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FDI Quality, Green Technology Innovation and Urban Carbon Emissions: Empirical Evidence from China

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Abstract: High-quality introduction and utilization of foreign investment is a new engine for China's further opening up and plays a significant role in urban carbon emission reduction in the context of carbon peaking and carbon neutrality strategies. By constructing a comprehensive assessment index of Foreign Direct Investment (FDI) quality and using panel data from 283 Chinese cities from 2006 to 2019, this paper systematically examines the impact of FDI quality on urban carbon emissions and identifies the mechanism of green technology innovation in order to clarify the correlation among the three. The results show that FDI quality upgrading can significantly reduce urban carbon emissions, which is mainly manifested by FDI management and FDI export capacity to suppress total carbon emissions. The above effect of FDI quality is more significant in cities with a low rationalization degree of industrial structure, high investment in science and technology, strong environmental regulation and high dependence on foreign capital. Green technology innovation is an intermediary mechanism for FDI quality to have a carbon emission reduction effect. Looking at different areas, foreign companies in the eastern regions can promote carbon emission reduction through independent innovation, while the central and western regions essentially rely on imitative innovation; however, there is a delay in the role of innovation quality. Further study suggests that the carbon emission reduction effect of FDI quality has an obvious characteristic of threshold, which will be slightly weakened with the increase in the quantity of imitative innovation but strengthened with the improvement of the quantity of independent innovation and the quality of innovation. The conclusion aims to provide policy implications for China to explore a sustainable pathway that combines promoted opening with carbon reduction targets.

Keywords: carbon emissions; sustainable pathway; FDI quality; green technology innovation

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1. Introduction

For a long time, China's extensive development with high energy consumption and high emissions has promoted rapid economic growth, resulting in a continuous increase in carbon dioxide emissions. According to the statistical data from the International Energy Agency (IEA), in 2021, China's carbon emissions accounted for 33% of the global total, a year-on-year increase that exceeded the decline in other parts of the world [1]. The contradiction between economic development and environmental protection is particularly prominent. The performance of carbon emissions is not only related to successfully realizing the target of carbon emission reduction in 2030 but also affects the survival and progress of all humankind. The report of the 20th National Congress of the Communist Party of China clearly pointed out that we should "promote green and low-carbon development and actively respond to the global governance of climate change" [2]. Therefore, finding a path that considers both economic development and carbon emission reduction is a great challenge for China at present.

Foreign direct investment (FDI), as an important driving force of China's economic growth, has maintained an elevated level of both scale and growth rate after entering the new stage. According to the statistical data of UNCTAD, in 2020, the scale of global transnational investment decreased by 34.7% year-on-year, and China achieved growth against this trend [3]. The amount of FDI inflow accounted for 15% of the world, ranking second only to the United States as the destination for global foreign investment and effectively driving economic growth and industrial upgrading in China. However, the indiscriminate introduction of FDI will also lead to a series of problems, such as energy consumption and environmental pollution [4]. The existing literature has not reached a unified conclusion on the two effects of "pollution paradise" or "pollution halo". In addition, China's economy has shifted from high-speed growth to high-quality development. In order to accelerate the transformation of the economy of China and adapt to environmental changes around the world, governments continue to improve environmental regulations internally. Moreover, extra attention is paid to the quality of FDI when opening up the economy.

Therefore, in 2021, the Ministry of Commerce of China issued a document called 'The Notice on Stabilizing Foreign Investment Around the Construction of a New Development Pattern', advocating the expansion of high-level opening-up, taking "stabilizing the total amount and optimizing the structure" as the primary goal of FDI's utilization during the period of the 14th Five-Year Plan and reducing the negative list of foreign investment access for five consecutive years [5]. In 2022, the scale of actual utilized foreign capital in China grew steadily and the quality of FDI improved significantly, which was reflected in the fact that the FDI structure continued to be optimized. Actual utilized FDI in high-tech industries increased by 28.3% year-on-year, accounting for 36.1% of the whole country and becoming a new point of attraction for investment [6].

In view of the above situation, the purpose of this study is to explore whether the quality upgrading of FDI can produce environmental effects. In other words, in the macro context of the low-carbon transition, this paper examines the impact of FDI quality upgrading on carbon emission reduction in Chinese cities and reveals the comprehensive effect of FDI quality upgrading. Moreover, both the difficult point and the focus of carbon peak and carbon neutrality are to upgrade the industrial structure and energy consumption structure, which are inseparable from green technology innovation [7]. This paper further explores the relationship among FDI quality, green technology innovation, and urban carbon emissions and clarifies whether the green technology spillover effect relying on high-quality FDI can truly promote carbon emission reduction.

The results of this paper provide enlightenment for China to identify the characteristics of FDI with different qualities, absorb the spillover of FDI's green technologies and formulate the policy while realizing both the carbon peaking and carbon neutrality goals. In the process of achieving the research objectives, a series of conclusions are obtained in this study, which contain elements of scientific novelty: (1) It enriches the research on the driving factors of carbon emission reduction. From the perspective of FDI quality upgrading for the first time, this paper expounds on the changing rules of carbon emissions in Chinese cities and explores the low-carbon transformation path under the open economy by revealing the role of FDI quality in export capacity, management level, profitability, technical content, actual scale and other dimensions. (2) It extends the research on the environmental effects of FDI quality. This paper, using the two-way fixed effects model and mediation effects model, theoretically analyzes and empirically tests the impact and mechanism of FDI quality on urban carbon emissions and discusses heterogeneous factors such as technical support, rationalization of industrial structure, environmental regulation and foreign capital dependence, which extends the multi-dimensional quantitative analysis. (3) Considering that the effect of FDI quality may be related to the city's own absorptive capacity, this paper includes green technology innovation into the threshold regression model, examines the nonlinear impact of FDI quality on urban carbon emissions and reveals the mechanism and threshold effect of "quality improvement and quantity increase" of green technology innovation. This study has practical significance for China to coordinate high-level opening-up and low-carbon transitions and to enhance the internal driving force of high-quality economic development.

Further material in this paper is divided into several parts as follows: In Section 2, literature related to this study is sorted out; in Section 3, theoretical analysis is carried out and research hypotheses are proposed; in Section 4, variables and data are introduced; in Section 5, empirical results are stated and analyzed; in Section 6, mechanism testing and analysis are conducted; and finally, in Section 7, research conclusions are summarized and policy suggestions are put forward.

2. Literature Review

2.1. Study on the Influencing Factors of Urban Carbon Emissions

As the environmental pollution problem becomes increasingly severe, the drivers of carbon emission reduction in cities are widely discussed. On the one hand, scholars focus on policy factors and analyze the impact of government environmental policies and regulations on carbon emissions in Chinese cities. It has verified the pilot policies of low-carbon and innovative cities and the carbon emission reduction effect of smart city construction [8], but there are still disagreements on whether environmental regulation has significantly reduced the total regional carbon emissions [9]. On the other hand, for non-policy factors, this paper analyzes trade openness, upgrading of industrial structure, adjustment of economic structure, foreign direct investment, regional integration, industrial agglomeration, digital economy [10,11] and other impacts on the total carbon emissions and carbon emission performance of Chinese cities. In addition, it pays attention to the space-time evolution characteristics of carbon emissions and the cooperative effect of low-carbon economic development.

In addition, there are two representative views in the current research about the impact of green technology innovation on carbon emissions: one believes that technological innovation has a positive impact on carbon emission reduction [12]. Technological progress is an important driving factor for improving the efficiency of carbon emissions. Additionally, inventive and improved green technology innovations are generally conducive to energy conservation and emission reduction [13]. The other holds that while improving energy efficiency, technological progress reduces unit product cost and price, leading to more energy consumption and thus increasing carbon emissions, i.e., the “rebound effect” [14], which ultimately leads to uncertainty about the impact of technological innovation on carbon emissions.

2.2. Research on the Effect of FDI Quality

FDI is considered an important channel for countries around the world, especially developing countries, to obtain technology spillovers, promote industrial structural transformation and drive economic growth. However, the “pollution halo” and “pollution shelter” effects caused by the growth of the FDI scale make relevant conclusions controversial [15]. In the critical period of China’s transformation into an economic development mode, the quality of FDI has gradually attracted attention. The first is about the connotation of FDI quality. Kumar (2002) first put forward the concept of “FDI quality” from the perspective of developing countries [16]. He pointed out that its connotation reflects the technical level of foreign capital related to the spillover effect of foreign capital, technology management strength, and willingness to transfer technology to the host country. Guo and Luo (2009) defined FDI quality earlier in China from four upgrading aspects [17]: investment scale, proportion of manufacturing industry, export volume and technology. Subsequently, Bai and Lv (2015) defined it as the ability to bring benefits and positive externalities to the host country [18]. The second aspect is about the measurement method for FDI quality. Experts believe that the evaluation of FDI quality cannot be covered by a single index. Therefore, a comprehensive evaluation index system is constructed from the aspects of profitability, technical content, project scale, industrial layout, export competitiveness and management experience, and the evaluation is carried out with the help of factor analysis or the entropy weight method [19,20].

In addition, the research on the impact of FDI quality mainly focuses on two aspects. First, focus on the contribution of FDI quality to improving capacity utilization, promoting China's economic growth and the transformation of development mode [21]. Second, focus on the environmental effect. There are very few relevant research results. Just mention a little bit of information here. For example, the improvement of FDI quality could reduce the emission of sulfur dioxide in Chinese provinces, among which the improvement of FDI project scale and technical content played a major role. Additionally, other research showed that FDI quality can improve the productivity of the total element energy of eastern provinces in China; FDI quality could promote the improvement of green development efficiency in the Yangtze River Economic Belt, among which FDI export capacity and project scale played a significant role, but this effect gradually weakened with the increase in environmental regulation intensity. To sum up, there is still a research gap on whether FDI quality reduces the carbon emissions of cities in China.

2.3. Analysis of the Mechanism of FDI Quality Affecting Urban Carbon Emissions

Because of the proposal of the concept of green development, many scholars started to consider both the economic and environmental effects of FDI and tried to find a way to reduce China's carbon emissions.

On the one hand, FDI is an important channel of technology spillover, and the introduction of foreign capital can produce spillover effects on regional green technology innovation through biased technological progress and present nonlinear characteristics under the influence of human capital, environmental regulation, intellectual property protection and so on [22,23]. However, there is little research on the green technology innovation (GTI) effect focusing on the quality of FDI. On the other hand, in order to transform the mode of economic development, green development must rely on technological innovation. The "Porter hypothesis" holds that technological innovation can promote green total factor productivity (TFP) by improving resource utilization efficiency, and independent research and development play a more significant role in driving a green economy than technology import [24]. Under the background of carbon peak and carbon neutrality, effective means to solve environmental pollution problems such as carbon emissions mainly rely on the development of technological innovation [25], especially the innovation oriented by green technology progress [26–28]. However, at present, there is little discussion on the impact of FDI quality on urban carbon emissions from the perspective of the mechanism of green technology innovation.

Through sorting out the literature, it is found that scholars have conducted a lot of research on the pairwise relationship among FDI, green technology innovation and carbon emissions, but there are still certain limitations. Firstly, the research on the driving factors of carbon emission reduction mainly focuses on domestic factors, such as environmental regulation and industrial structure, and only involves the factors of FDI entry or FDI scale in the aspect of the open economy, ignoring the important role of FDI quality in urban carbon emission reduction. Secondly, the existing research focusing on the environmental effect of FDI quality ignores its spillover into green technology innovation (GTI) and lacks quantitative analysis of the impact of FDI quality on carbon emissions. Thirdly, there is no systematic investigation that integrates FDI quality, GTI and urban carbon emissions into a unified analytical framework, let alone the role of the key variable GTI in it.

3. Theoretical Analysis and Research Hypothesis

3.1. The Impact of FDI Quality on Carbon Emissions in Chinese Cities

According to the Theory of Externality, the environment is a kind of public good with significant externalities, among which carbon emission is one of the external features. Carbon emissions can be internalized through administrative orders or economic means to achieve emission reduction [29], which provides a theoretical basis for the impact of FDI quality on urban carbon emissions. In the case of a certain scale of investment and unchanged own conditions, different quality of FDI has different impacts.

For different dimensions of FDI quality, firstly, the expansion of scale caused by the increase in FDI stock may worsen carbon emissions. However, with the strengthening of urban environmental regulations, the FDI dependent on resources has continued to decrease, and the scale of FDI in high-tech industries has increased. Thus, the FDI structure can be optimized, the regional industrial structure can be rationalized, and local enterprises can be forced to improve productivity and reduce resource consumption per unit output through industrial competition and the crowding-out effect. Secondly, the improvement of FDI management means that foreign enterprises have a more reasonable incentive and constraint mechanism. Through internal management, they can improve the efficiency of resource allocation, actively strengthen the research and introduction of technologies for carbon reduction, and promote technological progress toward resource and energy saving so as to conform to the strict environmental protection of the local government. Thirdly, the improvement of FDI technological content means that it has more advanced technologies for production and emission, and the technological gap makes it easier for high-quality FDI to generate technological spillovers. It not only increases the opportunity for local enterprises to learn advanced pollution technology but also optimizes the end treatment of enterprise carbon emissions. It is also conducive to improving the structure of production factors, enabling the green upgrading of traditional industries, promoting the advanced industrial structure, and reducing energy consumption and urban carbon emissions. Fourth, the enhancement of FDI export capacity intensifies the export competition between foreign enterprises and local enterprises in the short term, but in the long term, it can effectively integrate the global advanced factors and external scarce resources, then expand the source and type of high-quality intermediate imports, which is the key way to improve the technological content and low-carbon level of export. Fifth, the improvement of FDI profit level is conducive to supporting the in-depth layout of the whole industrial chain in China, which integrates production, research and development, sales and service, continuously introducing global advanced technology as well as experience in high-end intelligent manufacturing, which will feed urban green technology innovation and reduce the overall carbon emission. Based on the above analysis, this paper proposes the following hypothesis:

Hypothesis 1: *Quality improvement of FDI can significantly reduce carbon emissions in Chinese cities*.

3.2. The Mechanism of FDI Quality Affecting Urban Carbon Emissions

The introduction of high-quality FDI itself means a cleaner production mode. In the process of connecting with foreign enterprises, the local enterprises can promote their own technological progress in the direction of energy—saving through competitive effects, spillover effects and cooperative effects, that is, to drive the green technological innovation of local enterprises and reduce urban carbon emissions. First of all, high-quality FDI with advanced production technology and efficient management will crowd out the local enterprises that consume energy, enhance their environmental awareness and encourage them to carry out green technology innovation through competition within the industry. Secondly, high-quality FDI promotes urban environmental protection through the spillover effect of technology and human capital. The improvement of talent policies continuously attracts the inflow of excellent staff with good skill training in FDI enterprises, which becomes the endogenous driving force of green technology innovation and promotes the transformation of innovation achievements [30]. Finally, local enterprises achieve cooperative development by establishing forward and backward correlations with high-quality FDI enterprises. They could obtain high-quality FDI financial support, integrate their technology resources, obtain technology cooperation and scale synergy, and resist the uncertain risks of their own green technology research to alleviate financing constraints and improve green technology innovation [31,32].

Based on the Theory of Circular Economy, if enterprises want to improve their capability in green technology innovation, they must first pay attention to the innovation of terminal treatment technology in order to make the emission of pollutants harmless. Secondly, enterprises should use advanced production technology to realize green technology innovation that aims to control the source of environmental pollution. Thus, recyclable products can be developed to form a closed-loop green economy around the resource chain, and all these practices can promote urban carbon emission reduction. However, previous studies have shown that the environmental effects of FDI are not automatically generated along with the growth of the FDI scale but may also be restricted by some "intermediate factors", namely the absorptive capacity of the host country [33]. Therefore, the carbon emission reduction effect of FDI quality upgrading is bound to be affected by the absorption capacity of the city itself. As the basic guarantee for host countries to undertake high-quality FDI, green technology innovation is a key measurement standard for cities to transform from productive to ecological innovation [34], which is related to whether urban technological innovation can truly achieve carbon emission reduction, and this can be regarded as the urban absorption capacity in this study. The higher the level of green technology innovation, the better the city can introduce and utilize high-quality FDI and absorb its technology and knowledge. As a result, the spillover effect can act on its own to reduce carbon emissions. Based on this, this paper proposes the following hypothesis:

Hypothesis 2: *FDI quality control can promote the "quantity increase and quality improvement" of urban green technology innovation to reduce carbon emissions.*

Hypothesis 3: *The carbon emission reduction effect of FDI quality has threshold characteristics. Green technology innovation is used as the threshold variable, and only when green technology innovation reaches and exceeds a certain "threshold value" can the carbon emission reduction effect of FDI quality be effectively brought into play. With the "incremental quality improvement" of green technology innovation, the carbon emission reduction effect of FDI quality is gradually enhanced.*

4. Model, Variable and Data

4.1. Model Setup

4.1.1. Benchmark Regression Model

To test the influence of FDI quality on urban carbon emission in China, the following measurement model is designed:

$$Carbon_{it} = \beta_0 + \beta_1 FQ_{it} + \lambda Control_{it} + \delta_i + \eta_t + \varepsilon_{it} \quad (1)$$

In this model, the subscripts i and t stand for city and year, respectively. $Carbon_{it}$ represents the total carbon emission of the I city in China within t year(s). FQ_{it} is the core explanatory variable in this paper, which is used to measure the quality index number of foreign direct investment. $Control_{it}$ is a group of controlled variables. δ_i and η_t, respectively, indicate the fixed effect in certain cities for that year. β_0, λ and β_1 are the standardized influence coefficient of the variables. ε_{it} is an item of random disturbance.

4.1.2. Mediation Mechanism Test Model

In order to further explore the reasons why FDI quality upgrading achieves the effect of carbon emission reduction, and based on the theoretical analysis above, this paper attempts to build a model to test and identify the conduction effect of green technology innovation. The model settings are as follows:

$$M = \beta_0 + \beta_1 FQ_{it} + \lambda Control_{it} + \delta_i + \eta_t + \varepsilon_{it} \quad (2)$$

$$Carbon_{it} = \beta_0 + \beta_1 FQ_{it} + \alpha M + \lambda Control_{it} + \delta_i + \eta_t + \varepsilon_{it} \quad (3)$$

In these two formulas, M is the intermediary variable, covering the Quantity and Quality of green technology innovation. Formula (2) tests the influence of FDI quality change on each intermediary variable. Formula (3) tests the influence of various mediating variables on total urban carbon emissions.

In this paper, the panel threshold regression model is adopted to further investigate whether green technology innovation will become a nonlinear regulatory factor for FDI quality affecting urban carbon emissions.

$$\begin{aligned} Carbon_{it} = \beta_0 + \beta_{11} FQ_{it} \times I(M_{it} \leq \tau) + \beta_{12} FQ_{it} \times I(M_{it} > \tau) \\ + \lambda Control_{it} + \delta_i + \eta_t + \varepsilon_{it} \end{aligned} \tag{4}$$

In Formula (4), $Carbon_{it}$ is the total amount of urban carbon emission, FQ_{it} stands for the quality of FDI, and M_{it} is the threshold variable, representing the quantity (independent innovation, imitation innovation) and quality of green technology innovation. τ is the specific threshold value, and $I(\bullet)$ is the indicator function. β_{11} and β_{12} are the influence coefficients of FDI quality on urban carbon emission when threshold variables happen when $M_{it} \leq \tau$ and $M_{it} > \tau$, and ε_{it} is the random disturbance term.

4.2. Variable Selection

4.2.1. Core Explanatory Variable: FDI Quality (FQ_{it})

At present, the academic circles have not reached an agreement on how to measure this variable of FDI quality (FQ_{it}). Using for reference the opinions of Buckley et al., (2002) [19] and Bai J.H. and Lv X.H. (2017) [20], the index system of FDI quality would be constructed with the five aspects: FDI profitability, management ability, technology, actual scale and export capability. To put it concretely:

(1) Profitability

The stronger the FDI enterprise profitability, the better the operating conditions, and the more the capital support and capital reinvestment for the city technology innovation and relatively the higher the FDI quality. This profitability is measured by "FDI industries' ratio of profits to cost and expense/over scale industries' ratio of profits to cost and expense". Where, the ratio of profits to cost and expense = total profit/total cost expense $\times$ 100%.

(2) Management Ability

Perfecting the management could strengthen the incentive and restraint mechanism, which is the guarantee of the project's normal running. Since the property contribution rate reflects the enterprise management ability, the FDI management is measured by adopting "FDI industries property contribution rate/over-scale industries property contribution rate".

(3) Technology

Technology is an important source for the enterprise to gain sustainable competitiveness. Foreign-owned enterprises with hi-technology could facilitate the specialization of labor division within the host country and improve the use and output efficiency of production factors. Here, we use "(TFDI industries output value/FDI industries number of employees)/(Tover-scale industries output value/over-scale industries number of employees)".

(4) Actual Scale

The scale economy effect brought by the expansion of foreign investment benefits the reduction of enterprise average cost. The bigger the single FDI enterprise actual scale, the stronger the investment strength and willingness of the foreign-owned enterprise and the more favorable conditions the foreign-owned enterprise created for the city technology innovation. Here, this paper uses "FDI enterprise actual investment amount/FDI enterprise number" to analyze.

(5) Export Capability

Foreign investment could open up new channels for the host country to get into international market and increase its export opportunity. Additionally, the host country also could improve its own export product quality and sharpen its competition capability in the international market. Here the paper uses "FDI enterprise export amount/region export total amount" to indicate the export pulling effect of foreign-owned enterprise.

The above five indexes reflect FDI quality from different aspects. Based on this, this paper adopts Entropy Method to integrate these five indexes into one comprehensive indicator to embody FDI quality connotation.

4.2.2. Explained Variable: City Carbon Emission Level ($Carbon_{it}$)

The total carbon emission is used to measure the level of city carbon emission. The city carbon emission includes the emissions from the consumption of liquefied petroleum gas, natural gas, electric and thermal energy. The amount of carbon emission from these energy consumptions could be translated according to their carbon emission indexes. These figures are added and the total city carbon emission amount can be obtained. See also the Formula (5).

$$Carbon_{it} = \sum E_i \times C_i \tag{5}$$

In this formula, $Carbon_{it}$ is the total amount of urban carbon emission, E_i indicates the consumption of i energy, and C_i represents the carbon emission index of i energy.

4.2.3. Mechanism Variables

Green technology innovation refers to the behavior that pursues pollution and emission reduction based on the ecological economy; it aims to reduce the negative externalities on the environment during development [35], whose measurement standards have not been decided. At the same time, technology spillover from FDI is actually a gradual process that generally needs to go through three stages: First, the host country can directly introduce advanced foreign technology in the process of utilization of foreign capital. The second is "secondary innovation" by imitating and absorbing other countries' technologies. Finally, the third is that technology dependence can eventually be broken through independent innovation. Among them, the second and third stages directly reflect the effect of heterogeneous innovation stimulated by the host country's use of FDI. Based on the above logic, this paper distinguished the quantity (Quantity) of green technology innovation. First, the number of green utility model patent applications is used to measure the quantity of "imitative innovation" in the city, and then we define it as a secondary innovation based on the extensive absorption of global scientific and technological achievements; the essence of it is to actively introduce and learn foreign green technology. Second, the number of green invention patent applications is used to measure the number of urban "independent innovation", which refers to the process of creating the core technology with independent intellectual property rights and reflects the ability to conduct independent research or creation, so it is most conducive to breaking through the technical barriers. In addition, patent authorization can effectively discriminate and screen low-quality patent applications to a certain extent so as to ensure their high-quality characteristics. In view of the low urban independent innovation capacity reflected by green utility model patents, green invention patents have more technical content and core value [36]. In this paper, "the proportion of green invention patents granted to the total number of green patents granted" is used to measure the quality (Quality) of green technology innovation; the essence of it includes both the technological breakthroughs of green innovation and the environmental benefits brought by it.

4.2.4. Control Variable

It is necessary to control each city's carbon emission level, which tends to be affected by various factors. (1) Economic development level: It could be obtained by taking the logarithm of the city's gross domestic product (GDP). (2) Population density: The logarithmic value can be taken by means of the ratio between the city's total population and the city administrative division area. (3) Information industry: This could be measured with the logarithmic value of the number (10,000 people) of those employees who transmit information, serve and are engaged in the software industry. (4) Government green attention: This paper adopts the method of text analysis to crawl and measure the government's attention to the green development fields that benefit the public with the help of Python. (5) The optimization of industrial structure: This can be weighed through the ratio of added values between the tertiary industry and the secondary industry. (6) Human capital: It can be obtained by dividing the population proportion between the city's number of people in general institutes of higher education and its total population. (7) Financial development: This comes from the proportion of the city's loan balance to financial institutions at the end of the year in the city's GDP. (8) Technology support: It is the proportion of technology fiscal expenditure in the total fiscal expenditure. (9) Internet development: It is measured by the logarithmic value of the number of Internet users.

4.2.5. Heterogeneity Variable

The investment of foreign enterprises in China involves many regions, and there are large differences in the features and development plans of cities, which may make the quality of FDI have different impacts on total carbon emissions.

(1) Financial support for science and technology: In this paper, this support is expressed in terms of the proportion of financial expenditure on science and technology in total financial expenditure.

(2) Rationalization of Industrial structure: This paper draws on the method of Gan (2011) [37] and uses the Theil index to analyze this index [38]. Specifically, the reciprocal of the Theil index is used as an index to measure the rationalization of industrial structure. The calculation formula is shown in Equation (6).

$$TL = \sum_{i=1}^{n}\left(\frac{Y_i}{Y}\right)\ln\left(\frac{Y_i}{L_i}/\frac{Y}{L}\right) \quad (6)$$

where TL is the rationalization of industrial structure, i represents the type of industry, n represents the number of industries, Y represents the added value of industries, and L represents the number of employments.

(3) Environmental regulation intensity: This index is represented by the ratio of environmental vocabulary frequency to word frequency in the work report of the government.

(4) Foreign capital dependence: "(Actual utilization of foreign capital during the year in the form of RMB/regional GDP) $\times$ 100%" is used to measure this index.

4.3. Data Declaration

The samples in this paper come from the panel data of 283 cities in China from 2006 to 2019. Firstly, according to the related annual China Statistical Yearbook and the Statistic Yearbook and bulletin of China's 30 provincial administrative regions (Tibet, Hong Kong, Macao and Taiwan are not included), the FDI quality is to be calculated and then attributed to each city within its province. In addition, the carbon emission data and control variables for each prefecture-level city come from the annual China Urban Statistical Yearbook, Statistical Yearbook of Urban Construction in China, China Environmental Statistical Yearbook and China Energy Statistical Yearbook. The above statistical yearbook data comes from the "China Economic and Social Big Data Research Platform" [39]. The green patent data are obtained from GPRD in the Chinese Research Data Services Platform (CNRDS) [40]. The missing values in the data would be filled up by calculating the average value of the adjacent year and the annual average growth rate.

Table 1 shows the descriptive statistical results for each variable. The mean value of urban Carbon emission (Carbon) is 6.133, the maximum value is 9.533, and the minimum value is 0. These indicate that there was a significant gap in the total carbon emissions of different cities during the sample investigation period. The mean value of FDI quality

(FQ) is 0.298, the maximum value is 0.504, and the minimum value is only 0.080. These indicate that there is a large gap in the quality of FDI attracted by the study samples, and the backward regions need to break through technical barriers through green technology innovation so as to achieve carbon emission reduction. In terms of control variables, the difference between the maximum and minimum values of ITbasic, Pcapital, fin and Techsup of sample cities is large, and the median is small, indicating that the overall level is low and obvious regional differences exist. The development of GDP, Pdensity, indHigh and internet is more balanced.

Table 1. The descriptive statistics of major variables.

Variable	N	Mean	SD	Min	p50	Max
Carbon	3962	6.133	1.192	0	6.112	9.533
FQ	3962	0.298	0.071	0.080	0.294	0.504
GDP	3962	16.28	1.011	13.16	16.23	19.76
Pdensity	3960	5.736	0.919	1.547	5.885	7.923
ITbasic	3962	1.007	4.222	0	0.330	85.91
Green	3962	8.003	2.157	0	8.601	9.762
indHigh	3962	6.447	0.354	5.517	6.423	7.836
Pcapital	3962	1.879	5.793	0.006	0.886	241.3
fin	3962	0.895	0.576	0	0.721	9.622
Techsup	3960	0.015	0.015	0	0.010	0.207
internet	3962	12.92	1.152	5.468	12.92	17.76

In addition, the inclusion of FDI structure in the research framework of this paper (Figure 1) is an important supplement to the research on FDI quality. According to the statistics of the China Statistical Yearbook, from 2005 to 2020, the proportion of foreign investment utilized in China′s primary industry decreased from 0.99% to 0.3%, the proportion of secondary industry declined from 61.73% to 24.5%, and the proportion of tertiary industry increased from 37.28% to 75.2%. In terms of industry, the proportion of FDI absorbed by leasing and business services increased from 6.21% to 17.8%, and the proportion of scientific research and technology services and information technology services also increased significantly [37]. This shows that the continuous optimization of China's FDI structure provides solid support for the upgrading of FDI quality, and the green upgrading of this structure can also contribute to environmental protection.

Figure 1. Evolution of the FDI structure in China.

5. Analysis of Empirical Results

5.1. Benchmark Regression

According to the econometric model setting and Hausman's testing results, the fixed effect model is adopted in this paper to study the influence of FDI quality on urban carbon emissions in China. The results of the regression are listed in Table 2. The explained variables from Column (1) to Column (3) stand for the total amount of urban carbon emissions in China. All regression results control the fixed effects of time and region. In Column (1), only time- and region-fixed effects are controlled without adding other control variables, and the results show that the coefficient of the core explanatory variable FDI quality (FQ) is significantly negative at the statistical level of 5%. Subsequently, the control variables at the city level are added successively in Columns (2)–(3), and the influence coefficient of the core explanatory variable FQ is −0.426 and still significant at the statistical level of 1%. This shows that Hypothesis 1 is valid, that is, after excluding the influence of other factors, the improvement of FDI quality has a significant inhibitory effect on the total carbon emissions of Chinese cities. This also shows that, against the background of carbon neutrality and peak carbon dioxide emissions, the structure of energy consumption in Chinese cities should pay more and more attention to the quality upgrading of foreign direct investment in the process of transforming the energy consumption structure of Chinese cities to low-carbon, clean and green.

Table 2. All sample baseline regression.

Variable	(1)	(2)	(3)
FQ	−0.317 **	−0.383 ***	−0.426 ***
	(−2.389)	(−2.948)	(−3.293)
GDP		0.535 ***	0.509 ***
		(11.871)	(10.589)
Pdensity		0.464 ***	0.435 ***
		(3.199)	(3.005)
ITbasic		−0.026 ***	−0.020 ***
		(−8.134)	(−6.344)
Green		0.019	0.016
		(1.622)	(1.372)
indHigh			0.439 ***
			(6.078)
Pcapital			−0.002 *
			(−1.702)
fin			−0.004
			(−0.176)
Techsup			−1.959 ***
			(−2.617)
internet			0.082 ***
			(4.324)
_cons	5.669 ***	−5.338 ***	−8.451 ***
	(132.775)	(−5.418)	(−7.899)
FE-year	Yes	Yes	Yes
FE-region	Yes	Yes	Yes
N	3962	3960	3960
adj. R^2	0.547	0.573	0.581

Note: ***, **, * represent the significant level of 1%, 5% and 10% respectively, and the following table is the same.

Based on all sample regressions, this paper empirically tests the influence of FDI quality on urban carbon emissions in five dimensions. The results are shown in Table 3. The influence coefficient of FDI quality is negative from the perspective of management and export capability. This shows that the improvement of the management level of foreign enterprises and their driving effect on the exports of host countries are conducive to the emission reduction effect of foreign investment. On the one hand, a sound foreign-invested enterprise management system can constitute a reasonable incentive and restraint mechanism, which plays a positive role in adapting to the requirements of China's urban environmental standards and realizing cleaner production. On the other hand, the increase in foreign-funded enterprise export capacity provides diverse resources and markets for the export of Chinese enterprises. It can also improve the import quality and export technique of intermediate goods through the spread of technology. The low-carbon transformation could be promoted, and carbon emission reduction can be achieved within the export structure. However, from the perspectives of profitability, technology and actual scale, the influence of FDI quality on urban carbon reduction is not significant within the samples when investigated.

Table 3. Sub-index regression.

Variable	(1)	(2)	(3)	(4)	(5)
FDI-profitability	0.001				
	(0.067)				
FDI-technology		0.025			
		(1.364)			
FDI-management			−0.049 **		
			(−2.176)		
FDI-scale				0.007	
				(0.553)	
FDI-export					−0.236 ***
					(−3.963)
_cons	−8.674 ***	−8.669 ***	−8.452 ***	−8.710 ***	−8.730 ***
	(−7.994)	(−8.106)	(−7.875)	(−8.116)	(−8.178)
Control	Yes	Yes	Yes	Yes	Yes
FE-year	Yes	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes	Yes
N	3960	3960	3960	3960	3960
adj. R^2	0.579	0.580	0.580	0.580	0.581

Note: Due to space limitations, the regression results of all control variables are not listed separately, and the following table is the same. ***, ** represent the significant level of 1%, 5% respectively.

Compared with other studies, this paper verifies that every 1% increase in FDI quality reduces the total carbon emission of a city by 0.426%, which affirms the positive effects of improving FDI management and FDI export capacity. Bai and Lv (2015) [18] found that the improvement of FDI quality was conducive to the reduction of SO_2 emissions in China, which was mainly due to the expansion of FDI scale and the improvement of FDI technology. In addition, when FDI quality increased by 1%, China's SO_2 emissions decreased by 0.012%. Other scholars generally found that FDI quality can significantly promote the efficiency of green development; FDI export capacity and FDI scale play the most significant roles. Besides, this paper also has something in common with the above literature, i.e., the impact of FDI on China's green development depends not only on the scale of FDI but also on the quality of FDI, and different quality characteristics of FDI will produce different effects.

5.2. Endogenous Problem

Perhaps some endogenous problems need to be solved in this baseline regression. The main reasons leading to these problems are as follows: First, the core explainable variable and the explained variable have a reciprocal relationship. The improvement of FDI quality can lower the total amount of urban carbon emissions to some degree. However, at the same time, urban environmental regulations need to be enhanced. The efficiency of energy consumption in local enterprises must be raised, and the environmental benefit in the foreign-funded enterprises must be bettered [41]. When more and more attention is focused on the higher FDI quality in the city, some endogenous problems will arise. Secondly, some explainable variables are missing. Although in this paper the control variables related to the city are taken into account as far as possible, there are even more factors that can affect carbon emissions. Thus, some variables may be missed objectively, which causes these endogenous problems.

5.2.1. Endogenous Variables Delay

Since the impact of FDI quality upgrading in the current period on the carbon emission reduction of Chinese cities may have a certain time lag, the total amount of carbon emissions in the future cannot affect the FDI quality of the current period in advance. Considering this point, the FDI quality delayed by one or two periods can be taken as the instrumental variable of the current value, which is used to effectively solve the reverse causality. Both Column (1) and Column (2) of Table 4 show the delayed regression results of the first period when control variables are not added or when all the controlled variables are added. Based on this, it is obvious that L1.FQ plays an inhibiting role in the total amount of carbon emission in urban areas in China. Additionally, the influence is slightly lower than that of the current FDI quality. Both Column (3) and Column (4) in Table 4 stand for the regression results that lag by two periods. The carbon emission reduction effect in L2.FQ is carried out and passes the 10% significance test.

Table 4. Lagged regression of endogenous variables.

Variable	(1)	(2)	(3)	(4)
L1.FQ	−0.376 ***	−0.421 ***		
	(−2.736)	(−3.118)		
L2.FQ			−0.248 *	−0.269 *
			(−1.697)	(−1.867)
_cons	5.858 ***	−7.287 ***	5.894 ***	−6.949 ***
	(133.847)	(−6.262)	(128.545)	(−5.453)
Control	No	Yes	No	Yes
FE-year	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes
N	3679	3677	3396	3394
adj. R^2	0.531	0.560	0.523	0.550

Note: ***, * represent the significant level of 1%, 10% respectively.

5.2.2. Instrumental Variable Method

Based on the geographic features in various regions, the instrumental variable of FDI quality, that is, overseas market proximity, is to be constructed. This paper uses both Coast and Port as variables to conduct Two-Stages Least Squares (2SLS) regression, respectively. On the one hand, geographical distance exists objectively. It is not affected by any other external factors and can be regarded as an instrumental variable with strict exogeneity. On the other hand, geographical distance is endogenous. The distance between the coast and the port can reflect the connection between this city and the global shipping network. In opening up to the outside world, "the iceberg transportation cost" is considered to have an obvious influence on the import and export of cities. In addition, it is believed that there is a close correlation between trade and FDI. As a result, the closer the distance above, the higher the facilitation for the city to absorb FDI and the better the quality of FDI. The regression results are shown in Table 5. Column (1) and Column (2) represent the 2SLS regression when using coastal distance as an instrumental variable. Column (3) and Column (4) are the 2SLS regressions when using port distance as an instrumental variable. This information shows that the core explainable variables are appositive and all instrumental variables are valid. This also proves the robustness of the conclusions of this study.

Table 5. Instrumental variable regression.

Variable	(1) 2SLS1	(2) 2SLS2	(3) 2SLS1	(4) 2SLS2
FQ		−7.156 *		−4.021 *
		(−1.95)		(−1.95)
Coast	−0.003 ***			
	(−3.40)			
Port			−0.006 ***	
			(−5.32)	
_cons	0.099 ***	−11.854 ***	0.174 ***	−12.026 ***
	(3.16)	(−29.03)	(4.81)	(−36.14)
Control	Yes	Yes	Yes	Yes
FE-year	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes
N	3960	3960	3960	3960
adj.R^2	0.187	0.553	0.190	0.654

Note: ***, * represent the significant level of 1%, 10% respectively.

5.3. Robustness Test

5.3.1. Sample selection

(1) Winsorization: Removing the Influence of Extreme Values

In order to exclude outliers in the control variables, all controlled variables are winsorized at a 5% bilateral level. The regression results are shown in Column (1), Table 6. It suggests that with all the controlled variables added, the regression coefficients of the core explainable variables are significantly negative at the statistical level of 1%, but the results are still robust.

Table 6. Sample selection.

Variable	(1)	(2)	(3)	(4)
	Winsorization	Eliminate Municipalities	Prefecture-Level Cities	Policy
FQ	−0.404 ***	−0.424 ***	−0.494 ***	−0.393 **
	(−3.109)	(−3.270)	(−3.529)	(−2.401)
_cons	−9.746 ***	−9.272 ***	−11.090 ***	−7.983 ***
	(−8.470)	(−8.593)	(−9.326)	(−5.880)
Control	Yes	Yes	Yes	Yes
FE-year	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes
N	3960	3904	3470	2263
adj. R^2	0.579	0.586	0.599	0.515

Note: ***, ** represent the significant level of 1%, 5% respectively.

(2) Some Samples Being Eliminated

Considering that municipalities, provincial capitals and sub-provincial cities are quite different from ordinary prefecture-level cities in terms of economic development, energy consumption and green technology innovation, the samples of municipalities directly under the Central Government are first excluded for regression, and the results are shown in Column (2) of Table 6. Secondly, only the samples of ordinary prefecture-level cities are retained for regression, and the results are shown in Column (3). The regression coefficients of FQ are all significantly negative at the level of 1%, indicating that FDI quality upgrading has a significant inhibitory effect on the level of urban carbon emissions. This conclusion is still robust after removing the samples from cities with high administrative levels.

(3) The Policy Impact of the Low-Carbon City Pilot Being Excluded

The research period of this paper has a large time span, which lasts from 2006 to 2019. During this period, China carried out three batches of low-carbon city pilot projects in

2010, 2012 and 2017, respectively, which played an important role in controlling nationwide greenhouse gas emissions. Therefore, in order to exclude the impact of this policy on this study, we eliminated the samples in the year when the policy was implemented and the following year in order to verify whether the conclusion of the benchmark regression is still valid after the radiation effect of the policy gradually stabilizes. The regression results of the shortened sample period are shown in Column (4) of Table 6. Although the coefficient and significance of FQ have decreased after excluding the influence of policy effects, the conclusions of this paper are still robust.

5.3.2. Replacing the Explained Variable

In this paper, the total amount of carbon emissions is used for testing in the benchmark regression. In order to increase the robustness of the conclusions, carbon emission intensity (CarA) and per capita carbon emission (CarB) are further used as explained variables for regression. Where CarA is the ratio of total urban carbon emissions to urban GDP, and CarB is the ratio of total urban carbon emissions to the total urban population. Columns (1)–(4) of Table 7, respectively, show the regression results of CarA and CarB without control variables and with all control variables added. The regression coefficient of FQ is always significantly negative at the statistical level of 1%, which is consistent with the benchmark regression results. This shows that FDI quality upgrading will not only inhibit the total carbon emissions of cities but also significantly reduce the carbon emission intensity and per capita carbon emission level.

Table 7. Replacing the explained variable.

Variable	(1)	(2)	(3)	(4)	(5)
	CarA	**CarA**	**CarB**	**CarB**	**hdfe**
FQ	−4.166 ***	−3.931 ***	−3.184 ***	−2.809 ***	−3.595 **
	(−3.500)	(−3.393)	(−4.202)	(−3.871)	(−2.227)
_cons	8.758 ***	16.545 *	2.628 ***	37.976 ***	−11.645 ***
	(22.893)	(1.725)	(10.791)	(6.321)	(−3.917)
Control	No	Yes	No	Yes	Yes
FE-year	Yes	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes	Yes
FE-province	No	No	No	No	Yes
FE-interactive	No	No	No	No	Yes
N	3962	3960	3962	3960	3890
adj. R^2	0.082	0.150	0.082	0.177	0.908

Note: ***, **, * represent the significant level of 1%, 5% and 10% respectively.

5.3.3. The Fixed Effects of Other Dimensions Being Controlled

This paper controls the fixed effects of region and year in the benchmark regression and excludes the impact of non-observed factors on urban carbon emissions at these two levels. Secondly, since the location conditions, economic strength and industrial structure of different provinces may affect the carbon emissions of cities in the province, this paper adds the control of provincial fixed effects. Finally, since other variables that change over time may affect the carbon emission reduction of Chinese cities, especially the changes of major national and provincial strategies in different years, the cross-fixed effects of "province × year" should be controlled. The regression results in Column (5) of Table 7 show that the research conclusion of this paper is still robust.

5.4. Heterogeneity Test

5.4.1. Scientific and Technological Support Level

Scientific and technological support is an important support for urban innovation and a key factor in achieving carbon emission reduction. In order to test whether there are differences in the impact of FDI quality upgrading on urban carbon emissions under different degrees of scientific and technological support, this paper divides cities into low and high groups according to their annual median. The regression results in Columns (1)–(2) of Table 8 show that the estimated coefficient of FQ is significantly negative, indicating that FDI quality upgrading has a carbon emission reduction effect on cities with different levels of scientific and technological support, but this effect is more significant in cities with high-tech support.

Table 8. Heterogeneity test (1).

Variable	(1)	(2)	(3)	(4)
	Low Tech-Support	**High Tech-Support**	**High Rationalization**	**Low Rationalization**
FQ	−0.383 *	−0.630 ***	−0.382 **	−0.743 ***
	(−1.874)	(−3.048)	(−2.307)	(−3.592)
_cons	−13.441 ***	0.945	−4.021 ***	−8.839 ***
	(−8.288)	(0.514)	(−3.084)	(−4.052)
Control	Yes	Yes	Yes	Yes
FE-year	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes
N	1979	1981	1981	1979
adj. R^2	0.423	0.590	0.478	0.619

Note: ***, **, * represent the significant level of 1%, 5% and 10% respectively.

The reason is that increasing financial investment in science and technology, on the one hand, can provide capital and talent reserves for urban innovation and provide support for green technology innovation in carbon emission reduction. On the other hand, financial support can be provided for the governance of carbon emission reduction, such as reducing carbon emissions through subsidies to enterprises. Therefore, FDI quality can play a more significant role in carbon emission reduction in cities with high-tech financial investment.

5.4.2. Rationalizing Industrial Structure

Industrial structure will affect environmental quality [42,43], any industrial structure distortion will cause inefficient allocation or even misallocation of resources, forcing energy consumption to increase [44]. The rationalization of industrial structure refers to the degree of coordination among industries and the degree of effective utilization of resources. According to the median of the rationalization level of urban industrial structure, the sample cities are divided into two groups: low and high. According to the results in Columns (3) and (4) of Table 8, the estimated coefficients of FQ are significantly negative, but the emission reduction effect of FDI quality upgrading is more significant in cities with a low level of rationalization of industrial structure. Cities with low rationalization of industrial structure mainly rely on resource-based and heavy chemical industries with high pollution and high energy consumption to achieve economic growth, and green technology innovation is their weakness, which leads to an increase in carbon emissions.

At the same time, according to the theory of late-mover advantage, the learning cost of such cities is much lower than the innovation cost. By introducing, imitating and learning from the advanced technologies and systems of FDI enterprises, it can obtain the benefits of latecomers and improve the efficiency of the green economy. Therefore, cities with a low level of rationalization of industrial structure have greater development space to achieve carbon emission reduction with the help of high-quality FDI.

5.4.3. Environmental Regulation Intensity

Environmental regulation is one of the main means for governments at all levels to correct environmental externalities. This paper divides and tests it according to the median. The results in Columns (1) and (2) of Table 9 show that the coefficient of FQ is significantly negative in the samples of cities with strong environmental regulation, indicating that the promotion effect of FDI quality improvement on urban carbon emission reduction is more prominent in regions with strong environmental regulation. The reason is that the improvement of regional environmental regulation intensity raises the entry threshold for FDI in highly polluting industries. At the same time, foreign-funded enterprises have to carry out technological innovation and green transformation in order to compensate for the increased pollutant discharge costs caused by the government's environmental regulations. High-quality foreign investment is more capable of realizing the research and development of green technologies and technology spillover for local enterprises, which ultimately drives the reduction of overall urban carbon emissions.

Table 9. Heterogeneity test (2).

Variable	(1)	(2)	(3)	(4)
FQ	−0.313	−0.570 ***	−0.405 *	−0.445 ***
	(−1.620)	(−2.918)	(−1.777)	(−2.766)
_cons	−10.928 ***	−2.148	−12.035 ***	−0.915
	(−6.652)	(−1.276)	(−7.360)	(−0.650)
Control	Yes	Yes	Yes	Yes
FE-year	Yes	Yes	Yes	Yes
FE-region	Yes	Yes	Yes	Yes
N	1978	1982	1979	1981
adj. R^2	0.515	0.561	0.531	0.575

Note: ***, * represent the significant level of 1%, 10% respectively.

5.4.4. Foreign Capital Dependence

Most of the industries entered by FDI in the early stages have high carbon characteristics, making cities with high dependence on foreign capital fall into "pollution paradise". Can the improvement of FDI quality improve this situation? This paper divides the degrees into high and low groups according to the median. The results in Columns (3) and (4) of Table 9 show that the influence coefficient of FQ is always negative. However, the carbon emission reduction effect of FDI quality improvement is more significant in regions with higher foreign capital dependence. The reason for the high degree of foreign capital dependence is the difference in competitiveness caused by the technology gap between foreign capital and local enterprises, which provides conditions for FDI to realize positive technology spillover. High-quality FDI takes into account both economic and ecological benefits and is accompanied by the transfer of production technology and management experience to the host country. The technological progress caused by high-quality FDI is more focused on cleaner production technology, which can improve energy efficiency and reduce urban carbon emissions from the source.

6. Mechanism Test

6.1. The Mediation Mechanism of FDI Quality Affecting Urban Carbon Emissions

Table 10 shows the results of the mechanical test of green technology innovation quantity. Column (1) of Table 10 reports the influence of FDI quality on "independent innovation", and the estimated coefficient is significantly positive at the 1% statistical level. In Column (3), the estimated coefficient of FQ is positive but only passes the significance level of 5%, indicating that the incentive effect of FDI quality on "imitation innovation" is less than that of "independent innovation". In Column (2) and Column (4), the influence of mechanism variables on carbon emissions in Chinese cities was tested. The estimated coefficients of FQ and Quantity were both significantly negative at the 1% statistical level, which confirmed the conduction role of green technology innovation quantity represented by "independent innovation" and "imitative innovation" in this study.

Table 10. Mechanism test of green technology innovation quantity.

Variable	(1)	(2)	(3)	(4)
	Quantity of "Independent Innovation"		**Quantity of "Imitative Innovation"**	
FQ	0.230 ***	−0.385 ***	0.130 **	−0.392 ***
	(3.323)	(−2.986)	(2.344)	(−3.050)
Quantity		−0.178 ***		−0.258 ***
		(−5.782)		(−6.735)
_cons	4.268 ***	−7.126 ***	3.533 ***	−6.973 ***
	(7.465)	(−7.360)	(7.696)	(−7.209)
Control	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
N	3960	3960	3960	3960
adj. R^2	0.380	0.907	0.372	0.908

Note: ***, ** represent the significant level of 1%, 5% respectively.

Due to the large gap in innovation basis between different regions, in order to identify the forms of green technology innovation in eastern, central and western regions to achieve carbon emission reduction effects, this paper once again tests the conduction effect of "independent innovation" and "imitative innovation" after regional division (see Table 11). The results show that high-quality FDI in eastern China can promote urban carbon emission reduction by relying on "independent innovation", while in central and western China can restrain urban carbon emission mainly through "imitative innovation".

Table 11. Mechanism test of green technology innovation quantity by regions.

Variable	East		Middle		West	
	(1)	(2)	(3)	(4)	(5)	(6)
FQ	0.537 **	−0.478 **	−1.121 ***	0.184 ***	0.202	−0.183 ***
	(2.432)	(−2.513)	(−2.909)	(−5.964)	(0.422)	(−5.927)
"independent innovation" Quantity		−0.176 ***		−0.185		−0.156
		(−5.711)		(−0.435)		(−0.684)
FQ	−1.138 ***	−0.281	0.412 **	−0.255 ***	0.164 *	−0.207 ***
	(−6.250)	(−0.658)	(2.069)	(−6.626)	(1.671)	(−4.748)
"imitative innovation" Quantity		−0.265 ***		−0.468 **		−0.557 **
		(−6.881)		(−2.464)		(−2.163)

Note: ***, **, * represent the significant level of 1%, 5% and 10% respectively.

In terms of the quality of green technology innovation, Column (1) of Table 12 shows that the influence coefficient of FQ on the quality of green technology innovation is positive but not significant. Considering that there is a long time lag in green invention patent authorization, FDI quality variables are further treated with a one-period lag. The results in Column (3) show the estimated coefficients of L1.FQ are significantly positive at the 1% statistical level, and the estimated coefficients of L1.FQ and Quality in Column (4) are both significantly negative, indicating that FDI quality upgrading can promote the improvement of innovation quality, but there is an obvious time lag in the effect of this mechanism. To sum up, Hypothesis 2 is verified, and FDI quality upgrading significantly promotes the "quantity increase and quality improvement" of urban green technology innovation and enables the reduction of urban carbon emissions.

Table 12. The mechanism test for the quality of green technology innovation.

Variable	(1)	(2)	(3)	(4)
	Current Innovation Quality		Lag Phase Innovation Quality	
FQ	0.024	−0.422 ***		
	(0.862)	(−3.267)		
Quality		−0.143 *		−0.172 **
		(−1.873)		(−2.095)
L1.FQ			0.074 ***	−0.415 ***
			(2.582)	(−3.074)
_cons	−0.287	−7.931 ***	−0.279	−6.855 ***
	(−1.234)	(−8.233)	(−1.456)	(−6.541)
Control	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
N	3960	3960	3677	3677
adj. R^2	0.360	0.907	0.320	0.904

Note: ***, **, * represent the significant level of 1%, 5% and 10% respectively.

The common point between this study and others is that all of them focus on the impact of heterogeneous innovation. For example, Huo W.D. et al. (2019) [34] decomposed technological innovation into production-oriented and ecology-oriented innovations. However, our study believes that industrial production and environmental protection are carried out simultaneously. According to the technological content of innovation, it is decomposed into the quantity of independent innovation and imitation innovation and the quality of innovation, which corresponds to the three stages of FDI technology spillover and is of more practical significance. Other scholars generally found that FDI inflow is not conducive to imitation and independent innovation and reduces the efficiency of green development. Based on the FDI quality, our study proves the role of different innovation methods in the process of reducing carbon emissions.

6.2. Threshold Effect Test Based on Green Technology Innovation

As can be seen, FDI quality has a certain impact on urban carbon emissions, but the effect may be limited by urban green technology innovation. Only when Chinese cities have certain innovation strengths and absorption capacities, that is, when the level of green technology innovation reaches a certain “threshold”, can they learn, absorb and utilize the knowledge and technology spillover of high-quality FDI, and on this basis, give full play to the carbon emission reduction effect of FDI quality improvement. After the threshold testing, the level of green technology innovation presents significant threshold characteristics. Among them, the quantity of “independent innovation” has two thresholds, while the quantity and quality of “imitation innovation” have only one (Table 13).

Table 13. Threshold effect test.

Variable	Threshold Model (1)		Threshold Model (2)			Threshold Model (3)	
	Quantity $\leq$ 3.4012	**Quantity > 3.4012**	**Quantity < 1.0986**	**1.0986 < Quantity < 5.9965**	**Quantity $\geq$ 5.9965**	**Quality $\leq$ 0.1719**	**Quality > 0.1719**
Imitative model	−1.230 ***	−0.877 ***					
Quantity	(0.153)	(0.143)					
Independent innovation			−0.852 ***	−0.956 ***	−1.438 ***		
Quantity			(0.160)	(0.142)	(0.224)		
Quality						−0.806 ***	−1.079 ***
						(0.145)	(0.144)
_cons	−8.035 ***	−8.035 ***	−9.068 ***	−9.068 ***	−9.068 ***	−8.869 ***	−8.869 ***
	(0.434)	(0.434)	(0.430)	(0.430)	(0.430)	(0.409)	(0.409)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	3962	3962	3962	3962	3962	3962	3962
adj. R^2	0.507	0.507	0.505	0.505	0.505	0.506	0.506

Note: *** represent the significant level of 1%.

6.2.1. Threshold Regression for the Number of "Imitative Innovations"

When the threshold variable of the independent variable FDI quality is the quantity of "imitative innovation", its single threshold value is 3.4012. When the quantity of "imitative innovation" is less than or equal to 3.4012, the relationship between FDI quality and urban carbon emissions is significantly negative at the 1% statistical level, and the influence coefficient is −1.2295. When the quantity of "imitative innovation" is greater than 3.4012, its inhibitory effect on carbon emissions is weakened, and its effect coefficient is −0.8773, but it still passes the significance level of 1%. In the study period of this paper, the number of samples in the second stage of "imitative innovation" accounted for 56.76%.

6.2.2. Threshold Regression for the Number of "Independent Innovation"

When the threshold variable of the independent variable FDI quality is the quantity of "independent innovation", its double threshold values are 1.0986 and 4.4308, respectively. When the figure of "independent innovation" is less than 1.0986, the relationship between FDI quality and carbon emissions is significantly negative at the 1% statistical level, and the influence coefficient is −0.852. When the figure of "independent innovation" is less than 4.4308, its inhibitory effect on urban carbon emissions is slightly enhanced, with an effect coefficient of −0.956. When the number of "independent innovations" is greater than or equal to 4.4308, the influence coefficient becomes −1.438. It can be seen that with the increase in the number of "independent innovation", the carbon emission reduction effect of FDI quality shows a stepped-up strengthening trend. In the study period of this paper, the number of samples in the second stage accounted for 70.35%, while the number of samples in the third stage was only 3.6%.

6.2.3. The Threshold Regression Based on the Quality of Innovation

When the threshold variable of the independent variable FDI quality is innovation quality, its single threshold value is 0.1719. The regression results show that the effect of FDI quality on urban carbon emission reduction is highlighted by the improvement of green technology innovation quality. When the innovation quality $\leq$0.1719, the influence coefficient is −0.806; when the innovation quality is >0.1719, the influence coefficient becomes −1.079. Obviously, when the innovation quality exceeds the threshold value of 0.1719, the carbon emission reduction effect of FDI quality upgrading is greatly improved. In the study period, 66.89% of the samples were in the first stage of innovation quality.

The above results indicate that the inhibitory effect of FDI quality improvement on total urban carbon emissions shows threshold characteristics that slightly weaken with the increase in the number of "imitative innovations" and strengthen with the increase in the number and quality of "independent innovations". That is to say, FDI quality will not exert a stronger inhibition on carbon emissions when cities carry out green technology innovation. Instead, with the improvement of green technology innovation quality, continuous organizational learning, independent research and the development of advanced cleaner production technologies, FDI quality gradually gets rid of technology dependence, and FDI quality upgrading will lead to more significant carbon emission reduction effect. Of course, as more samples fall in the first and second stages of "independent innovation" quantity as well as the first stage of innovation quality, this indicates that the level of independent innovation in green technology is low at present and there is still room for improvement of innovation quality in the future.

7. Conclusions and Policy Suggestions

7.1. Conclusions

High-quality introduction and utilization of FDI play an important role in carbon emission reduction. Unlike previous studies that focused on the economic effects of FDI, we use the panel data of 283 cities in China from 2006 to 2019, focus more on the impact of FDI quality on urban carbon emissions and try to identify the mechanism and threshold effect of green technology innovation. Summing up the results of the conducted research, the following main conclusions can be formulated:

(1) FDI quality upgrading can significantly reduce urban carbon emissions. For every 1% increase in FDI quality, the total carbon emissions of Chinese cities will decrease by 0.426%. It is mainly manifested by the FDI management and FDI export capacity to suppress the total carbon emissions from the perspective of sub-dimensions, which shows significant negatives at the statistical level of 5% and 1%, respectively. This conclusion is still valid after robustness tests such as using the instrumental variable method, replacing the explained variable, excluding the policy impact of the low-carbon city pilot, changing the city sample and superimposing high-dimensional fixed effects.

(2) The heterogeneity test finds that the emission reduction effect of FDI quality is more significant in cities with a low rationalization degree of industrial structure, more investment in science and technology, stronger environmental regulation and higher dependence on foreign capital.

(3) Green technology innovation (GTI) is an intermediary mechanism for FDI quality to play a carbon emission reduction effect, which is specifically reflected in the improvement of the quantity and quality of GTI. From the perspective of different regions, the high-quality FDI in the eastern regions can promote urban carbon emission reduction through independent innovation, while the central and western regions mainly rely on imitation. However, there is a delay in the role of innovation quality.

(4) It is found in the expanded research that the carbon emission reduction effect of FDI quality has obvious threshold characteristics. Taking the quantity and quality of green technology innovation as threshold variables, it shows a nonlinear relationship with carbon emissions. Specifically, the carbon emission reduction effect of FDI would be slightly weakened with the increase in the number of "imitative innovations", but strengthened with the improvement of "independent innovation" and "innovation quality". From the aspect of empirical results, "imitative innovations" and "innovation quality" are the single thresholds, with the number of 3.4012 and 0.1719, respectively, and "independent innovation" have double thresholds, which values are 1.0986 and 4.44308, respectively. Now, the "independent innovation" of green technology in China has just made a start in our undertaking. There is a long way to go to upgrade innovation and improve quality.

(5) There is a need for further research on this topic. First of all, it is important for different cities to collaborate in the process of China's green transformation. Therefore, it is urgent to use the spatial econometric model to investigate whether the carbon emission reduction effect of FDI quality improvement has a spatial spillover effect. Secondly, with the evolution of the new technological revolution, the impact of digital technological progress on urban carbon emissions needs to be discussed, as does whether it can replace green technological innovation to play a conducive role in this study.

7.2. Suggestions

This paper further identifies the relationship among FDI quality, green technology innovation and urban carbon emissions and explores the low-carbon transformation path of Chinese cities. According to the results of the conducted research, it seems appropriate to provide the following proposals:

(1) To improve the quality of green technology innovation and the capacity of independent innovation to enhance its role as an engine for low-carbon development

Green technology innovation (GTI) has positive social externalities, so we must strive to improve the market-oriented GTI quality system. Firstly, the government should strengthen policy support for GTI. We will improve the system of green laws and regulations and the supply system of intellectual property rights, provide support for the application of independent innovation and enhance the strength of green technology innovation in key areas through green credit and the establishment of special funds for green innovation. Second, we should strengthen scientific and technological breakthroughs in green and low-carbon core technologies and enhance the ability to transform innovation achievements. We should encourage enterprises to increase investment in science and technology and personnel training and give corresponding financial and technical support to enhance their ability to absorb and transform foreign technologies. We should give full play to the government's macro-control ability, realize the transformation of enterprise innovation achievements through the active operation of the market and avoid unnecessary loss of resources. Thirdly, we should pay attention to the comprehensive implementation of various policies, such as green and low-carbon industrial layout policies, environmental access policies and policies on the internal energy consumption and social costs of carbon emissions, so as to encourage the quality upgrading of green technology innovation by market players in an all-round and multi-dimensional manner.

(2) To increase the scale of foreign investment in an appropriate and orderly manner and accelerate the attraction and utilization of high-quality FDI.

The government should actively guide the injection of high-quality foreign capital, improve the investment attraction mechanism, strengthen the absorptive capacity, give full play to the spillover effect of FDI and promote the improvement of enterprises' green technology innovation. First of all, it is suggested that the introduction of foreign capital should shift from quantity to efficiency, identify the relevant characteristics of FDI quality, give priority to the introduction of FDI with advanced management and significant export capacity, encourage high-quality foreign capital to enter landmark high-tech projects and form the demonstration effect of high-quality FDI in promoting urban carbon emission reduction. Secondly, in order to improve the profitability of FDI, financial institutions should be guided to tilt credit resources toward scientific and technological innovation and low-carbon projects, expand financing channels for foreign enterprises and reduce the cost of research and development innovation. Thirdly, in order to enhance the emission reduction effect of the actual scale of FDI, the foreign capital management and system should be innovated, such as by improving the negative list management and promoting the single window of international investment, so as to further improve the degree of investment facilitation and optimize the structure of foreign capital while steadily increasing the scale of foreign capital. Finally, we should stimulate the technology spillover effect of high-quality FDI, use high-quality overseas resources and its global R&D network and strive to establish local R&D centers so as to improve the pollution control of local enterprises through technology diffusion and absorption.

(3) To optimize the urban business environment and stimulate the carbon emission reduction effect of high-quality FDI.

First of all, we should adhere to investment and pollution prevention and control simultaneously. That is, we should consider the environmental effect of foreign investment when attracting investment, take environmental regulation as the entry threshold, improve the negative list of foreign investment access, including pollution emission control, one-to-one service for ecological innovation of domestic and foreign enterprises, environmental tax, green innovation subsidy policy, actively introduce green and high-quality foreign investment and gradually realize the coordinated development of opening up and ecological environment. Secondly, the government should increase its financial support for green investment in science and technology. It is necessary not only to cultivate green technology innovation platforms, such as scientific and technological resource-sharing service platforms but also to increase the procurement of green technology innovation products and strengthen the wide application of green technology innovation achievements in the industry, agriculture, construction, transportation and other fields, so as to effectively promote energy conservation and emission reduction in the whole industry. Finally, we should continue to deepen supply-side structural reform, create a favorable business environment and talent introduction mechanism and promote the attraction of high-quality FDI.

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