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VAR analysis of foreign direct investment and environmental regulation: China's case

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This paper employs impulse response function of VAR model and the estimation variance decomposition method to investigate the two-way dynamic relationship between environmental regulation and FDI during 1985 to 2009. The result of generalized impulse response shows the impact effects of environmental regulation exerting to FDI become less and less in long-term, which verifies "hypothesis of pollution haven". The inverse U-shape curve of "environmental regulation - FDI" depends on the choice of regulation indicators. Furthermore, the positive impulse response shows the inflows of FDI would cause the deterioration of ecology and the intervene of governments, which gives pressure to the transformation of environmental regulation standard.

JEL Classifications: Q5

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Introduction

China has attracted a great many of FDI since the reform and open up. Until the end of December, 2009, there were 683 247 authorized FDI industrial projects, which employed USD 944.4 billion in practice. FDI and foreign industries play an important role in China's economy. It can be seen that the increasing FDI is accompanied with the more and more serious environmental pollution. It is necessary to investigate the relations between FDI and environmental regulation that has great theoretical and practical significance.

The current literature in this area mainly focuses on the discussion of how environmental regulations would affect FDI. Some argue if there exists a trend that the foreign direct investments tend to be accompanied with the industries transfer from the site under strict environment regulation to the site under loose regulation.

The supportive view is "hypothesis of pollution haven" (Walter and Ugelow, 1979). Baumol and Oates (1998) systematically prove hypothesis of pollution haven in theory, taking the view that the developing countries would gather the serious pollution industries if they adopt the loose regulation policy. Xing and Kolstad (2002) find the loose regulation countries attract direct investment from the U.S, but only limited to the serious pollution industries.

Meanwhile, some researchers (e.g., Friedman, 1992) consider that environmental regulation has no direct negative effect on FDI, sometimes even has positive effect. Cole and Elliott (2005) discover that the "pollution haven" most possibly appears in

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countries where comparative advantages are completely determined by the strengthening of environmental regulation. However, these countries may not have enough capital accumulation which can attract the foreign pollution-relied industries. Ederington (2006) find the U.S pollution-relied industries did not significantly shift to the developing countries as seen from statistics between1974 and 1994.

Current Chinese researches mainly focus on discussing the times series models, cross-section data models and panel data models, and the conclusions differ among these researches. Ying and Zhou (2006) claim that the relation between environmental regulation and FDI fits the "hypothesis of pollution haven" after analyzing the time series model (1985-2003) and panel data model (2000-2003). Yang (2003) employs a panel data model using the data from 1998 to 2001. Wu (2007) also employs a panel data model but uses the data of 30 provinces of mainland China (except Tibet) in successive 7 years (1998-2004). Both of them find out that the environmental regulation indeed has a negative effect on FDI in some extent. Chen (2009) employs a province-level panel data of China from 1994 to 2006, and claims that the environmental regulation has significant restraining effect on FDI.

After discussing the above approaches, we can find that there exist some aspects requiring deeper research the relationship between environmental regulation and FDI. Firstly, most approaches chose a single index to illustrate environmental regulation which causes deviations when analyzing the relationship between environmental regulation and FDI. Secondly, the economic theory models used by most researchers still need to be improved.

Therefore, it is difficult to construct a model containing all influencing factors when studying the relationship between environmental regulation and FDI. But vector autoregressive model (VAR) presented by Sims (1980) provides a simple alternative method, as it can better be used to analyze the dynamic influence among the variables.

Compared to simultaneous equations and CGE model estimation method, VAR model has the following advantages: all the variables in VAR model are treated as endogenous variables and they are placed into equations symmetrically. The variables are less constrained by the current theories; and the model can be used to analyze the long-term dynamic influence among variables. The model can avoid the problem of missing variables. Besides, we usually adopt generalized impulse response function (GIRF) to achieve the object that better describes the economic meaning of VAR model results.

Therefore, this paper employs the VAR model, uses two kinds of Chinese environmental regulation indexes in 1985-2009 to investigate the two-way dynamic influence between environmental regulation and FDI. There are two principal research purposes in this paper. On the one hand, we are going to depict the long-term dynamic effects between environmental regulation and FDI based on investigating the dynamic impact response between environmental regulation and FDI using generalized impulse response function; On the other hand, we are going to employ variance decomposition technique to investigate the relative importance in explaining the changes of environmental regulation and FDI.

Econometrics method, data source and processing

Econometrics method

This section employs impulse response function of VAR model to construct econometrical model which is used to analyze the two-way dynamic relationship between environmental regulation and FDI.

Generalized impulse response function (GIRF)

Vector autoregressive models emphasize the dynamic effects exerted by a certain impact to the system. VAR models use impulse response function to depict an endogenous variable's response to a unit change of another endogenous variable, and provide the information on the direction of response, the lags of adjustment, and the stabilization process. Cholesky decomposition presented by Sims (1980) is the most popular method. However, the results of this method seriously depend on the order of the variables. Hence, this paper adopts generalized impulse response function (GIRF). The results of GIRF can depict FDI's dynamic process caused by the changes of different environmental regulations. The basic framework of GIRF can be illustrated by $VAR(2)$ model as follows:

$$x_t = a_1 x_{t-1} + a_2 x_{t-2} + b_1 y_{t-1} + b_2 y_{t-2} + \varepsilon_{1t}$$

$$y_t = c_1 x_{t-1} + c_2 x_{t-2} + d_1 y_{t-1} + d_2 y_{t-2} + \varepsilon_{2t}$$

Supposing the above system activated from $t = 0$, let $x_{-1} = x_{-2} = z_{-1} = z_{-2} = 0$, setting the initial disturbance term $\varepsilon_{10} = 1$, $\varepsilon_{20} = 0$. Afterwards both equal zero. Then the disturbance given in the initial stage will constantly pass to the following stages. We can get $x_0, x_1, x_2, x_3, \ldots$, which is the impulse function. Similarly, we can get $z_0, z_1, z_2, z_3, \ldots$, which is the response function. The above impulse response processes can clearly capture the system response to special impact.

Variance decomposition theory

According to the representation of $VMA(\infty)$, Sims (1980) puts forward the variance decomposition theory:

$$y_{it} = \sum_{j=1}^{k} (c_{ij}^{(0)} \varepsilon_{jt-1} + c_{ij}^{(1)} \varepsilon_{jt-1} + c_{ij}^{(2)} \varepsilon_{jt-2} + \cdots)$$

The content in each bracket represents sum effect of the *j*-th disturbance ε_j on y_t from the infinite past to now. Supposing ε_t sequences are independent, we can solve out its variance and get the following equation:

$$E[(c_{ij}^{(0)} \varepsilon_{jt} + c_{ij}^{(1)} \varepsilon_{jt-1} + c_{ij}^{(2)} \varepsilon_{jt-2} + \cdots)^2] = \sum_{q=0}^{\infty} (c_{ij}^{(q)})^2 \delta_{jj}$$

The result, represented by variance, shows the total effect of the *j*-th disturbance on the *i*-th variable from the infinite past to now. Besides, assuming covariance matrix of disturbance term vectors is diagonal matrix, we can get y_i's variance by simply summing the *k* terms of the above covariances.

$$\mathrm{var}(y_{it}) = \sum_{j=1}^{k}\{\sum_{q=0}^{\infty}(c_{ij}^{q})^2\delta_{jj}\}$$

y_i's variance can be decomposed to *k* kinds of different effects. Hence, to determine how much each disturbance affect the variance of y_i, we define the following measure:

$$RVC_{j\to i}(\infty) = \frac{\sum_{q=0}^{\infty}(c_{ij}^{(q)})^2\delta_{jj}}{VAR(y_{it})} = \frac{\sum_{q=0}^{\infty}(c_{ij}^{(q)})^2\delta_{jj}}{\sum_{j=1}^{k}\{\sum_{q=0}^{\infty}(c_{ij}^{(q)})^2\delta_{jj}\}}$$

RVC is the contribution of relative variance, in another words, we investigate how the *j*-th variable affect the *i*-th variable through $RVC_{j\to i}(\infty)$. In fact, we cannot calculate $c_{ij}^{(q)}, s=\infty$, but if the model fits stationary condition, $c_{ij}^{(q)}$ would present geometric decrease as variable *q* increases. Therefore, we only need to adopt finite *s* terms.

Indicator selection and data sources

In the empirical studies examining relationship between environmental regulation and FDI the following indicators are adopted to illustrate the environmental regulation: effluent charge (fee) and ratio, completed investment of pollution treatment projects in current year, management efficiency of the three wastes (waste gas,waste water and industrial residue), etc.

Considering the availability of data, this paper adopts effluent charge (fee) and ratio, completed investment of pollution treatment projects current year to measure environmental regulation. Pollution charge payment per enterprise (LNPDF) is calculated by pollution charge levy dividing the number of payment enterprises (unit: ten thousand RMB per enterprise). Completed investment of pollution treatment projects in current year (LNPAF) means the amount of actual capital used by environmental projects current year (unit: one hundred million RMB). Both of them have timing length ranging from 1985 to 2005.

All data are obtained or calculated through "China InfoBank", "China's environmental statistics compilation" (1981-1990) and corresponding issues of "China environment yearbook". The initial data of Foreign Direct Investment are measured in dollars, the Foreign Direct Investment (LNFDI) in this paper are calculated by the foreign direct investment inflows multiplying the mid-point-rate (unit: one hundred million RMB). The timing length of LNFDI is from 1985 to 2009, and all data are obtained from "China InfoBank" and corresponding issues of "China environment yearbook". It is easy to get a stationary sequence after taking natural logarithm on time series data, which also can keep the characteristics of time series. For this reason, the empirical analysis in this paper employs the natural logarithm values of variables.

Unit root test and cointegration test of variables

In the real economy, many economic variables are nonstationary time series. We will get a spurious regression if we simply employ nonstationary variables, which cause the failure of

standard T-test and F-test. Avoiding the spurious regression result, it is general to conduct the stationarity test on time series (also called Unit Root Test). This paper employs Augmented Dicky Fuller test. The results is shown in Table 1.

From the Table 1, we notice that all of the initial series are nonstationary. However, their first-order differences are stationary. So these variables are I(1) process and satisfy the necessary condition of cointegration test.

It will give rise to spurious regression if we construct a regression on non-stationary variables. However, some kind of linear combination of several I(1) sequences may be stationary, which means there exists a long-term equilibrium of relationship. Based on unit root test, this paper employs Johansen likelihood ratio test to conduct cointegration test of variables groups. According to AIC and SC, we let the lags of each variable group be 3. The results are in Table 2.

TABLE 1. UNIT ROOT TEST OF VARIABLES（ADF）

Variable	ADF statistic	Marginal value	Test type（C,T,K）	Result
LNFDI	-1.919193	-2.650413***	（C, 0, 2）	nonstationary
ΔLNFDI	-3.039836	-3.020686**	（C, 0, 2）	stationary
LNPDF	0.143696	-2.642242***	（C, 0, 2）	nonstationary
ΔLNPDF	-5.254270	-3.788030*	（C, 0, 2）	stationary
LNPAF	-0.259653	-2.642242***	（C, 0, 2）	nonstationary
ΔLNPAF	-5.082654	-3.788030*	（C, 0, 2）	stationary

Note:C means that the test containing a constant term(C=0 means none) ,T represents the case of containing a trend term(T=0 means none),K represents the number of lags term;△ represents first order difference operator, *** ,**, * means significance at significant level of 10%,5%,1% respectively.

TABLE 2. COINTEGRATION TEST OF VARIABLES

Variables group	Eigenvalue	Trace statistic	5%	Cointegraton number
LNFDI LNPDF	0.493264	23.77078	20.26184	1
LNFDI LNPAF	0.527359	18.18839	12.32090	1

According to Table 2,the variables groups of LNFDI and LNPDF, LNFDI and LNPAF are cointegrated at 5% significance level with cointegration number 1.Therefore ,we think this two groups has the unique cointegration relationship, which means there exists a long-term equilibrium relationship among variables.

Impulse response analysis of environmental regulation and FDI

In this part, we use GIRF to investigate the FDI's impact responses caused by two kinds of regulation indicators. The impact standard deviation is get by Monte Carlo simulation. We let the impact response period be 8 in consideration of sample data capacity. The results are shown in Table 3.

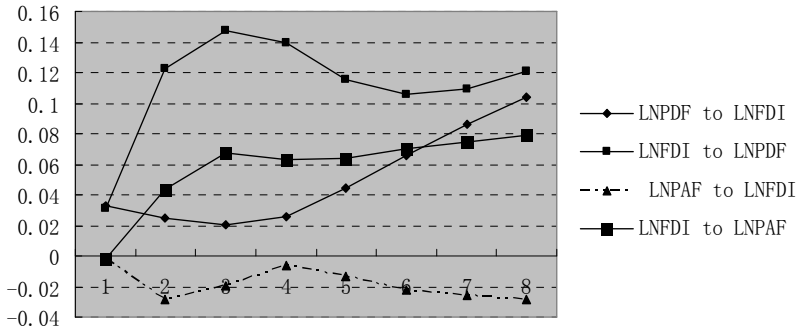
TABLE 3. IMPACT RESPONSE ANALYSIS RESULTS OF LNPDF, LNPAF AND LNFDI

Impact response period	LNPDF to LNFDI	LNFDI to LNPDF	LNPAF to LNFDI	LNFDI to LNPAF
1	0.033242	0.030893	-0.001580	-0.001990
2	0.024558	0.122551	-0.028458	0.043784
3	0.020178	0.147167	-0.019218	0.067591
4	0.025883	0.139386	-0.006194	0.063550
5	0.044593	0.115481	-0.013112	0.063768
6	0.065853	0.105801	-0.022367	0.070018
7	0.085953	0.109293	-0.025918	0.074552
8	0.104212	0.120652	-0.028820	0.078895
sum	0.404472	0.891224	-0.145667	0.460168
Impulse response curve	U-shape	N-shape	N-shape	Reverse U-shape

Pollution charge payment per enterprise (LNPDF) and Foreign Direct Investment

Firstly, from the first column of Table 3 and Figure 1, we find the response curve of LNPDF and LNFDI's unit impact appears U-shape in the whole impact response period, the response value of LNPDF is positive in current period.

FIGURE 1. IMPACT RESPONSE RESULTS OF LNPDF,LNPAF AND LNFDI



Afterwards, it gradually decreases; then gradually increases during 4th-8th periods; the accumulated response value of LNPDF reaches 0.404472, and LNFDI impact of current period affects LNPDF positively. Secondly, the impact response curve of LNFDI to LNPDF appears N-shape, response of LNFDI is positive and gradually increases in the first three periods; then deceases during 4th-6th periods, and increases in the last two periods. The accumulated response value of LNPDF reaches 0.404472, which means that the increase of FDI has positive influence to pollution charge payment per enterprise (LNPDF). In reverse, the increase of pollution charge payment per enterprise (LNPDF) also has positive influence to FDI.

Completed investment of pollution treatment projects current year and FDI

From the 3th and 4th columns of Table 3 and Figure 1, we know: the impact response of LNPAF to LNFDI appears N-shape, the impact response of LNPAF is negative and gradually decreases in the first two periods; it is negative and gradually increases in 3th,4rh periods, then gradually decreases in the 4th-8th periods. Its accumulative impact response value is -0.145667. Different to the impact response curve of LNPAF to LNFDI, the impact response curve of LNFDI to LNPAF appears inverse U-shape, which means the impact response of LNFDI to LNPAF is negative in current period, and gradually increases in the following two periods, then decreases in 4rh period, gradually increases in 5th-8th at last. Its accumulated response value is 0.460168.

We can draw the following conclusions after discussing the impact response results of two kind environmental regulation indicators to FDI.

Firstly, there are two types of impact response of two kind of regulations to LNFDI: U-shape (pollution charge payment per enterprise) and N-shape (completed investment of pollution treatment projects current year).

The method employed in this paper is distinct from the regression analysis employed in current studies. Therefore, the economic significance of "environmental regulation - FDI" depicted in this paper is also different from the current researches, the regression analysis focuses on the stationary effects, the generalized impulse response function method employed in this paper emphasizes on the dynamic effects in the economic system where environmental regulation and FDI influence each other. The result in Figure 2 partly proves the "hypothesis of pollution haven", for the FDI gradually decrease along with the increase of completed investment of pollution treatment projects. Besides, Figure 2 shows that the increase of pollution charge payment per enterprise would promote the increase of FDI, which is mainly because paying pollution fee is more economical when facing a low pollution tax. Hence, they would rather pay pollution fee than treat pollution. There were calculated cumulative impact response values of environmental regulation indicators and during 8 periods: the higher one is pollution charge payment per enterprise (0.891224), the other one is completed investment of pollution treatment projects current year (-0.145667).

Secondly, by observing the impact response curves in Figure 3, we can found that the impact response of FDI to environmental regulation is positive in most of the time, despite of the two curves are different. There were calculated the cumulative impact response values of FDI to two types of regulations: the higher is pollution charge payment per enterprise (0.404472), the other one is completed investment of pollution treatment projects current year (0.460168). We can verify that environmental regulation has positive effects to FDI according to the impact response curve of FDI to environmental regulation, which means the policy intervention and industrial structural adjustment would give rise to external pressure to regulation standard. Another interesting conclusion showed in Figure 3 is that the impact response has obvious hysteresis effect, impact response effect becomes more and more strong along with the impact period extends.

FIGURE 2. THE IMPACT RESPONSE CURVE OF ENVIRONMENTAL REGULATION TO FDI

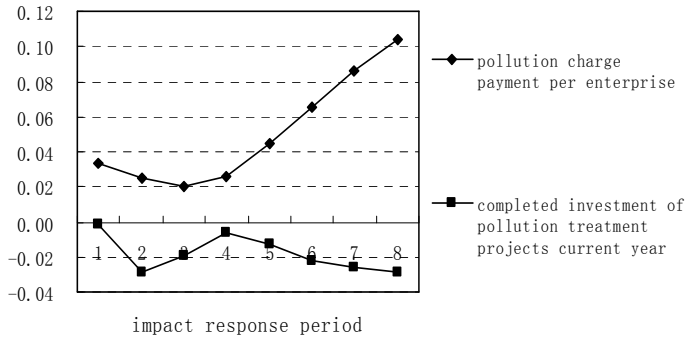
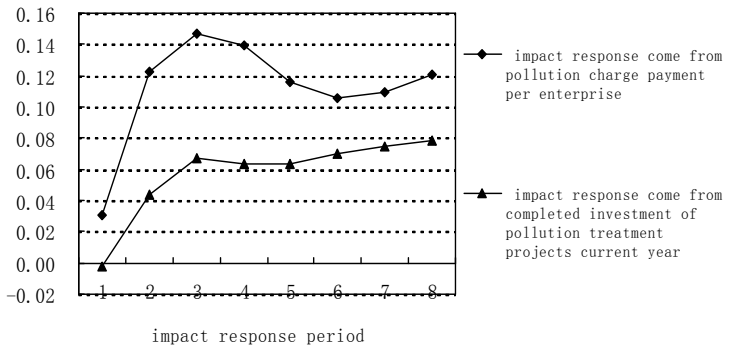


FIGURE 3. IMPACT RESPONSE CURVES OF FDI TO ENVIRONMENTAL REGULATION



Response curves of FDI to environmental regulation

According to variance decomposition theory, in this part we measured the mutual contribution of environmental regulation and FDI. The results are shown in Table 4. According to the results of variance decomposition, we can find that FDI play a relatively important role in explaining the estimation of each environmental regulation. FDI contribute the variance of pollution charge payment per enterprise over 6.89%, while it explains over 3.9% in variance of completed investment to pollution treatment projects in current year. This result depicts the dynamic relationship between FDI and environmental regulation since 1985. FDI bring the worse ecology quality along with becoming the basic driving factor in China's economic growth. However, in the wake of economic globalization and improvement of people's living quality, the governments at all levels and the public demand a better environment which rises environmental regulation standard.

TABLE 4. THE RESULTS OF VARIANCE DECOMPOSITION OF LNPDF, LNPAF AND LNFDI

Period	LNPDF to LNFDI	LNFDI to LNPDF	LNPAF to LNFDI	LNFDI to LNPAF
1	2.036460	0.000000	0.007968	0.000000
2	1.981612	3.019681	1.583152	1.247874
3	1.443407	5.085873	1.942806	2.481270
4	1.320132	6.977057	1.578067	3.300940
5	1.575145	8.287763	1.420554	4.206584
6	2.157946	9.390961	1.617462	5.352658
7	2.829349	10.50976	1.867188	6.635851
8	3.447652	11.86539	2.115511	8.033438
mean	2.098963	6.892061	1.516589	3.907328

Thus, the study demonstrates that regulation's contribution of estimated variance explanation is lower than contribution of FDI. The estimated variance contribution of pollution charge payment per enterprise to FDI is 2.1%, and the estimated variance contribution of completed investment of pollution treatment projects current year to FDI is only 1.52%.

Conclusion

Different to currents methods used to analyze the relationship of "environmental regulation and FDI," this paper employs impulse response function of VAR model and estimation variance decomposition method to investigate the two-way dynamic relationship between environmental regulation and FDI during 1985 to 2009.

The result of generalized impulse response shows, on the one hand, that environmental regulation is an important factor influencing FDI. On the other hand, FDI has positive effect to environmental regulation. The impact effects of environmental regulation exerting to FDI become less and less in long-term that verifies "hypothesis of pollution haven". The inverse U-shape curve of "environmental regulation - FDI" depends on the choice of regulation indicators. Furthermore, the positive impact response shows that the inflows of FDI would cause the deterioration of ecology and the subsequent interference of governments which gives pressure to the transformation of environmental regulation standard. This feedback mechanism usually has certain lag effects, so the feedback effect of FDI exerting to environmental regulation often appears after certain periods.

The result of variance decomposition shows that FDI play an important role in the estimated variance of environmental regulation; this means we need to pay attention and tale measures to promote the positive effects of FDI exerting to environmental regulation. On the other hand, the estimated variance contribution of environmental regulation exerting to FDI is relatively low. Considering some governments use none environmental regulation to attract FDI, which would cause a worse environmental condition, we must pay enough attention to the importance of environmental regulation. To avoid the case of "regulation race to the last", it is necessary to reform the environmental management system and to build a effective one.

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