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Research on Development Pattern of Low-Carbon Economy Industrial Park in Economic Zone of Guangxi Beibu Gulf

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Abstract: As the global climate warming, "haze" weather frequent, low-carbon economy research caused extensive concern of the academia, In this paper, we use panel data of 5 cites in China Guangxi province over the period 2000 to 2008, and construct a systematic model which concludes the factors of FDI technology of carbon emissions and carbon emission intensity. In addition, we refinement the relevant data of sub-regional study in order to receive an in-depth analysis of FDI impact on China's carbon emissions under the influence of technology. As a result, there exists hysteresis in the impact of FDI on carbon emission in china, and lad FDI (lag 1 period) has significant positive effects on carbon emission. This article first analyses the background and connotation of low-carbon economy, low-carbon economy industrial park is analysed the related theoretical basis, and then analysed the necessity of the construction of low-carbon economy industrial park of Guangxi Beibu Gulf economic zone, finally we propose the construction of development model of low-carbon economy industrial park of economic zone of Guangxi Beibu Gulf.

Keywords: Development model, economic zone of guangxi beibu gulf, low-carbon economy industrial park.

1. INTRODUCTION

1.1. Background of Low-Carbon Economy

In 2003, the UK Government firstly proposed low-carbon economy in an energy white paper ---- Our Energy Future: Creating a Low-carbon Economy [1, 2]. Afterwards, the low-carbon economy has been more and more concerned by the international society and meanwhile has gradually become a global consensus. Actually, the generation background thereof can be mainly summarized in three aspects: firstly, how to respond to the global climate change is a topic commonly concerned by all humans; a lot of waste gases and smokes have been discharged into air during global population increase process and economic growth process, so CO2 concentration in air is sharply increased, thus causing the global climate warming which is significantly unfavorable for human survival and development. Secondly, due to excessive and extensive resource utilization, the unit energy consumption and the unit resource consumption become high enough to further intensify resource exhaustion; in the global energy reserves, fossil energy has have relatively long exploration and utilization time, and under present technology level and exploration strength, coals can be utilized for about 200 years and petroleum can be utilized for about 40 years, but the hydrogen energy reserved in seawater will become the new energy able to be sustainably utilized in future; however, in order to utilize fossil energy, human needs to pay gradually increased economic and technical costs and meanwhile meet stricter requirements [3].

Thirdly, such untreated pollutants as waste water, waste gas and waste residue discharged during enterprise production not only severely threaten to human health and animal & plant life, but also directly or indirectly heavily destroy natural environment and ecological balance [4].

As a developing country, China has particularly prominent energy and environment problems. In 2008, Chinese Government issued a white paper [5, 6] ---- China's Policies and Actions on Climate Change and indicated the following information: during 1908~2007, the average surface air temperature of China was increased by 1.1℃ according to relevant statistics; during 1986~2006, China continuously had 21 nationwide warm winters according to relevant statistics; in recent years, such climate problems as "haze" weather and other disasters have frequently and intensively appeared, the water resource shortage has been gradually intensified, the ecological environment has been gradually deteriorated, the agricultural production losses have been increased day by day, and the subsequent food safety problem has become more and more prominent; meanwhile, the sea level is continuously raised, so the economic and social development of the coastal region has been severely threatened [7].

1.2. Connotation of Low-Carbon Economy

So far, theorists have not yet reached a consensus upon the connotation of "low-carbon economy". Bao Jianqiang, *et al.* [8-10] believe that carbon emission has become a new sign for evaluating human economic development, and the internationally reached carbon emission reduction agreement for low-carbon economy is superficially the result of the purpose for jointly reducing carbon dioxide release, but is substantially the revolution of human living style, economic development pattern and energy consumption mode, and such revolution will promote the industrial civilization relaying on fossil energy to be converted into ecological civilization. Liu Xiliang [11] indicates that during human social development process, the low-carbon economy is a rational balance made by humans not only between economic growth and welfare improvement, but also between economic development and environment protection; the low-carbon economy is human rational cognition on the harmonious relationship between man and nature, between man and society, between man and man; the low-carbon economy is the ecological civilization after human society has experienced original civilization, agricultural civilization and industrial civilization; the low-carbon economy is a new energy revolution after the human society has experienced industrial revolution and information revolution. Jin Yueqin [12, 13] indicates that the low-carbon economy is a new economic development pattern which not only can meet the requirements of the environment-friendly society with the features of sustainable development and resource conservation, but also has a close relation with the energy-conserving &emission-reducing and circular economy currently energetically promoted. Although scholars have different research views for low-carbon economy, they still commonly express that the low-carbon economy is a new revolution and a new economic form of human social and economic development, and aims at saving energy and reducing greenhouse gas emission [14].

2. RELEVANT THEORETICAL BASIS OF LOW-CARBON ECONOMY INDUSTRIAL PARK

2.1. Theoretical Framework

Most of the literature on the relationship between economic activities and the environment are drawing on Grossman and Krueger of the analytical framework. That is, to breakdown the environmental impact of economic activity into three aspects: scale, structure effects and technology effects [15-18, 20].

This paper refers to the idea of Grossman and Krueger and Hubler and Keller. The theoretical models is investigated from the above three aspects of impact of economic activity on carbon emissions which states above. The basic model is as follows:

$$E = Y \bullet S \bullet T \tag{1}$$

Here, E = Carbon emissions, Y= Gross domestic product (GDP), S = Economic structure [19], and T = Technology level. The description of the variable is stated as follows.

First, since the studies mainly focus on the provincial-level, Y is Gross Domestic Product of Region (GDPR). As it illustrated by Antweiler et al, the expansion of GDP has a significant negative impact on the environment. Additionally, the change of local production [21] which caused by FDI alteration would influence carbon mission. That is, a scale effect would arise to the extent that FDI impact on carbon emission. However, Acharkyya also mentions that it is hard to separate the scale effect of FDI and the scale effect of GDP as the relationship between carbon emission and GDP is complex. Our work considered the idea of Hubler and Keller, which indicated that the Variable Y had already contained the scale effect of FDI.

Second, Variable S represents the impact of economic structure on carbon emissions. The increase of the proportion of industries would cause the increase of energy and resource consumption, leading to increasing carbon emissions. We therefore consider that the influence of FDI on regional carbon emission exist structural effects, while the structural effects of FDI indirectly affect carbon emission through the structural effects of regional economic. Thus, the Variable S contains the structural effects of FDI.

Third, Variable T contains technological factors that affect the carbon emissions. In an open economy, technological progress occurs in both internal channel and external channels. As to internal channel, technological progress of carbon emissions could achieve through "learning by doing", or by increasing the research and development expenditure. In addition, as per capita income increasing, environmental regulations must be strengthening, which would lead to the development of regional carbon emissions technologies.Thus, Our study thereby considers the capital accumulation (indicator K) would contribute to develop the local technologies as well as the carbon emission technologies, and the internal channel should contain technology progress effect resulted from income arising.As to external channel, international technology transfer has been an essential vehicle to the technological progress. Developing countries could improve the carbon emission technologies by exportation [22].

Our study mainly investigates the impact of technology spillover effect of FDI on carbon emission in China, which is to verify the existence of "Porter hypothesis". The scale effect of variable Y is considered to have contained the scale effect of FDI, and structural effect of variable S is considered to have included the structure effect of FDI.

In summary, the technological function (T) is as follows:

$$T = f(K, RD, ey, EX, FDI) \tag{2}$$

After combining the function T (2) and the basic model (1), we summarize the carbon emission function:

$$E = Y \bullet S \bullet T(K, RD, ey, EX, FDI) \tag{3}$$

Under constant returns to scale, the carbon emission intensity equation is summarized as follows:

$$EI = E / Y = S \bullet T(K, RD, ey, EX, FDI) \tag{4}$$

Different level of economic and social development will lead to different carbon emission in the area. Thus, to fully examine the impact of FDI on carbon emissions, 30 provinces of China will be divided into eastern, central and western areas in our research

2.2. Related Theory

At present, the “Cleaner Production” is not internationally uniformly defined. Therein, the common definition was proposed by UNEP IE/PAC (Industrial and Environmental Planning Activity Center, Industrial United Nations Environment Programme) in 1989 [23, 24]:

"Cleaner Production" aims at applying the comprehensive preventive environment strategy sustainably to the production process, product and service in order to improve efficiency and reduce the hazards brought to human and environment. In the aspect of production process, "Cleaner Production" aims at saving energies and resources and eliminating harmful raw materials so as to reduce the generation of waste and hazardous substances; in the aspect of products, "Cleaner Production" aims at minimizing the adverse impacts brought to human and environment during the whole product life cycle; in the aspect of services, "Cleaner Production" aims at including the preventive environment in service designing and providing activities. Substantially, "Cleaner Production" is a production pattern that a preventive environment strategy is adopted for production process and product to reduce or even eliminate the hazards brought thereby to human and environment so as to comprehensively meet human needs and finally maximize the economic benefit of human society [25].

"Circular Economy", firstly proposed by American economist K Boling, is an economic form that is generated to realize the coordination of economic benefit, ecological benefit and social benefit after the developed countries have implemented the sustainable development strategy in 90s of the 20th century [26]. Actually, not only with the basic characteristics of closing material circulation and energy echelon utilization, but also with the expressions of low consumption, low pollution, high utilization ratio and high circulation rate, Circular Economy as the abbreviation of closing material circular economy aims at realizing the high-efficient and cyclic resource utilization and the low emission or even zero emission of pollutants through the basic principle of minimization, recycling and recirculation, thus to reach the material balance between economy and environment.

"Industrial Ecology", firstly appearing in the scientific and technical literatures in 60s and 70s, was further researched and developed in early 90s [27]. At present, the academia does not have uniform definition for "Industrial Ecology". According to Journal of Industrial Ecology, "Industrial Ecology" is adopted to not only systematically research the products from the specific layer, the regional layer and the global layer as well as the circulation and utilization of materials and energies in process department [28], industrial department and economic sector, but also intensively research the impact of environment pressure on the process of industrially reducing product life cycle. Industrial ecologists believe that no absolute waste materials exist in the industrial production process, and waste materials can be relatively regarded as resources, and after proper treatment, industrial production and environment protection can be completely unified with each other, so ideal industrial ecosystem can realize zero pollution and zero emission through a completely circular production pattern and the waste materials at one department may be the resources for another department, thus to eliminate the absolute waste materials.

2.3. Empirical Models and Estimation Methods

Based on the theoretical framework stated above, the empirical regression equation is as follows:

$$\ln EI_{it} = \beta_1 \ln S_{it} + \beta_2 \ln K_{it} + \beta_3 \ln RD_{it} + \beta_4 \ln ey_{it} + \beta_5 \ln EX_{it} + \beta_6 FDI_{it} + \varepsilon_{it} \quad (5)$$

Here, i = region, t = year, EI = carbon intensity, S = structural condition, K = capital position, RD = R & D investment, ey = per capita income, EX = exports situation, FDI = foreign direct investment position, εit = error term

When estimated the panel data using random effects, the default variables are required to be independent of the explanatory variables, we therefore adopt the fixed effects estimation to estimate the panel data. In addition, the variable of energy prices and environmental regulations which change over time will also affect carbon emission. Thus, we add some constant variable to fix the model in order to decrease the impact of regional and time factors. The Revised equation is as follows:

$$\ln EI_{it} = a + \lambda_i + \theta_t + \beta_1 \ln S_{it} + \beta_2 \ln K_{it} + \beta_3 \ln RD_{it} + \beta_4 \ln ey_{it} + \beta_5 EX_{it} + \beta_6 FDI_{it} + \varepsilon_{it} \quad (6)$$

Here, a = constant intercept, λi = constant region, θt = constant time

Hysteresis was occurred in FDI technology spillovers. In order to fix the effect of endogenous variable on FDI, we used lag FDI (lag 1 period) replaced the FDI variable in Model A1. Therefore, we got a new Model A2, which was overcome the problem of endophytism and underestimation of lag effect. Moreover, it could capture FDI more accurately. Nick, Rachel and John mentioned that host country's R&D investment would absorb the FDI technology spillovers, which would cause a significant effect. Hence, we added a cross-term of RD and FDI in our model in order to comprehensively investigate the effect of FDI on host country carbon emission through technical route. Correlation might exist between FDI and EX, thus, more statistical test would be administer through the analysis process. RD, FDI and their cross-term may be related, thus, for the avoidance of multiple-liner, we would analyze these variables respectively.

In order to comprehensively examine the impact of the scale effect, structural effect and technological effect on regional carbon emissions, the GDP (Y) should be included in the explanatory variables in the model. However, the variable GDP (Y) may correlate to the variable of per capita output (ey). Thus, we excluded the effect of per capita income. The regional carbon emission model is as follows:

$$\ln E_{it} = a + \lambda_i + \theta_t + \beta_1 \ln Y_{it} + \beta_2 \ln S_{it} + \beta_3 \ln K_{it} + \beta_4 \ln RD_{it} + \beta_5 \ln EX_{it} + \beta_6 FDI_{it} + \varepsilon_{it} \quad (7)$$

Here, E = regional carbon emission, Y= GDPR, a = constant intercept, λi = constant region, θt = constant time. In order to fix the effect of endogenous variable on FDI, we used lag FDI (lag 1 period) replaced the FDI variable in Model B1, and we got a new model B2. To eliminate the impact of heteroscedasticity problem, our study use the panels data to get standard error correction value as the t-test in order to determine the significant variables.

3. NECESSITY OF THE CONSTRUCTION OF LOW-CARBON ECONOMY INDUSTRIAL PARK IN ECONOMIC ZONE OF GUANGXI BEIBU GULF

3.1. The construction of Low-Carbon Economy Industrial Part is a Realistic Choice for Environment Pressure Reduction and High-Efficient Resource Utilization

The resources and the environment bearing capacity of Economic Zone of Guangxi Beibu Gulf have some conflicts with the development of its industrial economy. At present, Economic Zone of Guangxi Beibu Gulf is in the middle stage of industrialization and the industrial structure is significantly irrational, wherein the high-carbon secondary industry takes the leading position and the industrial production has the features of relatively single energy structure, relatively low energy utilization, energy waste, relatively high emission of industrially generated “three wastes”, thus to significantly influence environment bearing capacity. However, if the Low-carbon Economy Industrial Park is constructed, enterprises will take such circular economy measures as resource minimization and resource recycling & recirculation as well as resource regeneration from wastes in order to significantly improve resource utilization efficiency. Meanwhile, the enterprise cluster in the low-carbon economy industrial park can mutually and efficiently utilize the waste materials in order to make the waste materials of one enterprise become the raw material sources for another enterprise and accordingly realize the rational resource utilization.

3.2. The Construction of Low-Carbon Economy Industrial Park can Bring Cost Advantages to the Enterprises Therein

The low-carbon economy industrial park focuses on improving resource utilization ratio and recycling the waste materials in order to directly reduce the production costs of enterprises and meanwhile enable the enterprises therein to continuously create the products with market competitiveness and cost advantage. Furthermore, the enterprises therein can also share relevant fundamental services, thus to save costs and obtain more and better economic effects. Additionally, the enterprises sharing relevant services can correspondingly create economic value and increase the property asset value of the industrial park, thus to create new economic benefit to the management department of the industrial park.

3.3. The Construction of Low-Carbon Economy Industrial Park can create Obvious Social Benefit and Environmental Benefit

The enterprises in the low-carbon economy industrial park can adopt more environmental cleaner production pattern to reduce a lot of pollution sources and waste sources as well as natural resource consumption. Additionally, after the economic benefits of the enterprises in the low-carbon economy industrial park are significantly increased, a lot of new enterprises with good economic benefits will join the industrial park, thus to create more and better entrepreneurial climate and environment for the new enterprises and the original enterprises, and along with the positive circulation, this industrial park will develop into a large economic development base. Meanwhile, the new enterprises will create more employment opportunities and posts, and other enterprises in this economic zone will find new clients among the new enterprises in the industrial park, thus to increase revenues. Along with the significant reduction of waste emission, the quality of air, land and water therein will be gradually improved, so the environment of the industrial park and the economic zone will be overall improved and the industrial park will finally become a more attractive and vigorous industrial park.

4. DEVELOPMENT PATTERN OF LOW-CARBON ECONOMY INDUSTRIAL PARK IN ECONOMIC ZONE OF GUANGXI BEIBU GULF

Low-carbon economy industrial park is a new industrial park established according to the concept of “Circular Economy”, the requirement of “Cleaner Production” and the theory of “Industrial Ecology”, and can connect different enterprises to treat the waste gases generated by one enterprise through such technologies as carbon neutralization, carbon capturing and preservation so as to reduce CO2 emission. Meanwhile, the waste materials or the by-products of one enterprise after cleaner production treatment can be changed into the raw materials for another enterprise, thus to finally form the industrial chain circulation for resource sharing and by-product exchange. On the basis of simulating the natural system, a circular approach from producer to consumer and then to decomposer is established in the whole production system so as to finally realize the cyclic coexistence of materials, the multistage utilization of energy and the minimization of waste emission.

The development pattern of the Low-carbon Economy Industrial Park is based on ecosystem circulation and coexistence theory and the details are as follows: an industrial chain circulation for resource sharing and by-product exchange is formed among different enterprises through traffic network connection, environmental protection coordination, low-carbon technical treatment, cleaner production pattern, regional resource sharing, functional complementation, *etc*. in order to make the waste materials generated by one enterprise during the production process changed into the raw materials or the energies needed by another enterprise during the production process, realize the comprehensive resource utilization, reach the optimal allocation of shared resources, continuously prolong the production chain, realize the effective resource utilization for the whole economic zone or the enterprise clusters, minimize waste emission or even eliminate waste emission, and finally realize the win-win objective of economic development and environmental protection. The development pattern specifically involves the following four aspects: (I) material circulation inside enterprises: the solid wastes or the by-products generated during the production process are not thrown away to the environment, waste gases are not directly discharged to the atmosphere, but the above mentioned wastes are properly treated through carbon neutralization, carbon capturing and preservation as well as other low-carbon technologies in order to reduce environmental loads; (II) Inter-enterprise circulation: the waste materials generated by one enterprise during the production process is changed into the raw materials or the energies able to substitute natural raw materials and needed by another enterprise during the production process, thus to save energy,

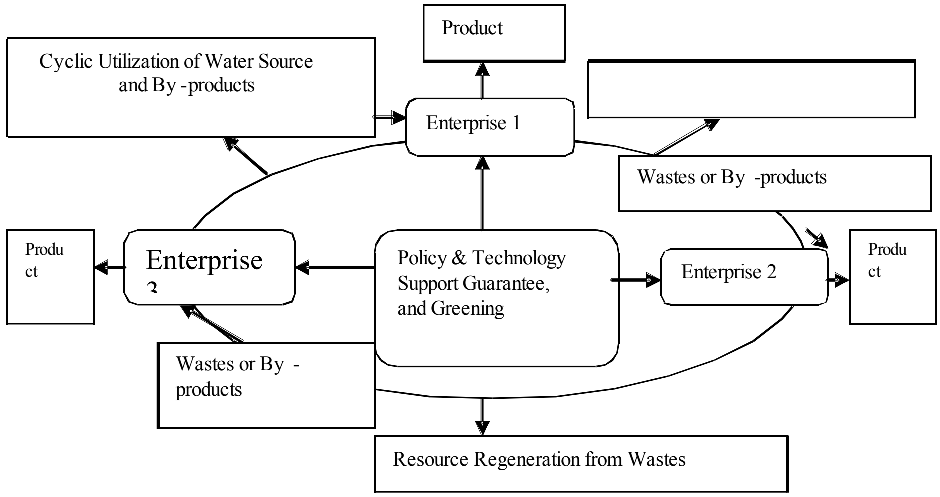

Fig. (1). Development pattern of low-carbon economy industrial park.

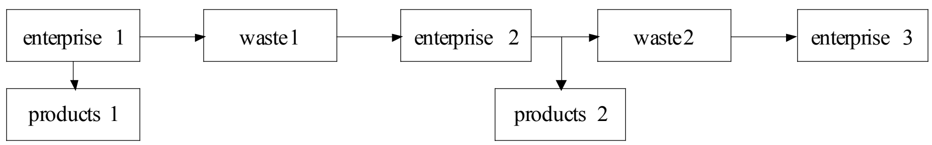

Fig. (2). Inter-enterprise serial connection patter.

reduce cost and indirectly increase economic benefits for enterprises; (III) material minimization: enterprises focus on product functions and try the best to reduce raw material consumption under the precondition of realizing product functions; (IV) Application of cleaner production: carbon sources are reduced for the raw materials and the energies, and then the cleaner production is applied in order to reduce the hazards brought to human and nature; (V) CO2 emission reduction: the end control mode is adopted to treat the waste gases generated during the production process through carbon neutralization, carbon preservation and other low-carbon technologies in order to reduce carbon emission. The specific process is as shown in Fig. (**1**).

As a concentrated site in the ecological industry, the low-carbon economy industrial park is composed of different enterprises, natural ecosystem and residential areas, and acts as a regional system in which the enterprises cooperate with each other and meanwhile harmoniously develop with the regional communities. Actually, it is an industrial ecosystem similar to the food chain in national ecosystem. The inter-enterprise circulation of the low-carbon economy industrial park mainly includes three patterns, namely serial connection pattern, parallel connection pattern and serial-parallel connection pattern (please refer to Figs. (**2-4**) for the details), and aims at coupling two or more enterprises or production links to realize multistage material and energy utilization, high output efficiency and sustainable utilization in order to change the wastes and the by-products generated by one enterprise during the production process into the raw materials needed by another enterprise during the production process through waste exchange, cyclic utilization, cleaner production, low-carbon technologies, *etc*., thus to realize the maximum utilization of materials and energies and the minimum emission of wastes for the industrial park.

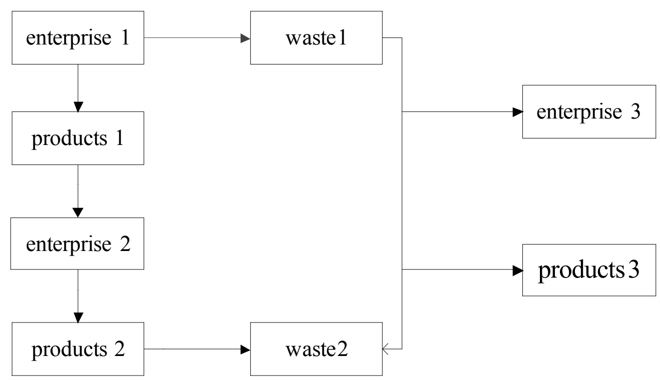

Fig. (3). Inter-enterprise parallel connection pattern.

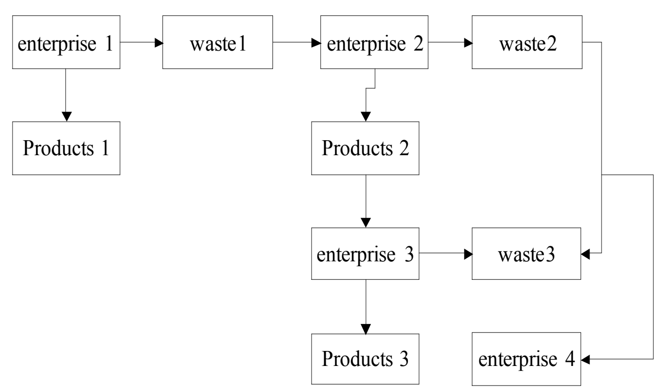

Fig. (4). Inter-enterprise serial-parallel connection pattern.

5. EMPIRICAL FINDING

In this section, we will list the regression results and the result analyze.

Table 1. Regression results for the EI model.

Model		1	2	3	4	5	6	7	8
Estimate method		FE	FE	FE	FE	LAG	LAG	LAG	LAG
S		0.03^{***}	0.03^{***}	0.03^{***}	0.02^{***}	0.03^{***}	0.03^{***}	0.03^{***}	0.03^{***}
		(6.85)	(7.62)	(9.37)	(6.20)	(7.62)	(12.88)	(12.10)	(10.90)
K		0.00	-0.02	-0.01	0.01	-0.02	0.03	0.02	0.01
		(-0.15)	(-0.47)	(-0.28)	(0.22)	(-0.47)	(0.95)	(0.45)	(0.17)
lnRD		-0.04^{*}	-0.01	-0.04^{*}		-0.02^{*}	-0.01	0.01	
		(-1.76)	(-0.78)	(-1.84)		(-1.65)	(-0.46)	(1.32)	
FDI		0.11	0.14			-0.01	-0.04^{**}		
		(1.39)	(1.63)			(-1.13)	(-2.49)		
lney		-0.80^{***}	-0.71^{***}	-0.89^{***}	-0.69^{***}	-0.51^{***}	-0.66^{***}	-0.51^{***}	-0.54^{***}
		(-8.31)	(-7.25)	(-7.09)	(-6.36)	(-4.63)	(-7.44)	(-4.58)	(-4.42)
EX		-0.86^{***}		-0.85^{***}		-0.49^{***}		-0.48^{***}	
		(-3.89)		(-3.55)		(-2.20)		(-2.84)	
FDI*lnRD					-0.01				-0.02^{**}
					(-1.31)				(-2.11)
C		7.95^{***}	6.85^{***}	8.72^{***}	6.88^{***}	4.81^{***}	6.16^{***}	4.79^{***}	5.02^{***}
		(9.35)	(8.34)	(7.22)	(7.53)	(4.27)	(8.16)	(4.19)	(4.13)
Adj.R^2		0.74	0.74	0.73	0.74	0.51	0.51	0.52	0.52
P		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: The t-values of coefficient estimates are in parenthesis; ***, **, *indicates significance at the 1%、5% and 10% level. FE is the fixed effects estimators, LAG represent the estimator contain the lag of FDI.

Table **1** was the estimate result of model A1 and A2. Model 1-4 illustrated a significant positive correlation between S and EI, which meant the increase of the proportion of secondary industry in GDP enhanced the carbon emission intensity. This was cause by the fact that the carbon emission intensity of the second industry was significantly greater than the first and the tertiary industry. The relationship between K and EI was not clear; similar result had been found in the research on developed country, which meant the accumulation of regional capital did not increase the regional carbon technologies. The possible reason for this is because of the capital accumulation in China focused on infrastructure, which will not improve the carbon emission technology. The average coefficient of RD is only -0.02 and the highest significant level is 10%. This might be due to the reason that the innovation in technology did not reduce energy consumption. Due to the difference of the model selection, the result in ey and EI, significantly negative correlated, was different from the previous studies from Xu and Song.

Significant negative correlation occurred between EI and EX, which was similar to the finding of Perkins and Neumayer, illustrated that increase in regional export was conducive to the improvement of regional carbon emissions technologies. There was a non-significant positive correlation between the current FDI and EI, which was also similar to the previous study demonstrated that the increase of current FDI may have some negative effect on carbon emission. Lastly, the cross-term of FDI and RD is non-significantly negative correlated with the regional carbon emission.

In model 5-8, a significant negative correlation between the FDI and carbon emission intensity was seen, which meant hysteresis in FDI on improvement of carbon emission technology existed. The cross coefficient of FDI hysteresis and RD was significant negative, indicating that both the FDI and RD increase the technology of the carbon emission. There is no significant change in other variables (except for EX), showing the robustness of result on the model 1-4.

Table **2** was the estimate result of model B1 and B2. In Model 1-8, the effects on all variables were almost the same as in Table **1** (except RD, the significant level increase), indicating the robustness of the results. Model 1-4 illustrated the current FDI, FDI and cross-term of RD have a non-significant positive correlation with E, which implied a possible positive relationship may occur between current FDI and regional carbon emission. In Model 5-8 illustrated a significant negative correlation between lag FDI (lag 1 period)

Table 2. Regression results for the E model.

Model	1	2	3	4	5	6	7	8
Estimate method	FE	FE	FE	FE	LAG	LAG	LAG	LAG
S	0.03***	0.03***	0.03***	0.02***	0.03***	0.03***	0.03***	0.03***
	(7.21)	(7.90)	(10.66)	(6.28)	(8.38)	(9.89)	(10.43)	(7.76)
K	-0.01	-0.02	-0.02	0.01	-0.03	-0.01	-0.03	-0.05***
	(-0.38)	(-0.72)	(-0.46)	(0.25)	(-1.59)	(-0.78)	(-1.45)	(-3.14)
lnRD	-0.04**	-0.02	-0.04**		-0.08**	-0.13***	-0.08*	
	(-2.05)	(-1.23)	(-2.28)		(-1.99)	(-3.21)	(-1.93)	
lnY	0.27***	0.29***	0.14	0.99*	0.90***	0.84***	0.91***	0.78***
	(2.80)	(3.06)	(1.23)	(1.84)	(12.29)	(9.38)	(11.70)	(9.67)
FDI	0.08	0.13**			-0.09*	-0.22**		
	(1.52)	(2.15)			(-1.67)	(-2.34)		
EX	-0.75***		-0.73***		-0.87***		-0.99***	
	(-4.37)		(-4.07)		(-5.28)		(-5.98)	
FDI*lnRD				0.02*				-0.05***
				(1.69)				(-3.47)
C	6.62***	6.21***	7.55***	6.88***	1.54***	2.46***	1.40**	2.39***
	(8.72)	(8.12)	(7.39)	(6.93)	(2.95)	(4.16)	(2.59)	(3.80)
Adj.R^2	0.90	0.90	0.90	0.90	0.81	0.79	0.81	0.78
p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: The t-values of coefficient estimates are in parenthesis; ***, **, *indicates significance at the 1%、5% and 10% level. FE is the fixed effects estimators, LAG represent the estimator contain the lag of FDI.

and E, which meant both lag FDI and RD reduced the carbon emission. Therefore, FDI has a hysteresis effect on the improvement of carbon emission technology. Qi Peng got a same result in his research, indicating the hysteresis in technology spillovers caused the positive effect of FDI on carbon emission lags. In summary, due to differences in variable and model selection, the result, the effect of FDI on carbon emission, may be different from the previous study.

Table **3** illustrated the effect of each factors on regional carbon emission (eastern, western and central). Model 1, 4, 7, based on Model A2, examined the effect of FDI, per capita income *etc*. on regional carbon emission intensity; Model 2, 6, 8, based on Model B2, examined the effect of FDI, output *etc*. on regional carbon emission; Model3, 6, 9, based on Model A2, examined the effect of export on regional carbon emission intensity.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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