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Is China's development conforms to the Environmental Kuznets Curve hypothesis and the pollution haven hypothesis?

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ABSTRACT

The Environmental Kuznets Curve and Pollution Haven hypotheses have been verified by many studies. However, there is still no consensus on whether China's situation is consistent with the abovementioned hypotheses. Therefore, to investigate whether China's development aligns with the Environmental Kuznets Curve and Pollution Haven hypotheses, this study considered provincial panel data from 1996 to 2015 and used the fixed effects panel data partially linear additive model, which integrates economic growth and foreign direct investment into the same framework, to investigate their impact on carbon emissions. The results revealed that there exists a reverse U-shape relationship between economic growth and carbon dioxide emissions, and an inverted N-shaped relationship between foreign direct investment and carbon dioxide emissions. Moreover, the results revealed that energy consumption has an accelerating effect on the production pace of carbon dioxide emissions. The upgrading of industrial infrastructure, technology diffusion, and trade liberalization can contribute to the reduction of carbon dioxide emissions. Additionally, this study proposes the following future research directions. First, considering the regional differences in China, the conclusions of this study should be re-examined by grouping different regions. Secondly, the formation mechanism of the inverted N-type relationship between foreign direct investment and carbon emissions is also an issue that requires further discussion. Finally, a comparative study between developed and developing countries is needed to test and verify the universality and adaptability of the conclusions drawn from this study.

1. Introduction

Global warming is a serious threat to human survival and development (Bakaki and Bernauer, 2018; Chen et al., 2018). Moreover, carbon dioxide (CO_2) emissions are the major contributor to global warming (Xu and Lin, 2016). Therefore, the international community is also increasingly more concerned with minimizing carbon emissions (Mundaca and Markandya, 2016). As the largest carbon emitter, China must become more energy efficient and reduce its carbon emissions, under the pressure exercised by the international community (Li et al., 2018). In response to the Paris Accord, China proposed an agenda for reducing the intensity of carbon dioxide emissions by 2030. This reduction will be 60%–65% less that the emission amounts in 2005 (Wang et al., 2018).

1.1. The problem discussion

Because of its rapid development for more than 30 years, China has become the second largest economy and contributed toward achieving a global economic growth of 25% (Jin et al., 2016). China's excellent development prospects have attracted a large number of foreign capital (Kolstad and Wiig, 2012; Dong et al., 2018). However, with rapid economic growth and the influx of foreign capital, the amount of carbon dioxide emissions has also rapidly increased (Jiang et al., 2018). By 2015, China's volume of carbon emissions accounted for 28% amongst the global volume (Zhang and Zhang, 2018). Undoubtedly, an immense amount of carbon emissions poses a challenge to the sustainable development of China's economy (Fufa et al., 2018; Guerrero and Muñoz, 2018). Therefore, the main problems studied in this paper are as below: (1) whether does the relation between economic growth and carbon emission in china conform to the Environmental Kuznets Curve (EKC) hypothesis? Whether can carbon emission and other environmental pollution problems be automatically solved with economic

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growth? The influencing mechanism between economic growth and carbon emission will be deeply explored by combining actual national conditions of China. (2) Whether does the inflow of huge amounts of foreign capital bring technology or contamination? In other words, whether does the relation between foreign direct investment (FDI) and carbon emission in China comply with Porter hypothesis or pollution haven hypothesis? The action mechanism of foreign direct investment on carbon emission will be discussed according to the empirical results. (3) What are the specific impacts of economic growth and foreign direct investment on carbon emission in different stages? The influencing degree of economic growth and foreign direct investment on carbon emission in different stages will be investigated by marginal effect analysis.

1.2. The contributions

Provincial panel data from 1996 to 2005 were chosen, and the fixed effects panel data partially linear additive model was applied in this study to bring economic growth and foreign direct investment into the same framework to investigate their effects on carbon emission. Relative to the previous studies, the major contributions of this study include the following aspects: (1) to solve the potential risk of parameter model presetting bias, the fixed effects panel data partially linear additive model was applied the first time. This model combines the advantages of parameter model and non-parameter model, which can not merely resolve the potential risk of “presetting bias” of parameter model, but also avoid “Curse of Dimensionality” problem of non-parameter model. (2) To study whether the development of China accords with Environment Kuznets Curve hypothesis and Pollution Haven hypothesis, different from previous literature, economic growth and foreign direct investment were put under the framework to probe into their joint influence on carbon emission. Besides, in view of possible multicollinearity problem between economic growth and foreign direct investment, further comparative analysis was performed in the robustness test part. (3) For exploring the specific influencing degree of economic growth and foreign direct investment in different stages on carbon emission, different from previous researches, marginal effect analysis was carried out for economic growth and foreign direct investment in different stages.

The rest of this paper is structured as follows: Section 2 reviews various related studies. The methodology and data used for this study will be presented in Section 3. The empirical results are presented in Section 4, and Section 5 presents the robustness test conducted on the results. Section 6 discusses the findings of this study and future research directions. Finally, section 7 concludes this paper by discussing various policy implications.

2. Literature review

The investigation of the relationship between economic growth and CO_2 emissions mainly focuses on whether this relationship follows the EKC hypothesis. Because it is the second largest economy and leading carbon emitter, China has attracted a lot of attention from scholars arguing about the existence of the EKC. However, a consensus has not yet been reached. Han et al. (2018) demonstrated that economic growth and CO_2 emissions follow the EKC hypothesis. Nevertheless, other researchers have arrived at different conclusions: an upside-down “N” relationship has been found between economic growth and CO_2 emissions from the provincial panel data from 1997 to 2012 to exam the hypothesis by Kang et al. (2016). Pal and Mitra (2017) have proved that there is no inverted U-shaped relationship between China's economic growth and carbon emissions according to the data from 1972 to 2012. Thus, whether the relationship between China's economic growth and CO_2 emissions follows the EKC hypothesis is still a matter of dispute.

Existing literature regarding FDI and CO_2 emissions in the host country has mainly focused on two objectives. The first one is to verify the Pollution Haven hypothesis by observing whether FDI has transferred pollution-intensive industries to the host country, which causes the increase of local carbon emissions (Prinz et al., 2018; Sinha et al., 2018; Wang et al., 2018; De Camargo Fiorini et al., 2018). The second objective is to prove the Porter hypothesis, that is, to determine whether, in developing counties, the decrease of local CO_2 emissions results from technological progress, which is enhanced by FDI through technological development (Aldawsari et al., 2015; Baker et al., 2017; Zomorodian and Tahsildoost, 2018; Hoseini Shekarabi et al., 2018; Gharaei et al., 2018; El-Kassar and Singh, 2018). As an emerging economy, China has attracted foreign investment capital, owing to its rapid economic growth. Therefore, scholars have been increasingly concerned with the influence of FDI on China's carbon emissions. Various scholars hold the view that the FDI has led to the growth of carbon emissions in China (Sun et al., 2017). However, Sung et al. (2018) analyzed the panel data of 28 manufacturing Chinese industries and concluded that the FDI may reduce carbon emissions. Therefore, presently, a consensus with regard to the nature of the relationship between FDI and carbon emissions has not been reached.

In conclusion, existing studies have the following shortcomings: (1)They have mostly used parametric models to investigate the non-linear relationship between carbon emissions and its influencing factors. However, parametric models are prone to model preset errors (Wang et al., 2015; Abdallh and Abugamos, 2017). (2) Other scholars have arrived at contradicting conclusions. In addition to the time span of the sample and model used, considering the intrinsic relationship between the EKC hypothesis and the Pollution Haven hypothesis, the most likely reason for the lack of consensus is that economic growth and FDI had not been placed under the same research framework. Consequently, it was possible to investigate their combined impact on carbon emissions (Han et al., 2018; Lei and Jing, 2016; Behera and Dash, 2017). This article fills these academic gaps and supplements the literature on China's hypotheses of the Environmental Kuznets Curve and the Pollution Haven.

2.1. Implications for theory

Semi-parametric additive panel model is applied in this study. The relationship between environmental pollution and economic growth is measured accurately, and the research literature about Chinese Environmental Kuznets Curve theory is enriched while empirical research method is expanded. In addition, this study also deepens the understanding of foreign investment environmental effect and deeply explores the action mechanism of Pollution Haven Hypothesis and Porter Hypothesis. This study well supplements relevant theoretical hypotheses and empirical approaches, and carries very important theoretical significance.

2.2. Implications for practice

In the face of severe situation of global warming, China proposes the objective of reducing carbon dioxide emission and improving ecological environmental quality. Semi-parametric additive panel model is adopted to carry out empirical analysis of the relationship among economic growth, FDI and carbon emissions, and to test whether Environmental Kuznets hypothesis exists in China. Meanwhile, the far-reaching influence of FDI on China's economy and environment is taken into account. As environmental situation is deteriorating and globalization process is accelerating, achieving harmonious development of economy and environment and assessing environmental effect of FDI have become a major problem for various countries. This study can not merely provide policy basis for China to achieve the task of reaching carbon emission standards, but also offer the reference for various countries to reduce carbon dioxide emission.

3. Methodology and model specification

3.1. Theoretical framework

This paper presents a review of existing literature, and attempts to investigate the nonlinear impact of both economic growth and FDI on carbon emissions by including the economic growth and FDI in the same framework. By applying the model as follows, Grossman and Krueger (1995) took the lead in researching the relationship of per capita income to environmental quality by applying the model as follows:

$$E = \alpha + \phi_1 GDP + \phi_2 (GDP)^2 + e, \quad (1)$$

Here, E denotes the carbon emissions per capita; GDP refers to the per capita GDP; e denotes the error; $\alpha$and $\phi_s$are unknown parameters. Two independent variables are introduced into the model to validate the correctness of the EKC hypothesis, namely, GDP and $(GDP)^2$. In addition to FDI, various other variables play an essential role in determining the CO_2 emissions, as has been reported by previous empirical studies (Lau et al., 2014; Kivyiro and Arminen, 2014; Rafindadi et al., 2018; Zhang and Zhang, 2018). Based on these reports, the following model can be used to determine how CO_2 relates to its determinants within the context of the Chinese economy.

$$CO2 = \alpha + \phi_1 GDP + \phi_2 (GDP)^2 + \phi_3 FDI + Z'\beta + e, \quad (2)$$

here, CO2 denotes the carbon emissions per capita; GDP refers to the per capita GDP; FDI stands for foreign direct investment; Z represents the relevant variables, and suggests a number of crucial factors contributing to CO_2 emissions; α, φ_s, and β are unknown parameter; e denotes the error. Because the natural logarithm transformation of data can avoid the violent fluctuation caused by the change of data, the model carries out the logarithmic processing of variables.

$$\ln CO2 = \alpha + \varphi_1 \ln GDP + \varphi_2 (\ln GDP)^2 + \varphi_3 \ln FDI + \ln Z'\beta + e, \quad (3)$$

here, CO2 denotes the carbon emissions per capita; GDP refers to the per capita GDP; FDI stands for foreign direct investment; Z represents the relevant variables; α, φ_s and β are unknown parameters; e denotes the error. Because model (3) is a parametric model, there are potential hidden dangers with regard to model preset bias (Abdallh and Abugamos, 2017). Thus, it becomes difficult to accurately explore the specific impact of GDP and FDI on carbon emissions. A study by Xu and Lin (2015) investigated the joint effects of economic growth and private vehicles on CO_2 emissions by using a more flexible non-parametric additive panel model for 30 Chinese provinces. However, this study ignored the marginal effect produced by the impact of key variables on carbon emissions at different stages. Based on the above analysis, we investigated the combined non-linear effects of economic growth and FDI on carbon emissions using the fixed effects panel data method; namely, a partially linear additive model expressed as follows:

$$\ln CO2_{it} = \alpha_i + f_1(\ln GDP_{it}) + f_2(\ln FDI_{it}) + \ln Z'_{it}\beta + e_{it}, \quad (4)$$

here, the province and year are indexed by i and t, respectively; i denotes a province-specific effect; CO2 denotes the carbon emissions per capita; GDP refers to the per capita GDP; FDI stands for foreign direct investment; Z represents the relevant variables; $\alpha$and $\beta$are unknown parameters; e denotes the error; $f_1(\cdot)$and $f_2(\cdot)$are unknown functions, whose forms are unspecified since the variables of economic growth and foreign direct structures, including parametric fixed effect panel model and non-parametric additive model as special cases (Ai et al., 2014). In addition, it can solve the course of dimensionality, to some extent, as it contains parametric and non-parametric models (Baltagi and Li, 2002).

To estimate Eq. (4), we followed a two-stage procedure (Ai et al., 2014). The advantages of the two-stage estimation are that it can make the final estimation computationally expedient, and easily establish the theoretical results and statistical inference with higher confidence. Moreover, it can estimate the gradients, which is particularly useful for marginal analysis. The detailed derivation and R code used in the estimation step are available upon request.

3.2. Data source

Considering the availability and integrity of data, this study focused on the related index data obtained from 29 provinces from 1996 to 2015. Owing to a partial lack of data, Hong Kong, Macau, and Taiwan were not chosen as source targets. Moreover, Tibet was also not chosen owing to the severe lack of data for this region. It is worth noting that, in 1997, Chongqing established a municipality directly under the central government. To ensure the consistency of statistics, the data from Chongqing were incorporated into the data from Sichuan province. Using the approach of Zhang and Zhao (2014), the CO_2 emission data were calculated according to the formula provided by the Intergovernmental Panel on Climate Change (IPCC) (2006) (available at: http://www.ipcc-nggip.iges.or.jp/).

Moreover, there exist various elements that can control the variable quantity and used to comprehensively investigate the CO_2 emissions, such as the consumption of energy, diffusion of technology, industrial upgrading, and trade liberalization. To directly represent the technical index, we applied technology diffusion measured by the annual funds allocated to technology transfer. Energy consumption refers to the total energy resources of the material and non-material production departments, and the consumption of life within a certain period, including raw coal and crude oil and its products, and natural gas and electricity, when all of those energy sources are converted into standard coal. Industrial upgrading is the ratio of the output value of the tertiary industry to that of the secondary industry. Trade liberalization depends on the ratio of the total export-import volume and the total production volume in local areas.

To eliminate the price effect, the variables of technology diffusion,GDP per capita, and FDI related to monetary measurement were deflated according to the 1996 consumer price index. All data used in the analysis were gathered from the China Statistical Yearbook (1997–2016), China Energy Statistics Yearbook (1997–2016), and the Statistics Yearbook of each province (1997–2016).

The model developed in this study is expressed as follows:

$$\ln CO2_{it} = \alpha_i + f_1(\ln GDP_{it}) + f_2(\ln FDI_{it}) + \beta_1 \ln ENE_{it} + \beta_2 \ln TMT_{it} + \beta_3 \ln INU_{it} + \beta_4 \ln TOP_{it} + e_{it}, \quad (5)$$

here, CO2 denotes the carbon emissions per capita; GDP refers to the per capita GDP; FDI stands for foreign direct investment; TMT denotes technology diffusion; ENE denotes the energy consumption; INU denotes the industrial upgrading; TOP denotes trade liberalization. The detailed definitions are listed in Table 1.

Table 1 presents the definition and descriptive statistics for all varia-bles. From the table, the heterogeneity across provinces is evident with th-e aggregate carbon emissions per capita ranging from 0.95 to 28.97 (minimum to maximum). Although both the income per capita and the FDI variables have a lower variance, the maximum income per capita is approximately five times higher than the variance. The maximum FDI is more than seven times higher than the average value. Furthermore, the other variables also reveal a relatively large range, which suggests that there are significant regional development differences. Fig. 1 demonstrates that economic growth has a non-linear relationship with the carbon emissions. This is also the case between the FDI and the carbon emissions, which is considered to provide further confirmation regarding the rationality of using the fixed effects panel data partially linear additive model.

4. Empirical results

The fixed effects panel data partially linear additive model was used to investigate the effect of economic growth and FDI on CO_2 emissions. Moreover, the parametric and non-parametric parts were analyzed, and a marginal effect analysis was carried out.

4.1. Relationship between determinants and CO_2 emissions

In Fig. 2(a), the X-axis represents the income per capita, while the Y-axis represents the contribution degree of income per capita to the carbon emissions per capita. The figure shows that the contribution gradually increases with the increase of income per capita. When the per capita income reaches 55,297.3 ($e^{10.8647}$) yuan, the contribution degree exhibits a turning point (i.e., Point A in Fig. 2 **(a)**) and begins to decrease afterwards. Therefore, the relationship between economic growth and carbon emissions exhibits an inverted U-shaped tendency, which coincides with the EKC hypothesis. Combined with the actual situation in China, the inverted U-shaped relationship is also in agreement with the stage of China's economic development. When the level of economic development is relatively lower, the mode of economic growth is mainly fixed asset investment, an extensive and energy-consuming production mode, and a consumption mode, which rapidly increase the total amount of carbon emissions. After economic development reaches a certain level, the social demand for better environmental quality starts to increase. In recent years, China has begun to change its economic model and explore new energy sources, which had a significant impact on the reduction of CO_2 emissions. For example, after 2011, approximately half of the electricity supply came from new energy sources, which reduced the total amount of carbon emissions resulting from energy production. The change of the industrial and energy use patterns is the main reason for the occurrence of the inflection point.

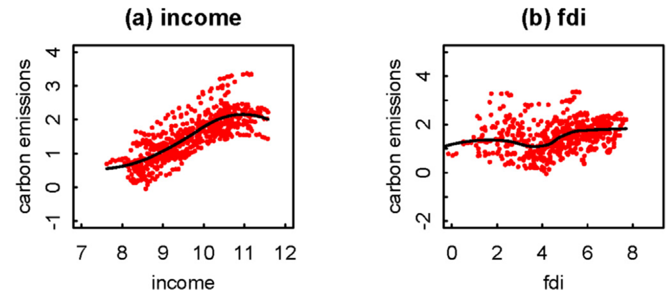

Fig. 1. Scatter plot of carbon emissions and their determinants.

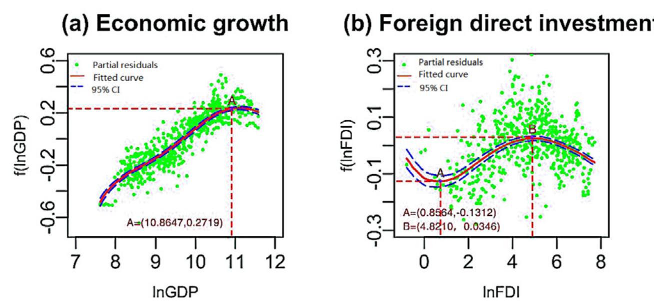

Fig. 2. Economic growth and FDI effect on carbon emissions.

In Fig. 2(b), the X-axis represents the FDI, while the Y-axis represents the contribution degree of FDI to the carbon emissions per capita. As can be seen in Fig. 2(b), the contribution of FDI to carbon emissions exhibits an inverted N-shaped structure, where in the change trend proceeds by falling, rising, and then falling again. According to the theory of Grossman and Krueger (1995) and the actual situation in China, the technological effect of FDI does not only enhance the energy utilization rate, but also reduces the per capita carbon emissions (Baker et al., 2013; Gupta et al., 2018) before the FDI amount reaches 235 ($e^{0.8564}$) million yuan. When the scale of FDI reaches Point A, the scale effect exceeds the effect of technology, which causes an increase in the contribution of FDI to carbon emissions. Considering the actual situation in China, local governments are rushing to lower the environmental standards and implement various preferential policies to attract foreign investments for the purpose of stimulating economic growth. With the scale expansion of some highly polluting enterprises, the contribution degree of FDI to the per capita carbon emissions has been rapidly increasing. Therefore, this stage effectively supports the Pollution Haven hypothesis. When the scale of foreign investment reaches 12.408 ($e^{4.8210}$) billion yuan, the demand of local governments for FDI declines, and local governments begin to raise the market access threshold, in terms of environmental standards and FDI screening, by focusing on attracting foreign investments to various high-tech industries. After Point B, the structural effect of FDI comes into effect. By adjusting the industrial structure, the

Table 1
The description of all variables in this paper.

Variable	Definition	Units	Mean	Std.dev	Min	Max
CO2	Carbon emission per capita	ton	5.66	4.47	0.95	28.97
GDP	Income per capita	yuan	23432.45	21007.01	2034.26	106904.90
FDI	Foreign direct investment	109yuan	300.68	399.19	0.45	2228.29
ENE	Energy consumption	109ton	96.53	75.37	3.45	388.99
TMT	Technical diffusion	109yuan	95.93	296.32	0.01	3453.89
INU	Industrial upgrading	percent	96.07	43.51	49.71	403.55
TOP	Trade liberalization	percent	15.83	18.43	1.46	90.63

contribution degree of FDI to the per capita carbon emissions begins to decrease (Baker et al., 2015; Xu et al., 2016; Jabbour et al., 2019). Table 2 presents the estimated effects of the control variables on the carbon emissions.

From Table 2, we can see that energy consumption promotes CO_2 emissions and has a significant impact at the significance level of 1%. The elasticity coefficient between the energy consumption and the CO_2 emissions is 0.7959. In other words, when all other variables remain unchanged, an increase of 1% in the energy consumption leads to an increase of 0.7959% in the carbon emissions. Industrial upgrading, technology diffusion, and trade liberalization have reduced CO_2 emissions with significant effects at the 5% and 1% levels, respectively. The elasticity coefficients between the carbon emissions and industrial upgrading, technology diffusion, and trade liberalization are −0.0618, −0.0135, and −0.0549, respectively, which means that, when all other variables remain unchanged and industrial upgrading, technology diffusion, and trade liberalization increase by 1%, respectively, the CO_2 emissions are reduced to 0.0618%, 0.0135%, and 0.0549%, respectively.

Moreover, the high value of R^2 demonstrates that the fitness of Eq. (5) is extremely good for all provinces ($R^2 = 0.9542 \rightarrow 1$). Additionally, the F-statistic, which measures the joint significance of all regressors in the model, is statistically significant at the 1% level.

4.2. Marginal effect analysis of determinants

To accurately understand the influence of the determinants, we performed a marginal key factor analysis on the CO_2 emissions. From Eq. (5), the gradient of $f_1(\ln GDP)$ can be expressed as follows:

$$f'_1(\ln GDP) = \frac{d \ln CO2}{d \ln GDP} \approx \frac{\Delta CO2/CO2}{\Delta GDP/GDP} = \frac{\Delta CO2}{\Delta GDP} \times \frac{GDP}{CO2}, \tag{6}$$

here, CO2 denotes the per capita carbon emissions; GDP refers to the per capita GDP, wherein Δ denotes a slight change. Eq. (6) means that a 1% change in GDP results in a change of $f'_1(\ln GDP)$ percent in CO_2 emissions. In other words, the gradient $f_1(\ln GDP)$ is simply the elasticity of CO_2 emissions with respect to the growth of the economy.

As shown in Fig. 3 **(a)**, the part of the economic development level derivative that is larger than zero corresponds to that before the turning point shown in Fig. 2 **(a)**, and the average derivative of this part, namely, the average elasticity, is 0.1787. This means that, when everything else is equal in the stage of economic growth that has a positive effect on the CO_2 emissions, for every 1% increase in the level of economic development, the CO_2 emissions increase by 0.1787%. Likewise, the part of the economic development level derivative that is less than zero corresponds to that after the turning point shown in Fig. 2(a). Additionally, the average elasticity of this part is −0.0309, which means that, when everything else is equal in the stage of economic growth that has a negative effect on the CO_2 emissions, for every 1% increase in the level of economic development, the CO_2 emissions increase by 0.0309%.

Similarly, the gradient of $f_2(\ln FDI)$ is expressed as follows:

$$f'_2(\ln FDI) = \frac{d \ln CO2}{d \ln FDI} \approx \frac{\Delta CO2/CO2}{\Delta FDI/FDI} = \frac{\Delta CO2}{\Delta FDI} \times \frac{FDI}{CO2}, \tag{7}$$

here, CO2 denotes the per capita carbon emissions; FDI stands for foreign direct investment; $f_2'(\ln FDI)$ represents the elasticity of CO_2 emissions corresponding to the FDI. This means that a 1% change in FDI leads to a change of CO_2 emissions by $f_2(\ln FDI)$ percent.

As shown in Fig. 3(b), in the part before the first time, the derivative of FDI that is less than zero corresponds to the part before the first turning point shown in Fig. 2(b), with an average elasticity of −0.0201. This means that, when all other conditions remain unchanged, FDI has a negative effect on CO_2 emissions at the initial stage. Thus, for every 1% increase in FDI, the CO_2 emissions are reduced by 0.0201%. The part where the FDI derivative is greater than zero corresponds to the part between the first turning point and the second turning point shown in Fig. 2(b). In this phase, the FDI has a positive effect on the CO_2 emissions, and the average elasticity is 0.0385. When all other conditions remain unchanged, for every 1% increase in FDI, there is a corresponding increase of 0.0385% in CO_2 emissions. The derivative of the second part of FDI that is less than zero corresponds to Fig. 2(b) after the turning point in the second part. In this phase, the FDI begins to curb the CO_2 emissions and the average elasticity is 0.0276%. This means that, when all other conditions remain unchanged, a 1% increase in FDI produces 0.0276% less CO_2 emissions.

5. Robustness test

In order to verify the reliability of the estimation results of the fixed effects panel data partially linear additive model, this paper carried out parametric test and non-linear test specific. The process is as follows:

5.1. Parametric test

Because the FDI can accelerate the economic growth, there are problems of the multi-collinearity. In order to test the robustness on the fixed effects panel data partially linear additive model, the parameter test can be divided into two parts. In the first part, according to the result of the fixed effects panel data partially linear additive model, this paper induces the lnGDP and its quadratic terms to express inverted U-shaped relationship between economic growth and carbon emissions. Meanwhile, this article utilizes lnFDI and its secondary and tertiary terms to match the inverted N-shaped relationship between FDI and carbon emissions. The detailed can be found in formula (8). In the second part, based on the regression results of the economic growth, FDI and the lagged term, we exclude the impact of foreign direct investment on economic growth and then follows the model (8) to test. The lnGDP influenced by the lnFDI and its lag phase is significant at 10%. lnGDP influenced by the lagging second stage of lnFDI is not significant. Therefore, we exclude the impact of foreign direct investment on economic growth according to the sum of 0.332 of the impact coefficient of lnFDI and its lag terms on lnGDP. The specific excluding

Table 2
Results for parametric estimations.

Variables	lnENE	lnINU	lnTMT	lnTOP	R^2	F-value
Coefficients	0.7959***	−0.0618**	−0.0135**	−0.0549***	0.9542	2276.4400***
t-statistic	31.1506	−2.4418	−2.6128	−4.8019		

Notes: * represents significance at 10% level. **represents significance at 5% level. *** represents significance at 1% level.

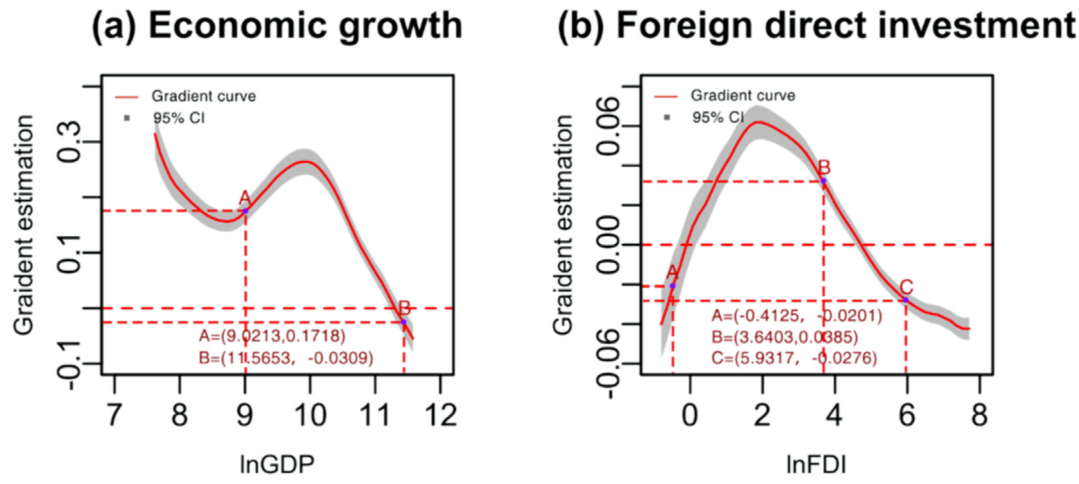

Fig. 3. Marginal effect analysis of economic growth and FDI.

method is to multiply by 0.668 (1–0.332) on the original the original lnGDP basis.

$$\ln CO2_{it} = \alpha_i + \varphi_1 \ln GDP_{it} + \varphi_2 (\ln GDP_{it})^2 + \varphi_3 \ln FDI_{it} + \varphi_4 (\ln FDI_{it})^2 + \varphi_5 (\ln FDI_{it})^3 + \beta_1 \ln ENE_{it} + \beta_2 \ln TMT_{it} + \beta_3 \ln INU_{it} + \beta_4 \ln TOP_{it} + e_{it}, \quad (8)$$

Here, the province and year are indexed by i and t, respectively; i denotes a province-specific effect; $\alpha\varphi$, and β are unknown parameter and e denotes the error term. CO2 denotes carbon emission per capita, GDP is referred to as the per capita GDP, FDI stands for Foreign Direct Investment. TMT denotes technology diffusion, ENE denotes energy consumption, INU denotes industrial upgrading and TOP denotes trade liberalization. In this part, parametric models such as mixed effect, fixed effect and random effect are used to estimate the influence of explanatory variables on carbon emissions. Their results of Hausman and F are not in line with the original hypothesis. Then we choose the fixed effect to test the robustness of the fixed effects panel data partially linear additive model. In addition, the fixed effect model can fully consider the heterogeneity of samples and effectively solve the problem of heterogeneity bias caused by the use of mixed effect model. The corresponding regression results are shown in Table 3 as follow.

It contains the estimated results of the FDI or it does not contain the estimated results of the FDI. From the estimation results of the variables in the above table, it can be known that: (1) Comparing the estimation results of fixed effect with and without the inclusiveness of FDI influence, it is obvious that the rest estimation results are maintaining the same, except the carbon emissions influenced by the linear term and quadratic term of economic growth; (2) The effects of linear term and quadratic term of economic growth on CO_2 emissions are all significant at the 1% level, and the coefficient of linear terms is positive and the coefficient of the quadratic term is negative, indicating that the impact of economic growth on CO_2 emissions basically conforms to an inverted U-shaped structure; (3) The effects of linear term, quadratic term and cubic item of foreign direct investment on CO_2 emissions also are significant at the 1% level, and the coefficient of linear term is negative, the coefficient of the quadratic term is positive, and the coefficient of the cubic coefficient is negative, indicating that the impact of foreign direct investment on CO_2 emissions basically conforms to the inverted N-shaped structure; (4) The coefficient estimation results of the control variables, whether size, direction or significance level, are basically consistent with the estimation results of the fixed effects panel data partially linear additive model. In summary, this section further validates the robustness of the fixed effects panel data partially linear additive model estimation results by means of parameter tests.

Table 3
The parameter test results.

Variables	Including FDI impact		Excluding FDI impact	
	Fixed effect	Random effect	Fixed effect	Random effect
lnGDP	1.1969***	1.3124***	1.7919***	1.9647***
	(0.1591)	(0.1722)	(0.2382)	(0.2578)
$(\text{lnGDP})^2$	−0.0466***	−0.0442***	−0.1045***	−0.0992***
	(0.0082)	(0.0089)	(0.0185)	(0.0200)
lnFDI	−0.0963***	−0.0808**	−0.0963***	−0.0808**
	(0.0346)	(0.0376)	(0.0346)	(0.0376)
$(\text{lnFDI})^2$	0.0399***	0.0309***	0.0399***	0.0309***
	(0.0098)	(0.0106)	(0.0098)	(0.0106)
$(\text{lnFDI})^3$	−0.0039***	−0.0033***	−0.0039***	−0.0033***
	(0.0007)	(0.0009)	(0.0008)	(0.0009)
lnENE	0.6169***	0.4245***	0.6169***	0.4245***
	(0.0406)	(0.0362)	(0.0406)	(0.0362)
lnINU	−0.2019***	−0.2235***	−0.2019***	−0.2235***
	(0.0339)	(0.0364)	(0.0339)	(0.0364)
lnTMT	−0.0319***	−0.0510***	−0.0319***	−0.0510***
	(0.0074)	(0.0077)	(0.0074)	(0.0077)
lnTOP	−0.0355**	−0.0278	−0.0355**	−0.0278
	(0.0167)	(0.0173)	(0.0167)	(0.0173)
F	132.1100(p-value = 0.0000)		115.2600(p-value = 0.0000)	
Hausman	72.3660(p-value = 0.0000)		87.3600(p-value = 0.0000)	

Notes: Standard errors in parentheses. * represents significance at 10% level. **represents significance at 5% level. *** represents significance at 1% level.

5.2. Nonlinear test

To further verify the optimal fitting effect of the fixed effects panel data partially linear additive model, this study conducted a nonlinear test on the relationship between the economic growth, FDI, and CO_2 emissions through polynomial settings, and used the Akaike information criterion (AIC) (Akaike, 1974) index to assess the model's fitting effect. According to the fitting figure of the non-parametric part, the contribution of economic growth to CO_2 emissions has an inverted U-shaped structure. Therefore, in model (9), the economic growth is set to a quadratic polynomial so as to fit the relationship between the two sides. Additionally, the contribution of FDI to CO_2 emissions exhibits an inverted N-shaped structure. Therefore, in model (10), we set the FDI to a cubic polynomial so as to fit the relationship between the two sides. The specific nonlinear test model was set as follows:

$$\ln CO2_{it} = \alpha_i + \varphi_1 \ln GDP_{it} + \varphi_2 (\ln GDP_{it})^2 + f_2(\ln FDI_{it}) + \beta_1 \ln ENE_{it} + \beta_2 \ln TMT_{it} + \beta_3 \ln INU_{it} + \beta_4 \ln TOP_{it} + e_{it}, \tag{9}$$

$$\ln CO2_{it} = \alpha_i + f_1(\ln GDP_{it}) + \varphi_3 \ln FDI_{it} + \varphi_4 (\ln FDI_{it})^2 + \varphi_5 (\ln FDI_{it})^3 + \beta_1 \ln ENE_{it} + \beta_2 \ln TMT_{it} + \beta_3 \ln INU_{it} + \beta_4 \ln TOP_{it} + e_{it}, \tag{10}$$

Here, the province and year are indexed by i and t, respectively; i denotes a province-specific effect; α,$\varphi$and $\beta$are unknown parameter and e denotes the error term,$f_1(\cdot)$and $f_2(\cdot)$are unknown functions. CO2 denotes carbon emission per capita, GDP is referred to as the per capita GDP, FDI stands for Foreign Direct Investment. TMT denotes technology diffusion, ENE denotes energy consumption, INU denotes industrial upgrading and TOP denotes trade liberalization.

Here, AIC refers to the calculation method.

$$AIC = -2 \log \hat{L}_C + 2df \tag{11}$$

where L_C is the mean square deviation, and df is the model's degree of freedom. The smaller the AIC exponent is, the better is the fitting effect of the model. The nonlinear test results and the estimation of the diffusion of clean production technology, and the diffusion of terminal treatment technology and its AIC index are presented in Table 4.

The following conclusions can be drawn from Table 4. First, the polynomial coefficient of model (9) can actively perform at approximately 1% and 5%. Its primary term coefficient is positive, whereas, the secondary term coefficient is negative, which largely confirms the upside-down "U" relationship between the economic growth and the CO_2 emissions. Secondly, the coefficient of model (10) is prominent at approximately 5%, 1%, and 5%, respectively. Its primary term coefficient is positive, while its secondary term coefficient is negative, and its tertiary term coefficient is negative, which demonstrates the inverse "N" relationship between the FDI and the CO_2 emissions. Finally, each AIC index of models (8), (9), and (10) is larger than that of model (5) amongst all CO_2 emission model estimations. Therefore, the results obtained by model (5) are more sound and stable. To sum up, the optimality and stability in the fixed effect results of the panel data partially linear additive model was demonstrated by nonlinear investigation.

6. Discussions and future research directions

Previous studies have focused on the efficiency of the EKC hypothesis from the perspective of economic growth, while ignoring the effects of other factors, such as foreign direct investment, on carbon emissions. Some literature try to test the validity of the Pollution Haven hypothesis from the single point of view of FDI, but ignore the requirements of environmental quality in different stages of economic development. Above all of these make the research results lack of authoritativeness. In order to be more faithful, this article considers the economic growth and FDI into the same model to analyze the situation in China that is in line with the EKC hypothesis or the Pollution Haven hypothesis. Then this article will discuss some research findings and propose future research directions.

6.1. Discussions

The first finding is that there is an inverted U-shaped curve relationship between economic growth and carbon emission per capita, which is consistent with the EKC hypothesis. This finding is supported by Wang et al. (2017). The situation in China is in line with the EKC hypothesis. But we cannot hold the idea that environmental pollution, such as carbon emissions, can be alleviated with economic growth. In the process of economic growth, there is an endogenous mechanism which can solve the problem of environmental pollution automatically. Then, China can experience the treatment after pollution. The problem of the environmental issue can not be resolved by the economic growth. The formation of inverted U-shaped of the EKC needs more efforts from all directions, realizes the promotion of the industry (Zhou et al., 2013), enhances the level of the technology (Majumdar and Kar, 2017; Shaharudin et al., 2019), introduces the orientation of the foreign investment (Zhang and Zhou, 2016; Sung et al., 2018) and increases the degree of the trade liberalization (Yu and Chen, 2016).

Table 4
Model estimation and selection results.

Model	Linear	Quadratic	Cubic	AIC
Our model(5)				−1133.24
Parametric fixed effect model(8)				−1037.00
Semi-parametric fixed effect model(9)	0.3915***	−0.0083**		−1045.14
Semi-parametric fixed effect model(10)	−0.0152**	0.0238***	−0.0028**	−1118.95

Notes: * represents significance at 10% level. **represents significance at 5% level. *** represents significance at 1% level.

The second result is that the nonlinear impact of foreign direct investment follows an inverted"N-shape"with two turning points in relation to CO_2 emissions, which is consistent with our expectation and with common sense. As a result of foreign direct investment, China can acquire advanced technology, make full use of energy, and reduce carbon emissions (Baker et al., 2018; Oliva et al., 2019). In this phase, the spillover of the technology result from the FDI plays a pivotal role and supports the Porter hypothesis that is mentioned in the literature review. When foreign direct investment reaches a certain level, local governments realize the stimulation of foreign direct investment. They decided to attract foreign capital by lower environmental standards. As a result, many foreign enterprises enter the Chinese market. It is characterized by high pollution, high energy consumption and a great burden on carbon dioxide emissions. In this stage, the scale effect of foreign investment exceeds the technical effect brought by foreign investment and it is a truth that China must undertake pollution transfer in developed countries, which is in line with the Pollution Haven hypothesis. With the improvement of living standards and the severe challenge of environmental problems, local governments have put forward higher standards and norms for foreign-funded enterprises. On the basis of joint efforts, carbon emissions are gradually reduced. At this stage, the structural effect of foreign direct investment played an important role, and the adjustment of industrial structure was conducive to reducing carbon dioxide emissions, which was also in line with the requirements of high-quality economic growth proposed by the 19th National Congress of China.

The third finding is that specific energy consumption has a positive impact on CO_2 emissions. This finding has been proved by Zhou et al. (2015). At present, the energy used in industrial production contains fossil fuels, and the increase of energy consumption inevitably leads to the increase of CO_2 emissions.

The fourth result is that there is a negative impact between technology diffusion and CO_2 emissions. This is consistent with the findings of Majumdar and Kar (2017). Technology diffusion can improve energy efficiency, especially the application of carbon emission reduction technology can effectively reduce CO_2 emissions.

The fifth finding is that the impact of industrial upgrading on CO_2 emissions is also negative. This finding has been proved by Zhou et al. (2013). Industrial upgrading can effectively reduce the application of fossil energy, especially the development of some new energy industries can effectively reduce CO_2 emissions.

The last finding is that trade liberalization has a positive effect on CO_2 emissions. This conclusion is keeping with the findings of Yu and Chen (2016). Trade can make full use of the advantages of technology. At the same time, it is a better way to take advantage of energy and reduce the CO_2 emissions.

6.2. Suggestions for future research

As for the further development, there are some uncultivated areas as follows. Firstly, the regional situation in China is very different. Taking into account differences in resource storage, geographical location and stage of development, is the relationship between economic growth and carbon emissions in different regions still consistent with the EKC hypothesis? By dividing different regions according to resource endowment, geographical location and development stage, the validity of EKC hypothesis can be further explored. Secondly, although the relationship between FDI and carbon emissions is discussed on the basis of the theory proposed by Grossman and Krueger (1995), whether these three effects play a role in different stages remains to be further studied. Finally, the national conditions of developed and developing countries are different. Consistency with developed and developing countries must be tested. The development of China can give a lesson to other developing countries to decrease the carbon dioxide or not.

7. Conclusion and policy implications

As we all know, in this paper, the validity of EKC hypothesis and Pollution Haven hypothesis in China is discussed by using the fixed effects panel data partially linear additive model, which filled in the gap of using the semi-parametric additive panel model method to study this problem (Whetten, 1989). Different from previous literature, this paper analyzes the marginal effects of economic growth and FDI at different stages, which can reveal the impact of economic growth and foreign direct investment on carbon emissions in details (Suddaby, 2014). To further test the robustness of the result, this paper has conducted parameter and nonlinear test. Then this article will make further studies from the conclusion and the enlightenment of the policy.

7.1. Conclusion

This paper has selected 29 provincial-level panel data from 1996 to 2015 to explore the validity of the Environmental Kuznets Curve hypothesis and the Pollution Haven hypothesis in China and obtained the following conclusions: (1) There is an inverted U-shaped relationship between economic growth and CO_2 emissions, which validates EKC hypothesis. However, it is impossible to automatically resolve carbon emission and other environmental pollution problems with economic growth, and the formation of inverted U-shaped of the EKC needs joint efforts of all parties. (2) Different from previous studies, this paper found that there is an inverted N-shaped relationship between foreign direct investment and CO_2 emissions. Although current foreign capital inflow does not support the Pollution Haven hypothesis, this does not mean the government of China can lower environmental standards and loosen foreign capital supervision. The formation of inverted-N curve is closely related to strict environmental supervision by the government of China. (3) Energy consumption has a positive and promoting effect on CO_2 emissions. Although energy consumption intensifies carbon emission, the types of energy consumption are not differentiated in this study, so the influencing degree of non-clean energy consumption on carbon emission cannot be obtained. Industrial upgrading, technological diffusion, and trade liberalization all have an inhibiting effect on CO_2 emissions. The three aspects can improve resource utilization efficiency and reduce carbon emission to some extent.

7.2. Policy implications

While the findings of this study support the EKC hypothesis, we cannot blindly assume that economic growth can automatically reduce carbon dioxide emissions. The turning point on the EKC must obtain more efforts from all direction. First of all, the government cannot attach importance to the speed of economic growth. We must implement the strategy of sustainable development, realize the coordinated development of economy and environment, and improve the quality of economy. At the same time, it is necessary to establish a sound carbon trading market, achieve resource allocation, and reduce carbon emissions (Gharaei et al., 2017; Singh and El-Kassar, 2019). Secondly, we should improve the environmental access standard of foreign investment and implement the environmental standard project by using the synergistic effect of regulation and market tools.

The introduction of extensive and service industries related to low pollution level and low emission level can accelerate structural adjustment (Gharaei et al., 2015). The existing foreign capital should be actively guided to adopt advanced environmental protection technology and management means in order to improve its environmental management capability (Duan et al., 2018). Finally, it is wise to develop clean energy such as wind and solar. At the same time, the use of foreign advanced clean technology can improve energy efficiency. Take various measures to encourage enterprises to use cleaner production technology and promote the promotion of environmental protection technology. A green trading system can increase spillover effects from trade.

Notes

The authors declare no competing financial interest.

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