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Research Article

The Heterogeneous Effects of FDI and Foreign Trade on CO_2 Emissions: Evidence from China

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The environmental impacts of foreign direct investment (FDI) and foreign trade have attracted much attention recently. This paper employs panel quantile regression to explore the effects of FDI and foreign trade on Chinese provincial CO_2 emissions for the period of 1997-2014. The results indicate that the effect of FDI on CO_2 emissions is negative and significant except at the 5^{th} and 10^{th} quantiles. Foreign trade has a significant negative effect on CO_2 emissions at upper quantiles, and the degree of the effect increases gradually with the increase of CO_2 emissions. The results also suggest that the inverted U-shaped environmental Kuznets curve (EKC) is valid only in the least and most polluted provinces. Nevertheless, the positive indirect effects of FDI and foreign trade on CO_2 emissions are greater than the negative direct effects; thus the total effects are positive. Finally, several policy implications are proposed for China based on the empirical results obtained.

1. Introduction

Since the Reform and Opening in 1978, China has witnessed and is still witnessing high speed economic development with an annual growth rate that exceeds 10%, ranking second throughout the world [1]. As the most important engine of economic development, FDI and foreign trade have made tremendous contributions to the rapid growth of economy. However, the inflow of FDI and the rising level of foreign trade are also identified to be fundamental causes of pollution in the environment [2]. Already the world's largest carbon emitter, China emits 9.15 billion tons of carbon emissions, accounting for 27.3% of the global total emissions in 2015 [3]. Such status quo has raised widespread public concern about the unprecedented rise in CO_2 emissions, which placed great pressure to China in dealing with anthropogenic environmental impact. Presently, economic globalization and trade liberalization have greatly promoted the inflow of FDI and the rapid growth of foreign trade. Assessing the environmental consequences caused by FDI and foreign trade will be of important significance in both restraining CO_2 emissions and achieving sustainable development.

Previous studies on the environmental impacts of FDI and foreign trade mainly concentrated on the 'direct' mechanism, while little attention has been paid to the 'indirect' mechanism that FDI and foreign trade affecting CO_2 emissions through their impacts on economic development [4]. According to the environmental Kuznets curve (EKC) hypothesis, the nexus between GDP growth and emissions is nonlinear and shaped like the typical inverted U [5]. The argument in favor of this hypothesis postulates that environmental pollution initially increases with the increase of per capita income but begins to decrease rapidly after the per capita income exceeds the threshold point. The applicability of EKC hypothesis has been widely verified in various countries and time periods. For example, in a study of 25 OECD countries, Jebli et al. [6] found an inverted U-shaped relationship between per capita carbon emissions and per capita real GDP over the period of 1980 to 2010. Likewise, the investigation of Riti et al. [7] supported the existence of

EKC hypothesis in China for the period from 1970 to 2015. Moreover, many studies have highlighted the important role of FDI and foreign trade in accelerating economic growth. Li and Liu [8] documented that FDI can significantly promote economic growth in a global scale of 84 countries. Lau et al. [9] claimed that foreign trade is positively correlated with economic growth. This raises the question that, besides the direct effects, FDI and foreign trade may indirectly affect CO_2 emissions by promoting economic growth. The neglect of the indirect effects may lead to the underestimation or overestimation to the environmental influences of FDI and foreign trade. Hence, further explorations of the indirect effects of FDI and foreign trade on environment are warranted to prevent their real impacts from being misestimated.

Besides, studies have ignored the likelihood that the impacts of FDI and foreign trade on CO_2 emissions might present heterogeneity throughhout the emissions distribution. Most previous literatures concerned with the determinants of CO_2 emissions adopted the traditional ordinary least square (OLS) method. Cade and Noon [10] argued that OLS estimations might be seriously under- or overestimated in heterogeneous distribution. There are pronounced differences in CO_2 emissions among Chinese provinces. The effects of driving factors on CO_2 emissions may be affected by different levels of carbon emissions; that is, the impact of the same determinant may be inconsistent in low- and high-emissions provinces. Since the widespread used OLS method can only estimate the mean effect, it is no longer reasonable and applicable. In the present article, this issue will be effectively solved by employing quantile regression approach. You et al. [11] argued that quantile regression can evaluate the effects of influence factors on CO_2 emissions throughout the conditional distribution. Lin and Xu [12] used the same methodology and confirmed that the impacts of influencing factors on CO_2 emissions in the manufacturing industry differ significantly across quantile levels.

This research extends existing literature in the following ways. First of all, this study quantitatively estimates the direct and indirect impacts of FDI and foreign trade on CO_2 emissions in 30 Chinese provinces. At the same time taking into account the direct and indirect impacts can help us get more accurate information about how FDI and foreign trade influence CO_2 emissions. Second, this paper employs panel quantile regression to study the environmental effects of FDI and foreign trade throughout the entire distribution of CO_2 emissions. In contrast to the OLS method, quantile regression allows examining whether FDI and foreign trade consistently affect CO_2 emissions across quantile levels, particularly in the lowest and highest quantiles. Third, certain related control variables are introduced into our model within the theoretical framework of STIRPAT (the stochastic impacts by regression on population, affluence, and technology), which can resolve the omitted-variable biases [13].

The remainder of the study proceeds as follows. Section 2 presents the relevant literature. Section 3 presents the empirical model, methodology, and data. The empirical results and relevant discussions are provided in Section 4. Section 5 reports the conclusions and policy suggestions.

2. Literature Review

2.1. FDI and CO_2 Emissions. The majority of research on FDI–emissions linkage is aimed at verifying the existence of pollution haven hypothesis (PHH). According to the PHH, foreign firms in dirty sectors are more likely to relocate pollution activities from developed countries to poorly regulated developing countries to avoid domestic environmental control costs, which directly undermines the environmental interests of recipient countries [14]. Many scholars have presented evidence in favor of this hypothesis. Among them, Shahbaz et al. [15] utilized the Fully Modified Ordinary Least Squares (FMOLS) method to analyze the nonlinear relation between FDI and carbon emissions in countries with different income levels. The results indicated that the influx of FDI would lead to the increase in carbon emissions. Tang and Tan [16] tested the correlation among FDI, carbon emissions, energy consumption, and income applying the cointegration test and Granger causality. Their results presented bidirectional causal connection between FDI and carbon emissions in Vietnam. Based on the 1981-2010 panel data of five ASEAN countries, Baek [17] introduced dynamic panel data model to explore the linkage among CO_2 emissions, FDI, economic growth, and energy consumption. They came to the same conclusion that FDI is detrimental to the reduction of CO_2 emissions. Seker et al. [18] employed the Autoregressive Distributed Lag (ARDL) model and Error Correction Model (ECM) to determine the effect of FDI on Turkish carbon emissions. The findings manifested that the elasticity of CO_2 emissions to FDI is positive, either in the long-run or short-run. Solarin et al. [19] and Sun et al. [20] used the same approach to examine the existence of PHH in Ghana and China respectively. Their results illustrated that FDI is positively correlated with CO_2 emissions, thus supporting the PHH. In the case of South and Southeast Asian (SSEA) countries, Behera and Dash [21] analyzed the impacts of FDI, urbanization, and energy consumption on CO_2 emissions by means of the FMOLS and Dynamic Ordinary Least Square (DOLS) techniques. The results revealed that the influence of FDI on CO_2 emissions depends on income level. Along with this, they found that FDI inflows deteriorate environment in countries with middle- and high-income. More recently, Salahuddin et al. [22] adopted the ARDL bounds testing approach to estimate the association among FDI, economic growth, financial development, electricity consumption, and carbon emissions in case of Kuwait. They also found that, in both the short and long run, FDI causes a rise in carbon emissions.

However, some studies have documented that FDI inflows are conductive to improve energy efficiency and ultimately curbing pollutant emissions, because FDI has positive spillover effects such as advanced management practices, up-to-date technologies, and employment expansion. This is also known as the pollution halo hypothesis. Evidence has provided strong support for this hypothesis. For example, Zhou et al. [23] used dynamic panel data model to assess the environmental impact of industrial structural transformation. The results stated that a larger amount of FDI inflowing would cut emissions, which validates the pollution halo effects in China. Mert and Bölük [24] used panel ARDL approach to estimate the effects of FDI and renewable energy consumption on environmental quality and found that FDI inhibits CO_2 emissions in the 21 Kyoto countries. Moreover, in a study by Al-mulali and Tang [25], the validity of PHH was tested by FMOLS method. It was discovered that the increase of FDI has no impact on pollutant emissions in the Gulf Cooperation Council (GCC) countries.

2.2. Foreign Trade and CO_2 Emissions. In addition to FDI, foreign trade may be another source of environmental pollution. The seminal exploration of trade-emissions nexus was provided by Grossman and Krueger [26], who concluded that the environment impact of trade can be divided into scale, technique, and composition effects. Since then a growing literature has been carried out to evaluate the impact of foreign trade on environmental quality, but empirical findings are ambiguous and fail to reach a consensus [27–29]. For instance, Tiwari et al. [30] inspected the relationship between economic growth, trade openness, CO_2 emissions, and coal consumption in India by applying OLS method. The results reported that increasing trade openness would contribute to CO_2 emissions. In a study by Ozturk and Al-mulali [31], the Generalized Method of Moments (GMM) and Two-Stage Least Squares (TSLS) method were adopted and the conclusions indicated that carbon emissions increase significantly with the increase of trade volume in Cambodia. On a regional level, Wang and Zhao [32] conducted an analysis of the driving factors that affect CO_2 emissions in three different income regions of China using Partial Least Square (PLS) method. Results demonstrated that trade growth is one of the positive drivers behind the increase in CO_2 emissions, and the influence of trade in underdeveloped region is greater than in the developing and highly developed region. In a recent study, Zhang [33] established the ARDL model to study the relationship between trade liberalization and CO_2 emissions in South Korea and noted that trade has a detrimental impact on environmental quality.

On the contrary, Helpman [34] argued that trade helps to promote the international movement of production elements and international transfer of technical knowledge, so as to realize the efficient utilization of resources. In this way, they believed that foreign trade is conductive to control the level of environmental pollution. Furthermore, Shahbaz et al. [35] have undertaken an analysis on the relationship between trade openness, financial development, economic growth, carbon emissions, and coal consumption using ARDL bounds testing approach. They also confirmed that the enhancement of trade has a significant contribution to environmental improvement in South Africa. Through exploration on 25 OECD countries, Jebli et al. [6] investigated the correlation among carbon emissions, international trade, GDP, and renewable and nonrenewable energy consumption. Results of panel FMOLS and DOLS supported that trade is effective in mitigating carbon emissions. In another study, Zhang et al. [36] used the same method to study the trade-emissions nexus for ten newly industrialized countries with results that suggested that trade liberalization is essential for achieving environmental improvement.

In general, most of the previous research on the environmental consequences of FDI and foreign trade applied the mean regression. Obviously, there are still some aspects that need to be improved. First, very little research has presented the indirect impacts of FDI and foreign trade on CO_2 emissions by taking economic growth as a key factor. Second, studies have failed to capture the comprehensive effects of FDI and foreign trade on the environment in pace with the changes of CO_2 emissions. This paper extends earlier investigations by estimating the direct and indirect impacts of FDI and foreign trade on CO_2 emissions across Chinese provinces within the panel quantile regression framework. In particular, we provide evidence that the influences of FDI and foreign trade on CO_2 emissions are heterogeneous at different emissions levels.

3. Methodology and Data

3.1. Methodologies

3.1.1. Empirical Model Specification. In this article, the effects of FDI (Panel A) and foreign trade (Panel B) on CO_2 emissions at provincial level are assessed separately for two main reasons. On the one hand, as important catalysts for economic growth in developing countries, both FDI and foreign trade reflect the openness degree of a country. On the other hand, there is a strong interaction between FDI and foreign trade [37]. The estimated results of foreign trade can be regarded as the robustness test for FDI [38]. To identify other socioeconomic factors affecting CO_2 emissions, the paper follows the STIRPAT model proposed by Dietz and Rosa [39], which is defined as

$$I_{it} = \alpha_i P_{it}^{b} A_{it}^{c} T_{it}^{d} e_{it} \quad (1)$$

where α stands for the intercept term and I, P, A, T, and e represent environmental impact, population size, average affluence, technological development, and the random error term, respectively. The subscripts i and t denote province and year.

This study extends the STIRPAT model to reduce specification bias in econometric model estimation. First, given that the possible nonlinear correlation between economy and the environment, the squared term of GDP is included. It makes sense to verify the EKC hypothesis, because whether economic growth is achieved with the cost of rapid environmental degradation has long been the center of debate in the field of low-carbon economics. Second, due to low prices and abundant reserves, China's energy consumption is heavily dependent on coal [40]. As the largest energy consumers in the world, substantial energy consumption and coal-dominated energy structure are bound to cause severe environmental concerns [41, 42]. Thus, energy consumption and energy structure are introduced in the discussion. Third, recent studies, such as Xu and Lin [43] and Xu and Lin [44], considered urbanization and industrialization as the main driving forces of environmental pollution. Indeed, China is now at a stage of accelerated urbanization and industrialization, which requires huge fossil energy consumption to meet social needs and inevitably triggers ever-increasing CO_2 emissions. It would be more appropriate to incorporate urbanization and industrialization into our analytical framework. All variables take a natural logarithmic form to eliminate possible heteroscedasticity and then the CO_2 emissions equation can be written as follows (in this section, we only display the regression equation for FDI. Both the CO_2 emissions equation and income equation for foreign trade are to replace FDI with foreign trade):

$$\begin{aligned} CO_{2_{it}} = {} & \alpha_i + \beta_1 FDI_{it} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 \\ & + \beta_4 ENC_{it} + \beta_5 URB_{it} + \beta_6 INDUS_{it} \\ & + \beta_7 ENS_{it} + \beta_8 POP_{it} + \xi_{it} \end{aligned} \tag{2}$$

where CO_2 is per capita carbon emissions in tons, *FDI* represents per capita of foreign direct investment (yuan), and *GDP* and GDP^2 denote gross domestic product per capita and its square term, measured in 2000 constant yuan. *ENC* indicates the total energy consumption (10,000 Standard coal), *URB* is the percentage of urban population in total population, *INDUS* is the percentage of industrial added value in GDP, *ENS* refers to energy structure measured as the percentage of coal consumption in total energy consumption, and *POP* indicates population size (10,000 persons).

Following the augmented classical macroeconomics growth equation proposed by Solow [45], FDI, domestic capital stock, and population growth are controlled for in the income equation. The formulation of income equation is given as follows:

$$GDP_{it} = \varphi_i + \gamma_1 FDI_{it} + \gamma_2 K_{it} + \gamma_3 PG_{it} + u_{it} \tag{3}$$

where *GDP* is the same as in (2), *K* is per capita domestic capital stock (yuan), and *PG* denotes population growth.

The two-stage least squares approach developed by Kelejian [46] is utilized to estimate (2) and (3). The potential endogeneity problem in (3) is addressed by using an instrumental variable (IV) method. In accordance with Zhang et al. [47], the squared term of the fitted values of GDP per capita is chosen as the instrument variable. Additionally, the Hausman specification tests yield a p-value less than 0.05, indicating that the random effects estimates are rejected and the model with fixed effects is preferred for both (2) and (3).

For a deeper understanding of the environmental consequence of FDI, the indirect effect of FDI on CO_2 emissions through its impact on per capita GDP should also be considered. Then, the total effect of FDI can be calculated by adding the direct and indirect effect as

$$\frac{dCO_2}{dFDI} = \frac{\partial CO_2}{\partial FDI} + \frac{\partial CO_2}{\partial GDP} \cdot \frac{\partial GDP}{\partial FDI} \tag{4}$$

where the first item of (4) is the direct effect of FDI on CO_2 emissions and the second item of the equation (i.e., the product of partial differential expression) is the indirect effect.

3.1.2. Quantile Regression. The quantile regression approach, firstly introduced by Koenker and Bassett [48], is a powerful tool to examine how covariates affect the location, scale, and shape at different points of response distribution. Compared with OLS regression, quantile regression proved to be more robust to the outliers and more efficient when the error term is a nonnormal and has heteroskedasticity [49]. The quantile regression model with fixed effect can be expressed as

$$Q_{y_{it}}\left(\tau \mid \alpha_i, x_{it}\right) = \alpha_i + x_{it}{}'\beta_\tau \tag{5}$$

where $\tau \in (0,1)$, α_i is the unobserved effect, x_{it} denotes a vector of independent variables, β_τ represents a vector of parameters to be estimated, and $Q_{y_{it}}(\tau \mid \alpha_i, x_{it})$ is the τ-th conditional quantile of y_{it}. For a given τ, the parameter vector β_τ in (5) can be estimated as

$$\widehat{\beta}(\tau) = \arg\min \sum_{i=1}^{n} \rho_\tau\left(y_i - x_i{}'\beta\right) \tag{6}$$

where $\rho_\tau(u) = u(\tau - I(u < 0))$ is the quantile loss function and $I(\cdot)$ denotes the indicator function. Zhu et al. [50] noted that the estimator is robust because it splits the residuals into positives and negatives and gives weights of τ and $1-\tau$. The parameter can be estimated by

$$\begin{aligned} & \left(\widehat{\beta}\left(\tau_k, \lambda\right), \left\{\alpha_i\left(\lambda\right)\right\}_{i=1}^{N}\right) \\ & \quad = \arg\min \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{n=1}^{N} w_k \rho_{\tau_k}\left(y_{it} - \alpha_i - x_{it}'\beta\left(\tau_k\right)\right) \\ & \qquad + \lambda \sum_{i=1}^{N} \left|\alpha_i\right| \end{aligned} \tag{7}$$

where w_k is the weight that controls the relative influence of the k quantiles $\{\tau_1, \ldots, \tau_k\}$, ρ_{τ_k} is the penalty function, and λ is the tuning parameter [51]. For $\lambda \longrightarrow 0$, the fixed effects estimator is obtained and the penalty term disappears, while as $\lambda \longrightarrow \infty$, the model without individual effects is obtained. Following Lamarche [52], the equally weighted quantiles are defined as $w_k = 1/k$. Accordingly, (2) can be further reconstructed to the following model:

$$\begin{aligned} Q_{co_{2_{it}}}\left(\tau_k \mid \alpha_i, x_{it}\right) = {} & \alpha_i + \beta_{1\tau} FDI_{it} + \beta_{2\tau} GDP_{it} \\ & + \beta_{3\tau} GDP_{it}^2 + \beta_{4\tau} ENC_{it} \\ & + \beta_{5\tau} URB_{it} + \beta_{6\tau} INDUS_{it} \\ & + \beta_{7\tau} ENS_{it} + \beta_{8\tau} POP_{it} \end{aligned} \tag{8}$$

3.2. Data Sources and Descriptions. Fossil fuel combustion is responsible for three-quarters of China's carbon emissions [53]. In China, there is a lack of official statistics on energy-related CO_2 emissions. It is suggested that the data of CO_2 emissions from different energy sources should be calculated first. Following the framework recommended by the Intergovernmental Panel on Climate Change [54], carbon emissions can be calculated as follows:

$$CE_t = \frac{44}{12} \times \sum_{n=1}^{8} EC_{nt} \times EF_n \times O_n \qquad (9)$$

where CE_t is CO_2 emissions from fossil fuels (10,000 ton) in year t, 44/12 is the conversion coefficient between C and CO_2, EC_{nt} denotes the fossil fuel consumption of n measured by 10^4 tce (tons of coal equivalent) in the year t, EF_n is the carbon emissions coefficient (t C/tce), and O_n represents the rate of carbon oxidation of fuel type n. The carbon emissions coefficient and the rate of carbon oxidation of eight fossil fuels are listed in Table 1.

Our sample dataset includes a balanced panel dataset of 30 Chinese provinces during 1997-2014. Due to data availability, Tibet, Taiwan, Hong Kong, and Macau were excluded. All data used are obtained from the China Statistical Yearbook, provincial statistical yearbooks, and China Energy Statistical Yearbook. The real GDP is standardized to be in the 2000 constant price (2000=100). Domestic capital stock is estimated by the perpetual inventory method. All variables are converted into natural logarithms except population growth rate (PG). Table 2 reports the details of related variables used in the model.

The results of descriptive statistics are tabulated in Table 3. The Jarque–Bera test is applied to check the normality of variables. All data series exhibit skewed and nonzero skewness, which indicates that most time-series variables reject the null hypothesis of being normally distributed, and justifies the appropriateness of applying quantile regression approach for empirical analysis.

4. Empirical Results

4.1. Unit Root Test and Cointegration Test. To avoid the mistakes resulting from the pseudoregression problems, it is necessary to first check the stationarity of each variable concerned. There have been several methods for panel unit root test. Specifically, these approaches can be roughly divided into two kinds [55]. The first is under the assumption that there is a common unit root for all panel units, including LLC (Levin-Lin-Chu) test, Breitung test, and Hadri tests. In the second category, the assumption of cross-sectional independence is relaxed and cross-sectional dependence is allowed. It primarily includes Fisher-ADF test, Fisher-PP test, and IPS (Im-Pesaran-Skin) test. Following Zhang et al. [47], three panel-based unit root tests, namely, Fisher-ADF, Fisher-PP, and LLC tests, are conducted to check the stationarity of each variable, and the results are depicted in Table 4. As we can see, all variables are stationary at the first-order difference, meaning that they are integrated at an order of one. Then, Kao residual cointegration test is performed to identify whether there is a long-run equilibrium relationship between variables considered. The results of the ADF stat (-6.849, P = 0.000), HAC variance = 0.0043 for panel A and ADF stat (-6.897, P = 0.000), HAC variance = 0.0043 for panel B suggest that there exist cointegration relationships between variables during the sample period.

4.2. Direct Effect Estimations Based on Panel Quantile Regression. On the basis of panel quantile regression technique, the effects of FDI and foreign trade on Chinese provincial CO_2 emissions are examined in the present paper. For comparison purposes, OLS regression is firstly utilized to estimate the average impacts. The OLS estimates with pooled and one-way individual fixed effects are given in columns 1 and 2 of Table 5. As Baltagi [56] pointed out, the parameter estimates of the two-way fixed effect model are more reliable. Therefore, the results presented in column 3 of Table 5 are discussed below. The estimated coefficient of FDI is -0.0378 and is significant at 1% level, meaning that a 1% increase in FDI will lead to about 0.04% decrease in CO_2 emissions. The result is in accordance with Zhou et al. [23], who noted that FDI plays a significant role in curbing carbon emissions in China. The estimated coefficient of foreign trade is -0.1042 and is significant at 1% level, showing that an increase of 1% in foreign trade will result in a reduction of about 0.10% in CO_2 emissions. The finding is consistent with Destek et al. [57], who concluded that a 1% increase in trade will reduce CO_2 emissions by 0.069%-0.097% in a panel of ten selected Central and Eastern European Countries (CEECs). However, OLS estimation results only reveal the influences of FDI and foreign trade in the center of the distribution of CO_2 emissions, which may cause a loss of important information in the tail distribution.

This paper then set up two panel quantile regression models for Panels A and B to examine the direct effects of FDI and foreign trade on different quantiles of CO_2 emissions in 30 Chinese provinces. The coefficients estimation for the 5^{th}, 10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th}, 70^{th}, 80^{th}, 90^{th}, and 95^{th} percentiles of the conditional CO_2 emissions distribution is presented in Table 6. Obviously, there is a significant distinction between parameters obtained by the quantile regression and OLS regression. Figure 1 graphically displays the change of parameter estimates for main variables (i.e., FDI, foreign trade, and GDP and its square terms), ranging from 0.01 to 0.99 quantiles of the distribution with 95% confidence intervals (the shaded area).

As observed from the results listed in Table 6, the direct effect of FDI on CO_2 emissions is heterogeneous under low, medium, and high quantiles. At the 5^{th} and 10^{th} quantiles, the coefficients associated with FDI is negative but statistically insignificant at the 10% level. Yet, the negative coefficients of FDI become significant at other quantiles, lending strong support to the halo effect hypothesis in middle- and high-emissions provinces. These findings indicate that a 1% increase in FDI will reduce CO_2 emissions by approximately 0.037%-0.073%. Furthermore, with the increase of quantiles, the degree of the impact displays an approximate increase trend, as shown in Figure 1. Therefore, it can be reasonably concluded that FDI is more conductive to mitigate CO_2 emissions in high-emissions provinces. This phenomenon is attributed to important differences in environmental regulations. Provinces with high emissions tend to be more environmental conscious and enforce stricter environmental control standards. The properly designed environmental management and supervision system raises the cost

Table 1: CO_2 emissions coefficients *Source*: IPCC (2006).

Energy type	Coal	Coke	Crude oil	Gasoline	Kerosene	Diesel	Fuel oil	Natural gas
Carbon emissions coefficient	0.7480	0.8550	0.5850	0.5538	0.5714	0.5921	0.6185	0.4440
Rate of carbon oxidation	0.913	0.928	0.979	0.980	0.986	0.982	0.985	0.990

Table 2: Definition of variables.

Variables	Definition	Unit
CO_2	Per capita CO_2 emissions from the energy consumption	Tons
FDI	Per capita FDI	Yuan
TRADE	Per capita foreign trade	Yuan
GDP	Per capita GDP (constant 2000 yuan)	Yuan
ENC	Total primary energy consumption	10^4 Standard coal
URB	The ratio of urban population to total population	Percent
INDUS	The ratio of industrial value added of GDP	Percent
ENS	The ratio of coal consumption to total energy consumption	Percent
POP	Population at the end of year	10^4 persons
K	Per capita domestic capital stock	Yuan
PG	Rate of annual population growth	Percent

Note: all the sample data are obtained from the China Statistical Yearbook, provincial statistical yearbooks, and China Energy Statistical Yearbook

Table 3: Descriptive statistics.

Variables	Mean	Std.dev	Min	Q1	Median	Q3	Max	Skewness	Kurtosis	Jarque-Bera
CO_2	1.668	0.719	-0.137	1.130	1.653	2.164	3.396	0.081	2.558	4.997∗
FDI	5.495	1.531	1.707	4.375	5.575	6.684	9.015	-0.123	2.417	8.997∗∗
TRADE	7.751	1.647	4.819	6.489	7.411	8.835	11.992	0.589	2.550	35.764∗ ∗ ∗
GDP	9.673	0.856	7.719	8.863	9.667	10.372	11.564	0.069	2.070	19.903∗ ∗ ∗
ENC	0.656	0.648	-0.726	0.160	0.618	1.139	2.209	0.236	2.498	10.710∗ ∗ ∗
URB	3.677	0.369	2.788	3.425	3.700	3.902	4.503	-0.041	2.732	1.768
INDUS	3.630	0.244	2.539	3.509	3.692	3.810	3.968	-1.576	6.322	471.768∗ ∗ ∗
ENS	4.111	0.296	3.227	3.968	4.181	4.311	4.572	-1.020	3.610	101.922∗ ∗ ∗
POP	8.123	0.793	6.207	7.788	8.244	8.768	9.280	-0.782	2.840	55.572∗ ∗ ∗
K	10.167	0.984	6.794	9.409	10.162	10.916	12.794	0.010	2.489	5.893∗
PG	5.727	3.305	-3.240	3.415	5.785	7.745	14.850	0.130	3.032	1.551

Note: ∗ ∗ ∗, ∗∗, and ∗ denote the significance at 1%, 5%, and 10% level, respectively.

Table 4: Results of panel unit root tests.

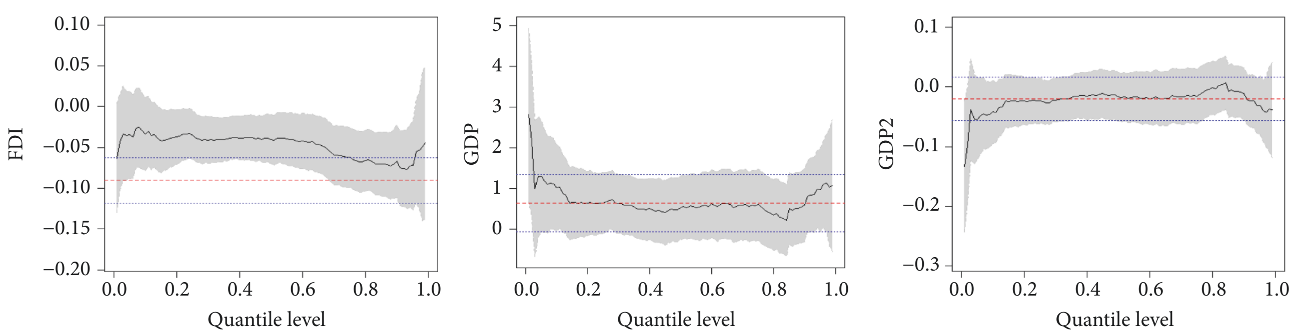
Variables	Level			First difference		
	Fisher ADF	PP	LLC	Fisher ADF	PP	LLC
CO_2	20.922(1.000)	12.227(1.000)	-1.471(0.071)	180.493(0.000)	157.604(0.000)	-8.568(0.000)
FDI	48.416(0.858)	36.450(0.993)	-0.237(0.406)	258.098(0.000)	566.982(0.000)	-13.547(0.000)
TRADE	31.844(0.999)	37.991(0.988)	-3.004(0.001)	258.445(0.000)	283.188(0.000)	-15.568(0.000)
GDP	47.844(0.871)	9.671(1.000)	-3.184(0.001)	109.447(0.000)	116.958(0.000)	-7.301(0.000)
ENC	93.574(0.004)	13.298(1.000)	-7.356(0.000)	168.118(0.000)	180.824(0.000)	-8.338(0.000)
URB	57.068(0.584)	113.371(0.000)	-5.644(0.000)	210.254(0.000)	248.986(0.000)	-9.850(0.000)
INDUS	54.068(0.691)	27.283(1.000)	-2.818(0.002)	167.560(0.000)	178.243(0.000)	-9.419(0.000)
ENS	59.887(0.480)	30.826(0.999)	-3.236(0.001)	259.630(0.000)	328.425(0.000)	-13.175(0.000)
POP	84.081(0.022)	159.431(0.000)	-3.968(0.000)	190.182(0.000)	494.071(0.000)	-7.034(0.000)
K	112.991(0.000)	32.505(0.999)	-7.064(0.000)	100.376(0.001)	132.666(0.000)	-3.789(0.000)
PG	156.678(0.000)	209.700(0.000)	-8.861(0.000)	208.064(0.000)	268.010(0.000)	-9.320(0.000)

Note: the significance probabilities for the corresponding tests are reported in parentheses.

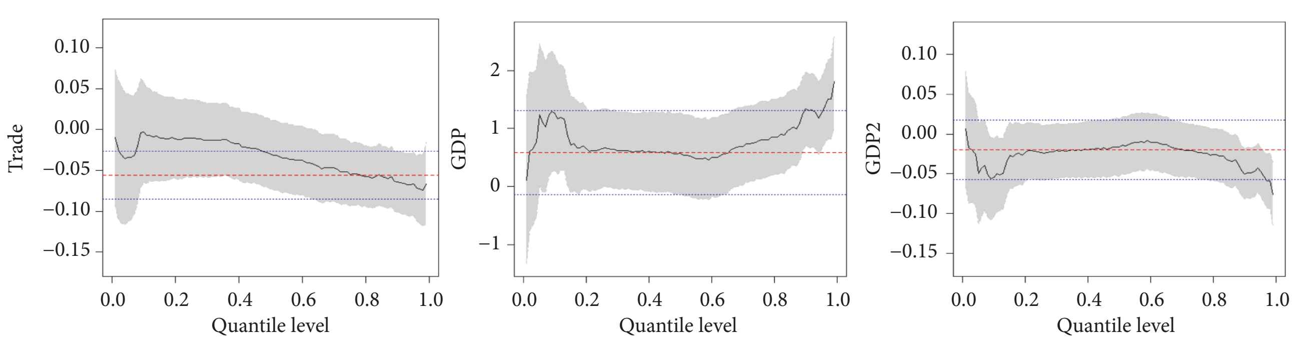
Table 5: OLS regression results.

Variables	Pooled OLS estimator	One-way fixed effects model	Two-way fixed effects model
Panel A. The effect of *FDI* on CO_2 emissions			
FDI	-0.0861***(-6.0537)	-0.0303***(-2.6362)	-0.0378***(-3.2531)
GDP	-0.5464***(-8.4726)	0.7252***(4.3412)	0.5601***(2.7978)
GDP^2	0.0409***(9.9236)	-0.0220**(-2.5783)	-0.0177*(-1.8022)
ENC	0.4988***(10.2447)	0.5895***(17.1908)	0.5835***(16.4875)
URB	0.3805***(7.0839)	0.0270(0.7101)	0.0287(0.7517)
INDUS	0.7248***(9.2724)	0.1521**(2.5424)	0.1330**(1.9823)
ENS	0.1023**(2.0703)	0.5054***(9.7519)	0.4718***(9.0297)
POP	-0.1484***(-5.6511)	-0.3451***(-2.6001)	-0.5184***(-3.3821)
Panel B. The effect of *TRADE* on CO_2 emissions			
TRADE	-0.0535***(-3.5188)	-0.0436**(-2.3486)	-0.1042***(-4.4433)
GDP	-0.4669***(-7.2834)	0.8256***(4.6551)	0.5718***(2.8822)
GDP^2	-0.1201***(-4.5837)	-0.2640**(-2.0332)	-0.6040**(-3.9081)
ENC	0.0342***(8.5707)	-0.0264***(-2.9828)	-0.0208**(-2.1235)
URB	0.5945***(13.0392)	0.5927***(17.2794)	0.5794***(16.5106)
INDUS	0.3256***(6.0314)	0.0410(1.0422)	0.0724*(1.8236)
ENS	0.6118***(7.9137)	0.1165*(1.9366)	0.1068(1.6137)
POP	0.1328***(2.6514)	0.5186***(10.0467)	0.4788***(9.3061)

Note: ***, **, and * denote the significance at 1%, 5%, and 10% level, respectively. Figures in parentheses are t-values.



(a) OLS and quantile regression estimates



(b) OLS and quantile regression estimates

Figure 1: Quantile regression estimates with 95% confidence intervals for the effects of main influencing factors on carbon emissions. The trended lines represent quantile regression coefficients. The red dashed lines represent the corresponding OLS estimations.

of pollution-intensive products and then triggers environmental innovation. Hence, in high-emissions provinces, the influx of FDI can directly relieve the environmental pressure by transferring environmentally friendly technologies and improving energy efficiency. In Chinese provinces with rigid environmental standards, as Dean et al. [58] pointed out, FDI inflows into high-pollution industries can be prevented. The evidence on pollution halo hypothesis is in line with empirical

Table 6: Quantile regression results.

Variables	Quantile levels 5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
Panel A. The effect of *FDI* on CO_2 emissions											
FDI	-0.0309	-0.0296	-0.0374**	-0.0420***	-0.0383**	-0.0392**	-0.0423**	-0.0604***	-0.0668***	-0.0731***	-0.0686**
GDP	1.3393**	1.2199**	0.6182	0.5770	0.4405	0.5283	0.5339	0.5810	0.3151	0.5255	0.9638**
GDP^2	-0.0565*	-0.0521**	-0.0227	-0.0198	-0.0130	-0.0168	-0.0161	-0.0156	0.0009	-0.0079	-0.0312
ENC	0.6591***	0.7026***	0.7286***	0.6957***	0.6992***	0.6920***	0.6819***	0.6223***	0.5624***	0.5205***	0.5126***
URB	0.0905	0.1250*	0.1183*	0.1345**	0.1178*	0.1121*	0.1099	0.1347*	0.1637**	0.1162	0.1742
INDUS	0.2787**	0.2110*	0.1864	0.2184	0.2136	0.1798	0.1381	0.1622	0.1095	0.1353	0.0701
ENS	0.4112***	0.4289***	0.4702***	0.4480***	0.4269***	0.4147***	0.4037***	0.3945***	0.3584***	0.3347***	0.3637***
POP	-0.1603***	-0.1419***	-0.1217***	-0.1368***	-0.1460***	-0.1471***	-0.1503***	-0.1686***	-0.1840***	-0.2092***	-0.2226***
Panel B. The effect of *TRADE* on CO_2 emissions											
TRADE	-0.0351	-0.0049	-0.0120	-0.0129	-0.0206	-0.0307	-0.0394*	-0.0479***	-0.0587***	-0.0657***	-0.0684***
GDP	1.2686**	1.2269**	0.7129*	0.6086*	0.6093*	0.5702	0.5028	0.7084**	0.8448***	1.3761***	1.2673***
GDP^2	-0.0513*	-0.0529**	-0.0261	-0.0204	-0.0198	-0.0163	-0.0105	-0.0194	-0.0253	-0.0519***	-0.0469***
ENC	0.6408***	0.7322***	0.6870***	0.6733***	0.6759***	0.6488***	0.6100***	0.5693***	0.5604***	0.5348***	0.5343***
URB	0.1578	0.0460	0.0533	0.0485	0.0498	0.0627	0.0559	0.0799	0.0826	0.1118*	0.1218*
INDUS	0.2455**	0.1805*	0.1064	0.0984	0.0989	0.1112	0.1127	0.0792	0.0896	-0.0370	-0.0470
ENS	0.4400***	0.4855***	0.4687***	0.4656***	0.4586***	0.4348***	0.4252***	0.3838***	0.3655***	0.3806***	0.4045***
POP	-0.1835***	-0.1342***	-0.1522***	-0.1574***	-0.1549***	-0.1645***	-0.1838***	-0.1895***	-0.1921***	-0.1980***	-0.2146***

Note: ***, **, and * denote the significance at 1%, 5%, and 10% level, respectively.

results provided by Zhang and Zhou [59], who also reported that FDI flows are beneficial to environmental protection in China.

Similarly, the effect of foreign trade on CO_2 emissions differs remarkably across quantile levels. Specifically, the coefficient of foreign trade is negative but insignificant on the left side of the CO_2 emissions distribution, which means that higher level of foreign trade does not appear to decrease CO_2 emissions in low-emissions provinces. However, the coefficient of foreign trade becomes statistically significant at upper quantiles (60^{th}, 70^{th}, 80^{th}, 90^{th}, and 95^{th}) and ranges from -0.0394 to -0.0684, suggesting that the expansion of foreign trade directly constrains CO_2 emissions in high-emissions provinces. The negative trade–emissions relation is also documented by Dogan and Seker [60] for a group of the top renewable energy countries. Additionally, as CO_2 emissions increase, the degree of impact of foreign trade increases gradually. That is, in high-emissions provinces, foreign trade plays more important role in reducing pollutant emissions. The reason is that the trade structure of high-emissions provinces has evolved from heavy industry to service industry and light manufacturing industry. Because of the advantages in the circulation of commodities, technology, and services, foreign trade contributes to propping up technological innovation, reducing the excess capacity, and thus improving the quality of environment. This evidence is corroborated by Wiedmann et al. [61], who argued that the export of industrial products results in air pollution (i.e., $PM_{2.5}$), while the export of tertiary industries is an effective strategy to control pollution.

When it comes to the income-related emissions nexus, the coefficient of per capita GDP is positive, and its squared term is negative and significant at extreme low and high tails (i.e., 5^{th}, 10^{th}, and 95^{th} quantiles). This constitutes empirical evidence for the EKC hypothesis in the least and most polluted provinces. That is, income follows an inverse U-type with pollution emissions in this region. The result highlights that provinces with the least and most emissions may have reached the desired level of per capita income, so environmental pollution will decrease along with economic growth. Conversely, there are signs that the current economic growth mode in middle-emissions provinces seems unsustainable, since raising economic development level is accompanied by environmental deterioration. The result is contradictory to the findings of Pao et al. [62], who proposed that the EKC hypothesis does not support the data from China. The reason for the absence of consensus may be that ignoring the heterogeneity within provinces eliminates the existence of inverted U-shaped EKC. This finding also casts doubt on the effectiveness of policy recommendations based on mean regression results. Quantile regression technique applied in this study can completely describe the income-emissions nexus. There are significant differences in the level of environmental pollution among Chinese provinces, which further confirms the importance of discussing the EKC hypothesis under the control of distribution heterogeneity.

This paper also draws the conclusion with respect to the impacts of control variables on CO_2 emissions from Table 6. First, the coefficients of energy consumption and energy structure are positive and significant for all the conditional quantiles, which indicates that massive energy consumption and coal-based energy structure will undoubtedly deteriorate the quality of environment. Second, the coefficient of urbanization suggests that the increase of urban population has a positive influence on CO_2 emissions as expected. Third, the coefficient of industrialization is positive but statistically significant only at the 5^{th} and 10^{th} quantiles, which means that the industrial development is one of the causes of environmental deterioration in the least polluted provinces. Fourth, the coefficient of population size is positive and significant across quantile levels, suggesting that population growth conduces to improving the environmental quality. This may be the reason that population accumulation makes it possible to utilize energy in a relatively efficient way (e.g., central heating).

4.3. Estimation Results of CO_2 Emissions Equation and Income Equation. The two-stage least square method is adopted to estimate the CO_2 emissions equation and income equation represented by (2) and (3), with the CO_2 emissions per capita and GDP per capita as the dependent variables, respectively. The results documented in Table 7 specify that FDI and foreign trade have negative effects on CO_2 emissions. An increase of 1% in FDI and foreign trade contributes to a reduction of about 0.04% and 0.11% in CO_2 emissions, respectively. Moreover, this study also presents empirical evidence on the role of FDI and foreign trade in accelerating China's economic growth. For every 1% increase in FDI and foreign trade, GDP per capita will increase by approximately 0.27% and 0.29%. The results are broadly in accord with Lee [63] and Halicioglu [64]. The former documented that FDI benefits the growth of economy of the group of 20 through direct capital financing and foreign technology transfer. The latter confirmed that foreign trade boosts economic growth in Turkey.

4.4. The Total Effects of FDI and Foreign Trade on CO_2 Emissions. In this subsection, the total environmental consequences of FDI and foreign trade in 30 provinces of China are reported in Table 8. According to (4), the indirect effects of FDI and foreign trade on environment are related to income level. The different income levels are calculated based on eleven quantiles of per capita income. In addition, Figure 2 provides the graphical illustrations for the environmental impacts of FDI and foreign trade across quantile levels.

Regarding FDI, its positive indirect effect on CO_2 emissions is greater than the negative direct effect and hence the total effect is positive. Our results imply that the motivation behind lowering environmental regulations to attract FDI flows has turned China into a “pollution haven.” The validation of the PHH in our study comes, however, as no surprise. It is generally acknowledged that China has become the most attractive host country of FDI due to its abundant natural resources, cheap labor cost, and lax environmental regulations. However, FDI inflows in China prefer high pollution industries such as equipment manufacturing and chemical and real estate industry and ultimately, resources

Table 7: Estimates of CO_2 emission equation and income equation.

Variables	Coefficient	Std. Error	t-statistic	P-value
Panel A. Dependent variable: CO_2				
Intercept	3.8374	1.4882	2.5785	0.0102
FDI	-0.0390	0.0126	-3.1045	0.0020
GDP	0.0913	0.1391	0.6564	0.5119
GDP^2	-0.0034	0.0074	-0.4558	0.6487
ENC	0.6147	0.0345	17.8171	0.0000
URB	0.0217	0.0389	0.5577	0.5773
INDUS	0.2354	0.0622	3.7873	0.0002
ENS	0.4544	0.0539	8.4234	0.0000
POP	-0.7050	0.1457	-4.8388	0.0000
Dependent variable: *GDP*				
Intercept	1.2158	0.1417	8.5820	0.0000
FDI	0.2740	0.0487	5.6213	0.0000
K	0.6831	0.0300	22.789	0.0000
PG	0.0011	0.0067	0.1583	0.8743
Panel B. Dependent variable: CO_2				
Intercept	5.4083	1.5379	3.5167	0.0005
TRADE	-0.1054	0.0241	-4.3675	0.0000
GDP	0.0936	0.1241	0.7541	0.4511
GDP^2	-0.0062	0.0073	-0.8509	0.3952
ENC	0.6108	0.0341	17.9329	0.0000
URB	0.0684	0.0402	1.7007	0.0896
INDUS	0.2004	0.0636	3.1531	0.0017
ENS	0.4721	0.0527	8.9581	0.0000
POP	-0.8106	0.1520	-5.3342	0.0000
Dependent variable: *GDP*				
Intercept	1.1656	0.1014	11.4895	0.0000
TRADE	0.2937	0.0230	12.7930	0.0000
K	0.6124	0.0196	31.3148	0.0000
PG	0.0008	0.0048	0.1759	0.8604

Table 8: The effects of FDI and foreign trade on CO_2 emissions.

Effects	Quantile levels										
	5^{th}	10^{th}	20^{th}	30^{th}	40^{th}	50^{th}	60^{th}	70^{th}	80^{th}	90^{th}	95^{th}
Panel A. The direct, indirect, and total effect of *FDI* on CO_2 emissions											
Direct	-0.0309	-0.0296	-0.0374	-0.0420	-0.0383	-0.0392	-0.0423	-0.0604	-0.0668	-0.0731	-0.0686
Indirect	0.1072	0.0908	0.0599	0.0593	0.0538	0.0557	0.0585	0.0718	0.0915	0.0972	0.0749
Total	0.0763	0.0612	0.0225	0.0173	0.0155	0.0165	0.0162	0.0114	0.0247	0.0241	0.0063
Panel B. The direct, indirect, and total effect of *TRADE* on CO_2 emissions											
Direct	-0.0351	-0.0049	-0.0120	-0.0129	-0.0206	-0.0307	-0.0394	-0.0479	-0.0587	-0.0657	-0.0684
Indirect	0.1198	0.0954	0.0745	0.0697	0.0697	0.0749	0.0863	0.0915	0.0925	0.0745	0.0674
Total	0.0847	0.0905	0.0625	0.0568	0.0491	0.0442	0.0469	0.0436	0.0338	0.0088	-0.0010

are destroyed and the environment is polluted carelessly. The result is consistent with earlier studies by Kivyiro and Arminen [65], which revealed that the rise in FDI inflows increases pollution emissions in sub-Saharan Africa due to outdated technologies and nonmandatory regulations.

As for foreign trade, its positive indirect effect is greater than the negative direct effect within most of the income range; thus the total effect of foreign trade on CO_2 emissions is also positive. It is held that increasing the liberalization of foreign trade will aggravate environmental pollution. After the accession to the World Trade Organization (WTO), China has benefited from low tariffs and nontariff barriers, and a large volume of "Made in China" products and services are exported through trade. This, however, comes

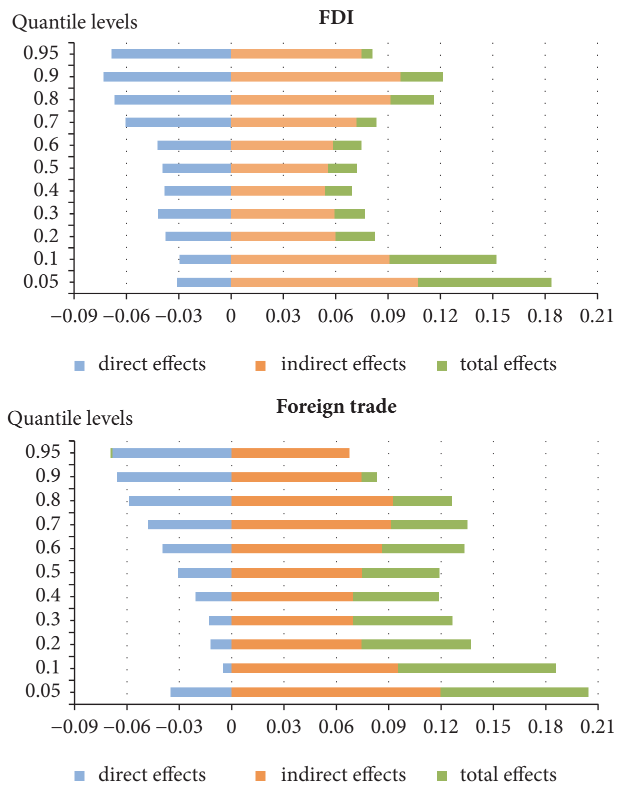


FIGURE 2: The effects of FDI and foreign trade on China's CO_2 emissions. The vertical axes represent the quantile levels of CO_2 emissions, and the horizontal axes represent the degree of effects. The blue bar indicates the direct effects, the orange bar indicates the indirect effects, and the green bar indicates the total effects.

at the expense of increased environmental pollutions. Under the concept of "trade causes growth," China has neglected the adverse impact of foreign trade on environment. As a "world factory," resource-intensive products such as steel, nonferrous metals, and petrochemical and building materials still account for a large proportion of China's total exports. The production activities of these products inevitably consume enormous fossil energy, resulting in more severe environmental issues.

Notably, the total environmental influences of FDI and foreign trade will decrease with CO_2 emissions increasing. At the 5^{th} quantile, as FDI or foreign trade rises by 1%, CO_2 emissions will increase by approximately 0.076% or 0.085%. At the 50^{th} quantile, for every 1% increase in FDI or foreign trade, CO_2 emissions will increase by about 0.017% and 0.044%. At the 95^{th} quantile, the total effects are found to be 0.006 and -0.001, respectively, which means that the direct effects of FDI and foreign trade on CO_2 emissions are almost offset by the indirect effects. In view of this, FDI and foreign trade are more responsible for environmental degradation in low- and middle-emissions provinces, while, in the most polluted provinces, their environmental impacts are negligible.

5. Conclusions and Policy Implications

Using provincial-level panel data in China over the period from 1997 to 2014, this paper aims to investigate the effects of FDI and foreign trade on CO_2 emissions. The panel quantile regression is applied to achieve the objectives. The results yield evidence of heterogeneity regarding the impacts of FDI and foreign trade on CO_2 emissions. Specifically, the effect of FDI on CO_2 emissions is negative and significant except at the 5^{th} and 10^{th} quantiles. Foreign trade has a negative and significant impact at higher quantiles, and the degree of the impact increases with the increase of quantiles. Our findings also validate the existence of EKC hypothesis in the least and most polluted provinces. However, the total environmental effects of FDI and foreign trade are determined by the indirect effects and appear positive. The above empirical findings have the following policy implications.

First, given that FDI inflows could act as a channel for environmentally friendly technologies, more stringent environmental regulations should be designed and implemented in low-emissions provinces to attract clean FDI inflows. Provinces with low- and middle-emissions are supposed to optimize the distribution structure of FDI inflows, motivating the quality-oriented mode of FDI inflows rather than a quantity-oriented mode.

Second, to upgrade trade structure in low- and middle-emissions provinces, the application of green technologies should be guaranteed in export-oriented industries. The government can take various incentives, such as tax reduction or exemption for nonpolluted industries, to encourage producers to shift toward environmentally sound industries. Again, the exports of pollution-intensive products in these areas are expected to be restricted or prohibited.

Third, to achieve the coordination between economy and carbon-cutting, it is suggested that middle-emissions provinces further adjust their economic structure and develop green economy and circular economy. Comparatively, the least and most polluted provinces should sustainably accelerate economic development, since higher income is conductive to the reduction of CO_2 emission.

Finally, the key implication of the empirical findings is that emission mitigation measures should be tailored according to the pollution level in different provinces, instead of a "one-size-fits-all" approach.

Still, our study has limitations. Since environmental pollution may have potential spatial dependence characteristics among adjacent provinces in China, further analyses can examine the spatial effects of FDI and foreign trade on CO_2 emissions.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Additional Points

Highlights. (i) This paper employs panel quantile regression approach to investigate the effects of FDI and foreign trade on CO_2 emissions in China. (ii) Heterogeneous effects of FDI and foreign trade on CO_2 emissions are found. (iii) The environmental Kuznets curve (EKC) hypothesis is valid only in the least and most polluted provinces.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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