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The effect of FDI on eco-efficiency performance: evidence from the BRICs

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Abstract

This paper aims to examine the effect of FDI on eco-efficiency performance. To serve this purpose, a time-dependent conditional slack-based measure model and nonparametric regression and test techniques are applied to BRICs during 2008-2015. It is found that there is an almost U-shape relationship between FDI and countries' eco-efficiency performance among three countries of BRICs.

Keywords: Slack based measure, Conditional efficiency, FDI, eco-efficiency performance

Introduction

Up to now, there has been no mature theoretical framework for the impact of FDI on the BRICs's environment. There are few concerns about the "environmental factors" in the modern mainstream FDI theory. Only some of the theories imply the explanation of the negative eco-efficiency performance of FDI. With the deepening of the research, many scholars have formed three kinds of research conclusions about the eco-efficiency performance of FDI with the view of "the transfer of pollution industry". The first is the representative point of view is harmful, "pollution haven" (Pollution Haven) hypothesis, that pollution intensive industries or enterprises from developed countries to developing countries relatively loose environmental regulation (Walter and Ugelow, 1979; Baumol and Oates, 1988). The second is a useful theory, representative point of view is "pollution halo" (Pollution Halo) that the FDI hypothesis, brought the advanced clean technology and environmental management system for developing countries, is conducive to the realization of green production and sustainable economic development (Clark, 1993; Romm, 1994; Cole, 2006). The third one is eclecticism. It is considered that the eco-efficiency performance of FDI is a complex transmission mechanism. The specific eco-efficiency performances depend on FDI's participation in pollution intensive industries, the effectiveness of environmental management of multinational corporations, and the degree of transfer of clean technologies (UNC-TAD, 2000).

With regard to the eco-efficiency performances of "BRIC countries" introducing FDI, most scholars' conclusions are not optimistic. Pao and Tsai (2011) believe that there is a strong two-way causality between the CO2 emissions of BRICs and FDI inflows, which seem to support the "pollution haven" hypothesis. L PEZ (2008) believes that the impact of transnational corporations on the environment of Brazil and local enterprises have no significant difference. Smarzynska and Wei(2004) the study of Russia and South Africa shows that some evidence can be found to support the "pollution refuge" hypothesis. The conclusions about the effect of the introduction of FDI on the environment in India are not consistent. Acharyya (2009) thinks that the rapid development of India's introduction of FDI supports the "pollution haven" hypothesis to a certain extent. The empirical research results also show that the proportion of India's introduction of FDI to GDP increases by 1%, and CO2 emissions increase by 0.86%. Chakraborty (2010) believes that there is no significant causal relationship between the introduction of FDI and environmental pollution in India. The phenomenon of "pollution haven" usually does not happen in India. There are also differences on the effect of China's introduction of FDI on the environment. Youfu Xia (1999) thinks that part of the FDI flows to the pollution intensive industries, especially the high pollution

intensive industries. The technology, equipment, production processes and hazardous wastes will be transferred to China, which will have a negative impact on the ecological environment. The results of empirical research many scholars also Chinese "pollution haven" phenomenon provides evidence (Yang Haisheng, 2005; Li Guozhu, 2007; Wen Huaide and Liu Yulin, 2008; Zhang Xuegang and bell Maochu, 2010). There are also findings denying that the eco-efficiency performances of FDI on China are positive. The effect of FDI on the emission of 6 types of pollutants, such as industrial wastewater, was investigated using the panel data of 36 industrial industries in 2001-2006 years in China (2010). The overall sample estimates show that there is a significant positive correlation between FDI and the level of per capita emissions, and does not support the "pollution refuge" hypothesis.

On the other hand, the relationship between FDI and sustainable environment development has drawn considerable attention in academic research. The trade-growth literatures hold that FDI can promote countries' economic growth via technological diffusion and specialization of production with comparative advantage. The trade-environment literatures show great controversies surrounding the role of trade in environmental quality. One argument is that FDI would lead to environmental degradation in BRICs while another view argues that FDI can be a means of environmental improvement (Frankel, 2003).This paper adds to the existing literatures from the perspective of eco-efficiency performance. Eco-efficiency performance is a concept connected with sustainable development which measures the ability to produce more goods and services while minimizing resource use and environmental degradation. We aim to examine the effect of FDI on eco-efficiency performance in .BRICs. To serve this purpose, we introduce a time-dependent conditional slack-based measure (SBM) model through integrating the SBM model developed by Tone (2004) and the idea of conditional efficiency analysis proposed by Daraio and Simar (2005). This method enables us to measure economy-wide eco-efficiency performance considering the influence of exogenous variables and time so that we are free from the assumption of "separability condition" .The proposed method is applied to evaluate economy-wide eco-efficiency performance in .BRICs during 2008-2015. Then nonparametric regression and test techniques are employed to explore the effect of FDI on countries' eco-efficiency performance

Methodology

Traditional SBM model

The SBM model was first proposed by Tone (2001), which is a non radial and non directional DEA model. In other words, in the SBM model, input-output variables can be retractable in different proportions. The traditional SBM model can be expressed as follows. The performance value of the evaluation subject can be calculated by calculating the objective function.

$$\rho = \min_{\{p_m^X,\ p_s^Y,\ p_j^B,\ \lambda_n\}} \frac{1-\frac{1}{M}\sum_{m=1}^{M}\frac{p_m^X}{x_m}}{1+\frac{1}{S+J}\left(\sum_{s=1}^{S}\frac{p_s^Y}{y_s}+\sum_{j=1}^{J}\frac{p_j^B}{b_j}\right)}$$

$$s.t. \quad x_m = \sum_{n=1}^{N}\lambda_n x_{mn} + p_m^X, m = 1,\ldots,M$$

$$y_s = \sum_{n=1}^{N}\lambda_n y_{sn} - p_s^Y, s = 1,\ldots,S$$

$$b_j = \sum_{n=1}^{N}\lambda_n b_{jn} + p_j^B, j = 1,\ldots,J$$

$$p_m^X \geq 0, p_s^Y \geq 0, p_j^B \geq 0,\ \lambda_n \geq 0, n = 1,\ldots,N$$

Conditional SBM model

The above radial DEA model and the non radial SBM model are all about the impact of input and output variables on the performance of decision makers in production activities, but no exogenous variables are considered. Therefore, with reference to Li et al (2017), this paper considers the inclusion of exogenous variables into the SBM model to measure the performance value of the decision maker.

Suppose Z is an exogenous variable, but this variable affects the overall production activity. Therefore, any decision maker in the whole process can be represented by a set (x, y, B, z). Therefore, the production technology set of the conditional DEA model can be expressed as:

$$H_{XYB|Z}\left(x,y,b\middle|z\right)=prob\left(X\le x,Y\ge y,B\ge b\middle|Z=z\right)$$

Accordingly, it is assumed that the exogenous variable Z under the time point t is given, and the production possibility set can be expressed as:

$$T^{z}=\left\{\left(X,Y,B\right)\middle|\begin{array}{l}\sum_{n\in\Gamma(t,z)}\lambda_n x_{mn}\le x_m,m=1,...,M\\ \sum_{n\in\Gamma(t,z)}\lambda_n y_{sn}\ge y_s,s=1,...,S\\ \sum_{n\in\Gamma(t,z)}\lambda_n b_{jn}\le b_j,j=1,...,J\\ p_m^X\ge 0,p_s^Y\ge 0,p_j^B\ge 0,\\ \lambda_n\ge 0,n=1,...,N\end{array}\right\}$$

Among them,

$$\Gamma\left(t,z\right)=\left\{\left(u,v\right)\middle\|Z_u-z\right|\le h_z;\left|v-t\right|\le h_t\right\}$$

On this basis, we can get the following DEA model:

$$\rho^{z}=\min_{\left\{p_m^X,\ p_s^Y,\ p_j^B,\ \lambda_n\right\}}\frac{1-\frac{1}{M}\sum_{m=1}^{M}\frac{p_m^X}{x_m}}{1+\frac{1}{S+J}\left(\sum_{s=1}^{S}\frac{p_s^Y}{y_s}+\sum_{j=1}^{J}\frac{p_j^B}{b_j}\right)}$$

$$s.t.\quad x_m=\sum_{j\in\Gamma(t,z)}\lambda_n x_{mn}+p_m^X,m=1,...,M$$

$$y_s=\sum_{j\in\Gamma(t,z)}\lambda_n y_{sn}-p_s^Y,s=1,...,S$$

$$b_j=\sum_{j\in\Gamma(t,z)}\lambda_n b_{jn}+p_j^B,j=1,...,J$$

$$p_m^X\ge 0,p_s^Y\ge 0,p_j^B\ge 0,\ \lambda_n\ge 0$$

In this model, the exogenous variable Z and the time variable T directly affect the position of the production frontier. Therefore, by solving the above model, the performance value of the decision maker under the influence of exogenous variables Z and T can be obtained.

Empirical results

Brazil and India introduction of FDI were early; Chinese have the FDI statistics data since the beginning of 1980, after the reform and opening up, Russia have the FDI statistical data of formal independence since 1993, South Africa since 1994, after the election, there has been little direct investment. In order to increase the reliability and can be compared to the results of the empirical analysis, we choose the data from 2008-2015. The choice of FDI index in five countries takes into account the role of capital accumulation in economic growth. In this paper, FDI inventory of UNCTAD statistics is used to analyze samples, and the overall economic level of each country is reflected by gross domestic product (GDP).And then, For the empirical study, this paper selects oil input as energy input and labor force salary as capital input variables, and gross domestic product (GDP) as desirable output variable, and carbon dioxide emissions (CO2) as undesirable output variables. The GDP data are from the China Network (2017). Capital input data from the "manual" BRICs statistics, using the perpetual inventory method, the depreciation rate of 10.96%, with 2001 as the base period. And the dollar is traded against a variety of currencies, in accordance with the exchange rate of January 24, 2018 and the energy data comes from the world energy statistics yearbook (2017).

The details are as follow:

Country	Year	Inputs		Desirable outputs	Undesirable outputs	
		Energy (oil)	Capital	GDP	CO_2	FDI
		Million tons	billion dollars	billion dollars	Million tons	hundred million dollars
Brazil	2008	243.9000	697.7516	967.7708	374.9000	507.0000
China	2008	2229.0000	3396.5357	5016.3949	7362.3000	748.0000
India	2008	475.7000	554.3984	856.6214	1472.2000	419.0000
Russia	2008	683.5000	290.5418	789.6002	1578.3000	924.0000
South Africa	2008	124.4000	79.0394	198.2014	447.5000	92.0000
Brazil	2009	243.0000	819.4116	1037.2419	352.1000	315.0000
China	2009	2328.1000	4147.6322	5480.5780	7692.5000	366.0000
India	2009	513.2000	607.9219	940.3570	1601.7000	377.0000
Russia	2009	848.0000	312.5570	742.3577	1464.1000	900.0000
South Africa	2009	124.3000	86.6176	209.7975	447.1000	75.0000
Brazil	2010	267.6000	977.9248	1209.2756	400.3000	885.0000
China	2010	2491.1000	4982.3561	6484.5757	8118.7000	432.0000
India	2010	537.1000	689.7949	1145.1305	1667.2000	360.0000
Russia	2010	673.3000	327.6878	885.8533	1509.8000	1057.0000
South Africa	2010	125.3000	84.4725	229.9044	449.2000	36.0000
Brazil	2011	279.7000	1151.4240	1361.9301	426.4000	1012.0000
China	2011	2690.3000	5891.7079	7682.0194	8806.7000	551.0000
India	2011	568.7000	825.7890	1344.7311	1741.2000	466.0000
Russia	2011	694.9000	387.3672	1070.6179	1572.1000	1160.0000
South Africa	2011	123.6000	87.7940	252.8557	440.7000	42.0000
Brazil	2012	284.8000	1335.6375	1498.3533	447.3000	866.0000
China	2012	2797.4000	6723.3668	8483.7682	8979.4000	506.0000
India	2012	611.6000	930.9653	1513.0161	1872.8000	343.0000
Russia	2012	695.2000	450.1254	1210.5905	1582.2000	1117.0000
South Africa	2012	121.9000	95.3975	271.4976	435.6000	46.0000
Brazil	2013	296.8000	1536.2222	1659.1998	486.6000	692.0000
China	2013	2905.3000	7453.1202	9345.3371	9218.8000	692.0000
India	2013	621.5000	1002.2042	1711.0059	1933.1000	360.0000
Russia	2013	686.8000	500.2912	1298.8581	1533.8000	1176.0000
South Africa	2013	123.6000	106.9426	296.1689	439.4000	83.0000
Brazil	2014	304.9000	1725.2508	1798.4102	508.3000	969.0000
China	2014	2970.6000	8098.6683	10110.3934	9224.1000	220.0000
India	2014	663.6000	1074.7812	1916.4009	2085.9000	451.0000
Russia	2014	689.2000	532.9424	1406.5860	1542.2000	1196.0000
South Africa	2014	125.2000	119.3496	317.6754	444.0000	58.0000
Brazil	2015	302.6000	1868.9596	1865.8889	491.3000	747.0000
China	2015	3005.9000	51273.0772	10818.1164	9164.5000	69.0000
India	2015	685.1000	1139.9217	2086.6658	2157.4000	556.0000
Russia	2015	681.0000	547.2817	1478.2113	1521.9000	1263.0000
South Africa	2015	120.1000	127.6466	337.4510	421.8000	17.0000

After the calculation, we can get some results as follows:

Table 1 reports countries' unconditional eco-efficiency performance scores and table 2 reports countries' conditional eco-efficiency performance scores, table 3 is the Nonparametric significance test result. The rest of diagrams are drew based on the calculated results.

Table 1: **Countries' unconditional eco-efficiency performance scores**

	Brazil	China	India	Russia	SA
2008	1	0.6003	0.5392	0.6247	0.6195
2009	1	0.5675	0.5460	0.5114	0.6285
2010	1	0.5926	0.6382	0.6718	0.7529
2011	1	0.6219	0.6709	0.8011	1.0000
2012	1	0.6293	0.6888	0.8106	1.0000
2013	1	0.6476	0.7669	0.8554	0.9950
2014	1	0.6681	0.8216	0.9290	0.9222
2015	1	0.2956	0.8768	1.0000	1.0000

Table 2: Countries' conditional eco-efficiency performance scores

	Brazil	China	India	Russia	SA
2008	0.9875	1.0000	0.8678	1.0000	0.6570
2009	1.0000	0.5926	0.9674	0.9356	0.7168
2010	0.9931	0.7899	1.0000	1.0002	0.9245
2011	1.0000	1.0000	0.8702	1.0009	0.8965
2012	0.8678	0.9670	1.0000	1.0013	0.7734
2013	0.7824	1.0000	1.0000	1.0019	0.6952
2014	1.0000	0.5932	0.7908	1.0030	0.8859
2015	0.6531	1.0000	1.0000	1.0049	1.0004

Table 3: Nonparametric significance test results (P-value).

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P Value:
ws 0.0630 .
t  0.7165
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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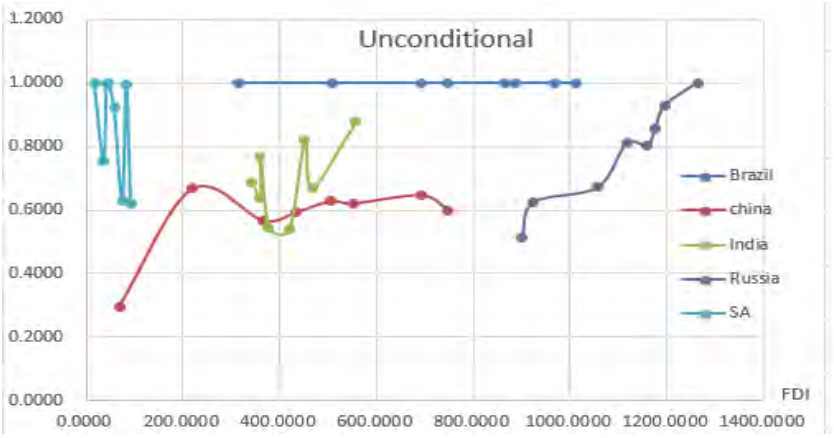

Diagram 1: Unconditional scores

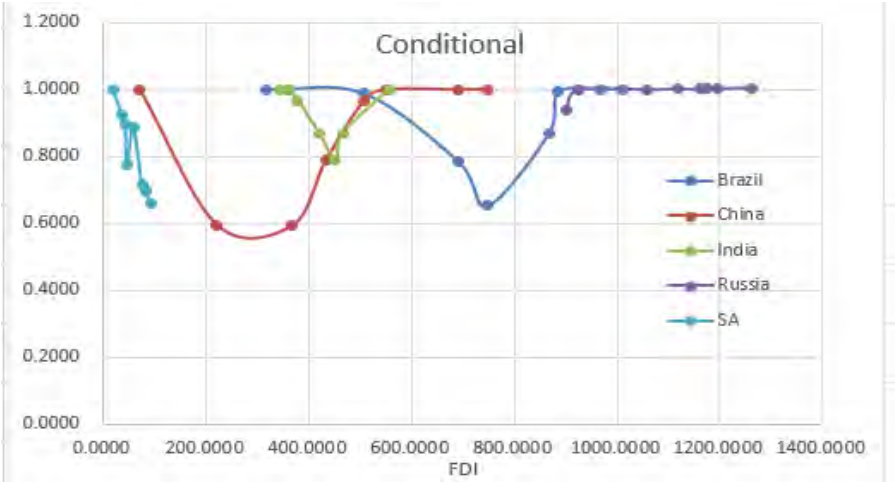

Diagram 2: Conditional scores

From the above results, we can see that regardless of the traditional models or conditional models, the impact of FDI on BRICs' eco-efficiency performance is positive in the past 8 years, and the value is greater than 0.5, which is similar to some other scholars' conclusions. In some countries with poor development, this value will generally be less than 0.3. But BRICs are relatively promising developing countries in the future, so the value is relatively high. Only China is below 0.3 in 2015.

On the other hand, these values are greater than 0 indicating that when the BRICs accept FDI investment, they can have a higher GDP and reduce environmental deterioration. Based on the traditional model, the impact of FDI on the eco-efficiency performance of the BRICs countries is positive, but time does not affect it. And based on the conditional model, although not in continuous years, larger values of FDI can be obtained in the BRIC countries of India, Brazil China, eco-efficiency performance with the increase of FDI value decreases first and then increases, showed a U-shaped relationship. This conclusion shows that when China, India and Brazil three countries had FDI investment in the beginning, the country's own eco-efficiency performance is greater than the initial eco-efficiency performance caused by introduction of FDI investment. So we can get the results that the environmental pollution caused by early stage of foreign investment in the three

countries is larger, but with the increasing of the scale of investment, foreign investment will gradually improve the technical level and to reduce environmental pollution to a certain extent, so with the amount of foreign investment increasing, the three national eco-efficiency performance decreases gradually. But in South Africa when foreign investment gradually increased, its eco-efficiency performance has been reduced, according to the conclusions of other scholars in the past. We can get the results that South Africa is not get too much foreign investment currently. The SA is still in the primary stage of foreign investment, so environmental pollution caused by foreign investment in South Africa is going beyond the limit of their ability to reduce pollution. But in Russia, Russia has a long time to invest of foreign investment because of the huge amount of foreign investment in Russia. Therefore, its eco-efficiency performance is increasing with the increase of foreign investment. At this time, foreign investment will pay a positive effect on the improvement of Russia's environment.

Conclusion

This paper uses a time-dependent conditional SBM model and nonparametric regression and test techniques to examine the effect of FDI on eco-efficiency performance. This paper uses the data from China Network (2017) and from the "manual" BRICs statistics. And the dollar is traded against a variety of currencies, in accordance with the exchange rate of January 24, 2018 and the energy data comes from the world energy statistics yearbook (2017). In this paper, the sample covering 5 developing countries during the period of 2008-2015 is collected for the empirical study. The main findings are as follows. First, the results of the nonparametric significance test suggest that FDI significantly affect the production process and positively affect the eco-efficiency performance. Second, there is a U-shape relationship between FDI and eco-efficiency among the three countries. Which means the countries' eco-efficiency performance would decrease with FDI up to a certain level; after this level, countries' eco-efficiency performance would benefit from FDI. In fact, these results are only appeared in three countries of BRICs. The South Africa and Russia are in the different stage of FDI.

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