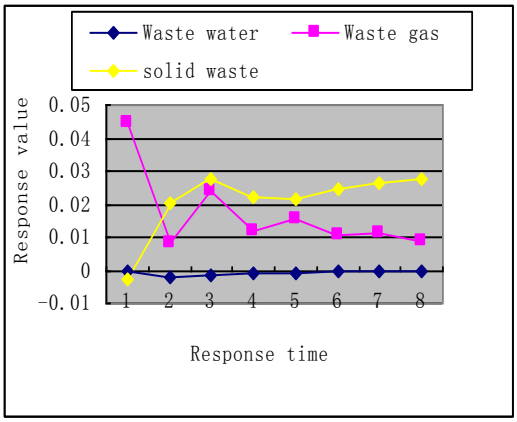

Figure 1 – Response of Industrial wastes to GDP

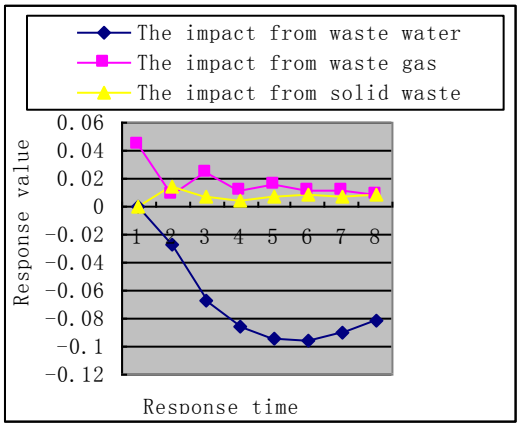

Figure 2 – Response of GDP to Industrial wastes

From the Figure 1, we can see the response function curve of industrial waste water caused by the impact of economic growth hovers around zero, indicating that the economic growth had little impact on the increase of industrial waste water. The response function curves of solid waste pollution and industrial emissions caused by the impact of economic growth fluctuate and both the cumulative value are positive, indicating that economic growth has brought an increase in solid waste pollution and industrial waste gas emission, the heavy industry of Hubei Province is on rapid growth and consumption of industry still exists.

From the Figure 2, we can see the response function curves of economic growth caused by the impact of solid waste pollution and industrial emissions hover around zero, indicating that the solid waste pollution and industrial emissions have little affect to economic growth. The response function curves of economic growth caused by the impact of waste water is U–shaped, and the cumulative response values is –0.540811, showed that an increase of industrial waste water has a negative effect on the economic growth.

Variance Decomposition. Variance decomposition is used to further evaluate the importance of the impact of different structures through analysising each structural shock contribution to inside variable changes (measured by variance) [3][4], we get the following conclusions (Table 3) by variance decomposition analysis of the VAR models.

Table 3 – Average percent Environmental pollution indicators variance and GDP variance

Environmental pollution indicators	Average percent environmental pollution indicators variance due to economical growth indicators	Average percent economic growth indicators variance due to environmental pollution indicators
Waste water	0.580036	78.06841
Industrial emissions	0.996646	50.05382
Solid waste pollution	85.49533	4.432238

From the Table 3, we can see the average percent solid waste pollution indicators variance due to economical growth indicators is very high, this is good agreement with pattern of heavy industrial and coal–based energy consumption patterns in Hubei Province. The average percents economic growth indicators variance due to waste water and industrial emissions are high, this shows that the impact of environmental pollution on economic growth relatively more.

Conclusion. According to the economic and environment indicators in Hubei Province from 1999 to 2009, and empirical analysis above ,we can see that the economic growth is an important reason for change of pollution emissions in Hubei Province, the average percent environmental pollution indicators variance due to economical growth indicators is very high, and the increase of polluting emissions hinders economic development. Therefore, we should focus on the proportion of industrial structure of Hubei Province in the future. In order to promote the coordinated development of the economy and the envi-

ronment of Hubei Province, we give the following suggestion: the main way to reduce the provincial pollutants is not the economic growth, but should increase and improve the technology and equipment, pollution treatment facilities to reduce pollution and promote the harmonious development of the economy. At the same time, Government should strengthen the pollution supervision, perfect scientific and effective supervision system, and set up the related legal policy[5].

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Summary

We establish the VAR (Vector Autoregressive)model, and apply the method of impulse response function and variance decomposition to make up long–term dynamic relationship between per capita GDP and three kinds of pollution indicator of Hubei Province during 1999–2009.The results show that: on the one hand, economic growth is an important reason for the impact of environmental pollution changes in Hubei Province, on the other hand, the increase of industrial waste has inverse function to economic growth. So we should pay more attention to environmental problems at the time of economic development.

Keywords: Economic Growth; Environmental Pollution; VAR; Impulse Response Function; Variance Decomposition.

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