Urban Environmental Legislation and Green Innovation

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Research Article

Keywords: Urban Environmental Legislation , GTFP , Green Patent

Posted Date: June 2nd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-497736/v1

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Abstract

With the panel data of 218 prefecture-level cities from 2003 to 2017, this paper empirically tested whether urban environmental legislation realized Porter Hypothesis(PH) in China. After a series of model estimation and robustness tests, the results show that urban environmental legislation increased the number of local green patents, which means that the weak Porter Hypothesis was established. However, the urban environmental legislation did not lead to an increase in green total factor productivity(GTFP). In other words, the strong version of PH did not hold. Further analysis shows that urban environmental legislation led to the decline of GTFP and the increase of green patents in the west of China, but not in the east and central cities. Besides, the legislation did not promote GTFP improvement through green innovation in the short term, which means it did not realize process compensation.

Keywords Urban Environmental Legislation • GTFP • Green Patent

1. Introduction

With the development of the sustainable development concept, green innovation has become an inevitable method to achieve both economic development and environmental protection. Due to the high investment, high risk, and significant externality of green innovation, it is necessary to intervene in green innovation through environmental regulation. Studies have shown that environmental regulation - an essential part of policy intervention - has become the main driving force of green innovation. For example, the market mechanism represented by marketable pollution permits is playing an increasingly important role in green innovation and green development(Fowlie et al., 2012). However, China's green innovation has not been significantly improved, and the driving force of green innovation is relatively low. This shows that China's current green innovation lacks a long-term mechanism, and the key to promoting the normalization of green innovation is environmental regulation.

As an essential part of local governance, the relationship between local environmental regulations and enterprise decision-making behavior has received widespread attention in academia(Milani, 2016). Existing literature that discussed local environmental regulations and corporate decision-making behaviors mainly

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focused on the innovative behavior and relocation behavior of enterprises. There are two popular theories: Pollution Haven Hypothesis and Porter Hypothesis.

The Pollution Haven Hypothesis(PHH) holds that in an open economy, companies in pollution-intensive industries will move to countries or regions with relatively low environmental standards. Specifically, when the product has a uniform price, the production cost determines the production location. If the conditions in all countries are the same except for environmental standards, polluters will choose to work in countries with less strict environmental regulations, and these countries will become a Haven for pollution(Levinson and Taylor, 2008; Dincer et al., 2018; Copeland and Taylor, 1994).

The Porter Hypothesis (PH) believes that the impact of environmental regulations on enterprises is dynamic because environmental regulations can stimulate enterprises to innovate. Although environmental regulations can increase the production and operation costs of enterprises, products can be more competitive through innovation. The revenues brought by innovation outweigh the increase in costs, so enterprises achieve innovation compensation, which ultimately makes the enterprise profitable (Porter, 1991). Later, PH was further developed. Porter and Linde (1995) divided innovation compensation into product compensation and process compensation. Product compensation refers to the fact that environmental management encourages enterprises to produce cleaner products, which can increase the profits of enterprises. Process compensation refers to that enterprises can improve the productivity of resources to improve production efficiency in the production process. Jaffe and Palmer(1997) divided the PH into three levels, namely Weak Porter Hypothesis, Strong Porter Hypothesis and Narrow Porter Hypothesis. The weak version of PH implies that stricter environmental policies will stimulate innovation, while the strong PH is that environmental regulation can increase the overall productivity of enterprises. The narrow PH states that under specific environmental policies, such as flexible and market-based tools, productivity improvements, and changes in the direction of innovation are more likely to be achieved. Most of the previous researches only focused on one level. Therefore, when analyzing the impact of environmental regulation on corporate decision-making behaviors, it is necessary to combine the strong Porter hypothesis and the weak Porter hypothesis to promote a deep understanding of this issue by economists and policymakers.

Environmental legislation[2] -the most direct and effective means of environmental regulation-is increasingly favored by policymakers. In recent years, to prevent environmental pollution and improve the ecological environment, the Chinese government has continuously strengthened and improved its environmental legal system. In particular, after the implementation of the Amendment to the Legislative Law of the People's Republic of China in 2015, local legislative power was extended to all prefecture-level cities, marking a new

[1] The environmental legislation refers to the legislative body through the enactment of laws and regulations to regulate the relationship between humans and the environment of legal acts, mainly manifested in the protection of natural resources, the restrictions of the use of natural resources.

starting point for China's environmental legal system. In general, since the Amendment of the Legislative Law in 2015 to the end of December 2017, a total of 206 prefecture-level cities promulgated 398 local laws, with an average of 14.74 issued by provinces and autonomous regions. The provinces with the highest number of such regulations are Shandong(38 pieces), Anhui(36 pieces), Jiangsu(33 pieces), Guangdong(28 pieces), Henan, Hubei, Zhejiang(27 pieces each), and Hunan, Sichuan(23 pieces each), accounting for 65.8% of the national total[3]. Whether increasingly sound urban legislation has led to Porter Hypothesis?

Based on the above analysis, this study used panel data at the city level in China to answer the following questions: (1) Did the promulgation and implementation of urban environmental legislation stimulate enterprises to conduct green innovation? Was the weak PH valid? (2) Did the implementation of legislation promote productivity? That is, whether the strong PH was realized; (3) Is there heterogeneity in the impact of urban environmental legislation? (4) If urban environmental legislation could promote the occurrence of the PH, then, what was the mechanism?

This paper used the panel data of 218 prefecture-level cities in China from 2003 to 2017 to systematically evaluate the PH of local environmental legislation and explore its mechanism as much as possible. Compared with previous literature, the main innovations of this paper are (1) Analysis of the impact of the improvement of the rule of law on the green economy and green innovation based on environmental legislation data at the city level. Compared with the national and provincial levels, the effect of environmental legislation at the city level on local green innovation is even more significant. (2) Based on newer statistical data, an empirical test of the short-term impact of urban environmental legislation on the number of green patent grants and green total factor productivity. (3) An empirical test of the mechanism of environmental legislation on green innovation.

The remainder of the paper is organized as follows. Section II is the literature review. Section III presents models, variables, and data. Section IV includes the analysis of benchmark results, the robustness test, and the extensibility analysis. Section V is the analysis of the mechanism. Section VI presents the conclusion and inspiration.

2. Literature review

In order to prevent environmental pollution, the government has continuously improved the construction of the environmental legislation system in which local environmental legislation is the most basic and vital political institution. Environmental legislation affects enterprise production, technology, and environmental management decisions through incentive and restraint mechanisms. Environmental legislation mainly restricts the enterprise's pollution behavior through the establishment of environmental quality standards, pollution emission standards,

[3] Data from：https://www.sohu.com/a/246720822_772384

environmental monitoring systems, and the approval of the issuance of pollution permits. It directly controls the production and pollution control processes of enterprises through the elimination system of pollution equipment and clean production system.

2.1. The impact of environmental legislation on the economy

Existing literature on environmental legislation mainly focuses on the impact of environmental legislation on productivity. Some studies have found that environmental legislation increased productivity. For example, Albrizio et al.(2017) focused on the changes in environmental policy stringency. They found that a tightening environmental policy could motivate industry-level productivity to grow in the short term. However, only the most productive firms experienced a temporary boost in the short term. Song et al.(2018) adopted the green total factor productivity(GTFP) instead of the traditional ones and found that only appropriate fiscal decentralization could stimulate GTFP growth with panel data of 11 provinces in the Yangtze River economic belt from 2000 to 2015.

Other studies have found that environmental legislation hurts productivity. Lanoie et al. (2008) tested the PH in the Quebec manufacturing sector and found a negative influence on contemporary productivity. Tombe and Winter(2015) demonstrated that environmental policies created distortions and then misallocated investment in pollution and cleaning between enterprises and sectors, reducing productivity. Hancevic(2016) discovered that *the 1990 Clean Air Act Amendments* had a negative influence on the productivity of coal-fired boilers in the U.S. Wang et al.(2018) found that water quality regulations had no statistically significant effects on surviving firms' productivity but could reduce their output values and their COD emissions. Li et al.(2019) found that *Clean Air Action* brought a decrease in the output of Hebei and Tianjin provinces instead of Beijing during 2013-2017.

From the above research results, we can see that environmental regulation has an essential impact on the economic benefits of enterprises; however, the specific effect is inconclusive. The underlying reasons are the data and the stringency of law enforcement in different regions.

2.2. The impact of environmental legislation on green innovation

Research on green innovation started with Driving eco-innovation by Fussier and James(Fussier and James, 1996). Green innovation is developed based on innovation. It has the novelty and value characteristics of innovation and can achieve resource conservation and environmental improvement. With the advancement of research, the measurement and interpretation of green innovation have been paid close attention by scholars.

Environmental legislation in some areas can spur innovation. Brunnermeier and Cohen (2003) analyzed the data of 146 manufacturing industries in the United States from 1983 to 1992. They found that environmental innovation only responded to increases in pollution abatement expenditures instead of increased monitoring and enforcement activities related to existing regulations. Moreover, environmental innovation was more likely to occur in internationally competitive industries. A study of Japanese manufacturing industries showed that pollution control expenditures had a positive relationship with the R&D expenditures and negatively affected the average age of capital stock. Simultaneously, the increase of R&D investment stimulated by the regulatory stringency could contribute to the total factor productivity (Hamamoto, 2006). As well as Yang et al. (2012) who researched Taiwan industries in 1997–2003, found a similar conclusion that a positive relationship existed between more reliable environmental protection and R&D expenditure. However, this relationship did not have a statistical significance. A more stringent environmental regulation provided a positive impulse for increasing investments in advanced technological equipment and innovative products (Testa et al., 2011).

Environmental legislation in other regions has not promoted or even inhibited innovation in most local enterprises. Kneller and Manderson (2012) used data from the UK manufacturing industry. They indicated that there was no positive impact of environmental regulation on total R&D or total capital accumulation, and environmental R&D may crowd out non-environmental R&D. Miguel and Pazo (2017) found that environmental regulations in Spain positively impacted process innovation only in large firms while it positively impacted product innovation exclusively in small firms (up to 200 workers). Qiu et al.(2018) revisited the PH under monopolistic competition and found that the growth of innovation investment only held for high-capability firms and increased the average industry productivity. Shi et al.(2018) found that China's Carbon Emissions and Trading Pilot(CCETP) would significantly reduce enterprise innovation, even had a significant impact on non-regulated enterprises and other enterprises in the local region. Zhang et al.(2019) found a positive and significant relationship between green patenting and state-owned enterprises' performance. Those enterprises had a closer relationship with the government. Besides, this kind of relationship mainly existed after 2006, when the government began to provide formal legislative support to the green industry.

Previous researches provide us with ideas for analyzing the relationship among environmental legislation, productivity and green innovation. However, there are still some deficiencies:

Firstly, the current researches mainly focus on pollution charges and marketable pollution permits. However, these indicators have a rough understanding of policy characteristics and lack considerations such as environmental legal constraints and legal enforcement. Secondly, most of the literatures study the impact of environmental legislation on traditional productivity, ignoring undesired outputs and inputs. Finally, most literatures only discuss the impact of environmental regulation on economic effects, but do not distinguish between the strong PH and the weak PH.

3. Models, variables, and data

3.1. Models

After the implementation of the new *Legislative Law of the People's Republic of China* in 2015, local legislative power was extended to all prefecture-level cities. There were some differences in the enactment and implementation of environmental regulations by the city, which creates a valuable opportunity to evaluate the effect of urban environmental legislation on green innovation using the difference-in-difference (DID) method. According to the regional and time differences of environmental laws promulgated by cities, we empirically test the impact of urban environmental legislation on green innovation by constructing the following models:

$$GM_{it} = f_1(treat_{it} * post_{it}, treat_{it}, post_{it}, Z_{it}) + \mu_{it} + e_{it} \tag{1}$$

$$GP_{it} = f_1(treat_{it} * post_{it}, treat_{it}, post_{it}, Z_{it}) + \mu_{it} + e_{it} \tag{2}$$

As shown in equations (1) and (2), GM_{it} represents the growth rate of GTFP of city *i* at time *t*, and GP_{it} represents the green innovation of city *i* at time *t*. $treat_{it}$ is a city dummy variable. The city implementing environmental regulations in year t has a value of 1, and the others are 0. $post_{it}$ is a time dummy variable. After the implementation of urban environmental regulations, the value is one and vice versa. Interaction term $treat_{it} * post_{it}$ represents urban dummy variables after the implementation of environmental legislation in cities. Its estimated coefficient is the difference between the impact of urban environmental legislation on the treatment group and the control group. μ_{it} is the individual fixed effect, and e_{it} is the residual.

This paper divides the impact of urban environmental legislation on green innovation into strong PH testing (impact on green productivity) and weak PH testing (impact on the number of green patent grants). The significance of the distinction between the strong-weak PH is that the impact of urban environmental legislation on green productivity and green patents is different. Porter Hypothesis believes that strict and proper environmental regulations can force companies to engage in innovation because companies can improve their technological innovation level to reduce the cost of their environmental governance (Porter et al., 1995).

Besides, two theories on environmental regulation affecting enterprises' decision-making behaviors (Pollution Haven Hypothesis and Porter Hypothesis) seem to be independent. However, there is an internal connection. For polluting companies, local innovation and off-site transfer have a substitutive effect on reducing the cost of environmental governance, but most previous studies have ignored this. It can be considered that the decision of local innovation and off-site transfer of an enterprise depends on the relative environmental regulation cost. From the perspective of city-level green productivity, high-energy-consumption, high-pollution enterprises (referred to as "two high" enterprises), whether local innovation or relocation, may improve green productivity at the city level. On the one hand, if the "two high" enterprises innovate locally, their green patents and green productivity may increase at the same time. Based on data from Japan's rapid industrialization from 1960 to 1970, Hamamoto (2006) found that strict environmental regulations are conducive to research and development capabilities improvement and further promoted productivity improvements. On the other hand, if the “two high” enterprises are transferred to other regions, from the perspective of city-level input and output, energy consumption will be reduced, and bad output such as pollution will be reduced, which will promote green productivity, but not increase local green patent output. In order to carry out a comparative study, we also considered the equations of the traditional productivity and non-green patent which are the dependent variables without considering energy-environment factors.

3.2. Variables

(1) Green total factor productivity

Similar to the method of Song et al.(2018), this paper used the slacks-based measure (SBM) method to measure the growth rate of green total factor productivity. The input includes (a) Labor, the number of employees (10,000 people) at the end of the year. (b) Capital[4]. For the estimation of the capital stock of constant prices, we used actual investment amount divide by the sum of urban economic growth rate and depreciation rate to estimate the capital stock at the beginning of the period. It used the price index to deflate to the constant price of 2003 (10,000 yuan). (c) Energy. We used prefecture-level electricity consumption data as an indicator of energy consumption (10,000 kWh).

The output includes (d) Expected output, GDP of prefecture-level cities with constant prices in 2003 (10,000 yuan). (e) Soot, industrial soot emissions (tonnes). (f) Sulfur dioxide, industrial sulfur dioxide emissions (tonnes). (g) Wastewater, industrial wastewater discharge (10,000 tons).

(2) Green innovation

Green innovation is challenging to measure directly. There are two popular categories of indicators: the first is research and development input (R&D) that measures green innovation investment; the second is patents that measure the output of green innovation. However, among these indicators, only patent data can provide sufficient green and non-green technology information. Therefore, We chose the amount of green patent authorization as the proxy indicator of green innovation.

The World Intellectual Property Organization[5] (WIPO) launched an online tool *the Green List of International Patent Classifications*, designed to facilitate retrieval of patent information related to environmentally-friendly technologies in 2010. There are seven major classifications: transportation, waste management, energy conservation, alternative energy production, administrative supervision and design, agriculture and forestry, and nuclear power.

(3) Urban environmental legislation

[4] Since the China Urban Statistical Yearbook (2018) does not count the amount of fixed asset investment. We estimated the fixed asset investment in each city in 2017 based on the average annual growth rate of fixed asset investment in each city from 2014 to 2016 and the fixed asset investment in each city in 2016.
[5] https://www.wipo.int/classifications/ipc/en/green_inventory/

Many previous studies used environmental pollution charges and pollution permits to describe the stringency of environmental regulation. Some studies also selected some indirect indicators as proxy variables for environmental regulation, such as the relative emissions of pollutants, the amount of environmental pollution treatment investment per capita, and the operating costs of governance facilities. These indicators have a rough description of environmental regulations and lack specific binding power. Based on this, we establish a binary dummy variable to represent the urban environmental legislation.

As shown in Table 1, the research object is 218 general prefecture-level cities. The treatment group consists of 22 cities that have implemented environmental laws from 2015 to 2017. A total of 49 urban environmental laws were implemented. The value of urban environmental legislation in this group is 1. The control group was 196 cities that had not implemented environmental laws, and the value of urban environmental legislation was 0.

When selecting the samples, we excluded 52 special cities that had implemented urban environmental regulations before 2015, including 4 municipalities, 4 special economic zones, 18 provincial capital cities, and 26 megacities designated by the State Council.

Table 1
Classification of cities

Year	Special cities (52)	General cities	
		treatment group (22)	control group (196)
2003-2014	Implemented	Not promulgated	Not promulgated
2015-2017	Implemented	Promulgated &Implemented	Not promulgated / Not implemented

Environmental legislation refers specifically to the number of environmental laws promulgated and implemented by local NPC deputies. It differs from national and provincial environmental laws. First, environmental regulations at the city level must be consistent with regulations at a higher level. Second, city regulations are often more specific than laws at the top. For example, in the urban laws on water pollution, the sewage treatment methods of residents and enterprises are clearly defined, and the penalties for illegal acts are clear, different and targeted. Most importantly, urban environmental regulations can reflect regional characteristics. If the city is a heavy metal pollution area, it is more likely to promulgate laws to prevent and control heavy metal pollution.

The information on environmental laws promulgated and implemented by cities each year comes from China National Knowledge Internet(CNKI).We used CNKI's advanced search and Python to crawl all related legal links which include titles, release date, effectiveness level, author organization, keywords, and other data. Based on the crawled data, we manually collated and formed panel data on the number of environmental laws in prefecture-level cities and municipalities.

(4) Control variables

(a)Government fiscal expenditure level. Facing market failure, the government's financial leverage can provide companies with material security and strong financial support for green innovation. We used the ratio of local fiscal expenditure to local GDP to represent the level of local government fiscal expenditure.

(b)Industrial structure. The optimization and upgrading of the industrial structure are conducive to the improvement of green innovation. We used the ratio of the output value of the secondary industry to the regional GDP to represent the region's industrial structure.

(c)Degree of openness. The higher the degree of opening to the outside world, the more intense the competition, and the more urgent the desire to increase investment in science and technology, which may lead to the improvement of green innovation capabilities. Besides, in the process of opening to the outside world, cities can also introduce advanced technologies and improve their green innovation capabilities. We used the proportion of foreign direct investment in regional GDP to indicate regional openness.

(d)Regional economic development level. The higher the level of regional economic development, the less capital pressure companies face in developing green innovation, which is conducive to promoting green innovation. We used the GDP per capita to represent the level of economic development in the region.

(e)The number of provincial and national environmental legislation. We used the number of environmental laws promulgated by provincial and national people's congresses and standing committees and have entered into force to represent provincial and national environmental legislation.

3.3. Data

The data in this paper is composed of panel data of 218 prefecture-level cities in China from 2003 to 2017. The data are mainly from the China City Statistical Yearbook (2004-2017). The numbers of environmental regulations promulgated by prefecture-level cities and municipalities each year come from CNKI. Patent and green patent data comes from the World Intellectual Property Organization (WIPO). All price-type indicators are current prices. In order to eliminate the impact of inflation, we used the provincial-level GDP index (2003 = 100) for deflation. The GDP index of each province comes from the China Statistical Yearbook (2004-2017). The actual use of foreign direct investment has been adjusted to be denominated in RMB after the exchange rate adjustment, and the exchange rate comes from the website of the National Bureau of Statistics. Table 2 gives descriptive statistics of the main variables.

Table 2
Descriptive statistics of the main variables

Variables	Definition	Mean	Std
TFP	Productivity growth rate without consideration of energy and environmental factors (labor and capital as inputs; GDP as output)	0.936	0.210
GTFP	The growth rate of productivity considering energy and environmental factors (labor, capital and energy as inputs;	1.041	0.279

	GDP, soot, sulfur dioxide, wastewater as output)		
Green patent	Number of green patents retrieved according to the International List of Green Patent Classifications (unit: pieces)	47.212	111.148
Non-green patent	Number of non-green patents (unit: pieces)	743.998	1843.303
Urban environmental legislation	Whether the city implements local environmental laws (1 = yes; 0 = no)	0.110	0.313
Government expenditures	Government fiscal expenditure as a percentage of regional GDP (%)	20.072	23.349
Industrial structure	The output value of the secondary industry as a percentage of the regional GDP (%)	48.668	11.658
Foreign capital dependence	The actual amount of foreign capital utilized in that year as a percentage of regional GDP (%)	1.921	2.767
GDP per capita	GDP per capita (Unit: 10,000 yuan, 2003 price)	3.204	11.486
National environmental law	Number of national environmental laws implemented in the year	1.533	1.258
Provincial environmental law	Number of provincial environmental laws implemented in the year	1.379	1.629

4. Empirical analysis

4.1. Benchmark model

Table 3 reports the benchmark regression results, where column (1) is the regression result with traditional TFP as the explanatory variable, column (2) is the regression result with GTFP as the explanatory variable, column (3) is the regression result with the traditional patent grant as the explanatory variable, and column (4) is the regression result with the green patent grant as the explanatory variable.

It can be seen from Table 3 that urban environmental legislation had a significant negative impact on GTFP at the level of 1%, that is, urban environmental legislation reduced local green productivity. The possible reason was policy distortions among enterprises. Environmental regulations limited the amount of energy used or emissions produced by a company's units. High-productivity companies were easier to achieve than low-productivity companies, making an improper allocation of resources between high-productivity and low-productivity companies and significantly reduced the overall productivity (Tombe et al., 2015).

Urban environmental legislation had a significant positive impact on green patents; that is, urban environmental legislation increased the number of green patents in a region. The possible reason was that environmental regulation stimulated polluters to innovate. Specifically, under the increasingly perfect environmental legislation system, enterprises may be forced to improve production technology and reduce pollution. Otherwise, polluting enterprises would face the risk of fines or other penalties. Whether it is innovative or not, the cost of the business would rise in the short term. If a company innovated, it would invest more in technology. If not, it would move out from the local or be fined for pollution. Environmental regulations may stimulate companies' environmental R&D expenditures, replacing non-environmental R&D expenditures. Environmental regulations would not lead to a decline in overall R&D levels. This increased environmental R&D was applied to the production of knowledge, resulting in more patent applications. The increase in patent activity may come from two different processes. On the one hand, it can be entirely attributed to green patents. For example, if environmental innovation requires more patents than overall innovation, it will promote green patents. On the other hand, the shift of R&D activities to green innovation may indeed encourage companies to overcome inertia and increase non-green innovation (Rassier and Earnhart, 2015; Rubashkina et al., 2015).

In summary, urban environmental legislation can promote the establishment of the weak PH, but the strong PH is not valid in a short time.

Table 3
Results of benchmark regression

	TFP	GTFP	Non-green patent	Green patent
Urban environmental legislation	-0.0434	-0.1203***	1571.0105**	113.2856***
	(0.0411)	(0.0404)	(639.6923)	(42.1988)
Government expenditures	0.0053***	0.0073***	-7.9927**	-0.5939***
	(0.0011)	(0.0013)	(3.4518)	(0.2240)
Industrial structure	0.0006	0.0026	-37.6901***	-2.4423***
	(0.0014)	(0.0019)	(11.4358)	(0.6861)
Foreign capital dependence	0.0052	-0.0050	-75.9218***	-4.6778***
	(0.0059)	(0.0042)	(28.2584)	(1.7061)
GDP per capita	-0.0004***	0.0002	0.0302	-0.0119
	(0.0001)	(0.0001)	(1.6838)	(0.1210)
National environmental law	-0.3958***	-0.0118	-1116.263***	-80.8947***
	(0.0633)	(0.0672)	(185.6192)	(11.2675)
Provincial environmental law	0.0002	0.0030	6.3912	0.9050
	(0.0021)	(0.0031)	(23.0281)	(1.4420)
Constant	1.2563***	0.8186***	6673.0788***	465.0209***
	(0.0793)	(0.0853)	(1153.4696)	(70.0402)
Year fixed effect	yes	yes	yes	yes
City fixed effect	yes	yes	yes	yes
N	3052	3052	3270	3270
R-squared	0.2506	0.3401	0.2726	0.3222

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

4.2. Robustness test

(1) PSM-DID

Heterogeneity among cities may be significant, and they may not have the same time effect. Therefore, in order to eliminate sample selection bias, we used Propensity Score Matching (PSM) to select a group of non-legislative cities as the control group whose characteristics were similar to those of the treatment group. We drew the kernel density function curve after matching the propensity scores of the treatment group and the control group(see Figure 1). Before the kernel matching, there was a specific difference in the probability density distribution of the propensity scores of the two groups of samples. If they were not matched, a direct comparison of the differences between the two groups of sample cities would result in estimation bias. After the nearest neighbor matching was completed, the probability density distribution of the two groups of samples tended to be consistent, and the selectivity bias of the samples was eliminated. In this study, the impact of urban environmental legislation on green productivity and green innovation was re-estimated using the PSM-DID. The estimation results were consistent with the benchmark results (see Table 4).

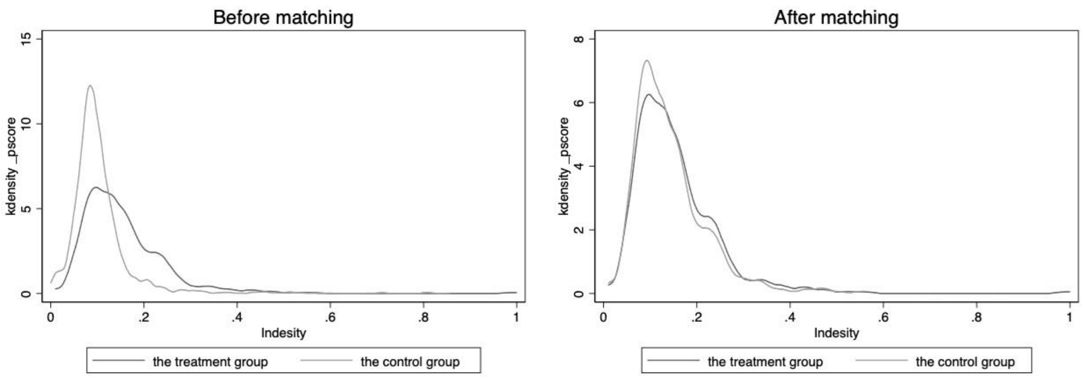

Fig.1. Kernel Density Distribution of the Tendency Scores

Table 4
Results of PSM-DID

	TFP	GTFP	Non-green patent	Green patent
Urban environmental legislation	-0.0104 (0.0404)	-0.0805** (0.0310)	1433.8838** (637.8361)	104.5866** (41.7182)
Control variables	yes	yes	yes	yes
Constant	1.2954*** (0.0745)	0.7916*** (0.0654)	8399.1342*** (1563.7763)	577.2680*** (92.0704)
N	2995	2995	3213	3213
R-squared	0.2205	0.1626	0.2893	0.3401

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

(2) The samples were grouped according to the time of introduction

The promulgation of laws generally means that relevant voting procedures are passed, and the news is announced to the public, but the laws are not necessarily in effect. Therefore, some cities have enacted relevant urban environmental legislation, but it will not be formally implemented until next year. When the law is introduced, it will have an impact on the productivity and innovation activities of enterprises or cities, even if they are not implemented. Therefore, this paper set the control group and treatment group again based on the introduction time, and the regression results were consistent with the benchmark results(see Table 5).

Table 5
Estimated results based on the time of introduction

	TFP	GTFP	Non-green patent	Green patent
Urban environmental legislation	-0.0089 (0.0344)	-0.0736*** (0.0269)	1363.0785** (575.9438)	101.9562*** (38.8113)
Control variables	yes	yes	yes	yes
Constant	1.2956*** (0.0743)	0.7924*** (0.0651)	8416.3229*** (1566.1399)	577.9549*** (92.1629)
N	2995	2995	3213	3213

R-squared	0.2205	0.1626	0.2899	0.3416

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

(3) Counterfactual estimation

The comparison between the control group and the treatment group is a hypothetical prerequisite for analyzing the impact of urban environmental legislation on green innovation. If the fact that urban legislation does not exist, the green innovation between the treatment group and the control group will not change over time. Therefore, this hypothesis is tested empirically using the counterfactual test. We selected the cities from 2015 to 2017 that had not promulgated environmental legislation. Assume that they were cities with environmental legislation, and test them based on the benchmark regression. According to the regression results in Table 6, the conclusions of the benchmark results lead to the placebo effect with the change of the control group, thus explaining the robustness of the benchmark results (see Table 6).

Table 6

Counterfactual test

	TFP	GTFP	Non-green patent	Green patent
Urban environmental legislation	-0.0488 (0.0364)	-0.0913* (0.0533)	-118.9754 (280.5396)	-0.1751 (19.2499)
Control variables	yes	yes	yes	yes
Constant	1.2625*** (0.0768)	0.8374*** (0.0834)	7088.5138*** (1271.7227)	487.6648*** (77.5787)
N	3052	3052	3270	3270
R-squared	0.2517	0.3413	0.2605	0.3066

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

(4) Set policy timing

Referring to the research method of Shaw et al.(2014), we selected December 31, 2016, as the time node for implementing urban environmental legislation, and took cities that have implemented local environmental laws before December 31, 2016, as the treatment group. However, it would be unreasonable to use all remaining cities that did not implement environmental regulations before December 31, 2016, as a control group. Because after January 1, 2017, some cities also implemented environmental laws. Therefore, we removed cities that implemented environmental legislation from January 1, 2017, from the control group. The results of common policy points were consistent with the benchmark results (see Table 7).

Table 7

Estimated results（2016 is the common policy time point）

	TFP	GTFP	Non-green patent	Green patent
Urban environmental legislation	-0.0460*** (0.0176)	0.0063 (0.0247)	1325.5183** (615.0889)	88.3300** (42.2909)
Control variables	yes	yes	yes	yes
Constant	1.3058*** (0.0763)	0.7864*** (0.0671)	8185.9087*** (1598.6608)	556.5817*** (93.6446)
N	2974	2974	3192	3192
R-squared	0.2170	0.1651	0.2729	0.3169

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

4.3. Extensibility analysis

(1) Discussion by region

The impact of urban environmental legislation on green productivity and innovation varies from region to region. Hering et al.(2014) considered the differences in location characteristics in the empirical analysis. Regardless of the TCZ policy, differences in location characteristics may lead to higher demand for clean environments in TCZ cities. They found that in the inland provinces where labor and land were cheaper, more businesses have been relocated or established. Polluting companies may find less developed areas more attractive as there may be fewer concerns about environmental damage.

The gap between different regions of China is relatively large. In 2017, eight of the country's top ten cities were in the east and only two in the middle. Also, income affects environmental legislation and innovation to a certain extent. The higher the income, the stronger the demand for a pleasant environment, and the more likely it is to promote corporate innovation. It can even force polluters to move out of the area. Different regions have different industrial structures and environmental pollution. The tertiary industry has the most significant proportion in the eastern region, and the secondary industry with the most severe environmental pollution has a more complex distribution. For example, the textile and clothing industry clusters are mainly distributed in the eastern coastal regions, while the machinery manufacturing industry is mainly concentrated in the central regions. In order to further analyze the situation in different regions, we divide China into eastern, central, and western regions and conduct regressions. The results are shown in Table 8.

Table 8
Regression results by region samples

	The eastern region		The central region		The western region	
	GTFP	Green patent	GTFP	Green patent	GTFP	Green patent
Urban environmental legislation	0.0081	37.7621	-0.1393	-0.4525	-0.2871**	27.415***
	(0.0325)	(63.8230)	(0.0866)	(15.9739)	(0.1125)	(8.8020)
Control variables	yes	yes	yes	yes	yes	yes
Constant	0.8539***	788.89***	0.8559***	53.6934	0.51***	140.57***
	(0.0790)	(258.18)	(0.2433)	(40.5936)	(0.1772)	(23.1988)
Year fixed effect	yes	yes	yes	yes	yes	yes
City fixed effect	yes	yes	yes	yes	yes	yes
N	938	1005	1176	1260	938	1005
R-squared	0.1946	0.4798	0.5569	0.4611	0.2412	0.4859

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

Table 8 reports the regression results for the sub-region samples. The impact of urban environmental regulations on GTFP in western cities was significantly negative, but not significant in the eastern and central regions. Urban environmental legislation had a significant impact on green patents in the western region but had no significant impact on green patents in the eastern and central regions. The possible reason was that the polluting industries in the east and central regions were transferred to the western region, so their green productivity and patents were not significant. After the western region has undertaken the industrial transfer from the east and central regions, the environmental legislation has been strengthened, which promoted green patents in the western region as the level increases. Industries in the western region could not move to the central and eastern regions where environmental regulations were stricter, and their land and labor prices were higher, so their green productivity had declined.

(2) Heterogeneity analysis

Local environmental legislation has various forms, including general environmental legislation such as *the Environmental Protection Regulations* of each province, and different types of environmental legislation for specific pollutants, such as *the Water Pollution Prevention Regulations*, *Regulations on the Prevention and Control of Air Pollution* and *Regulations on the Prevention and Control of Environmental Pollution by Solid Waste*. We collected and organized information on policies and regulations published on the websites of regional environmental protection bureaus, and finally selected environmental legislation related to water pollution and air pollution to examine the impact of different types of environmental legislation on GTFP and green patents. Table 9 reports the impact of different types of environmental legislation on GTFP and green patents. From the regression results in Table 9, it can be seen that the regression results of different types of environmental legislation are similar to the benchmark results.

Table 9
Impact of different types of environmental legislation on green innovation

	Environmental legislation related to water pollution		Environmental legislation related to air pollution	
	GTFP	Green patent	GTFP	Green patent
Urban environmental legislation	-0.0495 (0.0517)	90.3272** (42.2471)	-0.1441** (0.0678)	230.3955** (114.3627)
Control variables	yes	yes	yes	yes
Constant	0.8390*** (0.0841)	478.6495*** (74.1902)	0.8324*** (0.0841)	477.9144*** (70.3653)
Year fixed effect	yes	yes	yes	yes
City fixed effect	yes	yes	yes	yes
N	3052	3052	3052	3270
R-squared	0.3383	0.3391	0.3391	0.3261

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

5. Mechanism analysis

5.1. Mediation effect analysis

A potentially important channel for environmental policies to affect companies is innovation. Increased innovation activities may lead to increased efficiency and productivity (Albrizio et al., 2017). To test the impact mechanism of urban environmental regulations on green productivity, we have introduced a model of intermediary mechanisms.

This paper used green patents as the mediation, and constructed the mediation effect model as follows:

$$GM_{it} = f_1(treat_{it} * post_{it}, treat_{it}, post_{it}, Z_{it}) + \mu_{it} + e_{it} \quad (3)$$

$$GP_{it} = f_1(treat_{it} * post_{it}, treat_{it}, post_{it}, Z_{it}) + \mu_{it} + e_{it} \quad (4)$$

$$GM_{it} = f_1(treat_{it} * post_{it}, GP_{it}, treat_{it}, post_{it}, Z_{it}) + \mu_{it} + e_{it} \quad (5)$$

GM_{it} is the green total factor productivity, GP_{it} is the number of green patent authorization, Z_{it} is a series of control variable vectors, μ_{it} is the individual fixed effect, and e_{it} is the residual. According to the principle of the mediation effect model (Pessoa, 2005), if the regression coefficients of $treat_{it} * post_{it}$ in equations (3), (4) and the regression coefficients of GP_{it} in equations (5) are all significant, it indicates the existence of the intermediary effect. The specific regression results are shown in Table 10.

Table 10 reports the intermediary effect regression results. The study found that urban environmental legislation could significantly promote green innovation. However, the number of green patent grants had no significant impact on green productivity and traditional productivity. It can be considered that urban legislation has promoted green innovation and formed product compensation. However, innovation has not yet further promoted enterprises to increase GTFP, and the intermediary effect was not significant. Therefore, urban legislation has not improved GTFP through green innovation.

Table 10
Regression results of the intermediary effect

	GTFP	Green Patent	Green Patent
Urban environmental legislation	-0.1203***	113.2856***	-0.1233***
	(0.0404)	(42.1988)	（0.0400）
Green patent	——	——	0.0001
	——	——	（0.0001）
Control variables	yes	yes	yes
Constant	0.8186***	465.0209***	0.8200***
	(0.0853)	(70.0402)	（0.0851）
Year fixed effect	yes	yes	yes
City fixed effect	yes	yes	yes
N	3052	3270	3052
R-squared	0.3401	0.3222	0.3401

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

The possible reason for this phenomenon is that some green patents are not developed by enterprises and applied for authorization, but obtained by non-enterprise, such as universities. According to the China Green Patent Statistics Report (2014-2017), among the top 20 green patent applicants in China from 2014 to 2017, 16 were domestic universities and only 4 were domestic enterprises. It can be seen that most of the domestic green technology is in the hands of universities, and the green innovation of universities is not as rapid in implementation and application as that of enterprises, and cannot be applied in production quickly, thus failing to promote the green productivity.

5.2. Hysteresis effect analysis

Another possible reason that green innovation has not contributed to green productivity is that environmental policy may have a long lag in its dissemination through patent innovation. The process from policy incentives to innovative research and development, the implementation of innovative technologies, the application of patents, and the adoption of economic effects, will take many years (Andrews et al., 2014). Therefore, we used the lagging term of green innovation to make further tests, and respectively put the lagging term of green innovation into one period, two periods and three periods, and combined with the mediation effect model to analyze whether environmental legislation affects green productivity through the lagging term of green innovation. Table 11 only shows the regression results of equation (5) in the mediation effect model. The results show that green innovation has no significant effect on green productivity, no matter how many lag periods. Therefore, process compensation has not been implemented yet.

Table 11
Regression results of the hysteresis effect

	GTFP		
	One phase lag	Two phases lag	Three phases lag
Urban environmental legislation	-0.124***	-0.120***	-0.123***
	(0.0361)	(0.0355)	(0.0358)
The lag of Green patent	6.62e-05	2.45e-05	5.04e-05
	(7.65e-05)	(9.47e-05)	(0.000111)
Control variables	yes	yes	yes
Constant	0.816***	0.774***	0.795***
	(0.0857)	(0.0960)	(0.105)
Year fixed effect	yes	yes	yes
City fixed effect	yes	yes	yes
N	3,052	2,834	2,616
R-squared	0.340	0.357	0.366

Note: Standard errors are in parentheses. *, **, and *** represent significance at 10%, 5%, and 1% significance levels, respectively.

6. Conclusion and inspiration

6.1. Conclusions

In recent years, the concept of green development has become popular, and environmental protection has become a significant concern for policymakers and academia. Environmental legislation is considered to be the most direct and effective means of environmental protection. The public starts to wonder whether the increasingly perfect environmental legal system will help to induce the regional Porter effect. Based on the panel data of 218 prefecture-level cities, we used DID model to estimate the impact of environmental legislation on GTFP and green innovation. The result shows that urban environmental regulations have promoted the increase in the number of green patents and formed product compensation; that is, the weak PH was established. However, urban environmental regulations also lead to a decline in GTFP in the short term; that is, the strong PH did not hold. This conclusion is held after considering a series of robustness tests.

Besides, urban environmental regulations have different impacts on the eastern, central, and western regions. Environmental legislations have a significant impact on GTFP and green patents in the western region, but not a significant impact on the central and eastern regions. Through the analysis of the intermediary mechanism, there is no intermediary mechanism between urban environmental regulations, green innovation and green productivity. Legislation encourages companies to innovate. The costs of enterprises have risen in the short term, which has led to a decline in productivity, and the role of green innovation in promoting green productivity has not been significant.

6.2. Policy suggestions

We examined the relationship between prefecture-level environmental legislation and GTFP. Its analysis shows that green innovation would not only help coordinate the relationship between environmental legislation and green innovation, but also help achieve a win-win situation for economic development and environmental protection. Based on this, we make the following recommendations:

First, improve environmental laws to stimulate regional green innovation. Environmental legislation can effectively promote regional green innovation, but in reality, China's regional environmental legislation is still incomplete. Therefore, local people's congresses and governments should actively promote the formulation and revision of environmental laws. Besides, they must formulate environmental laws suitable for achieving a win-win situation for the economic and environmental effects of the region according to the specific environmental characteristics and economic development level of the region.

Second, use green patents to play a positive role in the green economy effect of environmental legislation. The intermediary effect result in this paper found that green patents expected to improve the green economic effects have not played their intended role. In specific practice, when the environmental law is promulgated, fitting reward and punishment measures must be matched to facilitate the implementation of the law.

6.3. Shortcomings of this paper

This paper examines Porter effect of prefecture-level environmental legislation and affirms the positive role of local environmental legislation in the green economy and green innovation. However, there are still some deficiencies and issues worthy of further study in study:

First, this paper used the number of new patents granted each year as a proxy for innovation, but potential bias may exist in the analysis. For example, many innovations are not patented in practice because companies may just want to improve the production process rather than applying for a patent. Moreover, the cost of the patent application is relatively high. We also consider other innovative proxy variables for robust tests, such as the number of green loans[6] and R&D expenditure. Yang et al. (2012) found that pollution control costs were directly related to R&D expenditure, which meant that stronger environmental protection triggers more R&D. However, this is not possible because there is no relevant data.

Second, the stringency of enforcement was not considered. Although some cities have promulgated and implemented local environmental regulations, there were still differences in the supervision and enforcement of enterprises by local governments. The common problem was that it was difficult for some government officials with interest in companies that damage the environment to enforce pollution restrictions (Hering and Sandra, 2014). Therefore, it is necessary to track the implementation of legislative cities further and measure their strictness. At the same time, environmental regulations promulgated by administrative agencies will also affect the behavior of enterprises. However, it is difficult to distinguish the impact of administrative regulations and laws.

Third, the law has not been implemented for a long time. The people's congress representatives of the prefecture-level cities studied in this paper were only allowed to make local regulations in 2015. There were only a few cities that have formulated and implemented urban environmental regulations, and the implementation time was short. At present, some long-term effects cannot be seen. Besides, the lack of legislative experience of people's congress deputies in some cities made laws not applicable locally, and the effects of regulations were not apparent.

Acknowledgments This paper is a phased achievement of the Chinese National Funding of Social Sciences "Research on the Potential and Dynamics of China's Economic Growth" (14ZDA023), and is subject to the China Postdoctoral Science Foundation (2018M632270) , We gratefully acknowledge the financial supported by the "A Project Funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD)", "China Center for Food Security Studies, Nanjing Agricultural University" in China.

Data and material availability The authors declare that the data are not available and can be presented upon the requested of the readers.

Author's contributions Fan Zhang: Conceptualization; formal analysis; methodology; original draft

Qinqin Han: Collecting data; review and editing

Junjie Shao: Original draft; supervision; review and editing

Ethical Approval Not applicable.

Declarations

[6] A financial instrument for financial ecological protection, ecological construction, and green industries

Consent to participate The authors declare that they agree to publish this paper in Environmental Science and Pollution Research.

Consent to publish The authors declare that they agree with the publication of this paper in this journal.

Conflict of interest The authors declare no competing interests.

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Figures

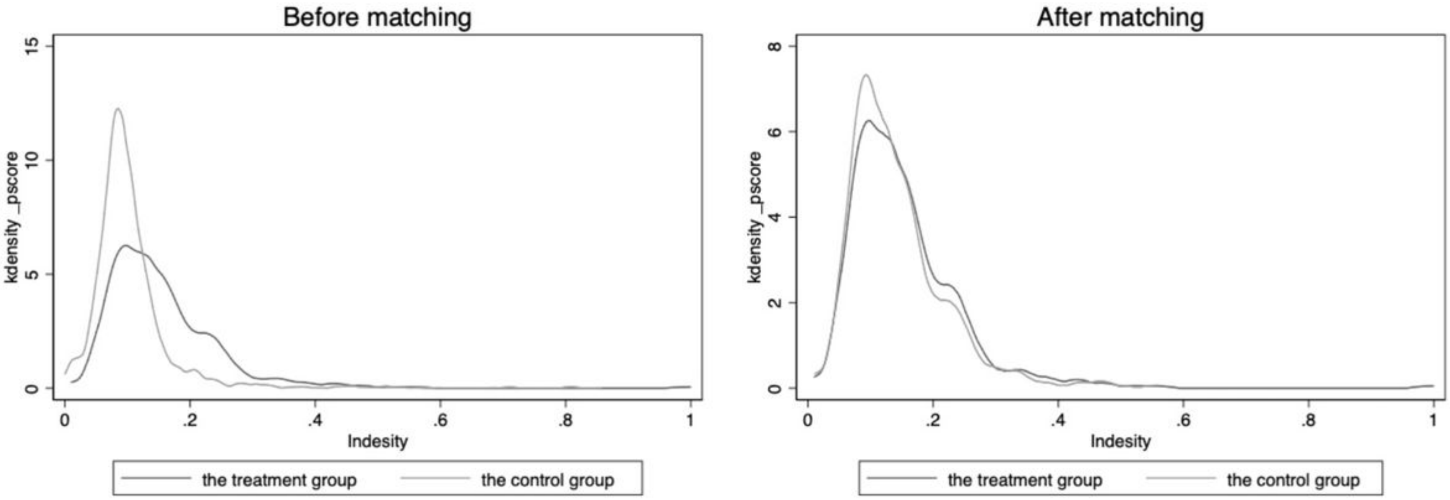

Figure 1

Kernel Density Distribution of the Tendency Scores