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Has the Development of FDI and Foreign Trade Contributed to China's CO_2 Emissions?

An Empirical Study with Provincial Panel Data

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Abstract

Since the reform and opening up in 1978, China's Foreign Direct Investment (FDI) and foreign trade have grown rapidly. At the same time, China's Carbon Dioxide (CO_2) emissions surged and China has become the world's biggest CO_2 emitter. The purpose of this paper is to investigate the relationship between FDI, foreign trade and Carbon Dioxide emissions in China. Using a two-equation model adapted from Halkos and Paizanos (2013), the total impact of FDI on emission is divided into the direct and indirect impacts and estimated accordingly. The results suggest that the increase in per capita FDI helps to inhibit the growth of China's per capita CO_2 emissions. Concretely, the dominating direct effect of FDI on carbon emissions is negative and the indirect effect is positive. However, for foreign trade, both direct and indirect effects on CO_2 emissions are insignificant after taking consideration of potential endogeneity and introducing dynamics.

Key words: **Foreign Direct Investment** **Panel Data** **CO_2 Emissions** **Direct and indirect impacts**

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1 Introduction

All economic activities interrelate with the environment, and FDI and trade are no exception. Since the 1990s, economic globalization has greatly stimulated the growth in international trade. In this context, China’s economy boomed during the last three decades. At the same time, more and more environmental problems have emerged, such as global warming, environmental deterioration and pollution. In essence, it's an inevitable conflict between the limited supply provided by the ecological system, which has certain self-stabilizing abilities, and the limitless demand for natural resources stemming from the trade activity, which demonstrates more of a self-expanding quality. Due to the externality of environmental pollution and the difficulty in defining the environmental property, the "market failure" and the "government failure" can hardly be avoided. Consequently, it has become a focus of academic research to study the relationship between economic development and environmental protection with the hope of finding the balance point.

Since the economic reforms in 1978, China's foreign trade and the inflow of FDI have increased rapidly, specifically after joining the World Trade Organization in 2001. To date, China has become the world's largest trading nation and the largest exporter. In 2013, the import and export trade of China amounted to \$ 4.16 trillion. The rapid growth of foreign trade has greatly promoted China's economic development. According to the International Energy Agency (IEA) statistics, in 2010, China's energy consumption accounted for 20% of total world energy consumption with a carbon emissions value of 6.8 billion tons, making it surpass the United States and become the world's largest carbon emitter. Consequently, China has been suffering from severe restriction on sustainable development domestically and enormous pressure during climate change negotiations internationally. Therefore, it is very important to investigate the relationship between FDI and trade and carbon emissions in China.

The growing literature on foreign trade and the environment suggests a potentially high level of interaction between trade liberalization and pollution. Grossman and Krueger (1991) provided a systematic analysis of the relationship between trade and the environment, which broke down the resultant impact into three parts-scale, composition and technique effect and established the basic framework for the analysis of the environmental effects of trade. Initially introduced by Grossman and Kruger (1991, 1995), the Environmental Kuznets Curve, or EKC, is a theory that describes an inverted U-shaped relationship between economic development and the environment: In the early stage of economic development, the pollution increases and the environment deteriorates; after the turning point of the pollution is achieved, the pollution decreases and the environment improves as the economy continues to grow. Currently, there are two main methods for this study. One method focuses on the carbon embodied in international trade while the other is the empirical study of the impact of FDI and trade on carbon emissions.

With regard to the calculation of embodied carbon and the discussion of its propelling factors, internationally, the research subjects and research methods have been increasing both in quantity and quality. A common practice is to calculate the embodied carbon in import and export based on input-output tables of the country of interest.

Since the early work of Leontief (1970), input-output analysis (IOA) has gained wide application. A lot of work has been done to estimate the pollution embodied in trade for many countries using a variety of assumptions. Here are some examples of the IOA approach: Wyckoff and Roop (1994) found that about 13% of the total carbon emissions from the six largest OECD (Organisation for Economic Co-operation and Development) countries were embodied in imports of manufactured products. Sánchez-Chóliz and Duarte (2004) found that “a slightly exporting behavior in the Spanish economy hides important pollution interchanges.” The study of Peters and Hertwich (2006) showed that “CO_2 emissions embodied in imports was 67% of Norway's domestic emissions. Around a half of this embodied pollution originates in developing countries." Shui and Harriss (2006) examined the influence of US-China trade on national and global carbon emissions of carbon dioxide and suggested that "the export of US technologies and expertise related to clean production and energy efficiency to China could be a 'win-win' strategy for both countries for reducing their trade imbalance and mitigating global CO_2 emissions". Yunfeng and Laike (2010) estimated the amount of carbon dioxide embodied in China's foreign trade during 1997–2007. It was found that 10.03%–26.54% of China's annual CO_2 emissions were produced during the manufacture of export goods destined for foreign consumers, while the CO_2 emissions embodied in China's imports accounted for only 4.40% at 1997 and 9.05% at 2007. Most recently, the study of Mizgajski (2013) found that Polish exports contained significantly more embodied carbon than Polish imports, despite the fact that the level of the imports was higher. The study of Ren et al. (2014) calculated CO_2 emissions embodied in China's international trade using an input–output analysis, for the period 2000–2010. The results suggested that China's growing trade surplus was one of the important reasons for the rapidly rising CO_2 emissions.

The Pollution Haven Hypothesis (PHH) could potentially explain such trade patterns. The PHH claims that differences in the stringency of environmental regulations between the North and the South will provide the latter with a comparative advantage in pollution intensive production. Now there are many empirical studies of the impact of FDI and trade on carbon emissions. Copeland and Taylor (1994) used a simple static model of North-South trade to examine the linkages between national income, pollution, and international trade. They claimed that "free trade increases world pollution, an increase in the rich North's production possibilities increases pollution, while similar growth in the poor." Cole and Elliott (2003) argued that pollution-intensive sectors may be subject to opposing forces of comparative advantage since these sectors are also typically capital intensive, yet regions with low environmental regulations tend to be least abundant in capital stock. Cole (2004) estimated EKCs for 10 pollutants while controlling for the share of GDP in manufacturing, trade openness, and dirty trade flows. He found evidence that trade openness and the proportion of dirty imports affect emissions in developed countries, offering support for the PHH. However, he noted that the effect is small relative to other determinants of emissions. Eskelanda and Harrison (2003) also examined the PHH hypothesis. By asking the question whether multinationals were flocking to developing country "pollution havens", they found some evidence that foreign investors are more willing to locate in sectors with high levels of air pollution. However, the evidence was weak at best. Kearsley and Riddel (2010) estimated EKCs for seven oft-studied pollutants, and their regression results indicate that trade openness is not generally correlated with increased emissions. Using the data of Turkey over the period of 1987Q1–2009Q4, the analysis of Mutafoglu (2012) suggested that there is a stable long-term equilibrium relationship among the variables under consideration. However, there appears to be no evidence of FDI-led growth in the data.

Although the existence of traditional EKC is still controversial, as long as the environmental condition is related with economic growth, FDI and trade will play a role. Thus, it is still worthwhile to look into the impact of FDI and trade on the environment in China. Part of the impact is indirect, because FDI and trade influence economic growth first, which in turn may pose impact on the environment. Besides, FDI and trade will have direct impact on carbon emissions. On the one hand, advanced foreign technology will be introduced by way of FDI, which will improve energy efficiency and reduce carbon emissions in China. On the other hand, the possible introduction of some high-polluting industries would worsen environmental pollution. Both factors will directly affect China's carbon dioxide emissions. In accordance with previous studies, we also distinguish between the direct and indirect effects of FDI and trade on China's carbon emissions. The panel data of 29 provinces covering the period between 1995 and 2011 are utilized to estimate a two-equation model. So far as we know, there has been no research on the direct and indirect impacts of FDI and trade on Carbon Emissions. Therefore, to divide the total impact of FDI and trade into direct and indirect effects and make proper estimations accordingly is the main contribution of this study.

2 Methodology and Data

2.1 Methodology

Following suit of Halkos and Paizanos (2013) and Hao et al. (2014), the proposed model consisted of two equations jointly estimated, one being a conventional square formulation of the EKC augmented by the FDI/ foreign trade and the other expressing income as a function of FDI/ foreign trade and other factors. The regression specifications for FDI are represented as equations (1) and (2) below:[1]

$$\ln(CO_2/c)_{it}=\mu_i+\delta_t+\alpha_1\ln(FDI/c)_{it}+\alpha_2\ln(GDP/c)_{it}+\alpha_3(\ln(GDP/c))_{it}^2+\alpha_4X_{it}+\varepsilon_{it} \quad (1)$$

$$\ln(GDP/c)_{it}=\gamma_i+\tau_t+\beta_1\ln(FDI/c)_{it}+\beta_2Z_{it}+u_{it} \quad (2)$$

Where subscripts i and t represented province and time respectively and all variables were expressed in natural logarithms, unless otherwise stated.

Eq. (2) was based on the economic growth equation proposed by Solow in 1956. In this model, Solow assumed a two-factor Cobb - Douglas production function: $\mathrm{Y}=\mathrm{F}(\mathrm{K},\mathrm{L})=K^{\alpha}\cdot L^{1-\alpha}$, in which Y, K and L represent output, domestic capital stock and labor force, respectively; α and 1-α stand for the output elasticities of capital and labor, respectively. As summarized by de Mello (1997) and Yao and Wei (2007), the domestic capital stock and FDI might play different roles in production for several reasons: first, FDI could help to speed up the adoption of general purpose technologies (GPT) in the host countries; second, the technologies and know-how embedded in the foreign investors are usually more advanced and inaccessible in the host countries; third, through the introduction of alternative management practices and better organizational arrangements, FDI may stimulate knowledge transfers both in terms of labor training and skill acquisition. As a result, FDI should be treated as another factor of production which has a similar status as domestic capital stock. In other words, the Cobb-Douglas production function could be written as $\mathrm{Y}=\mathrm{F}(\mathrm{K},\mathrm{L},\mathrm{FDI},)=K^{\alpha}\cdot L^{\beta}\cdot(FDI)^{\gamma}$.[2] Dividing both sides of the equation with L yields the production function in per capita terms: $\mathrm{y}=k^{\alpha-\beta}\cdot(FDI/L)^{\gamma-\beta}$, where the lowercase characteristics y and k stand for GDP per capita and domestic capital stock per capita, respectively. By taking the logarithm, we obtain the specification of Eq. (2).

In the first formula, we estimated the impact of FDI on carbon emissions with the environmental EKC equation. After estimating Eq. (2), the fitted values of GDP per capita were calculated based on the estimates of the coefficients of Eq. (1). These fitted values of GDP per capita rather than their original values were used in Eq. (1) to capture the indirect effect of FDI on the environment. By the fitted values, we could use the chain rule to take derivatives. As a result, the total impact of FDI on environment could be evaluated according to the following equation, which measured how much carbon emissions would change as the level of FDI changes by one percentage:

$$\frac{\mathrm{d}\ln(\mathrm{CO_2/c})}{\mathrm{d}\ln(\mathrm{FDI/c})}=\frac{\partial\ln(\mathrm{CO_2/c})}{\partial\ln(\mathrm{FDI/c})}+\frac{\partial\ln(\mathrm{CO_2/c})}{\partial\ln(\mathrm{GDP/c})}\cdot\frac{\partial\ln(\mathrm{GDP/c})}{\partial\ln(\mathrm{FDI/c})} \quad (3)$$

The first expression on the right side of Eq. (3) stood for the direct effect of the FDI on the environment, while the second estimated the indirect effect. The sum of the two effects was the total effect of the FDI on carbon emissions, as showed in Figure 1.

The most appropriate method to estimate Eqs. (1) and (2) is the Generalized Method of Moments

[1] To save space, only regression equations for FDI are represented here. The regression equations for foreign trade are similar, and the only difference is to substitute FDI with foreign trade. For the same reason, in following equation (3) and Figure 1 FDI is used, but we could also simply use foreign trade to replace FDI as the research target.

[2] The similar forms of production function with domestic capital stock or investment and FDI as different input factors have been utilized in several researches, including Madariaga and Poncet (2007), Yao and Wei (2007), Lan et al. (2012), Yang et al. (2013).

(GMM) developed by Arellano and Bover (1995) and Arellano and Bond (1998). Compared with the conventional OLS method and the fixed- or random-effects for panel data, GMM has several apparent advantages. First, GMM allows incorporating the lags of dependent variable and regressors as predetermined explanatory variables. In this way the dynamics could be easily taken into account. Second, GMM could put under control the potential inertia that may exist when the dependent variables are determined. Third, the potential reverses causality biases of the regressors by setting predetermined and exogenous variables as instruments in a reasonably systematic way. Bond et al. (2001) pointed out that the first difference GMM method was prone to large downward bias when there were not many time series of observations. Given that our sample data only ranged from 1995 to 2011, we regarded the results generated by SYS-GMM method as the most reliable.

2.2 Data

Our sample consisted of 29 provinces with a full set of CO_2, GDP/c, FDI/c and other explanatory variables information for the period of 1995–2011. The analysis ended at the year 2011 because of limited availability of data on CO_2. Consequently, for reasons of comparability, we also performed the analysis of TRADE (the sum of import and export)/c.

We choose both the environment impacts of FDI and foreign trade as the research targets, because there exists high correlation between these two indicators, and they both reflect the openness of a country. In fact, many researchers have analyzed the influences of FDI and foreign trade on China's economic performance at the same time (e.g. Branstetter and Feenstra, 2002; Liu et al. 2002; Yao, 2006), and Liu et al. (2001) and Liu et al. (2002) found empirical evidence that there exists causal relationship between China's imports, exports and FDI. Due to the close relationship between FDI and foreign trade, in this paper we investigate both of them, and the estimation results on the basis of foreign trade could be treated as a robustness check for the results for FDI.

The other explanatory variables included domestic capital stock per capita, population growth rate, and the ratio of secondary industry in GDP. The first two variables are generally included in standard growth regressions, while the last one is often used as controlling variable in regressions examining the EKC-type relationships. The data for FDI, foreign trade volume, population and nominal GDP were collected from *China Statistic Yearbook* 1996-2012. Then simple calculations were done to obtain population growth rate and real GDP per capita that is measured at constant 1978 price. As stressed by many researchers, measuring capital stock in China is a challenging task. In this study, the perpetual inventory method suggested by He et al. (2007) was utilized to compile the domestic capital stock. It is noteworthy that the similar method to calculate domestic capital stock was also employed by Yao and Wei (2007) and Yang et al. (2013).

Because there have been no official statistics for CO_2 emissions in China, the provincial CO_2 emissions were calculated using data of energy consumptions and cement production on the basis of the estimation method suggested by IPCC (2006). Concretely, the total CO_2 emissions from fossil fuel combustions were estimated using the formula:

$$\mathrm{EC} = \sum_{i=1} EC_i = \sum_{i=1} E_i \times EF_i \tag{4}$$

where EC denotes the total CO_2 emissions from the use of fossil fuel; EF_i is the emission factor of the ith type of fossil fuel. Because the CO_2 emissions generated from cement production are also considerable, we also consider the CO_2 emissions produced in cement production in this study.[3] The total CO_2 emissions from the cement production were calculated using the formula:

$$\mathrm{CC} = Q \times EF_{cement} \tag{5}$$

[3] According to the estimations of the CDIAC and Liu et al. (2009), CO_2 emissions from cement production account for approximately 10-15% of total CO_2 emissions in China.

where CC denotes the total CO_2 emissions from the cement production, Q is the cement output, and EF_{cement} represents the CO_2 emission factor of cement. The total CO_2 emissions are therefore the sum of EC and CC. Because the carbon emissions embodied in China's exports have already been generated within the territory of China (Shui and Harriss, 2006; Yunfeng and Laike, 2010), the CO_2 emissions calculated using this method have accounted for the embodied carbon emissions in China's foreign trade.

As a brief description, the statistics and definitions of the variables used in this research are showed in the following table.

Table1. Sample Statistics and Definitions

Variable	**Means**	**Standard deviation**	**definition**
ln(FDI/c)	4.198	1.598	Logarithmic per capita FDI (1978 yuan)
ln(TRADE/c)	6.323	1.661	Logarithmic per capita TRADE (1978 yuan)
ln(CO_2/c)	8.163	0.606	Logarithmic per capita CO2 emissions (kg/person)
ln(GDP/c)	8.073	0.757	Logarithmic per capita GDP (1978 yuan)
ln(K/c)	9.260	0.816	Logarithmic per capita domestic capital stock (1978 yuan)
Popgrowth	0.969	1.470	Population growth rate, year-on-year

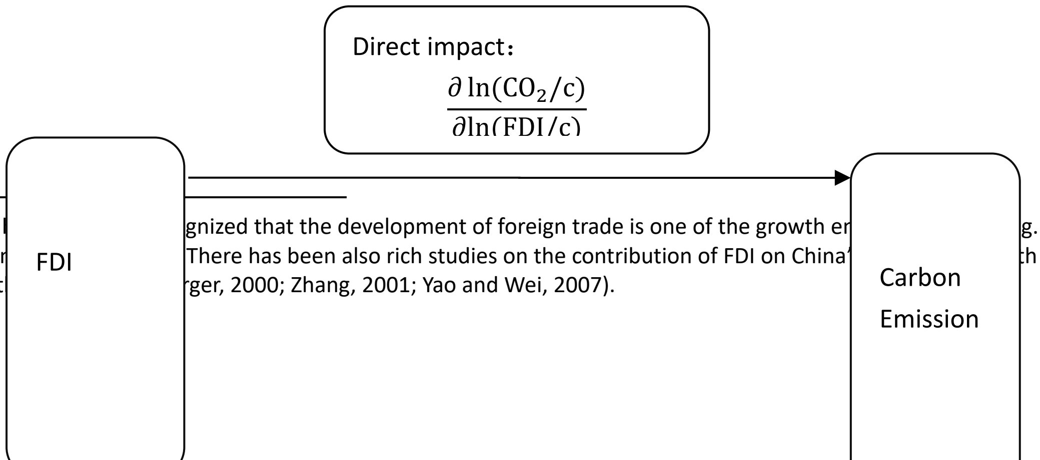
2.3 Research framework

The purpose of this study is to investigate how FDI and foreign trade would affect pollution in China. In doing so, following Halkos and Paizanos (2013), the total impact is divided into the direct impact and indirect impact. On the one hand, because the increase in FDI and foreign trade would foster economic growth, and also because the possible relationship between GDP per capita and pollution as predicted by EKC, the FDI and foreign trade may affect pollution indirectly through their effects on GDP per capita.[4]

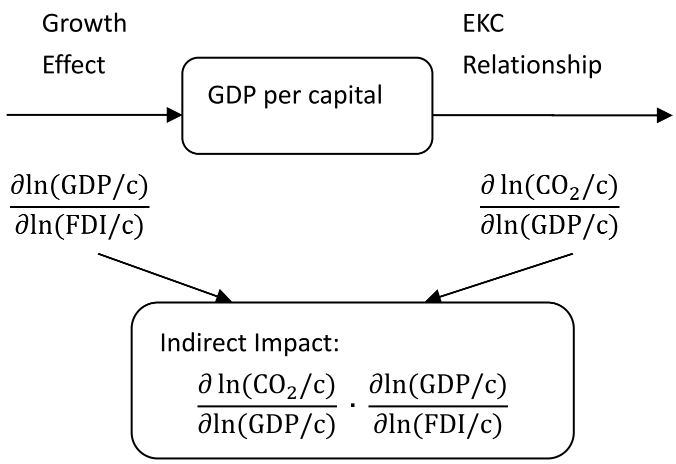
On the other hand, FDI and foreign trade may also affect pollution in a direct way. As discussed previously, an influential theoretical hypothesis that states that FDI may affect environmental quality directly is so called "pollution havens" hypothesis. Foreign trade also has direct impact on pollution. First of all, processing trade accounts for a considerable part of total trade volume in China, but the pollution produced by the processing trade enterprises is usually high, because the processing trade undertook by China is generally done by low-end and pollution-intensive industries. Besides, primary products and industrial products such as steel, glass and cement are also important to China's export, but the producers of these products usually utilize backward technologies, consume large amounts of energy and generate heavy pollution (Zhang and Wen, 2008).

In order to present the research idea of this study intuitively, in following Figure 1 the two components of total impact of FDI on environment – the direct and indirect impacts – are distinguished and shown. The measurements of these two impacts are also depicted.

Figure1. Research Framework



[4] It ... gnized that the development of foreign trade is one of the growth en... g. Lardy, 1992; Chen... There has been also rich studies on the contribution of FDI on China'... h (e.g. Bert... ger, 2000; Zhang, 2001; Yao and Wei, 2007).



3. Results Analysis and Discussion

Eq.(2) was estimated first to get the impacts of FDI and trade on GDP. Table 2 and Table 3 depict the results by employing different estimation approaches.

Table2. Estimates of the impact of FDI on GDP per capita

	FE	Diff-GMM	Sys-GMM
ln(FDI/c)	0.025***(0.007)	0.049**(0.022)	0.274***(0.077))
ln(K/c)	0.927***(0.009)	0.928***(0.043)	0.713***(0.079)
Popgrowth	0.006*(0.003)	-0.018(0.012)	-0.046**(0.021)
R^2	0.9719		
F test	0.000		
Hausman	0.001		
Wald test		0.000	0.000
Hansen test		0.038	0.677
A-B test of AR(1)		0.895	0.045
A-B test of AR(2)		0.003	0.681
Nobs/provinces	493/29	464/29	493/29

Note: Standard errors are in parentheses. The probabilities are reported for all tests. The meanings of all variables are shown in Table 1. *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

Table3. Estimates of the impact of trade on GDP per capita

	FE	Diff-GMM	Sys-GMM
ln(TRADE/c)	0.098(0.013)	0.098***(0.017)	0.161***(0.046)

ln(K/c)	0.836***(0.016)	0.854***(0.032)	0.727***(0.064)
Popgrowth	0.004(0.003)	-0.014(0.011)	-0.058(0.021)
R^2	0.9746		
F test	0.000		
Hausman	0.000		
Wald test		0.000	0.000
Hansen test		0.023	0.588
A-B test of AR(1)		0.861	0.063
A-B test of AR(2)		0.002	0.104
Nobs/provinces	493/29	464/29	493/29

Note: Standard errors are in parentheses. The probabilities are reported for all tests. The meanings of all variables are shown in Table 1. *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

The first column reports the fixed-effects (FE) estimates of stationary panel data. We included it to address the potential correlation between the cross-section specific error-component and the explanatory variables. Moreover, the Hausman test results supported the usage of FE approach. In the following two columns, the results of both first-difference GMM and SYS-GMM estimates are reported. As mentioned above, we chose the results of sys-GMM method as the most appropriate. In the GMM estimation, the per-capita capital stock is treated as an endogenous variable. In all the results of SYS-GMM method, AR (1) is rejected, indicating that there is no first order correlation, while AR (2) is accepted, indicating the existence of second order correlation. Hansen test is used to check the validity of instrumental variables, where the null hypothesis is accepted, indicating that the overall tool is effective.

It is shown in table2 and table3 that the coefficients of foreign trade and FDI are significantly positive, which suggests that FDI and trade have a significantly positive effect on GDP. Therefore, the sign of $\frac{\partial \ln(\mathrm{GDP/c})}{\partial \ln(\mathrm{FDI/c})}$ in Eq. (3) is significantly positive. Utilizing the fitted values of per capita GDP, Eq. (1) is estimated in the following table, where both FE and GMM approaches are used as well.

Table4. Estimates of Eq. (1) with FDI independent variable

	FE	**Diff-GMM**	**SYS-GMM**
ln(FDI/c)	-0.125***(0.021)	-0.165***(0.045)	-0.091***(0.258)
ln(GDP/c)	0.463***(0.157)	-0.219(1.057)	1.172***(0.434)
$(\ln(GDP/c))^2$	-0.003(0.010)	0.040(0.070)	-0.056**(0.027)
Secondind	2.065***(0.199)	3.230***(0.986)	0.536**(0.027)
R^2	0.9277		
F-test	0.000		
Hausman FE v RE	0.000		

Wald test		0.000	0.000
Hansen test		0.314	0.999
A-B test of AR(1)		0.040	0.001
A-B test of AR(2)		0.825	0.548
Nobs/provinces	493/29	435/29	464/29

Note: Robust standard errors are in parentheses. The probabilities are reported for all tests. The meanings of all variables are shown in Table 1. *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

Table5. Estimates of Eq. (1) with trade independent variable

	FE	**Diff-GMM**	**SYS-GMM**
ln(TRADE/c)	-0.102***(0.026)	0.054(0.049)	-0.029(0.022)
ln(GDP/c)	0.623***(0.196)	-0.540(0.824)	1.180***(0.427)
$(\ln(GDP/c))^2$	-0.017(0.013)	0.048(0.054)	-0.060**(0.026)
Secondind	2.027***(0.198)	1.520(1.055)	0.634***(0.276)
R^2	0.9278		
F-test	0.000		
Hausman FE v RE	0.259		
Wald test		0.000	0.000
Hansen test		0.313	0.999
A-B test of AR(1)		0.011	0.001
A-B test of AR(2)		0.883	0.462
Nobs/provinces	493/29	435/29	464/29

Note: Robust standard errors are in parentheses. For all tests the probabilities are reported. The meanings of all variables are shown in Table 1. *, ** and *** indicate 10%, 5% and 1% significance levels, respectively.

In the GMM estimation the first order lag of CO_2 and the secondary industry are treated as endogenous variables. The key results are as follows：

First, the coefficients of FDI are significantly negative at the 1% level in both the dynamic and the static models, which indicates that the direct effect of FDI on China's carbon emissions is negative. On the one hand, the technological level of foreign direct investment is generally higher than that of China's at the present stage. The FDI’s technological spillover enhances the country's total factor productivity and technology level quite remarkably, which will improve the resource use efficiency in the production process. On the other hand, foreign direct investment makes more funds and technology available for the improvement of the environment, which facilitates the exchange between environmentally friendly products, services and technologies. Therefore, FDI could help to reduce the growth of China's carbon dioxide emissions.

Second, for foreign trade, the coefficient is significantly negative in the fixed effects estimates, but the coefficients in the GMM model are not significant. Moreover, the coefficient in diff-GMM model is positive, while that in the system GMM is negative. The result reflects that the potential environmental influence of foreign trade might not be so important when the effect of industrial structure is reasonably accounted for. Part of the reason might be the higher level of technologies and environmental awareness of enterprises with foreign investments compared with those of domestic ones. There are a large number of high-pollution and high-emission products in the exports of China. On the other hand, China still has a great volume of processing trade, which relies heavily on labor and energy and often results in higher emissions and pollution.

Third, the overall effect of GDP on CO_2 emissions reflected by Eq.(1) is inverted U-shaped. Specifically, the positive sign with income and negative sign with the quadratic term of income confirms the existence of EKC for CO_2 emission in the case of China. As indicated by the first half of the inverted U shape, when the GDP is not high enough, as is the case for the Chinese data, CO_2 emissions per capita increases as GDP per capita increases. It is noteworthy that the coefficients of the ratio of second industry value-added to GDP are estimated to be highly significant in all models, consistent with the long-established statement that the industrial structure plays an important role in determining the emissions of CO_2.

By using the results above, the direct, indirect and total effects of FDI and foreign trade on the environment could be calculated based on Eq. (3). Since the indirect effect and thus the total effect depend on the level of income, the effects in Table 6 are calculated based on the sample median level of income. The estimates by SYS-GMM approach are chosen as benchmark estimates because the SYS-GMM estimates shown in Tables 4 and 5 are the most reasonable.

Table6. Impact of FDI and trade on CO_2

	FDI			**TRADE**		
Effects	Fe	Diff-GMM	Sys-GMM	Fe	Diff-GMM	SYS-GMM
Direct	-0.125***	-0.165***	-0.091***	-0.102***	0.054	-0.029
Indirect	0.114	0.117	0.073	0.056	0.038	0.034
Total	-0.011	-0.048	-0.018	-0.046	0.092	0.005

Note: robust standard errors in parentheses. * Significant at 10%., ** Significant at 5%, ***Significant at 1%.

As indicated in table 4, there is a negative direct effect of FDI on CO_2 emissions as estimated by all models. For SYS-GMM results in particular, an increase of FDI by 1%, ceteris paribus, results in a 0.091% reduction of CO_2/c. The indirect effects are positive at the median income level due to the positive relationship between income and emissions at the median income level. Additionally, the estimated direct effects are notably larger than the indirect effects, leading to a negative total effect of FDI on CO_2 emissions. In one word, an increase in the FDI leads to a reduction in CO_2 emissions during the sample period. At the same time, the direct effect of foreign trade on CO_2 is not significant. Trade has a positive but statistically insignificant impact on CO_2 emissions.

To test for the robustness and reliability of this study, it is necessary and interesting to compare our conclusions with those of similar researches. Our finding is similar to that of Zhou et al. (2012), who found that FDI would reduce CO_2 emissions by inducing technical innovation. This conclusion is also consistent with that of Al-mulali and Foon Tang (2013) who reported that inflows of FDI in gulf cooperation council (GCC) countries would lower carbon emission intensity because foreign investment firms possess a higher level of clean production technology and pay more attention to environmental effects of production. In a recent research, using China's provincial data, Lan et al. (2012) found that the impact of FDI on CO_2 emissions depends on the level of human capital: FDI has negative influence on pollution emissions in provinces with higher levels of human capital, whereas the relationship between FDI and pollution emissions is positive in provinces with the lower levels of human capital. This conclusion is to some extent consistent with our findings that the direct and indirect impacts of FDI on CO_2 emissions have different signs, because the negative indirect impact of FDI on CO_2 emissions is more obvious when provincial per capita GDP is high. Generally speaking, the provinces with higher amount of human capital tend to have higher GDP per capita. It is noteworthy that our finding contradicts the conclusion of Ren et al. (2014b) who found that FDI and trade comparative advantage are two main elements boosting China's carbon emissions. However, because Ren et al. (2014b) investigated the CO_2 emissions of China's industry sectors which contributed most CO_2 emissions in China, in a strict sense their estimation results are not comparable to those of this study.

4. Conclusions

This paper examined the impacts of FDI and foreign trade on CO_2 emissions in China. Using a two equation model jointly estimated and the sample of 29 provinces for the period between 1995 and 2011, both the direct and indirect effects of per capita FDI and per capita trade volume on CO_2 emissions are estimated.

According to the estimation results, ceteris paribus, the direct effect of FDI on carbon emissions is negative and the indirect effect is positive, and the direct effect dominates the indirect effect. Therefore, FDI helps to inhibit the growth of China's carbon dioxide emissions on the whole. As for foreign trade, the direct and indirect effects on carbon dioxide emissions are statistically not significant after controlling for the endogeneity and introducing dynamics. The empirical results of this study show conclusive evidence for the existence of EKC and also confirm that the secondary industry plays a key role in China's CO_2 emissions.

From these results, several policy implications could be made as follows.

1. China should continue to actively introduce foreign investment, exploit the advanced clean technology brought by foreign enterprises, and strengthen the cooperation with developed countries in low-carbon industry. Foreign capital should be used for promoting the industrial technical level and the efficiency of resource utilization. It is advisable to strengthen guidance for foreign investment in the industrial sector (Ren.et al 2014). In the meantime, China should increase the environmental standards and improve the efficiency of energy use.

2. When the GDP is not high enough, as is the case for the Chinese data, CO_2 emissions per capita would increase as GDP per capita increases. Contrarily, the increase in the high income levels of GDP per capita will reduce carbon emissions. Since China has not yet reached the turning point of CO_2 emissions, the contaminations will not go away by themselves. Therefore China should maintain reasonable economic growth before finally solving the environmental problem.

3. The results suggest that secondary industry has a great impact on CO_2 emissions in China, since the secondary industry accounts for about 40% of China's GDP but consumes about 70% of energy in China. Therefore, China should strongly encourage the growth of sectors with high energy efficiency in the

secondary and the tertiary industries while decreasing the reliance on the manufacture industries with low energy efficiency.

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