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Effects of FDI on Environment Pollution based on Carbon Dioxide Emissions in the Pearl River Delta Region

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ABSTRACT

Issues related to global climate change have attracted widespread attention around the world, and China is no exception. With the introduction of a huge number of foreign direct investment (FDI), carbon dioxide emission pollution, such as ocean acidification, has become a serious threat in the Pearl River Delta (PRD) region. This study constructs models to analyse the effects of FDI on carbon dioxide emissions in the PRD region, as well as to analyse the scale, technique and composition effects in the area. Results indicate that the introduction of FDI can effectively reduce carbon dioxide emissions in the region because the foreign capital could bring environmental-friendly and energy-saving technologies, reduce carbon dioxide emissions per unit of GDP, and lessen damage to the environment. In addition, foreign capital flowing into the secondary sector has caused more serious damage to the environment than those flowing into the tertiary sector. Therefore, the area should actively guide foreign investment into industries with lower pollution and lower emissions. At the same time, strict standards should be developed to slow down the inflow of foreign capital in sectors which are energy-intensive, environmentally damaging, and have low levels of value-added production.

INTRODUCTION

The Pearl River Delta (PRD) region is a major economic zone in China. The economically developed PRD is considered an open region which consists of Shenzhen, Dongguan, Huizhou, Zhuhai, Zhongshan, Jiangmen, Guangzhou, Foshan and Zhaoqing. However, the influx of massive foreign direct investment (FDI) in the region has resulted in serious environmental pollution, especially carbon dioxide emissions. Massive fossil fuel consumption produces nasty side effects, such as climate change and acidified oceans (Mohapatra & Mohapatra 2008). For example, ocean acidification results from too much carbon dioxide reacting with seawater to form carbonic acid. In recent years, ocean acidification in the South China Sea has worsened. The consequences of ocean acidification include the shrinking of coral islands and disappearance of coral reefs. By disrupting the fundamental processes of growth and reproduction, ocean acidification threatens the health and survival of species. Rising ocean temperatures, water pollution, and ocean acidification continually pummel the reefs and cause mass coral bleaching.

Although the PRD region is already in the process of trying to transform its pattern of economic development, save energy and reduce emissions, it still faces heavy pressures. During the early years, FDI in the PRD region tended to be oriented towards industries with low added value and high energy consumption. In recent years, the PRD region has accelerated efforts to upgrade the industrial structure, as well as explored the idea of establishing foreign investment selection criteria. It is necessary to study the correlation between FDI and carbon dioxide emissions in the PRD for the dual purposes of transforming the pattern of economic development and promoting industrial structural in the region. Effective approaches should be explored on this basis to achieve energy saving and emissions reductions and improve the quality of foreign investment as a reference for other regions in China. Addressing the issue of environmental destruction necessitates the study of the relationship between FDI and carbon dioxide pollution. The PRD region should establish a regulatory framework that treats carbon dioxide emissions as pollution and set goals for reduction in energy use and pollution emissions.

STATE OF THE ART

In recent years, many studies have warned of impending disasters resulting from climate change and global warming. In these studies, carbon dioxide has been identified as the most common greenhouse gas. With the expansion of scientific research into carbon dioxide emissions, climate

scientists have agreed on the urgency of understanding the threat of global climate change (Stocker 2013). In the 20th century, atmospheric concentrations of key greenhouse gases have increased due to the corresponding increase in human activities. Climate change resulting from increased atmospheric carbon dioxide concentration has been reported to be irreversible for 1,000 years even after emissions have stopped (Solomon et al. 2009). For example, the climate in southwestern North America would become more arid throughout the current century as a consequence of rising greenhouse gases (Seager & Vecchi 2010). Other scholars have indicated the need for new diplomatic strategies. Suggestions have been made for diplomats to consider pollutants other than carbon dioxide, such as soot, which would be easier to regulate in the international community (Burney et al. 2013). Understanding the various ways to decrease CO_2 emissions would influence global temperatures.

Many studies have demonstrated the relationship between FDI and environmental pollution, and tested "Pollution Halo Hypothesis" and "Pollution Haven Hypothesis". Shahbaz et al. (2015) investigated the nonlinear correlation between FDI and environmental degradation. Their study revealed that FDI increased environmental degradation, which confirmed the pollution haven hypothesis (PHH). Most studies have ignored the heterogeneity of FDI; further, FDI in a host country has been affected by local environmental regulations and those implemented in proximate countries. In some countries, export-oriented FDI has exhibited greater sensitivity to local environmental regulations than local market-oriented FDI (Tang 2015). Saboori et al. (Saboori et al. 2015) investigated the existence of the environmental Kuznets curve (EKC) hypothesis in Vietnam from 1981 to 2011, and found that PHH exists in Vietnam because foreign capital increased pollution. However, the EKC hypothesis did not exist because the relationship between GDP and pollution was positive. Several studies on the relationship between energy consumption and FDI have been carried out. Hassaballa (2014) reported the presence of a two-way relationship between FDI inflows and emissions from energy use. Omri et al. (2014) investigated causality links among CO_2 emissions, FDI and economic growth by using dynamic simultaneous-equation panel data models, and revealed bidirectional causalities between FDI inflows and economic growth for all the panels and between FDI and CO_2 for all the panels, except in Europe and North Asia.

Almost all related research have agreed that CO_2 is a major greenhouse gas, and thus, studies on the correlation between FDI and carbon dioxide emissions have focused on empirical research. Ren et al. (2014) suggested that large FDI inflows further aggravated CO_2 emissions in China. In addition, the per capita income and CO_2 emission relationship of the industrial sector showed an inverted-U environmental Kuznets curve. Therefore, China should exert efforts to transform its trade growth mode, adjust foreign investment structure, strengthen energy efficiency, and develop a low-carbon economy. Khalil & Inam (2006) conducted regression analysis on time series Pakistan data from 1972-2002 and found that FDI had a positive effect in reducing carbon dioxide emissions. However, Jorgenson (2007) believed that the introduction of FDI increased carbon dioxide emissions. FDI has increased carbon dioxide emissions of host countries because FDI has been used to transfer high-energy-consuming industries to developing countries with weak environmental regulations (Grimes & Kentor 2003).

Also, many studies have believed that the influence of FDI on carbon dioxide emissions had a correlation with other factors. Heil & Selden (2001) indicated that FDI played a significant role in accelerating carbon dioxide emissions in low-income countries but had an insignificant impact on the carbon dioxide emissions of high-income countries. Hoffmann et al. (2005) showed the causal relationship between FDI and the environmental pollution of a host country depended on the economic level of the host country. Lee (2009) found that FDI had a significant effect on carbon dioxide emissions in the short term. Generally, current research on the correlation between FDI and carbon dioxide emissions is not systematic or complete enough.

DATA SOURCES AND RESEARCH METHODS

In the literature, scholars usually break down the relationship between trade and the environment into scale, composition, and technique effects. This breakdown was first proposed by Grossman & Krueger (1995) in their study on sulphur dioxide and suspended particles. The method was then developed further by later researchers, such as Cole (2006) who applied this analytical framework to energy utilization, given that energy use is the main source of most air pollutants. This study adopts this analytical framework in analysing the impact of FDI on carbon dioxide emissions from three aspects: scale, composition and technique effects.

Data sources and data processing: The initial data used in this study came from statistics during the years 2006-2012 harvested from the China Energy Statistical Yearbook 2013, Guangdong Statistical Yearbook 2013 and China Statistical Yearbook 2013, and the data processing is following behind.

In the study, data of carbon dioxide emissions and data of the consumption of energy resources cannot be directly acquired from statistical yearbooks, only data of the total consumption of primary energy and electricity consump-

tion are available, which means carbon dioxide emissions can only be estimated. Data on carbon dioxide emissions in this paper consist of direct emissions from fossil fuels and indirect emissions from electricity. Energy consumption data released by the Intergovernmental Panel on Climate Change (IPCC) is multiplied by the carbon dioxide emission factor to calculate energy carbon dioxide emissions. As the nine cities have not specifically released final energy consumption data, their primary energy consumption is multiplied by the carbon dioxide emission factor. Based on the percentage of coal utilization, the National Development and Reform Commission (NDRC) suggests that the carbon content of coal is 67%. That means combusting 1kg of standard coal will emit 2.46 kg of carbon dioxide. Indirect emission from electricity is equal to power consumption multiplied by regional power grid baseline emission factor, and the regional power grid baseline emission factor is released by NDRC.

In this paper, the amount of actually utilized FDI is used. Only the value in USD is given for each year in the statistical yearbooks, so the study converts the USD value acquired from the statistical yearbooks into RMB based on the exchange rate for each year. The statistical yearbooks give the prevailing value, but analysis of the composition effect of FDI on carbon dioxide emissions will be affected by price fluctuations, so this paper takes the year 2000 as the base period and converts F into a constant price based on the consumer price index (CPI). As the measurement of per capita GDP in the statistical yearbooks is based on current prices, this paper takes the year 2000 as the base period and converts per capita GDP into a constant price based on the average per capita GDP index of each city. Several cities in the Pearl River Delta have not released total energy consumption data, so this paper uses data of energy consumption per unit of GDP and total GDP to estimate, which will have an influence on carbon dioxide emissions data. The measurement of per capita disposable income in the statistical yearbooks is based on current prices, so this paper takes the year 2000 as the base period and converts urban per capita disposable incomes into a constant price based on the CPI.

Research models: As there are many factors affecting carbon dioxide emissions, this study could not simply and directly use FDI data and carbon dioxide emission data from the Pearl River Delta region to create a treatment regression model and discuss the impact of constant increases in the scale of FDI on carbon dioxide emissions. Instead, the Carbon Kuznets Curve (CKC) is used to build a model of the scale effect of FDI on carbon dioxide emissions in the PRD region, and is expressed below.

$$LnC_{it} = \alpha_0 + \alpha_1 F_{it} + \alpha_2 EX_{it} + \alpha_3 IGRI_{it} + \alpha_4 GDI_{it} + \alpha_5 LnAGDP_{\mathrm{it}} + u_{it} \quad ...(1)$$

In the equation above, i=1,2,...9; t=1,2,...7; C_{it} refers to carbon dioxide emissions; F_{it} refers to foreign capital scale; FDI stands for the amount of actually used foreign investment; EX_{it} is the degree of dependence on exports, which is an indicator for measuring the foreign trade structure; $IGRI_{it}$ is the rate of contribution of industry to GDP, representing the economic development structure; GDI_{it} refers to new fixed asset investment; GDP_{it} refers to the scale of new fixed assets; and $AGDP_{it}$ is the per capita GDP representing the level of economic development.

Energy consumption per unit of GDP is a key indicator for measuring energy consumption levels as well as energy saving and cost reductions. The model shows the energy utilization level of a country, and directly reflects its energy technology. Therefore, this study conducted an empirical analysis on the energy consumption per unit of GDP of the PRD region, in order to study the technique effect of FDI on carbon dioxide emissions. Energy consumption per unit of GDP is then used as a dependent variable to build the technique effect model for the impact of FDI on carbon dioxide emissions.

$$UDE_{it} = \beta_0 + \beta_1 F_{\mathrm{it}} + \beta_2 RD_{it} + \beta_3 \mathrm{y}_{\mathrm{it}} + \varepsilon_{it} \quad ...(2)$$

In the formula, UDE_{it} refers to the energy consumption per unit of GDP, which is a variable that reflects energy technology; RD_{it} is the level of investment in scientific research; RD_{it} refers to the R&D expenditures; and y_{it} refers to urban per capita disposable income, which represents the living standard.

Composition effect refers to changes in economic structure that has an impact on carbon dioxide emission levels. A regression analysis is conducted to analyse the effect of proportions of FDI in three industry sectors on total carbon dioxide emissions in the PRD region. The correlation between independent and dependent variables is analyzed to reveal problems with the FDI structure in the region.

$$LnC_{it} = \eta_0 + \eta_1 f_{1it} + \eta_2 f_{2it} + \eta_3 f_{3it} + \sigma_{\mathrm{it}} \quad ...(3)$$

In the formula, C_{it} refers to carbon dioxide emissions; f_{1it} is the amount of actually utilized FDI in the primary sector; f_{2it} is the amount of actually utilized FDI in the secondary sector; and f_{3it} is the amount of actually utilized FDI in the tertiary sector.

As a special note, in this study, three different dependent variables are used to analyse the three effects of FDI on carbon dioxide emissions in PRD. For the scale effect, car-

bon dioxide emissions are used as the dependent variable to study the impact of the scale of FDI on carbon dioxide emissions. For the technique effect, energy consumption per unit of GDP is used as the dependent variable, which can reflect energy technology. As the scale of FDI increases, total carbon dioxide emissions may increase as well. However, due to the technique effect of FDI, energy efficiency may improve, thus reducing energy consumption per unit of GDP. Therefore, this study does not use the same dependent variable as the scale effect or composition effect when looking at the technique effect of FDI on carbon dioxide emissions.

RESULTS AND DISCUSSION

Panel data models can be classified into fixed effect models and random effect models based on the types of sample data used. In this study, Hausman tests were used to decide whether a fixed effect model or random effect model should be selected. In this section, Stata analysis software is used to study the scale, composite and technique effects of FDI on carbon dioxide emissions in the Pearl River Delta using the aforementioned panel data models. In accordance with common practice in academia, the contents of the hypothesis and random effects and serial correlation tests are not listed here in order to simplify the analysis process, because these contents have already been run by the software as precondition before we get the correct final results, and usually these contents are not very accurate, so these contents need to be corrected at last.

Results of the scale effect of FDI on carbon dioxide emissions: The goodness of fit of model regression for the scale effect of FDI on carbon dioxide emissions in the Pearl River Delta region is 0.9414, with a high degree of fit, indicating that the regression line has a good degree of fit toward the observed value. Table 1 shows that the coefficient sign of F is negative, indicating that the scale of FDI has a positive effect on carbon dioxide emissions. In other words, an increase in the scale of FDI can reduce carbon dioxide emissions in the PRD region. The coefficient sign of EX is positive, which indicates that increased foreign-trade dependence will increase carbon dioxide emissions in the PRD region. IGRI and GDI are not significant. Hence, changes in the contribution rate of industrial GDP and new asset size have an insignificant effect or have no effect on carbon dioxide emissions in the PRD region. The coefficient sign of AGDP is positive; thus, carbon dioxide emissions will continuously increase along with rapid economic development.

This is mainly the result of the technology spillover effect of FDI. The explanation for the scale effect is that foreign capital could bring environmental-friendly and energy-saving technologies, reduce carbon dioxide emissions per unit of GDP, and lessen damage to the environment. According to Table 2, we can also find that FDI has a positive effect on energy consumption per unit of GDP in the PRD region. So, Pollution Haven Hypothesis does not exist in the PRD region, and the region should actively introduce FDI, make the best use of foreign technological and personnel advantages, and promote low-carbon economy in an all-round way.

Results of the technique effect of FDI on carbon dioxide emissions: The goodness of fit of model regression for the technique effect of FDI on carbon dioxide emissions in the Pearl River Delta region is 0.8836, with a high degree of fit, indicating that the regression line has a good degree of fit towards the observed value. Both variables F and Y are significant, with a degree of confidence of 1%, while RD is not significant and the sign of F is negative. Table 2 indicates that the introduction of FDI has a positive technique effect on carbon dioxide emissions in the PRD region. In other words, a continuous increase in the scale of FDI can enhance the energy utilization level of the PRD region. The sign of variable Y is negative. Hence, an increase in per capita disposable income has a positive effect on the energy utilization level of the PRD region. Variable RD is not significant. Thus, the problems of carbon dioxide emissions and energy utilization have not drawn a great deal of attention from enterprises.

The increase of foreign direct investment and per capita disposable income can both effectively improve the energy utilization efficiency of the PRD region, and thus ease the carbon dioxide emissions. The explanation is FDI has brought about the improvement of production technology in the region. With the increase of per capita disposable income, the awareness of environmental protection is gradually enhanced. Enterprises are forced to carry out technological innovation of energy-saving and emission reduction, and thus improve the energy efficiency in the PRD region.

Results of the composition effect of FDI on carbon dioxide emissions: The goodness of fit of model regression for the composition effect of FDI on carbon dioxide emissions in the Pearl River Delta region is 0.5686. Despite being lower than that of the other two models, the degree of fit is relatively good. It can be directly seen from the above table that the regression coefficient of f_1 is not significant, while the regression effects of variables f_2 and f_3 are very good and their coefficients are significant, with a degree of confidence of 1%. The regression results indicate that the amount of FDI in the secondary sector has a positive correlation with carbon dioxide emissions in Table 3. The regression coefficient of variable f_3 is positive. Therefore, the

Table 1: Results of the scale effect of FDI on carbon dioxide emissions.

	Regression coefficient	Standard deviation	z-value	P>|z|
F	-0.0566***	.0136	-4.16	0.000
EX	0.0010***	.0003	3.38	0.001
IGRI	-0.0027	.0019	-1.42	0.156
GDI	-0.0016**	.0011	-1.56	0.018
AGDP	0.5662***	.1449	3.91	0.000
Cons	1.6406**	.7741	2.12	0.034
R^2	0.9414			

Table 2: Results of the technique effect of FDI on carbon dioxide emissions.

	Regression coefficient	Standard deviation	t-value	P>|z|
F	-0.0246***	.00603	-4.07	0.003
RD	-0.0001	.00011	-0.76	0.466
Y	-1.3713***	.10108	-13.57	0.000
Cons	7.2271***	.48490	14.90	0.000
R^2	0.8836			

Table 3: Results of the composition effect of FDI on carbon dioxide emissions.

	Regression coefficient	Standard deviation	t-value	P>|z|
f_1	-0.00894	.006048	-1.48	0.173
f_2	0.37318***	.029228	12.77	0.000
f_3	0.16686***	.007936	21.03	0.000
Cons	1.27206***	.166933	7.62	0.006
R^2	0.56860			

amount of FDI in the tertiary sector has a positive correlation with carbon dioxide emissions as well. By comparing the regression coefficients of variables f_2 and f_3, the coefficient of f_2 is more than two times that of variable f_3. If the same amount of FDI is introduced into secondary and tertiary sectors, the carbon dioxide emitted by the secondary sector is more than two times that emitted by the tertiary sector. Furthermore, the regression results show that FDI has an industrial composition effect on carbon dioxide emissions in the PRD region.

Therefore, the PRD region should improve environmental regulation specifications, set strict entry criteria for foreign capital, strengthen supervision of FDI, and guide foreign investment into industries with lower pollution and lower emissions. At the same time, strict standards should be developed to slow down the inflow of foreign capital in sectors that are energy-intensive, environmentally damaging, and has low levels of value-added production. The PRD region should also actively guide foreign investment to develop the tertiary industry, such as professional management consulting, technology research and financial services industry, which is strongly supported by the Pearl River Delta region.

CONCLUSIONS

The impact of FDI on carbon dioxide emissions in the PRD region is analyzed from the three aspects of scale, technique, and composition effects. Panel data (2006-2012) were used in the empirical analysis. The following statements indicate the research findings.

The introduction of FDI can effectively reduce carbon dioxide emissions pollution in the PRD region, which goes against PHH. This finding is the result of the technology spillover effect of FDI. When developed countries invest in the PRD region with their advanced technologies, the technology spillover effect is observed on production practices of local enterprises. Consequently, the technological level of local enterprises is improved, energy consumption level of the PRD region is enhanced, and carbon dioxide emissions are reduced.

FDI has a positive effect on energy consumption per unit of GDP in the PRD. This finding provides evidence for the above notion. Foreign investment is likely to bring advanced technology, reduce carbon dioxide emissions per unit of GDP, and lessen damage to the environment.

Foreign capital flowing into the secondary sectors has caused more serious damage to the environment than that flowing into the tertiary sector. FDI has a composition effect on carbon dioxide emissions in the PRD region. When the same amount of FDI is introduced into the secondary and the tertiary sectors, the amount of carbon dioxide emitted by the secondary sector is more than two times that emitted by the tertiary sector. The government should thus actively guide foreign investment into industries with lower pollution and lower emissions. Simultaneously, the government should develop strict standards to slow down the inflow of foreign capital in sectors that are energy-intensive, environmentally damaging, and with low levels of value-added production.

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