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FDI, Technology Spillovers, and Green Innovation: Theoretical Analysis and Evidence from China

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Abstract: Foreign direct investment (FDI) technology spillovers play an increasingly important role in a host country's development. Evaluating the positive effect of FDI inflows on green innovation is essential for correct city design. Based on the panel data of 262 cities in China from 2004 to 2018, we first analyzed the impact of FDI technology spillovers on green innovation in Chinese cities and then tested the threshold effect in four absorptive capacity factors: environmental regulation, economic growth, human capital, and industry size. Finally, we compared the time and space of two types of cities crossing the threshold from the perspective of innovative and non-innovative cities. The results show that FDI can significantly promote green innovation in Chinese cities and the promoting effect of FDI on green innovation has nonlinear characteristics, namely, such effects only make sense when absorptive capacity is above the threshold points. Additionally, among the four absorptive capacity factors, the development degrees of innovative cities are ahead of non-innovative cities; in particular, there is a significant difference between them in terms of economic growth. Local governments should develop reasonable policy combination tools according to the absorptive capacity characteristics of different cities to effectively promote the technology spillover effect of FDI and achieve coordinated ecological and economic development.

Keywords: foreign direct investment; technology spillovers; green innovation; absorptive capacity; threshold model

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1. Introduction

Since the 1990s, China has attracted a large amount of foreign direct investment (FDI) making it the largest recipient of FDI in developing countries. According to the report "Global Investment Trends Monitor" released by the United Nations Conference on Trade and Development (UNCTAD), the global scale of cross-border investment plunged by 34.7% in 2020 and the amount of FDI inflows was only USD 998.89 billion. While, China ranks second in the world for its achievements in counter-trend growth, accounting for 15% of the global total, and has ranked first among developing countries for 29 consecutive years, maintaining the status of the second largest foreign capital inflows country in the world for four consecutive years. (See http://kz.mofcom.gov.cn/article/jmxw/202111/20211103215050.shtml (accessed on 5 November 2021)).

Prior scholars have concluded that FDI inflows help stimulate economic growth in the long run, but its negative effects cannot be ignored [1,2]. With the sharp increase in the amount of foreign investment introduced, China's environmental quality is also steadily worsening and extreme weather events, greenhouse gas emissions, and haze weather occur frequently [3]. The relationship between FDI and environmental pollution has attracted wide attention from scholars. They believed that the foreign capital introduced by developing countries is mostly pollution-intensive industries. To attract such foreign investment, the governments of host countries tend to relax domestic environmental regulations and accelerate the development of natural resources, thus consuming fossil fuels, producing a large number of industrial wastes, and producing more pollution-intensive products, which deteriorates the environmental quality and social welfare. What is more, the continuously declining environmental protection standards will lead to the phenomenon of "race to the bottom line (environmental standards)", therefore FDI will aggravate the environmental pollution of the host country [4]. However, other scholars believed that FDI does not deteriorate the environmental quality of the host country, but helps to improve regional environmental pollution [5]. This is mainly due to the spread of cleaner production technology and environmental management systems consistently implemented by multinational companies in the host country. In addition, their production and pollution control activities are characterized by increasing scale efficiency and the indirect production spillover effect can improve the environmental quality of the host country [4]. It can also drive host governments to attach importance to environmental protection and improve their environmental regulation standards, thus promoting the diffusion of environmental technologies and the development of environmental protection [5]. Moreover, financial FDI can contribute to host countries by increasing the added value of products manufactured, creating new jobs, or through the fiscal facilities granted to companies investing in this region, while foreign-invested firms may also damage Chinese companies by squeezing out market share and stealing skilled workers [6–10].

Facing such unprecedented environmental challenges, the Chinese government has approved several laws and enforced environmental protocols in an effort to establish a coordinated government system for ecological protection [11], for example, the "blue sky defensive war" strategy. These strict environmental regulations compel enterprises to seek green innovation approaches aimed at simultaneously decreasing pollution and increasing the production of goods [12]. Green innovation has become a common choice among countries and enterprises which refers to new products, processes, and methods that reduce the negative impacts of environmental risks, pollution, and resource consumption [13]. For example, energy firms can obtain innovation performance through digital innovation [14]. Research shows that in resource-constrained, low-income countries, green innovation creates an effective way to achieve long-term growth because it creates new jobs, activities and consumption needs [15]. However, there is insufficient incentive for companies to innovate because it is a long-term investment that generally does not give a return in the short term. In addition, an uneven level of regional development lowers the diffusion rate of green innovation in practical applications. It is commonly agreed that innovation is not easy in practice.

It is in these circumstances that the investigation of the relationship between FDI and green innovation in host countries is based. For example, the pollution halo effect has become the focus of scholars' attention due to its claims that a host country can improve its green innovation ability through FDI by introducing clean technologies and equipment and excellent expertise [16]. This is clearly in opposition to the pollution-haven hypothesis. Although this was tested empirically, the results are diverse. Zhang et al. [17] found that FDI can positively affect urban green innovation efficiency, while Jiang et al. [18] arrived at the opposite conclusion. Some scholars have tried to explain this divergence in terms of the various conditions in local factors that are mainly manifested in the "absorptive capacity" proposed by Cohen and Levinthal [19].

Therefore, we address the following questions: Does import FDI promote the improvement of green innovation in the host country? Is the technology spillover effect of FDI restricted by the host country's local conditions? What factors will influence the host country to exert the FDI technology spillover effect? Earlier studies have tried to address these issues from the perspective of either the country or provincial level. However, the development level of different cities in the same province is not balanced, which is mostly manifested as the development gap between provincial capital cities and prefecture-level cities. According to the Statistics Bureau and statistical bulletin, in 2020, the per capita GDP of Changsha, the capital of Hunan Province, was CNY 120,821, and the per capita GDP of Hunan Province was CNY 62,886. The per capita GDP of Changsha, the capital of Hunan Province, was 1.92 times the provincial per capita GDP. With the launch of the "strong provincial capital" strategy in some regions in recent years, this situation is likely to become worse. Therefore, taking cities as the research object, we may draw different conclusions from previous articles that took provinces as the research object, thus drawing more targeted suggestions. We also hope to inspire those cities with low development levels.

To achieve this objective, we use the panel data of 262 cities in China from 2004 to 2018 to analyze the impact of FDI technology spillovers on green innovation in cities, which enriches the empirical research on FDI and green innovation to a certain extent. Then, considering the impact of policies, we conduct heterogeneity analysis on different types of cities and comprehensively analyze the differences in FDI utilization and development degree of cities under the construction of innovative cities. The above are possible contributions that we wish to make to this field. A comprehensive discussion on these issues may not only provide several suggestions for how to introduce and utilize foreign capital in China but also trigger scholars' debate on the rational path of urbanization in developing countries, providing a reference for others facing a similar development "dilemma".

The remainder of this paper is organized as follows. Section 2 presents a literature review. Section 3 introduces the methodology and data used in the study. Section 4 presents the empirical results. Section 5 analyzes the differences between innovative and non-innovative cities. Section 6 discusses our research results in the context of other studies. Section 7 concludes the paper with important findings and policy implications.

2. Literature Review

Since the initial work conducted by Macdougall, who proposed the theory of the FDI technology spillover effect, a vast body of literature on the influence mechanisms of FDI in promoting regional green innovation has been created [20]. However, there is no consensus on whether FDI inflows promote the technological progress of host countries and the factors that influence the FDI technology spillover effect.

2.1. FDI Technology Spillover Effect

Existing research on the FDI technology spillover effect can be divided into two main aspects. The first is whether FDI can promote the host country's technological innovation capacity. Current research on this question has not reached a unanimous conclusion. As most new technologies have appeared in developed countries, these technologies are introduced to developing and emerging countries through various channels, and FDI, as one of them, is considered to be the most economical and effective way [21]. Blomström and Persson [22] conducted empirical studies on Mexico and verified the existence of the FDI technology spillover effect. Hu and Jefferson [23] arrived at similar conclusions using Chinese data. They argue that FDI introduced by developing countries can promote regional green innovation by providing external capital sources, creating new employment opportunities, and simplifying technology and management skills [24–26].

However, some scholars believe that FDI does not significantly promote technological innovation in the host country and could even have a negative impact [27]. Domestic investment in the host country is severely drained by FDI thereby increasing its external vulnerability and intensifying domestic competition, which inhibits the improvement of the local technological innovation ability [28]. Romijn and Albaladejo [29] tested the FDI spillover hypothesis and concluded that the promotion effect of FDI on the host country's technological innovation capacity is weak. The reasons for this may lie in the choice of research methods, differences between countries, and characteristics of enterprises [23].

2.2. FDI Technology Spillover Effect and Absorptive Capacity

Due to the prominent difference in the impact of FDI on technological innovation in different countries and regions, scholars have explored which factors have influenced the FDI technology spillover effect. Numerous scholars have explained this from the perspective of absorptive capacity; the ability to transform external knowledge into new usable knowledge through evaluation, digestion, and application [30]. The institutional and policy support of the host country determines the speed and characteristics of technological change, thus affecting the absorptive capacity of enterprises and industries and shaping the knowledge stock of FDI recipient countries in the long term [31]. The existing literature mainly expounds on absorptive capacity from the perspectives of economic openness, infrastructure construction, economic development level, and financial development, among others [32]. The environmental regulation system has become the focus of scholars' attention in terms of the institutional constraints of the host country. This is primarily manifested in "following the cost theory" and "innovation compensation theory", which will be elaborated on in detail below.

Additionally noteworthy is the relationship between absorptive capacity and FDI technology spillovers, among which there are two representative viewpoints. First, the more backward the technology level of the host country, the greater the potential for technological progress, and the more significant the technology spillover effect of FDI [33]. However, Cohen and Levinthal (1989) argued that the absorptive capacity of the host country should reach at least a level or "threshold", for the superior technologies brought by multinational enterprises (MNS) to be identified, absorbed, and applied [18]. When examining the threshold value of the FDI technology spillover effect, the threshold regression analysis method proposed by Hansen [34] is widely used. Meanwhile, Girma [35] confirmed the threshold effect of absorptive capacity on FDI technology spillovers by studying the data of 7516 UK companies.

2.3. Different Absorptive Capacity Factors and Green Innovation

In this study, we explored the threshold characteristic between Chinese FDI inflows and green innovation using three absorptive capacities, environmental regulation, economic growth, and human capital from 2004 to 2018. Neoclassical economics holds that environmental regulation increases the production cost of enterprises through the internalization of environmental externalities, forcing enterprises to change their original optimal production decisions, which then reduces innovation ability and market competitiveness, known as "following the cost theory" [36–38]. However, ultimately, well-designed and well-enforced environmental supervision ensure that enterprises choose innovative technologies and upgrade their equipment, while the resulting "innovation compensation" will reduce or even offset the increased production costs, thus achieving emission reduction and production efficiency improvement [39,40]. These opinions were also tested using the data [41]. Conversely, an empirical test of German enterprise data shows that environmental regulations significantly promote green innovation [42]. We thus assume that there may be a reasonable range of environmental regulations which do not only limit the entry of foreign investment with serious pollution [43,44] but also attract environmentally friendly FDI inflows enhancing the diffusion of cleaner production technologies [45,46].

The economic development of the host countries is closely related to their absorptive capacity. As the economic development of high-income host countries has reached a certain level, they have formed a strong competition tolerance and absorptive capacity, and FDI can produce a robust positive pulling effect. However, for low-income host countries, FDI has an insignificant or even a negative effect on green innovation [46]. Pan analyzed Chinese industrial data and found that FDI in central and eastern China has a positive technology spillover effect on local industrial sectors, whereas FDI in western China has a negative technology spillover effect [47]. One possible reason is that the comprehensive economic development level formed by the residents' income and consumption levels, infrastructure construction, geographical location, and other factors in western China has not yet crossed the "threshold". For the review of previous studies, we chose economic growth as a threshold variable to investigate the relationship between FDI inflows and green innovation in Chinese cities.

Human capital also affects a city's absorptive capacity, which in turn impacts the host country's digestion and utilization of new technologies. Scholars have confirmed the substantial influence of human capital in high-tech industries using China's firm-level panel data [48]. Extant literature also reveals that FDI technological spillovers require the human capital of the host country to reach at least a minimum threshold before it can identify new knowledge and absorb it into the knowledge base for application [49]. Xu and Wang [50] studied American FDI in 40 countries and found that FDI had significant technology spillover to developed host countries but not to developing host countries. They believed that the main reason for this was the high level of human capital in developed countries. Other scholars also drew similar conclusions on the FDI of OECD countries to developing countries [22]. Chinese provincial data has also confirmed this view that the spillover effect of FDI increases as the threshold of human capital increases [26].

The industry size is also an important factor affecting green innovation. Shan believes that industries with different industry sizes not only have huge differences in capital power but also that capital power determines the size of their technological innovation ability [51]. We consider that when foreign capital enters the host country, it may exhibit economies of scale through industrial agglomeration and other reasons, and then promote technological innovation. However, this effect may have a dynamic evolution process. In other words, this effect is not obvious at the initial stage of entry, but with the continuous increase in foreign capital and expansion of industrial scale, the production factors will gradually concentrate within a certain area, which expands the economic benefits of the whole industry and improves green innovation performance. Therefore, there may be nonlinear (threshold) linkages between industry size and green innovation efficiency.

Referring to the relevant literature, Figure 1 shows the theoretical framework of this study. While existing references on the FDI spillover effect and its influencing factors have laid the foundation for further exploration of this study they have also left many gaps. Previous studies have mainly focused on the provincial level in China, whereas this study identifies the FDI spillover effect on green innovation and its influencing mechanism in cities. We selected 262 cities as the research object to study the impact of urban FDI on green innovation and to provide new theoretical evidence for the FDI green technology spillover effect in cities.

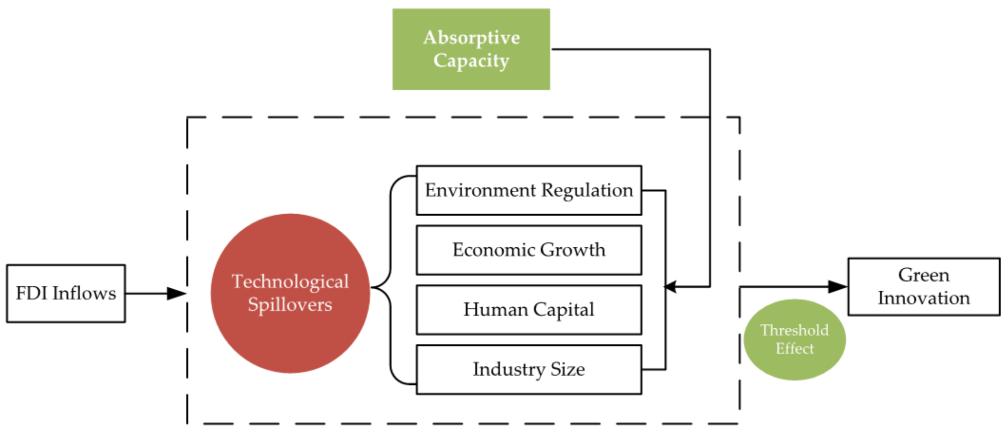


Figure 1. Theoretical framework.

Moreover, considering that neither the total factor productivity (TFP) nor non-parametric envelopment analysis (DEA), which is mostly used in the extant literature, can not accurately represent green innovation performance, we used the number of green patent applications to represent green innovation performance. Both TFP and DEA represent the progress of the total technology level; however, neither can separate general technological progress from green technological innovation, making it difficult to accurately reveal the level of green innovation. By contrast, the number of green patents can better reflect the innovation of green technology because it is classified by the World Intellectual Property Organization (WIPO) and is strictly supervised by the China National Intellectual Property Administration (CNIPA).

We further examined the impact of FDI inflows on urban green innovation from the perspective of innovative cities. Owing to increasingly prominent contradictions among limited resources, environmental constraints, and rapid economic growth, innovation is regarded as a vital development strategy in China. Innovative cities are designed to strengthen independent innovation capacity and accelerate the transformation of economic development patterns. We divided the 262 cities into innovative and non-innovative cities according to related policies and explored how innovative cities affect the spillover effect of FDI green technology in time and space. To our knowledge, this is the first study to associate green innovation with innovative cities to analyze whether the construction of innovative cities causes the FDI technology spillover effect on green innovation.

3. Methodology and Data

3.1. Model Specification

3.1.1. Benchmark Linear Regression Model

We examine the effect of FDI on urban green innovation in an integrated framework and build on earlier models in studies by Luo [12]. We first construct a classic panel model estimated by ordinary least square (OLS) which is presented as follows:

$$\ln \mathrm{GRE}_{i,t} = \alpha_0 + \alpha_1 \ln \mathrm{FDI}_{i,t} + \beta Control_{i,t} + \mu_i + \nu_i + \varepsilon_{i,t} \quad (1)$$

where $\mathrm{GRE}_{i,t}$ is the number of green patent applications or grants for the city I in year t; $\mathrm{FDI}_{i,t}$ is the foreign direct investment utilized; $Control_{i,t}$ is a series of control variables, including industrial structure (EI), infrastructure construction (IC), degree of economic openness (OPEN), and research and development (R&D) input (GOV); μ_i is the unobservable individual fixed effect of a city; and ν_t is the time fixed effect; $\varepsilon_{i,t}$ is a random disturbance term. We take the natural logarithm of the above variables to avoid heteroscedasticity.

3.1.2. Nonlinear Threshold Regression Model

Grouping tests and cross-term models are commonly used to investigate the threshold effect. However, the grouping test is difficult to objectively grasp the criteria of sample grouping and cannot estimate the specific threshold value and judge its significance from the perspective of mathematical statistics. Although the cross-term model method can estimate the specific threshold value, it is difficult to verify the correctness of the estimated threshold value. The threshold regression analysis model proposed by Hanse makes up for the shortcomings of the previous two methods. It takes the threshold value as an unknown variable into the research model, constructs a piecewise function, and can also estimate and test the threshold value and threshold effect.

Since the threshold model was proposed, scholars have carried out a lot of empirical studies using it. Based on this model, Wang and Liu took environmental regulation as the threshold variable and found that there was a double threshold effect of environmental regulation on the impact of FDI on environmental pollution in different regions of China [52]. Similarly, Fang also found that the development of the Internet and the development of entrepreneurship have a marginal increasing nonlinear impact on green innovation performance [53]. Combining a wide range of studies and our assumptions, we choose this model to conduct our empirical tests.

As discussed earlier, we suppose that the threshold effect of the FDI spillover effect may exist in four absorptive capacity factors: environmental regulation, economic growth, human capital, and industry size. To verify this assumption, we employ Hanse's panel threshold model, which introduces the threshold values into the model as unknown variables, and divides the equation into three or more regimes with different coefficients to build a piece-wise function. Specifically, in our study, when the threshold variables are greater or less than a certain value, the effect of FDI on green innovation is in different degrees and even in different directions. Considering the related control variables, we construct the panel threshold model as follows:

$$\begin{aligned} \ln \mathrm{GRE}_{i,t} &= \alpha_0 + \alpha_1 \ln \mathrm{FDI}_{i,t}(Z_{i,r} < r_1) + \alpha_2 \ln \mathrm{FDI}_{i,t} \times I(r_1 < Z_{i,t} \le r_2) \\ &+ \ldots + \alpha_n \ln \mathrm{FDI}_{i,t} \times I(r_{n-1} < Z_{i,t} \le r_n) + \alpha_{n+1} \ln \mathrm{FDI}_{i,t} \times I(Z_{i,t} > r_n) \\ &+ \beta_1 \ln \mathrm{EI} + \beta_2 \ln \mathrm{IC} + \beta_3 \ln \mathrm{OPEN} + \beta_4 \ln \mathrm{GOV} + \mu_i + \nu_t + \varepsilon_{i,t} \end{aligned} \quad (2)$$

where i represents the city; t represents time; $I(*)$ is an indicator function; r is a threshold value (point) to be estimated; Z is threshold variables including environmental regulation, economic growth and human capital in our study; μ_i is the unobservable individual fixed effect of a city; ν_t is the time fixed effect; and $\varepsilon_{i,t}$ is a random interference term. Obviously, when the threshold variable Z is less than the threshold value r_1, the coefficient of FDI on green innovation is α_1; when the threshold variable Z is greater than the threshold value r_1 and less than r_2, the coefficient of FDI is α_2, all the way to r_n.

3.2. Variables Definition

3.2.1. Dependent Variable

We select the level of green innovation as the dependent variable. As patent applications are closely monitored by CNIPA, the number of green patents accurately reflects innovation and R&D performance [54]. Therefore, we adopt the number of green patent applications and grants to measure green innovation performance.

3.2.2. Core Independent Variable

The independent variable is the amount of FDI inflows. We aim to examine the impact of FDI inflows on green innovation, the amount of FDI is the core independent variable, both in the benchmark linear regression model and panel threshold model. However, the measurement of FDI in academia has not been unified yet and the existing statistical data in China only publish annual FDI flows data. Referring to other scholars, we use the utilized FDI inflows to measure FDI inflows and convert FDI inflows calculated in USD into RMB according to the exchange rate of RMB against USD each year [55].

3.2.3. Threshold Variables

Absorptive capacity mainly refers to the ability to deal with advanced knowledge and technology through the process of identification, acquisition, digestion, absorption, and application, which mainly occurs in the technology absorption of a country (region) from multinational companies or external regions. As discussed above, we select environmental regulation, economic growth, human capital level, and industry size as absorptive capacity indicators to investigate the potential threshold effect of absorptive capacity of inward FDI technological spillovers on the performance of green innovation in a city.

Environmental regulation (ER). Previous studies have utilized the ratio of investment in environmental pollution controlling the provincial gross domestic product (GDP) to denote environment regulation [54,56]. However, a lack of this data in many cities prevents this approach. Following the study of Kuang and Lu [57], we use the index of the green coverage rate of urban built-up areas to measure the level of environmental regulation. Because the green coverage rate of built-up areas of municipal districts could reflect the degree of environmental governance in the region and is less affected by green innovation, it can effectively alleviate the endogenous problems.

Economic growth (GDP). Economic growth may reflect many aspects of a city's development, such as residents' income and consumption level, and financial development level, which can be regarded as a comprehensive development indicator of a city. We choose economic growth as the threshold variable and adopt the most representative GDP per capita to measure it in each city.

Human capital (HUM). Human capital captures the level of the labor force in a city, which will in turn affect the absorptive capacity of the city's FDI inflows. Existing literature mostly measures human capital by the average education level. However, such data are not available for most cities, therefore we refer to other scholars' approaches, using the proportion of the number of undergraduate and junior college students in the total population at the end of the year to measure the level of human capital.

Industry size (IND). Industry scale affects the utilization efficiency of regional resources, including natural resources, other technologies, and production resources, and further affects the level of regional green technology innovation. We learned from the practice of Kuang and measured the industry size by the number of industrial enterprises above the designated size [57].

3.2.4. Control Variables

The existing literature and empirical studies have highlighted important absorptive capacity factors that influence urban green innovation except the factors stated above. Following previous studies, we introduce industrial structure (EI), infrastructure construction (IC), degree of economic openness (OPEN), and R&D input (GOV) as control variables.

Industrial structure. The rising proportion of secondary industry output in the entire economy reduces carbon emission performance, which leads to the deterioration of the industrial structure and the ecological environment [58]. We use the proportion of the added value of the secondary industry in GDP to denote industrial structure. We expect the industrial structure will hurt green innovation.

Infrastructure construction. The level of infrastructure not only determines the choice of destination for FDI but also gathers outstanding scientific and innovative talents, which will facilitate green innovation [59]. We take the ratio of fixed asset investment to the GDP of each city to denote the level of infrastructure construction.

Economic openness. Previous evidence has shown that economic openness is closely related to FDI inflow attraction. Especially in cross-sectional studies, more open countries tend to attract more FDI [59]. We thus adopt the degree of economic openness as a control variable and measure it as the ratio of total import and export volume to GDP.

R&D input. Government support exerts a critical effect on the process of green innovation as it reduces expenditure and risk of innovation [60]. In this paper, the ratio of the science and technology expenditure of the government to the GDP of the city is used to represent R&D input. The descriptive statistics of each variable are shown in Table 1.

Table 1. Summary statistics.

Variable	Obs	Mean	Std.Dev.	Min	Max
lnFDI	3930	11.7035	1.8405	3.0089	16.8344
lnGRE	3930	3.0585	1.9723	0	9.5030
lnGRE2	3930	1.7217	1.7589	0	8.5192
lnGOV	3930	−6.6684	1.1304	−17.3916	−2.8538
lnEI	3930	3.8520	0.2377	2.6391	4.4534
lnOPEN	3930	−2.3922	1.4650	−8.1303	3.9406
lnIC	3930	−0.4304	0.5356	−2.7817	2.3960
lnER	3930	3.6021	0.3274	−1.0217	5.9575
lnGDP	3930	10.2621	0.7714	4.5951	13.0557
lnHUM	3930	−4.6886	1.0993	−9.4423	−1.0492
lnIND	3930	6.5866	1.0596	2.9444	10.6308

3.3. Samples and Data Sources

Considering the availability of data, we select the panel data of 262 cities in China from the 2004 to 2018 period, excluding cities with serious data deficiency. The data mainly comes from the China city statistical yearbook, EPS database, and statistical bulletin of each city over the years. Among them, green innovation determines the green patent code according to the green patent list issued by the World Intellectual Property Organization (WIPO). Then, we search the number of green patent applications and grants in each city in the CNIPA. The missing values are corrected by the interpolation method in individual years.

4. Empirical Results

We take logarithmic processing for all variables used in this study to eliminate the influence of heteroscedasticity. At the same time, to avoid multicollinearity, we test both correlation coefficients and variance inflation factors for all variables. The result shows that the correlation coefficients of variables are all less than 0.7 and the maximum VIF is 1.621, indicating that all variables are not multicollinearity. The panel data regression analysis usually adopts a fixed-effect model and a random-effect model. In our study, the result of the Hausman test shows that we should select a fixed-effect model to conduct our empirical research. Therefore, we use the fixed-effect model to conduct benchmark regression analysis by gradually adding control variables.

4.1. Baseline Regression Analysis

Table 2 reports the influence of FDI inflows on green innovation by gradually adding control variables. It can be seen that FDI can significantly promote green innovation at the confidence level of 1%, which indicates that FDI can promote green innovation in host cities, and this performance also exists when control variables are gradually added. This is similar to the conclusion drawn by Luo (2021), which indicates FDI produces green technology spillovers, verifying the "Pollution halo hypothesis" in China [12]. This may be because foreign-invested enterprises bring "hard" technologies, such as new products and new manufacturing methods, and "soft" technologies, such as progressive technologies, and marketing strategies, together with their capital to China to gain competitive advantages. By imitating and absorbing these superior technologies, domestic enterprises can optimize manufacturing processes to promote local green innovation.

Table 2. Baseline regression results.

Variable	GREEN1				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
lnFDI	0.5149 *** (0.0469)	0.0875 *** (0.0312)	0.1176 *** (0.0307)	0.1208 *** (0.0305)	0.0787 *** (0.0293)
lnGOV		0.8677 *** (0.0318)	0.8614 *** (0.0327)	0.8548 *** (0.0328)	0.7099 *** (0.0397)
lnEI			−1.4342 *** (0.2137)	−1.4619 *** (0.2086)	−1.4664 *** (0.2031)
lnOPEN				0.0669 (0.0466)	−0.0267 (0.0477)
lnIC					0.5691 *** (0.0771)
_cons	−2.9675 *** (−0.5490)	7.8208 *** (0.4988)	12.9512 *** (0.9064)	13.1364 *** (0.8890)	12.7011 *** (0.9139)
Year FE	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES
R-squared	0.1386	0.5349	0.5521	0.5530	0.5757
N	3930	3930	3930	3930	3930

Notes: *** presents the significance levels at 1%.; The standard errors are in parentheses.

Turning to the perspective of control variables, the influence coefficient of R&D input on green innovation is statistically significant and positive, which indicates that increased R&D input promotes local green innovation. The industrial structure measured by the proportion of the added value of the secondary industry in GDP is significantly unfavorable to green innovation. This is in line with our expectations. The development of the second industry will consume a large amount of energy, resulting in ecological environment pollution, which hampers the upgrading of urban industrial structures and green technology. The effect of economic openness on green innovation is negative and insignificant, indicating that import or export trade may hurt green innovation. Compared with developed countries, even China has a comparative advantage in exporting polluting industrial products, but it is not conducive to green innovation performance. The impact of infrastructure construction on green innovation is significantly positive, which means that cities with higher levels of infrastructural bases tend to generate more green innovations. That is partly because these cities with well-developed systems of communication, information technology, and transportation, also exert high significance for innovation and choice of MNC destination [59].

4.2. Threshold Effect Analysis

To further explore the potential nonlinear relationship between FDI inflows and the green innovation ability of cities, we analyze the threshold effect of FDI on green innovation from the perspective of absorptive capacity, taking environmental regulation, economic growth, human capital, and industry size as threshold variables. The result is presented in Table 3. We find that environmental regulation, economic growth, human capital, and industry size all have a double threshold effect, that is, with different levels of environmental regulation, economic growth, human capital, and industry size, the impact of FDI inflows on green innovation presents a nonlinear change characteristics.

Table 3. Results of the panel threshold effect test.

Threshold Variables	Type of Threshold	F-Value	*p*-Value	Critical Value		
				10%	5%	1%
ER	Single threshold	150.04 **	0.0000	67.8063	75.5584	86.9549
	Double threshold	23.49 **	0.0400	19.3730	22.2764	29.8180
	Triple threshold	16.26	0.9233	46.2359	51.4753	60.9712
GDP	Single threshold	642.09 ***	0.0000	206.5318	219.8059	249.4416
	Double threshold	406.82 ***	0.0000	91.8658	98.1381	116.3813
	Triple threshold	315.27	1.0000	707.6014	728.2977	785.5064
HUM	Single threshold	114.36 ***	0.0000	66.3132	74.7725	86.7657
	Double threshold	104.50 ***	0.0000	43.7216	45.9733	55.2355
	Triple threshold	77.64	1.0000	238.5864	254.5625	283.5260
IND	Single threshold	271.86 ***	0.0000	33.2871	36.1458	46.6526
	Double threshold	239.39 **	0.0100	28.2406	32.2014	39.0340
	Triple threshold	217.43	0.9500	97.3599	104.5451	115.4140

Notes: The *p*-value and threshold value are obtained using Bootstrap with 300 repeated samples; *** and ** present the significance levels at 1%, and 5% respectively.

4.2.1. Environmental Regulation Effect

The threshold effect test result shows that environmental regulation has a double threshold effect at the significant level of 5%, and the threshold values are 3.4701 and 3.6816 respectively. More specifically, when the strength of environmental regulation is lower than the threshold value of 3.4701, the regression coefficient of FDI insignificant is not significant, indicating FDI has no significant effect on regional green innovation. When the strength of environmental regulation is between 3.4701 and 3.6816, the regression coefficient of FDI is 0.054, passing the significance test of 5%. When the strength of environmental regulation is greater than 3.6816, the influence coefficient of FDI is 0.086 at the significance level of 1%, that is, when the strength of environmental regulation crosses the second threshold, FDI could significantly promote green innovation. This means that the impact of FDI inflows on regional green innovation partly depends on the intensity of local environmental regulation. Environmental regulation at different levels has different relative strengths of "reverse forcing effect" and "following the cost effect" on green innovation. When the strength of environmental regulation increases to a large enough extent, enterprises will be encouraged to introduce clean technologies or increase R&D input. At this point, the "innovation compensation effect" of environmental regulation forcing technological innovation of enterprises far exceeds the inhibition effect of "following the cost" and that will lead to a stimulation effect of FDI inflows on green innovation.

We divide the 262 cities into three groups with a high-environmental regulation regime, medium-environmental regulation regime, and low-environmental regulation regime, taking 3.4701 and 3.6816 as threshold values, to further analyze the specific situation of all cities. The result in Figure 2 shows that in 2004, 120 cities do not pass the first threshold of environmental regulation intensity, accounting for about 46% of the total number. The number of cities with medium environmental regulation intensity is 104, accounting for about 40% of the total number. While, 38 cities, or 15 percent of the total, have high environmental regulation levels. With the enhancement of public awareness of environmental protection, the number of cities with low environmental regulation is decreasing by the year. While the number of cities with high environmental regulation keeps increasing and accounts for 70% of 262 cities in 2018, compared with only 2% of the total number of cities with low environmental regulation levels. Therefore, until 2018, the strength of environmental regulation in most cities in China is reasonable, which makes FDI pose a positive effect on green innovation. However, there are still several cities with unreasonable environmental regulation strengths that should be paid more attention to.

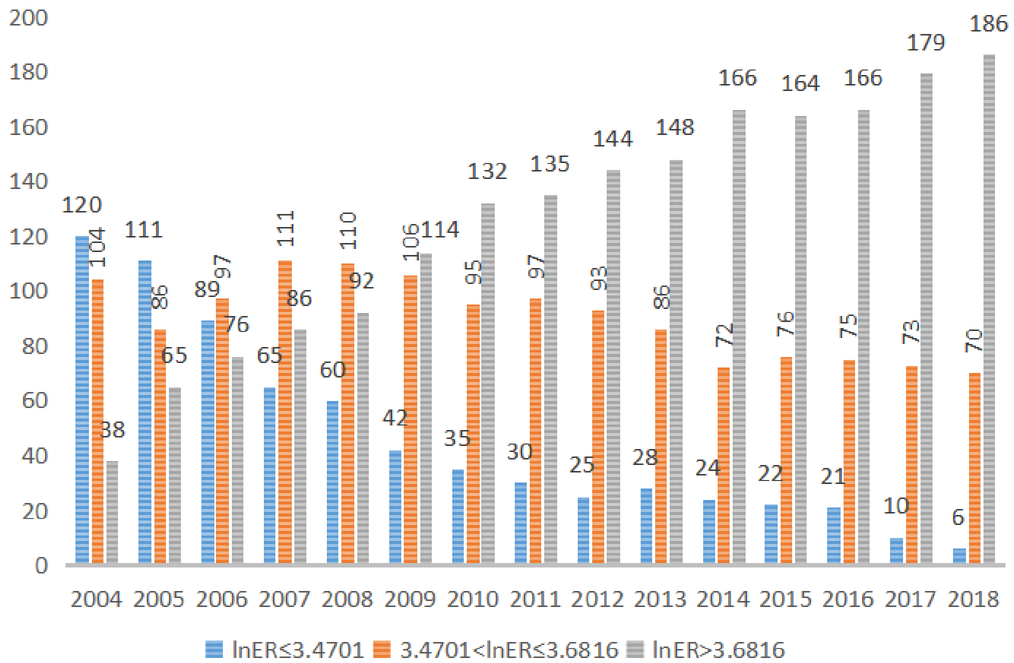


Figure 2. The number of cities in different environmental regulation zones from 2004 to 2018.

4.2.2. Economic Growth Effect

Table 4 reports that the economic growth at the significant level of 1% has a double threshold effect of the FDI green technology spillover effect and the threshold value is 10.028 and 11.200, respectively. When the economic growth of a city is lower than 10.028, the influence coefficient of FDI on local green innovation is statistically significant and negative. In other words, when the regional economic growth is relatively low, the FDI is not conducive to local green innovation. This may be because when the economy is not fully developed, the focus of development tends to be on economic construction rather than environmental protection. However, when the first threshold is crossed and the level of economic growth is between 10.028 and 11.200, the influence coefficient of FDI turns from negative to positive and holds at the significance level of 10%. This means that with the improvement of economic growth, the efficiency of using foreign capital was also improved. When the level of economic growth exceeds the second threshold value of 11.200, the influence coefficient of FDI is 0.128 at the significance level of 1%. At this time the local economic growth is relatively high and the FDI inflows will exert a positive effect on green innovation to a large extent.

Table 4. Threshold model results.

Threshold Variable: lnER		**Threshold Variable: lnGDP**		**Threshold Variable: lnHUM**		**Threshold Variable: lnIND**	
Variables	**(1)**	**Variables**	**(2)**	**Variables**	**(3)**	**Variables**	**(4)**
lnFDI (lnER < 3.4701)	0.0338 (0.0383)	lnFDI (lnGDP ≤ 10.0277)	−0.0437 * (0.0253)	lnFDI (lnHUM ≤ −5.8244)	0.0102 (0.0305)	lnFDI (lnIND ≤ 5.6240)	0.0226 (0.0281)
lnFDI (3.4701 < lnER ≤ 3.6816)	0.0538 ** (0.0290)	lnFDI (10.0277 < lnGDP < 11.1996)	0.0474 * (0.0243)	lnFDI (−5.8244 < lnHUM ≤ −4.3187)	0.0649 ** (0.0291)	lnFDI (5.6240 < lnIND ≤ 6.7214)	0.0608 ** (0.0285)
lnFDI (lnER > 3.6816)	0.0857 *** (0.0280)	lnFDI (lnGDP > 11.1996)	0.1283 *** (0.0252)	lnFDI (lnHUM > −4.3187)	0.1197 *** (0.0291)	lnFDI (lnIND > 6.7214)	0.0967 *** (0.0301)
lnFI	0.5501 *** (0.0741)	lnFI	0.3950 *** (0.0594)	lnFI	0.5505 ** (0.0717)	lnFI	0.5064 *** (0.0742)
lnOPEN	−0.0315 (0.0464)	lnOPEN	0.0582 (0.0364)	lnOPEN	−0.0169 (0.0431)	lnOPEN	−0.0241 (0.0469)
lnEI	−1.3499 *** (0.2000)	lnEI	−1.0303 *** (0.1839)	lnEI	−1.4888 *** (0.1969)	lnEI	−1.7289 *** (0.2007)
lnGOV	0.6474 *** (0.0383)	lnGOV	0.4574 *** (0.0337)	lnGOV	0.6458 *** (0.0389)	lnGOV	0.6724 *** (0.0400)
_cons	11.9547 *** (0.9004)	_cons	10.0622 *** (0.8570)	_cons	12.3768 ** (0.8979)	_cons	13.5159 *** (0.8879)
Year FE	YES	Year FE	YES	Year FE	YES	Year FE	YES
City FE	YES	City FE	YES	City FE	YES	City FE	YES
R-squared	0.5939	R-squared	0.6699	R-squared	0.5985	R-squared	0.5853
N	3930	N	3930	N	3930	N	3930

Notes: ***, **, and * present the significance levels at 1%, 5%, and 10%, respectively; The standard errors are in parentheses.

To further analyze the changes in the level of economic growth of cities, we divide the 262 cities into three types: high level, medium level, and low level, using 10.028 and 11.200 as threshold values. The result in Figure 3 shows that from 2004 to 2018, there is an apparent downward trend in the number of cities in the low-value zone. To be specific, the number of cities in the low-value range has decreased year by year from 225 at the beginning to 3 at the end of this period. On the contrary, the number of cities in the high-value range keeps increasing, accounting for about 29% of the total number in 2018. The number of cities in the median area increases firstly and then decreases, accounting for about 70% of the total number by the end of the period. As a whole, most cities have passed the first stage and are in the second and third stages, that is, FDI plays a positive role in promoting green innovation.

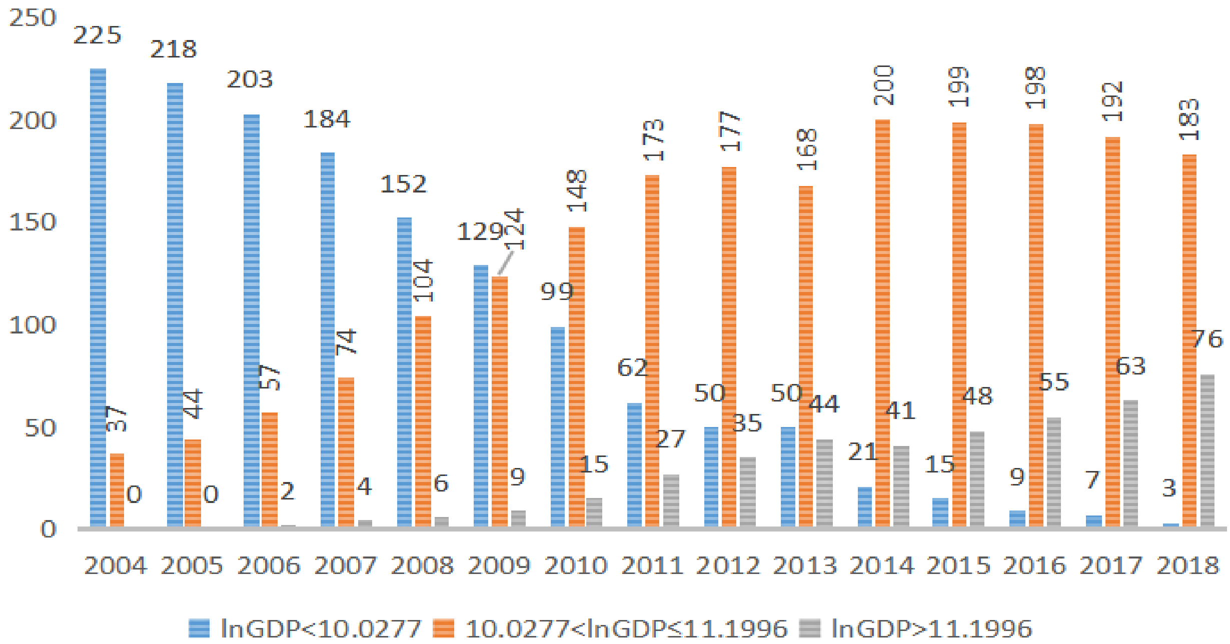


Figure 3. The number of cities in different levels of economic growth zones from 2004 to 2018.

4.2.3. Human Capital Effect

When we take human capital as a threshold variable to analyze the threshold effect of FDI inflows on green innovation, the result is shown in Table 4. The level of human capital is divided into three stages. In the first stage, when the human capital level of each city is less than −5.824, the influence coefficient of FDI on green innovation is insignificant. In the second stage, when the human capital level of each city is between −5.824 and −4.319, the coefficient of FDI is 0.065 and passes the significance test of 5%, which means that the pulling effect of FDI on regional green innovation performance becomes obvious. In the third stage, when the human capital level is greater than −4.319, the coefficient of FDI is 0.12 at the significance level of 1%, which indicates that with the improvement of the regional human capital level, FDI inflows significantly promote green innovation in the city. The human capital threshold of FDI technology spillover in this paper is consistent with the previous empirical evidence. Generally speaking, the higher human capital of host cities means that domestic enterprises have a strong absorptive capacity and can deal with the competitive pressure from multinational enterprises. Domestic enterprises adopt excellent technologies from abroad while improving and innovating them. Thus, FDI can produce a positive technology spillover effect on green innovation.

According to the threshold model result, we classify all cities into three types: low-value area, median-value area, and high-value area, using −5.824 and −4.319 as threshold values. The result in Figure 4 shows that in 2004, the proportion of cities in the low-value region is about 35% (the number is 91), the proportion of cities in the median region is about 45% (the number is 117), and the proportion of cities in the high-value region is about 21% (the number is 54). While, in 2018, this proportion changed to 5%, 53%, and 42%, respectively. Therefore, we conclude that by the end of the period, the number of cities in the middle-high value region accounted for more than 90%, that is, most cities have crossed the first threshold and are in the stage where FDI inflows can significantly drive green innovation.

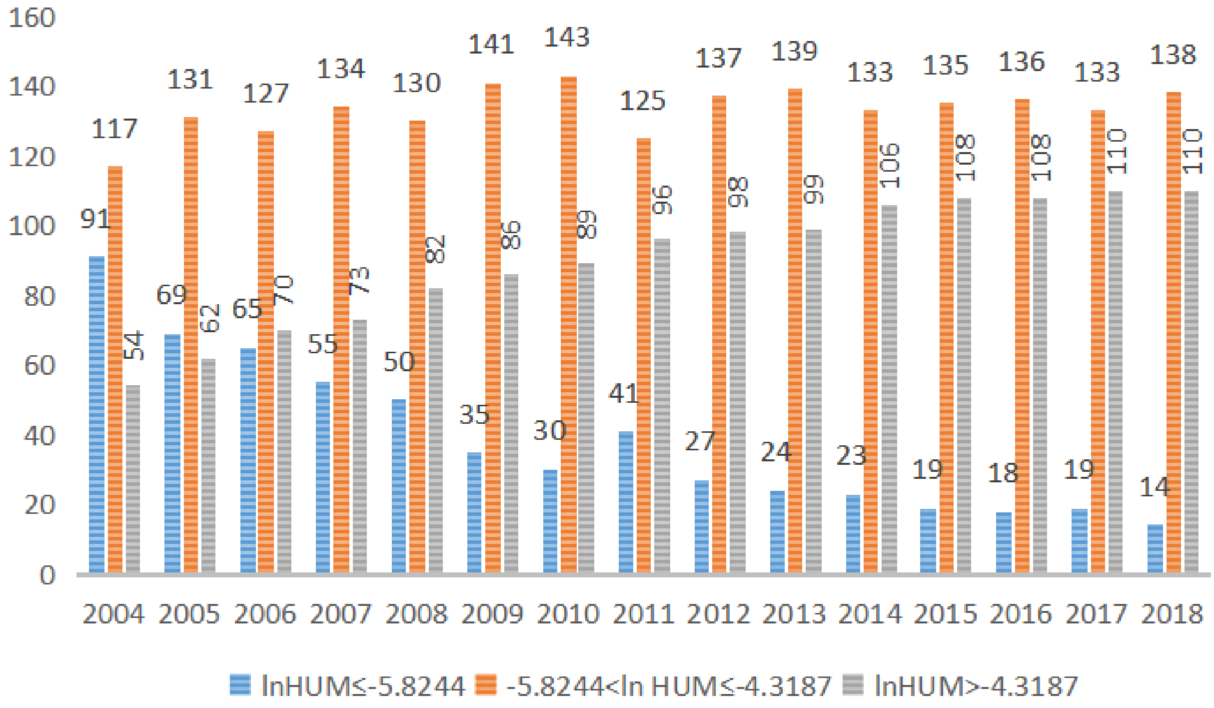


Figure 4. The number of cities in different levels of human capital zones from 2004 to 2018.

4.2.4. Industry Size Effect

When we take industry size as a threshold variable to analyze the threshold effect of FDI inflows on green innovation, the result is shown in Table 4. As shown in the result, when the industry size is less than 5.6240, the driving effect of FDI on green innovation is not obvious. When the industry size is between 5.6240 and 6.7214, the influence coefficient of FDI on green innovation is 0.061 at the significance level of 5%. When the industry size is greater than 6.7214, the impact of FDI on green innovation becomes stronger and more obvious, that is, 0.097 at the significance level of 1%. It can be concluded that with the expansion of the industry scale, the green innovation effect of FDI will gradually increase. When the industry scale expands to a certain range, an agglomeration effect may occur, which makes enterprises in the region learn from each other and promote the flow of knowledge elements within or between industries. Meanwhile, it can also bring the concentration of technology, labor and other resources, to form the scale economy effect and promote the improvement of green innovation performance. This is also consistent with our previous speculation.

According to the threshold regression results, we divided the 262 cities into three stages with 5.6240 and 6.7214 as the threshold values: high-value area, median-value area and low-value area. As can be seen from Figure 5, the proportion of the number of cities in the low-value area decreased from 33% at the beginning to 15% at the end of the period. On the contrary, although the number of cities with high value increased to 132 from 2007 to 2010 and then decreased, the overall number still showed an upward trend, accounting for more than 50% in 2018. In 2018, FDI significantly promoted local green innovation in more than half of the cities and the number of these cities will continue to rise in the future, indicating that the green technology effect of FDI will become more and more obvious.

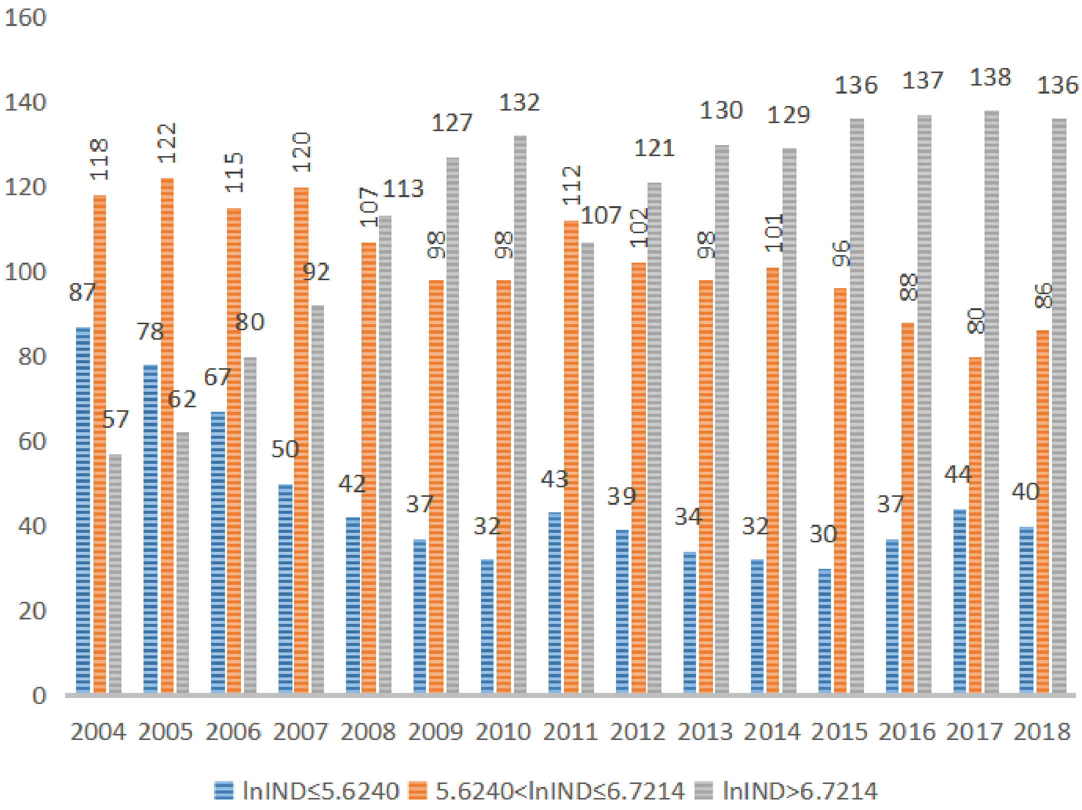


Figure 5. The number of cities in different stages of industry size from 2004 to 2018.

4.3. Robustness Test

To check the reliability of the above research, we conduct a series of robustness tests including excluding the singular values, replacing the explained variables and adding additional determinants. The results are presented in Tables 5–7.

Table 5. Robustness Test excluding the influence of singular values.

Threshold Variable: lnER		Threshold Variable: lnGDP		Threshold Variable: lnHUM		Threshold Variable: IND	
Variables	**(1)**	**Variables**	**(2)**	**Variables**	**(3)**	**Variables**	**(4)**
lnFDI (lnER ≤ 3.4701)	0.0356 (0.0303)	lnFDI (lnGDP ≤ 10.0277)	−0.0419 * (0.0264)	lnFDI (lnHUM ≤ −5.8244)	0.0128 (0.0307)	lnFDI (lnIND ≤ 5.6240)	0.0249 (0.0294)
lnFER (3.4701 < lnER ≤ 3.6816)	0.0540 * (0.0293)	lnFDI (l0.0277 < lnGDP ≤ 11.1996)	0.0455 * (0.0253)	lnFDI (−5.8244 < lnHUM ≤ −4.3187)	0.0659 ** (0.0298)	lnFDI (5.6240 < lnIND ≤ 6.7214)	0.0598 ** (0.0295)
lnFDI (lnER > 3.6816)	0.0841 *** (3.0600)	lnFDI (lnGDP > 11.1996)	0.1225 *** (5.0900)	lnFDI (lnHUM > −4.3187)	0.1171 *** (0.0295)	lnFDI (lnHUM > 6.7214)	0.0918 *** (0.0308)
Control Variables	YES	Control Variables	YES	Control Variables	YES	Control Variables	YES
_cons	11.955 *** (12.9301)	_cons	10.2470 *** (0.8469)	_cons	12.5398 ** (0.8611)	_cons	13.6277 *** (0.8719)
Year FE	YES	Year FE	YES	Year FE	YES	Year FE	YES
City FE	YES	City FE	YES	City FE	YES	City FE	YES
R-squared	0.6062	R-squared	0.6748	R-squared	0.6108	R-squared	0.5978
N	3930	N	3930	N	3930	N	3930

Notes: ***, **, and * present the significance levels at 1%, 5%, and 10%, respectively; The standard errors are in parentheses.

Table 6. Robustness Test replacing the explained variables.

Threshold Variable: lnER		Threshold Variable: lnGDP		Threshold Variable: lnHUM		Threshold Variable: IND	
Variables	**(1)**	**Variables**	**(2)**	**Variables**	**(3)**	**Variables**	**(4)**
lnFDI (lnER ≤ 3.6816)	0.0289 (0.0245)	lnFDI (lnGDP ≤ 10.4486)	−0.0275 (0.2146)	lnFDI (lnHUM ≤ −5.0532)	0.0130 (0.0252)	lnFDI (lnIND ≤ 6.9187)	0.0332 (0.0282)
lnFER (lnER > 3.6816)	0.0538 ** (0.0243)	lnFDI (10.4486 < lnGDP ≤ 11.1996)	0.0462 * (0.2134)	lnFDI (−5.0532 < lnHUM ≤ −4.3187)	0.0432 ** (0.0248)	lnFDI (6.9187 < lnIND ≤ 7.3179)	0.0638 ** (0.0256)
	0.0841 *** (3.0600)	lnFDI (lnGDP > 11.1996)	0.1204 *** (0.0244)	lnFDI (lnHUM > −4.3187)	0.0988 *** (0.0252)	lnFDI (lnHUM > 7.3179)	0.1010 *** (0.0280)
Control Variables	YES	Control Variables	YES	Control Variables	YES	Control Variables	YES
_cons	12.5809 *** (0.8963)	_cons	9.4443 *** (0.8032)	_cons	12.8506 ** (0.9139)	_cons	13.3723 *** (0.8919)
Year FE	YES	Year FE	YES	Year FE	YES	Year FE	YES
City FE	YES	City FE	YES	City FE	YES	City FE	YES
R-squared	0.5051	R-squared	0.6024	R-squared	0.5116	R-squared	0.5118
N	3930	N	3930	N	3930	N	3930

Notes: ***, **, and * present the significance levels at 1%, 5%, and 10%, respectively; The standard errors are in parentheses.

Table 7. Robustness test adding additional external determinants.

Threshold Variable: lnER		Threshold Variable: lnGDP		Threshold Variable: lnHUM		Threshold Variable: lnIND	
Variables	**(1)**	**Variables**	**(2)**	**Variables**	**(3)**	**Variables**	**(4)**
lnFDI (lnER ≤ 3.4701)	0.0330 (0.0290)	lnFDI (lnGDP ≤ 10.0277)	−0.0437 * (0.0253)	lnFDI (lnHUM ≤ −5.8244)	0.0091 (0.0304)	lnFDI (lnIND ≤ 5.6240)	0.0247 (0.0294)
lnFDI (3.4701 < lnER ≤ 3.6816)	0.0531 * (0.0282)	lnFDI (10.0277 < lnGDP ≤ 11.1996)	0.0474 * (0.0243)	lnFDI (−5.8244 < lnHUM ≤ −4.3187)	0.0642 ** (0.0290)	lnFDI (5.6240 < lnIND ≤ 6.7214)	0.0590 ** (0.0295)
lnFDI (lnER > 3.6816)	0.0851 *** (0.0280)	lnFDI (lnGDP > 11.1996)	0.1281 *** (0.0252)	lnFDI (lnHUM > −4.3187)	0.1190 *** (0.0291)	lnFDI (lnIND > 6.7214)	0.0914 *** (0.0307)
Control Variables	YES	Control Variables	YES	Control Variables	YES	Control Variables	YES
_cons	11.9605 *** (12.930)	_cons	10.0667 *** (0.8544)	_cons	12.3845 *** (0.8952)	_cons	13.6231 *** (0.8729)
Year FE	YES	Year FE	YES	Year FE	YES	Year FE	YES
City FE	YES	City FE	YES	City FE	YES	City FE	YES
R-squared	0.5944	R-squared	0.6700	R-squared	0.5991	R-squared	0.5983
N	3930	N	3930	N	3930	N	3930

Notes: ***, **, and * present the significance levels at 1%, 5%, and 10%, respectively; The standard errors are in parentheses.

4.3.1. Excluding the Influence of Singular Values

Due to the large research sample used in our study, some deviations in the measurement and collection of macroeconomic data may exist. To make the research results more credible and improve the regression accuracy, we exclude singular values by winsorizing all variables by 1% and re-estimate the threshold regression model. The threshold panel regression results in Table 5 indicate that environmental regulation, economic growth, and human capital all have a double threshold effect, and the threshold values remain the same as before, so the above findings can be considered credible.

4.3.2. Replacing the Explained Variables

The number of "green patent grants" can also capture the green innovation performance. To test the robustness of the above empirical test results, we replace "green patent applications" with "green patent grants" as the explanatory variable and conduct another empirical test using the threshold regression model. Table 6 presents the results and shows that when taking environmental regulation, economic growth, and human capital as the threshold variables, the results are similar to our main result. Therefore the above findings can be considered reliable.

4.3.3. Adding Additional External Determinants

Urbanization level reflects the concentration degree of the urban population to a certain extent. Theoretically and practically, the level of urbanization will affect the economic and environmental conditions of the city and then affect the absorptive capacity of the city. We refer to the approach of previous scholars and measure the level of urbanization by the ratio of the urban population to the total population, and include it as an additional control variable in the empirical test model for robustness testing. The result in Table 7 confirms our above findings in that the threshold effects and threshold values of environmental regulation, economic growth, and human capital do not change significantly after adding urbanization level as an additional control variable, so we may consider the above empirical test results as fairly robust.

5. Heterogeneity Analysis

As the primary driving force for development, "innovation" has become an important development strategy in China. Since the 19th National Congress of the Communist Party of China, the quality of FDI has replaced the scale of FDI and become the main objective of the "bring in" strategy. China has begun to accelerate the construction of national innovative cities to promote the transformation of the economic development model from factor-driven to innovation-driven. Since the Outline of the National Plan for Medium and Long-term Scientific and Technological Development (2006–2020) was first proposed in 2005, the number of national innovative cities (regions) in China had reached 78 by 2020, including 72 prefecture-level cities.

The construction of innovative cities naturally includes green innovation. Therefore, will the construction of innovative cities affect the driving effect of FDI inflows on green innovation? We divided 262 prefecture-level cities into innovative cities and non-innovative cities to conduct basic regression, respectively. The results are shown in Table 8. The baseline regression result of innovative cities is in Column (1). The baseline regression result of non-innovative cities is in Column (2) and Column (3) is the total baseline regression result, which is previously presented in Table 2. It can be seen that the coefficient of FDI on green innovation in innovative cities is the highest among the three groups of baseline regression results, while that in non-innovative cities is the lowest. We therefore conclude that in innovative cities, FDI has the most predominant driving effect on green innovation. The construction of innovative cities is posing an optimistic influence of the FDI inflows on green innovation.

First of all, taking environmental regulation as the threshold variable, 59 innovative cities are in the third stage in 2018. Cities that do not pass the second threshold are mostly located in central and western regions, and they do not pay enough attention to environmental issues. (These cities include Wuhan, Xi'an, Qingdao, Shenyang, Harbin, Jiaxing, Lanzhou, Jilin, Nanyang, Yuxi, and Hanzhong.) Secondly, taking the level of economic growth as the threshold variable, 49 innovative cities crossed the second threshold in 2018, which is at the stage where FDI is significantly driving green innovation. The number of cities that have not crossed the second threshold is 21 (these cities include Harbin, Shijiazhuang, Weifang, Luoyang, Zhuzhou, Nanning, Haikou, Lanzhou, Qinhuangdao, Jilin, Lianyungang, Jingdezhen, Pingxiang, Jining, Nanyang, Hengyang, Zunyi, Yuxi, Baoji, Hanzhong, and Xining), among which two-thirds of them are located in the central and western regions, indicating that the economic growth of a few innovative cities is still not high, meaning the FDI spillover effect cannot be fully down to green innovation. Then, taking human capital as the threshold variable, the human capital level of 56 innovative cities is in the third stage in 2018, that is, the coefficient of FDI on green innovation is statistically significant and positive, and FDI can significantly drive green innovation. The human capital of the other 14 innovative cities has not crossed the second threshold (these cities include Nantong, Taizhou, Huzhou, Xuzhou, Lianyungang, Longyan, Jingdezhen, Jining, Nanyang, Zunyi, Yuxi, Baoji, and Hanzhong), indicating that the human capital of these cities is still at a low level. Finally, 54 innovative cities entered the third stage of the industry size in 2018, accounting for more than 70% of the total number. Most of the remaining cities are in China's central and western regions where resource endowments are at a lower level.

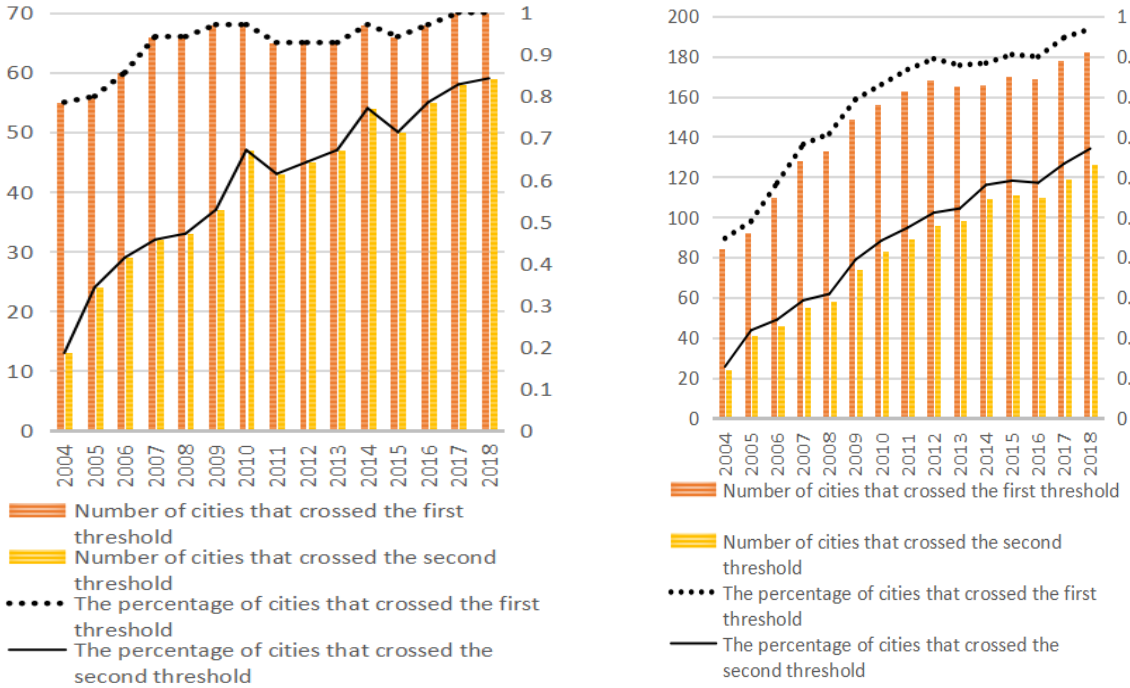
Table 8. Baseline regression results for innovative cities and non-innovative cities.

Variable	**GREENP1**		
	(1)	**(2)**	**(3)**
lnFDI	0.0944 ** (0.0487)	0.0633 ** (0.0326)	0.0787 *** (0.0293)
lnGOV	0.6084 *** (0.0736)	0.7224 *** (0.2245)	0.7099 *** (0.0397)
lnEI	−3.6554 *** (0.4660)	−0.9648 *** (0.2086)	−1.4664 *** (0.2031)
lnOPEN	−0.1249 (0.0954)	0.0039 (0.0557)	−0.0267 (0.0477)
lnIC	0.9544 *** (0.1644)	0.4817 *** (0.0789)	0.5691 *** (0.0771)
_cons	12.9512 *** (0.9064)	10.4845 *** (1.0255)	12.7011 *** (0.9139)
Year FE	YES	YES	YES
City FE	YES	YES	YES
R-squared	0.7236	0.5302	0.5757
N	1050	2820	3930

Notes: *** and ** present the significance levels at 1%, and 5%; The standard errors are in parentheses.

Through comparative analysis, we find that most innovative cities where environmental regulation, economic growth, human capital and industry size have not crossed the second threshold are located in the central and western regions of China, and their development level is generally behind that of eastern China. The results reveal that in the consumption and innovation-driven era, the south area has a higher degree of marketization, and it has gradually become a gathering place of talent, technology, and capital and a pioneer in the innovation-driven and high-quality development model.

Turning to the perspective of threshold crossing time, we can see a difference between innovative cities and non-innovative cities, as shown in Figures 6–9. First of all, in terms of environmental regulation, 70 innovative cities passed the first threshold in 2017 and 60 of them entered the third stage in 2018, where FDI plays a significant role in promoting green innovation as shown in Figure 6. In 2018, 126 of the 188 non-innovative cities were in the third stage and only about one-third of the cities were still in the second stage. The differences in environmental regulation strength in innovative cities and non-innovative cities are relatively small, illustrating that they have reached a consensus that the protection of the ecological environment cannot be neglected while developing the economy.

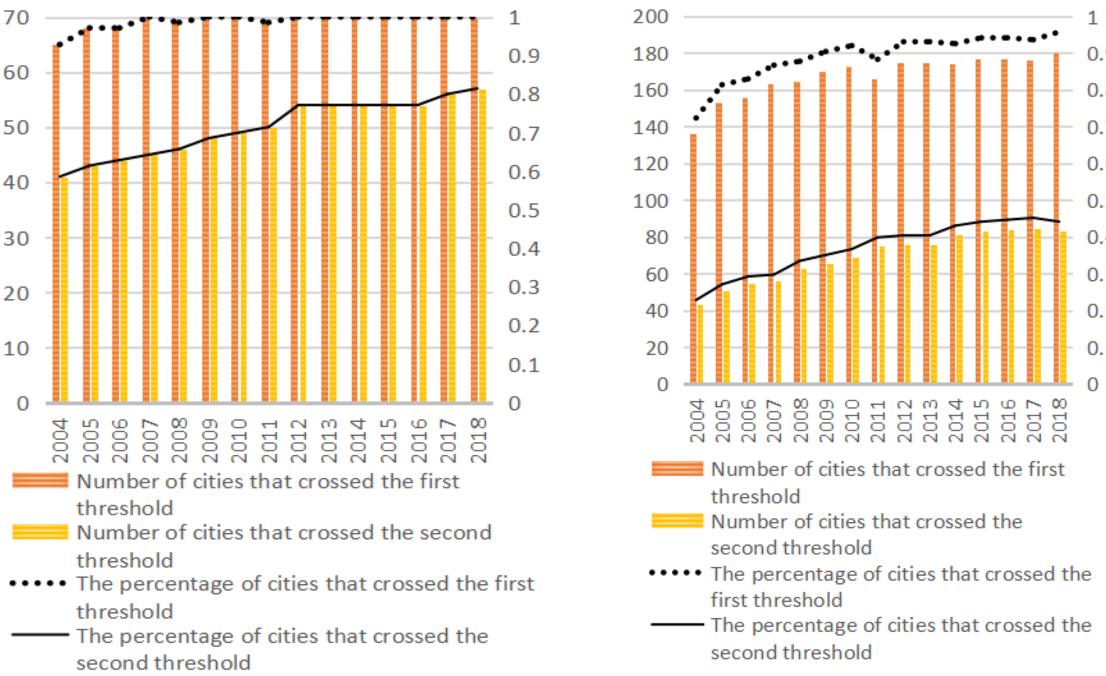


(**a**) (**b**)

Figure 6. Comparison of threshold crossing between innovative and non-innovative cities (taking the environmental regulation as threshold): (**a**) Innovative city, (**b**) Non-innovative city.

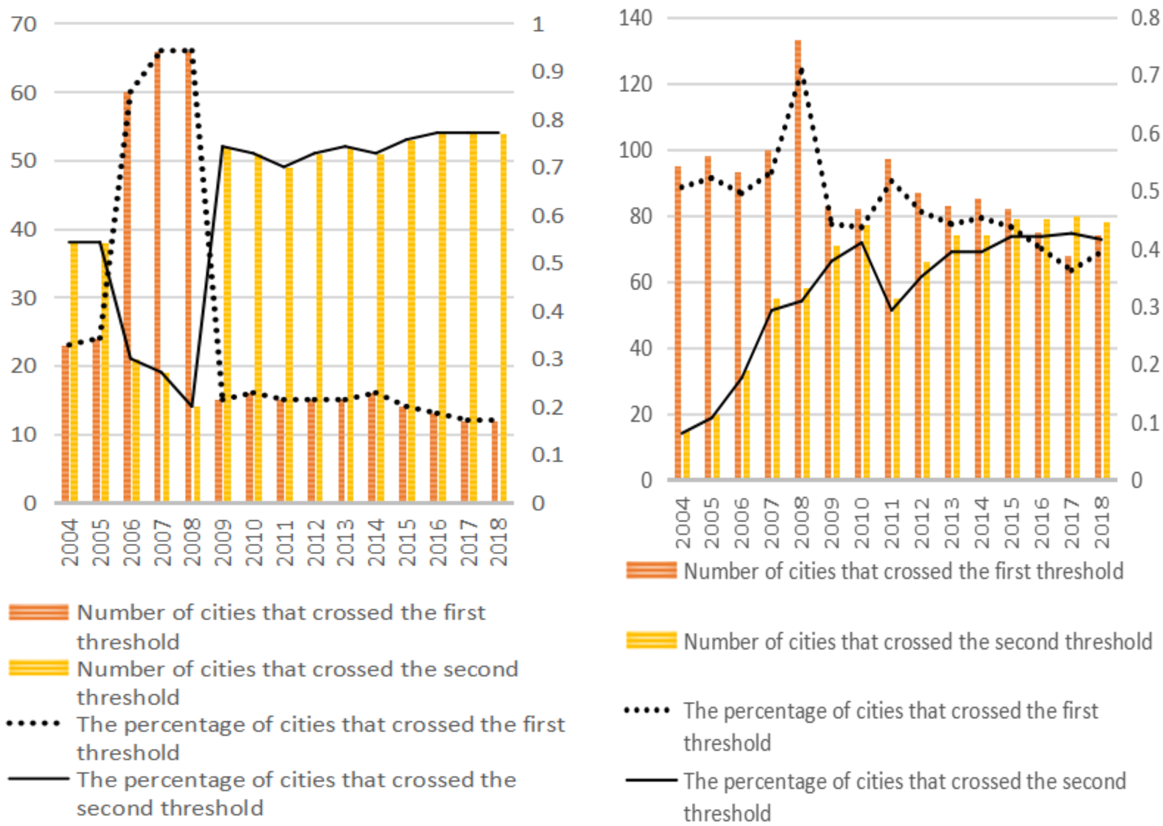
(**a**) (**b**)

Figure 7. Comparison of threshold crossing between innovative and non-innovative cities (taking economic growth as threshold): (**a**) Innovative city, (**b**) Non-innovative city.



(**a**) (**b**)

Figure 8. Comparison of threshold crossing between innovative and non-innovative cities (taking the human capital as threshold): (**a**) Innovative city, (**b**) Non-innovative city.



(**a**) (**b**)

Figure 9. Comparison of threshold crossing between innovative and non-innovative cities (taking the industry size as threshold): (**a**) Innovative city, (**b**) Non-innovative city.

By contrast, the difference in economic growth between the two types of cities is noticeable. As shown in Figure 7, innovative cities all entered the second stage of economic growth in 2014, while a few non-innovative cities still did not cross the first threshold until 2018, and were in the stage where FDI hampers green innovation. In the process of economic growth, only more than 10 non-innovative cities crossed the first threshold from 2008 to 2017, less than one-tenth of the total number of cities, while more than half of innovative cities crossed the second threshold values in 2018.

The development of human capital is a long-term process, therefore the growth of urban human capital is relatively slow. However, there is also a gap between both innovative and non-innovative cities from Figure 8. The human capital level of innovative cities all crossed the first threshold in 2007, while non-innovative cities did not all cross the first threshold until 2018. Referring to the number of cities across the second threshold, innovative cities increased from 41 cities in 2004 to 57 cities in 2018 (the total number of innovative cities is 70), and non-innovative cities increased from 43 cities to 83 cities between 2004 and 2018 (the total number of non-innovative cities is 188). We conclude that compared with innovative cities, the human capital level and the growth rate of non-innovative cities are relatively low.

In terms of industry scale, these two types of cities show a situation of rapid development at the beginning, a decline in the middle, and then growth just as shown in Figure 9. Given that this decline occurred in 2007–2009, we think it may have been influenced by the economic crisis. However, after that, the size of the industry also showed a trend in growth, as shown by the steady increase in the number of cities crossing the second threshold from the two categories. In 2017, the highest number of cities in both categories crossed the third stage. However, as China's economy moves in a more stable direction, we expect that the industry size in China will likely not increase massively in the future and that the emphasis will be on quality and efficiency.

6. Discussion

At present, when China's economy is shifting from a stage of high-speed growth to a stage of high-quality development, the technology spillover effect of FDI on the host country, especially the driving role of green technology, has attracted widespread attention. Based on panel data of 262 cities from 2004 to 2018 in China, we found that FDI significantly promotes green innovation in cities and environmental regulation, economic growth, human capital, and industry size all have a double threshold effect in the relationship between FDI inflows and green innovation performance, which means only when the absorptive capacity of the host country reaches a certain level can FDI promote green innovation.

Previous studies have also focused on the relationship between FDI and green innovation in host countries but failed to reach a consistent conclusion. Wang and Zhang constructed a multi-stage decision model, showing that FDI can facilitate cleaner-production technologies [61]. This is consistent with the basic view of this paper, that is, FDI can significantly promote green innovation in host countries, which provides theoretical evidence for the pollution halo hypothesis that has not been concluded in academia. In addition, there are preconditions in terms of green spillovers, i.e., FDI can improve or has no impact on the environmental performance of local firms under different conditions. This is the same as the conclusion we reached with the threshold effect, that is, the green technology spillover effect of FDI can only play out under certain circumstances. Different from us, the former study takes marketization and innovation capacity as the threshold, while the empirical study in this paper takes four absorptive capacities as the threshold, but also confirms our point of view: the relationship between FDI and green innovation in host countries is nonlinear. Song and Han used the stochastic frontier model to find that the inhibitory effect of FDI on green innovation efficiency is less than the promoting effect and the combination effect of FDI and FDI is not obviously positive [62]. While we believe that FDI can significantly promote green innovation and our findings are not similar, the reason for this may be the different samples as the former is the Chinese provincial data from

2007 to 2018, and our research is 2004–2018 data of Chinese cities. Therefore, the different conclusion also illustrates the necessity of research at the city level.

In terms of absorptive capacity, Kuang found that environmental regulation has a double threshold effect on green innovation [57], and environmental regulation only stars in green technology innovation when environmental regulation is increased to a large enough among. Taking Zhang Yu and other scholars as representatives, the threshold model was constructed to conclude that the regional economic foundation has obvious threshold characteristics on the spillover effect of FDI technology [63]. However, most of them did not focus on the impact of FDI on green innovation and most of them took China's provincial panel data as the research object. This paper constructs a threshold model to explore the nonlinear threshold relationship between urban FDI and green innovation to fill this gap. Xu agreed with Xiong that human capital could significantly promote green innovation and high-quality economic development after reaching a certain threshold [64]. Wang also drew the conclusion that a scientific high-tech industry agglomeration mode and an appropriate degree of agglomeration can effectively improve the efficiency of green innovation [65]. These conclusions are basically consistent with our findings, indicating that our findings have high credibility.

7. Conclusions and Policy Recommendations

The direction and magnitude of FDI's technological spillover effect on green innovation are limited by the characteristics of absorptive capacity in a host country. We empirically investigate the existence of the FDI technological spillover effect on green innovation and its influencing mechanism. Based on panel data from 262 cities from 2004 to 2018, we constructed both a baseline linear regression model and a nonlinear threshold model to empirically study the impact of FDI inflows on urban green innovation in China. The baseline regression results indicate that FDI significantly promotes green innovation in cities.

Furthermore, when considering the threshold effects of FDI technology spillovers, we find that environmental regulation, economic growth, human capital and industry size all have a double threshold effect in the relationship between FDI inflows and green innovation performance. When the environmental regulation, economic growth, human capital, and industry size reach the tipping point, the green technology spillover effect of FDI inflows to host countries is statistically significant and/or positive. Specific conclusions are as follows: when environmental regulation is greater than 3.4701 and less than 3.6816, the influencing coefficient of FDI on green innovation is 0.0538, and when the environmental regulation is greater than 3.6816, this effect is stronger and more significant. When the economic growth is greater than 10.0277, the effect of FDI on green innovation changes from negative to positive and when it is greater than 11.996, the influence coefficient of FDI on green innovation is 0.1283 and passes the significance test of 1%. When human capital is greater than −5.8244, the influence coefficient of FDI on green innovation is 0.0649, and the greater the human capital, the stronger and more obvious the promoting effect. When the industry size is larger than 5.6240, the influence coefficient of FDI on green innovation is 0.0608, and the greater the industry size, the stronger and more obvious the promoting effect.

In addition, when we compare the space and time for innovative and non-innovative cities to cross the threshold points, we find that the former is far ahead of the latter in their degree of development in the four absorptive capacity factors, especially economic growth. This implies that the construction of innovative cities in China has achieved remarkable results, for which there is vigorous innovation power and good quality development momentum.

Our findings have rich implications for policymakers with respect to improving FDI quality and enhancing urban absorptive capacity.

First, the current emphasis on the quantity of imported foreign capital in the past should be changed to quality and firms should be encouraged to cooperate with high-quality foreign-funded companies by the local government. More attention should be paid to improving the structure of foreign capital rather than its quantity.

Second, our findings also highlight the importance of improving absorptive capacity, for example, by formulating appropriate environmental regulation policies according to urban conditions, including strengthening the orientation of environmental regulation policies to foreign direct investment, especially in cities in central and western regions. Market-based environmental regulations should be used appropriately as they may encourage enterprises to invest more in green and technology-intensive industries. The focus of urban development should no longer be economic growth. The threshold regression results indicate that blindly pursuing high-speed economic development is not conducive to green innovation and industrial structure upgrading. In addition, creating a good environment and gathering all types of innovative resources, such as introduction and training for innovative talent, is essential for cities with scarce science and education resources.

Finally, cities should start with their characteristics to fully enable their innovative comparative advantages. Most innovative cities are provincial capitals, which are home to research institutions and universities, high-end talent, and vigorous innovation capabilities. Non-innovative cities are more likely to be located in the central and western regions and are always the neighboring areas of developed cities. They could increase investment in scientific research to become "talent bases" to undertake scientific research projects at scientific research institutions and universities in innovative cities.

Limitations and Future Research

Although this paper may improve the current research, there are still many limitations, which we may continue to explore in the future. First of all, due to the availability of data, this paper only takes 262 cities as the research object, and data from more cities may be included in the analysis in the future to make the research results more credible. Secondly, although the measurement of indicators in this paper is derived from previous experience, its rationality is still worth discussing. For example, whether it is reasonable to use the proportion of undergraduate and junior college students in the total population at the end of the year to measure the level of human capital. In the future, we will adopt more comprehensive indicators to measure the indicators of the model. Finally, this paper is based on the urban dimension of the study, this paper can not obtain more inspiration from the perspective of more micro-enterprises. This is our future research direction.

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