frontiers | Frontiers in Environmental Science

HYPOTHESIS AND THEORY
published: 01 July 2022
doi: 10.3389/fenvs.2022.944383

Would the Urban Environmental Legislation Realize the Porter Hypothesis? Empirical Evidence Based on Panel Data of Chinese Prefecture Cities

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Specialty section:
This article was submitted to
Environmental Economics and
Management,
a section of the journal
Frontiers in Environmental Science

Received: 15 May 2022
Accepted: 30 May 2022
Published: 01 July 2022

Citation:
Zhang F, Yang Y, Ahmad M and Shao J (2022) Would the Urban Environmental Legislation Realize the Porter Hypothesis? Empirical Evidence Based on Panel Data of Chinese Prefecture Cities.
Front. Environ. Sci. 10:944383.
doi: 10.3389/fenvs.2022.944383

The Porter hypothesis suggests that well-designed environmental regulation can trigger regional technological innovation that helps gain competitiveness. Little attention has been paid to whether China's urban environmental legislation supports Porter hypothesis (PH). An empirical test was conducted based on panel data of 218 prefecture-level cities during 2003–2017 to examine the effects of urban environmental legislation on innovation and green total factor productivity (green TFP). The findings reveal that the 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 TFP so that the strong version of PH did not hold. Further analysis showed that the urban environmental legislation led to the decline of green TFP and the increase of green patents in the west of China, but in the east and central cities, the changes were not visible. Besides, the legislation did not promote green TFP improvement through green innovation in the short term, which means it did not realize process compensation.

Keywords: urban environmental legislation, green TFP, green patent, porter hypothesis, China

1 INTRODUCTION

The green innovation is necessary for sustainable economic development (Peng et al., 2020a; Zhao et al., 2020). Due to the high investment, high risk, and significant externality of green innovation, it is necessary to stimulate green innovation through environmental regulation (Peng et al., 2019c; Tu et al., 2019; Zhong et al., 2020; Peng et al., 2021a). Environmental legislation -the most direct and effective means of environmental regulation-is gradually favored by policymakers. In recent years, to prevent environmental pollution and improve the ecological environment, the Chinese government has been continuously improving its environmental legal system (Fowlie et al., 2012; Gu et al., 2020; Zhang et al., 2020; Zhong et al., 2021). In particular, after the implementation of the Legislation Law of the People's Republic of China (2015 Amendment), local governments (municipalities with districts established) are allowed to exercise greater legislative power than before, especially in the realm of environmental regulation, marking a new starting point on China's environmental regulation dynamics (Wang et al., 2019a; Wang et al., 2019b; Wang et al., 2021). In general, from 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.

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, 2017). Existing literature that discussed local environmental regulations and enterprise decision-making behaviors mainly focused on the innovative behavior and relocation behavior of enterprises (Zheng et al., 2020; Elahi et al., 2021b; Elahi et al., 2022a). There are two popular theories: Pollution Haven Hypothesis and Porter Hypothesis. The Pollution Haven Hypothesis (PHH) holds that in an open economy, companies of pollution-intensive industries will move to countries or regions with less strict environmental policies (Sheng et al., 2019; Peng et al., 2021b; Wang et al., 2021), and these countries will become a Haven for pollution (Copeland and Taylor, 1994; Levinson and Taylor, 2008; Dincer et al., 2018). The Porter Hypothesis (PH) believes that the impact of environmental regulations on enterprises is dynamic because environmental regulations can stimulate enterprises to innovate (Porter, 1991; Porter and Linde, 1995). Although environmental regulations can increase the production and operation costs of enterprises, products can be more competitive through innovation (Peng et al., 2018; Peng et al., 2019b; Peng et al., 2021c). 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 policy can increase the overall productivity of enterprises. The narrow PH states that under the specific environmental policy, such as flexible and market-based tools, productivity improvements and changes in the direction of innovation are more likely to be achieved.

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 can be written as: 1) Based on the implementation of national environmental legislation after 2015, the virtual variables of urban environmental legislation are set to characterize environmental decentralization, and DID model is used to evaluate the impact of environmental decentralization on green innovation. 2) This paper explores the impact of environmental decentralization on green innovation from the perspectives of green patent and green TFP, and avoids the phenomenon of "pseudo innovation" in environmental decentralization.

The remainder of the paper is organized as follows. **Section 2** belongs to the literature review. **Section 3** presents models, variables, and data descriptions. **Section 4** includes the analysis of benchmark results, the robustness test, and the extensibility analysis. **Section 5** is related to the analysis of the mechanism. **Section 6** presents the conclusion and discussion.

2 LITERATURE REVIEW

To prevent environmental pollution, the government has continuously improved the construction of the environmental legislation system, of which local environmental legislation is an important element and the most basic institutional arrangement (Gu et al., 2019). 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 discharge standards, environmental monitoring systems, and approval systems for issuing pollution permits (Peng et al., 2019a; Shen et al., 2019; Tu et al., 2020). It also regulated the production and discharge of enterprises through a phase-out system for polluting equipment and a new cleaner production system. Cleaner production is imperative for the sustainability of services, in the industrial, and agricultural sectors (Elahi et al., 2019c; Elahi et al., 2020; Elahi et al., 2022b).

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 TFP instead of the TFP and found that only appropriate fiscal decentralization could stimulate green TFP growth with the 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 enterprises and sectors misallocated investment in pollution and cleaning inputs, thereby 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 the *Clean Air Action* resulted in a decrease in production in the provinces of Hebei and Tianjin between 2013–2017, with no significant impact on Beijing. Lange and Redlinger (2019) found that new oil regulations had no manifest effect on drilling and production rates, but some of the small operators reduced production and exited the market.

Previous studies found that environmental regulation has an essential impact on the performance 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 (1996). Green innovation is based on innovation and can be characterized by novelty, value, and the ability to save resources and protect the environment (Elahi et al., 2019a). With the advancement of research, the measurement and interpretation of green innovation have received a great deal of attention from scholars. The measurement of corporate innovation usually depends on R&D expenditure and the number of patents. Brunnermeier and Cohen (2003) analyzed the data of 146 manufacturing industries in the United States from 1983 to 1992. They found that firms will only innovate when spending on pollution abatement increases, regardless of the increase in existing regulations and enforcement activity, and innovation is 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 a negative relationship with the average age of capital stock. Simultaneously, the increase in R&D investment, stimulated by the regulatory stringency, could contribute to total factor productivity growth (Hamamoto, 2006). As well as Yang et al. (2012) who researched Taiwan industries from 1997 to 2003, found a similar conclusion that a positive relationship existed between stricter environmental enforcement and R&D expenditure, and the increased R&D expenditure furthermore positively affected the productivity. However, this relationship is not statistically significant. Endres and Friehe (2011) argued that if technological change reduces the marginal abatement costs at all levels, then it is socially optimal for polluters with advanced abatement technologies to be incentive by law to diffuse their technologies under strict liability. However, if technological change reduces (increases) the marginal costs of low (high) levels of abatement, negligent behavior may give rise to better incentives for diffusion than a strict legal liability. A more stringent environmental regulation provided a positive effect on increasing investments in advanced technological equipment and innovative products (Testa et al., 2011).

However, the literature showed that the environmental legislation in other regions has not promoted innovation in most local enterprises (Peng et al., 2020b; Huang et al., 2021; Zhao et al., 2022). Kneller and Manderson (2012) analyzed data from the UK manufacturing industry to show that environmental regulation does not have a positive effect on total R&D or total capital accumulation, and environmental R&D may crowd out non-environmental R&D. de Miguel and Pazo (2017) found that environmental regulations in Spain positively affected process innovation in large firms, but product innovation only occurred in small firms (up to 200 workers). Qiu et al. (2018) revisited the PH in monopolistic competition and found only innovation investment by high-capacity firms grows. Shi et al. (2018) found that China's Carbon Emissions and Trading Pilot (CCETP) would significantly reduce enterprise innovation, and it even had a significant effect on non-regulated enterprises and other enterprises in the local region. Zhang et al. (2019) found a positive relationship between green patenting and the performance of state-owned enterprises. This kind of relationship mainly existed after 2006 when the government began formal legislative support to the green industry.

Previous researches provide us with ideas for analyzing the relationship between environmental legislation, productivity, and green innovation. However, there are still several deficiencies as follows: Firstly, previous studies mainly focused on pollution charges and marketable pollution permits. However, these indicators have a rough understanding of policy characteristics and lack consideration of environmental legal constraints and legal enforcement. Secondly, most of the existing studies found the impact of environmental legislation on traditional productivity and ignored undesired outputs and inputs. Thirdly, most of the existing literature only discussed the impact of environmental regulation on economic effects, but does not distinguish between the strong PH and the weak PH.

3 MATERIAL AND METHODS

3.1 Source of Data

From 2003 to 2017, the panel data was collected from 218 cities in China. The data were collected from the China City Statistical Yearbook (2004–2017). The number of environmental regulations enacted by prefecture-level cities and municipalities each year comes from CNKI. Patent and green patent data comes from the World Intellectual Property Organization (WIPO). All price-based indicators are current prices. To eliminate the impact of inflation, we used the provincial-level GDP index (2003 = 100) for deflation. The GDP index of each province was collected 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 is found on the website of the National Bureau of Statistics.

3.2 Statistical Model

After the implementation of the new *Legislative Law of the People's Republic of China* in 2015, prefecture-level municipalities are allowed to exercise greater legislative power than before. However, there were some differences in the announcement and implementation of environmental regulations by each city, which creates an opportunity to evaluate the effect of prefecture-level urban environmental legislation on green innovation using the difference-in-difference (DID) method. According to the regional and temporal differences of environmental law enactments by cities, we empirically test the impact of urban environmental legislation on green innovation by constructing the following models:

$$GM_{it} = f_1\left(treat_{it}{}^{*}post_{it}, treat_{it}, post_{it}, Z_{it}\right) + \mu_{it} + e_{it} \quad (1)$$

$$GP_{it} = f_1\left(treat_{it}{}^{*}post_{it}, treat_{it}, post_{it}, Z_{it}\right) + \mu_{it} + e_{it} \quad (2)$$

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

As shown in **Eqs 1**, **2**, GM_{it} represents the growth rate of green TFP of the 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 one; otherwise 0. $post_{it}$ is a time dummy variable. After the implementation of urban environmental regulations, the value is one and 0 and vice versa. Interaction term $trat_{it}{}^{*}post_{it}$ 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 error term which is assumed to be normally distributed at zero mean value and constant variance (Elahi et al., 2018; Elahi et al., 2019b; Elahi et al., 2021a).

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 patents granted). 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's Hypothesis believes that strict and proper environmental regulations can force companies to engage in green innovation research because companies can reduce their environmental management cost through technological innovation (Porter et al., 1995).

Besides, the Pollution Haven Hypothesis and the Porter hypothesis, two seemingly independent theories of environmental regulation affecting corporate decision-making behavior, are intrinsically linked. Most existing studies have ignored that for polluting companies, local innovation and relocation are choices for reducing environmental management costs. It can be considered that the decision of local innovation and offsite transfer of an enterprise depends on the relative environmental regulation cost. In terms of green productivity at the city level, the reduction of pollution from energy-intensive and pollution-intensive enterprises (referred to as the double-intensive enterprises), whether using local innovation or relocation, may contribute to green productivity growth at the city level. On the one hand, if the "double-intensive" enterprises choose the alternative of local innovation, 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 were conducive to research and development capabilities improvement and further realized productivity improvements. On the other hand, if the "double-intensive" enterprises are relocated, energy consumption and bad output will be reduced, which will improve green productivity. However, relocation does not increase local green patent output. To conduct a comparative study, we also considered the equations of the traditional productivity and non-green patent in which the dependent variables are not energy-environment factors.

3.3 Variables

3.3.1 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 1) Labor, the number of employees (10,000 people) at the end of the year. 2) Capital[1]. For the estimation of the capital stock at constant prices, we used the actual investment amount divided by the sum of the 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). 3) Energy. We used prefecture-level cities' electricity consumption data as an indicator of energy consumption (10,000 kWh). The output includes 4) Expected output, GDP of prefecture-level cities with constant prices in 2003 (10,000 yuan). 5) Fume, industrial fume emissions (tonnes). 6) Sulfur dioxide, industrial sulfur dioxide emissions (tonnes). 6) Wastewater, industrial wastewater discharge (10,000 tons).

3.3.2 Green Innovation

Green innovation is difficult to measure directly. There are two general categories of indicators: the first is research and development input (R&D) which measures green innovation investment; the second is the number of patent approvals that measure the output of green innovation. However, of these indicators, only patent data can provide sufficient green and non-green technology information. Therefore, we choose the number of green patents granted as the proxy indicator of green innovation. To develop a comparative analysis, we also analyze the results of the model with the number of patents granted as the dependent variable.

The World Intellectual Property Organization[2] (WIPO) launched an online tool *the Green List of International Patent Classifications*, designed to facilitate the retrieval of environmentally-friendly patents in 2010. There are seven major categories: transportation, waste management, energy conservation, alternative energy production, administrative supervision and design, agriculture and forestry, and nuclear power.

3.3.3 Urban Environmental Legislation

Many previous studies used environmental pollution charges and pollution permits to describe the stringency of environmental

[1]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.

[2]https://www.wipo.int/classifications/ipc/en/green_inventory/.

regulation. Some studies also selected some indirect indicators as proxy variables, such as the relative discharge of pollutants, the amount of environmental pollution treatment investment per capita, and the operating costs of treatment facilities. These indicators have a rough description of environmental regulations and lack legal binding power. Based on this, this study intends to use the implementation of environmental legislation by prefecture-level municipalities to characterize environmental legislation. The annual environmental laws enacted and implemented by each prefecture-level city and municipality directly under the central government were obtained from the CNKI. The detailed steps were as follows: based on the advanced search of the CNKI, first, we use Python to crawl all the law-related links, and then crawl the data such as their titles, publication dates, validity levels, and author institutions and keywords one by one. According to the crawled data, we manually collated and formed a panel data of the number of environmental laws and regulations of each prefecture-level city and municipality under the Central Government.

As shown in **Table 1**, the research object is 218 general prefecture-level cities. The treatment group consists of 22 cities that had implemented environmental laws from 2015 to 2017, and their value of urban environmental legislation is 1. The control group was 196 cities that had not implemented environmental laws, and whose value of urban environmental legislation was 0. We also found that 52 special cities had implemented urban environmental regulations before 2015, including four directly-controlled provinces, four special economic zones, 18 provincial capital cities, and 26 megacities designated by the State Council.

Environmental legislation refers to the number of environmental regulations promulgated and implemented by local prefecture-level municipalities. It differs from national and provincial environmental laws. First, environmental regulations at the city level must be consistent with laws of the higher level. Second, city-level regulations are often more specific than national and provincial laws. For example, according to the city-level regulations on water pollution, the sewage treatment methods of residents and enterprises are clearly defined. The penalties for different levels of offense are clear. Most importantly, urban environmental regulations can adapt to regional characteristics. If the city is a heavily metal polluted area, it is more likely to enact regulations for heavy metal pollution.

3.3.4 Control Variables

1) Government fiscal expenditure level. Facing the failure of market mechanisms, the government's financial leverage provides companies with material and 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. 2) Industrial structure. The optimization and upgrading of the industrial structure are conducive to the improvement of green innovation. The ratio of the output value of the secondary industry to regional GDP represents the industrial structure in each region. 3) Degree of openness. The greater its degree of openness to the world, the more intense the competition, and the more urgent the desire to increase investment in science and technology to improve the green innovation capabilities. Besides, in the process of opening to the world, each city absorbed advanced technologies to improve its green innovation capabilities. The proportion of foreign direct investment in regional GDP is used to indicate regional openness. 4) Regional economic development level. The higher the level of regional economic development, the less capital pressure companies face in green innovation. GDP per capita is used to represent the level of economic development in the region. 5) The number of provincial and national environmental legislation. We used the number of environmental laws enacted by provincial and national people's congresses and standing committees to represent provincial and national environmental legislation. The summary of descriptive statistics is given in **Table 2**.

4 RESULTS AND DISCUSSION

4.1 Benchmark Regression

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 green TFP as the explanatory variable, and 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.

Results found that urban environmental legislation had a significant negative impact on green TFP at the level of 1%, that is, urban environmental legislation reduced local green productivity. The result is basically consistent with the conclusion of Xie et al. (2017). They argued that notwithstanding the improvements in energy efficiency and environmental efficiency of the manufacturing industry enticed by environmental regulation, the emergence of rebound effect leads to increased energy consumption and aggravated environmental damage and thus green TFP is significantly restrained. Furthermore, current environmental legislations in China are not systematic and comprehensive so that they cannot work together to energize green development of the manufacturing industry. Although environmental quality has improved, it is not conducive to technological progress, thus inhibiting green TFP (Yuan and Xiang, 2018).

Urban environmental legislation had a significantly positive impact on green patents; that is, urban environmental legislation increased the number of green patents in a region. The result is consistent with the conclusion of Kesidou and Wu (2020). They find that firms, located in provinces with stricter pollution targets, produced a higher volume and intensity of green patents. The possible reason was that environmental regulations stimulated polluters to innovate. Specifically, under the increasingly complete 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 a short term, because under the stricter environmental regulations, a company has to choose whether to invest more in discharge

TABLE 2 | Descriptive statistics of the main variables.

Variables	Definition	Mean	Standard deviation
TFP	Productivity growth rate without consideration of energy and environmental factors (labor and capital as inputs; GDP as output)	0.936	0.210
Green TFP	The growth rate of productivity considering energy and environmental factors (labor, capital and energy as inputs; GDP, fume, sulfur dioxide, waste water as output)	1.041	0.279
Green patent	Number of green patents retrieved according to the International List of Green Patent Classifications (unit: piece)	47.212	111.148
Non-green patent	Number of non-green patents (unit: piece)	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

TABLE 3 | Results of benchmark regression.

Variables	TFP	Green TFP	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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

reduction technology or relocate, or be fined for pollution (Peng et al., 2022a; Peng et al., 2022b; Wu et al., 2021; Zhao et al., 2021). 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 and resulted 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 patent research work. 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). The urban environmental legislation can promote the establishment of the weak PH, but the strong PH is not valid in a short time.

4.2 Robustness Test

4.2.1 Propensity Score Matching-Difference-in-Difference Model

Heterogeneity among cities may be significant, and they may not have the same time effect. Therefore, to eliminate sample selection bias, Propensity Score Matching (PSM) was used to select a group of non-legislative cities as the control group whose characteristics were similar to those of the treatment group. The kernel density function curve was drawn after matching the propensity scores of the treatment group and the control

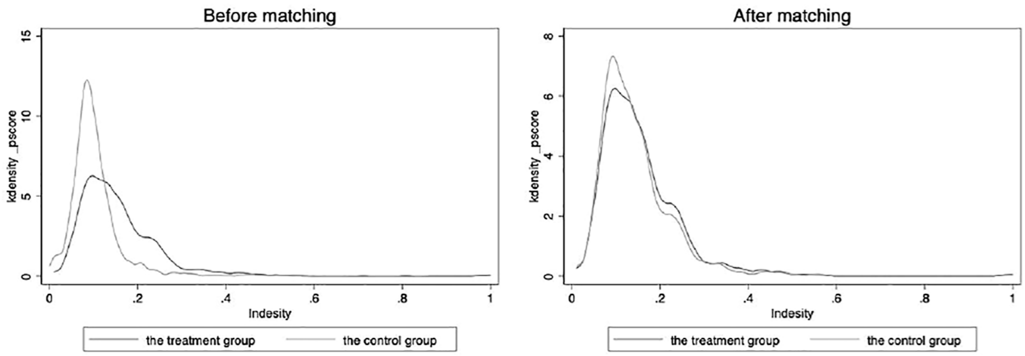

FIGURE 1 | Kernel density distribution of the tendency scores.

TABLE 4 | Results of PSM-DID.

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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

group (**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 (**Table 4**).

4.2.2 Grouped Sample

The promulgation of laws generally means that relevant voting procedures are passed, and the news is announced to the public, but the laws do not necessarily take 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 yet. Therefore, the control group and treatment group were set again based on the introduction time, and the regression results were consistent with the benchmark results (**Table 5**).

4.2.3 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 would 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. The benchmark results lead to the placebo effect with the change of the control group, thus explaining the robustness of the benchmark results (**Table 6**).

4.2.4 Set Policy Timing

Following Shaw et al. (2014), we selected 31 December 2016, as the urban environmental legislation implement node for city cluster construction, and took cities that have implemented local environmental laws before 31 December 2016, as the treatment group. Because some cities also implemented environmental laws after 1 January 2017, we removed those cities from the control group. The results of common policy points were consistent with the benchmark results (**Table 7**).

4.3 Heterogeneity Analysis

4.3.1 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 TCZ

TABLE 5 | Estimated results based on the time of introduction.

Variables	TFP	Green TFP	Non-green patent	Green patent
Urban environmental legislation	−0.0089	−0.0736***	1363.0785**	101.9562***
	(0.0344)	(0.0269)	(575.9438)	(38.8113)
Control variables	yes	yes	yes	yes
Constant	1.2956***	0.7924***	8416.3229***	577.9549***
	(0.0743)	(0.0651)	(1566.1399)	(92.1629)
N	2995	2995	3213	3213
R-square	0.2205	0.1626	0.2899	0.3416

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

TABLE 6 | Counterfactual test.

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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

TABLE 7 | Results of policy timing when 2016 is the common policy time point.

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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

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 factors 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 economic gap between different regions of China is large. In 2017, eight of China's top ten *GDP per capita* cities were in the east and only two in the middle. Moreover, income affects environmental legislation and innovation to a certain extent. The higher the income, the stronger will be demand for a clean environment, and the more likely it is to stimulate corporate innovation. Polluters may be forced to relocate for environmental reasons. Different regions have different industrial structures and environmental pollution. The tertiary industry has the largest share in eastern regions. The secondary industry causes pollution enormously, which 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. To further analyze the situation in different regions, we divided China into eastern, central, and western regions and performed regression analysis. The results are given in **Table 8**.

Table 8 reports the regression results for the sub-region samples. The impact of urban environmental regulations on green TFP 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 eastern and central regions were transferred to the western region, so the impact of local environmental regulations on their green productivity and patents was not significant. As a result of undertaking the industrial transfer from the eastern and central regions, local environmental legislation in western regions would be strengthened and green patents would be stimulated. However, industries in the western region could not move to the central and eastern regions where environmental regulations were stricter and land and labor prices were higher, so the green productivity declined.

TABLE 8 | Regression results by region samples.

Variables	The eastern region		The central region		The western region	
	Green TFP	Green patent	Green TFP	Green patent	Green TFP	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-square	0.1946	0.4798	0.5569	0.4611	0.2412	0.4859

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

TABLE 9 | Impact of different types of environmental legislation on green innovation.

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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

TABLE 10 | Regression results of the intermediary effect.

Variables	Green TFP	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

*Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.*

4.3.2 Impact of Different Types of Environmental Legislation

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 from policies and regulations published on the websites of regional environmental protection bureaus, and selected environmental legislation related to water pollution and air pollution to examine the impact of different types of environmental legislation on green TFP and green patents. **Table 9** reports the impact of different types of environmental legislation on green TFP and green patents. Moreover, it is found that the regression results of different types of environmental legislation are similar to the benchmark results (**Table 9**).

5 MECHANISM ANALYSIS

5.1 Mediation Effect

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 introduced a model of intermediary mechanisms.

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

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

TABLE 11 | Regression results of the hypotheses.

Variables	Green TFP		
	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

$$GP_{it} = f_1\left(treat_{it}{}^{*}post_{it}, treat_{it}, post_{it}, Z_{it}\right) + \mu_{it} + e_{it} \qquad (4)$$

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

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 **Eqs 3**, **4**, and the regression coefficients GP_{it} of **Eq. 5** are all significant, it indicates the existence of the intermediary effect (**Table 10**).

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 indicates that urban legislation has promoted green innovation and formed product compensation. However, innovation has not yet contributed to green TFP, and the intermediary effect was not significant. Therefore, urban legislation has not improved green TFP through green innovation.

The possible reason for this phenomenon is that some green patents are not invented or applied by enterprises but 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 four were domestic enterprises. It shows that most of the domestic green patents are contributed by universities instead of enterprises, but universities alone cannot complete the transformation of inventions into production, thus, the relationship between green patents and green TFP is not distinctive.

5.1.1 Testing of Hypothesis

Another possible reason that green innovation has not contributed to green productivity is that the effect of environmental policy may have a time lag. 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 it with the mediation effect model to analyze whether environmental legislation affects green productivity through the lagging term of green innovation. Results of **Table 11** show the regression results of **Eq. 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 have been taken into consideration. Therefore, process compensation has not been implemented yet.

Standard errors are given in parentheses. *, **, and *** represent level of significance of parameters at 10, 5, and 1%, respectively.

6 CONCLUSION AND POLICY IMPLICATIONS

6.1 Conclusion

In recent years, environmental protection has become a major 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 would 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 green TFP and green innovation. The result showed that urban environmental regulations have facilitated the increase in the number of green patents and formed product compensation; and therefore, the weak PH was established. However, urban environmental regulations lead to a decline in green TFP in the short term. Robustness tests were performed. Besides, the urban environmental regulations have different impacts on the eastern, central, and western regions. Environmental legislation has a significant impact on green TFP 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. The legislation encourages companies to innovate, so the costs of enterprises rise in the short term, which would lead to a decline in productivity. Besides, the role of green innovation in increasing green productivity has not been significant.

6.2 Policy Implications

We examined the relationship between prefecture-level environmental legislation and green TFP. The result showed 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 the study findings, we propose the following policy implications.

Firstly, improve environmental laws to stimulate regional green innovation. Environmental legislation can effectively promote regional green innovation. However, regional environmental legislation in China is in the beginning phase. Therefore, local people's congresses and governments should actively conduct the formulation and revision of environmental laws based on the local environmental characteristics and economic development phase of the region to achieve a win-win situation for both economic and environmental benefit.

Secondly, utilize green patents for the green economy effect. The intermediary effect results in this study showed that the green patents have not improved the green economy as expected. Therefore, the government should encourage universities and enterprises to cooperate and turn green patents into a green economy.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

FZ proposed the main research idea, grasped the research direction, and have written the first draft of article. YY and MA contributed to the data analysis, editing, and revising the manuscript. JS contributed to empirical analysis.

FUNDING

This study was funded by the Chinese National Funding of Social Sciences, grant number 14ZDA023, Major projects of China Social Science Foundation, grant number 20ZDA073, the China Postdoctoral Science Foundation, grant number 2018M632270, and Chinese National Founding of Natural Science, grant number 71873061.

REFERENCES

Albrizio, S., Kozluk, T., and Zipperer, V. (2017). Environmental Policies and Productivity Growth: Evidence across Industries and Firms. *J. Environ. Econ. Manag.* 81, 209–226. doi:10.1016/j.jeem.2016.06.002

Andrews, D., Criscuolo, C., and Menon, C. (2014). "Do Resources Flow to Patenting Firms?," in *OECD Economics Department Working Papers, No.1127* (Paris: OECD Publishing). doi:10.1787/5jz2lpmk0gs6-en

Brunnermeier, S. B., and Cohen, M. A. (2003). Determinants of Environmental Innovation in US Manufacturing Industries. *J. Environ. Econ. Manag.* 45 (2), 278–293. doi:10.1016/S0095-0696(02)00058-X

Copeland, B. R., and Taylor, M. S. (1994). North-south Trade and the Environment. *Q. J. Econ.* 109 (3), 755–787. doi:10.2307/2118421

de Miguel, C., and Pazó, C. (2017). Environmental Protection, Innovation and Price-Setting Behavior in Spanish Manufacturing Firms. *Energy Econ.* 68, 116–124. doi:10.1016/j.eneco.2017.10.030

Dincer, O. C., and Fredriksson, P. G. (2018). Corruption and Environmental Regulatory Policy in the United States: Does Trust Matter? *Resour. Energy Econ.* 54, 212–225. doi:10.1016/j.reseneeco.2018.10.001

Elahi, E., Abid, M., Zhang, L., Ul Haq, S., and Sahito, J. G. M. (2018). Agricultural Advisory and Financial Services; Farm Level Access, Outreach and Impact in a Mixed Cropping District of Punjab, Pakistan. *Land use policy* 71, 249–260. doi:10.1016/j.landusepol.2017.12.006

Elahi, E., Khalid, Z., Tauni, M. Z., Zhang, H., and Lirong, X. (2021a). Extreme Weather Events Risk to Crop-Production and the Adaptation of Innovative Management Strategies to Mitigate the Risk: A Retrospective Survey of Rural Punjab, Pakistan. *Technovation* 4, 102255. doi:10.1016/j.technovation.2021.102255

Elahi, E., Khalid, Z., Weijun, C., and Zhang, H. (2020). The Public Policy of Agricultural Land Allotment to Agrarians and its Impact on Crop Productivity in Punjab Province of Pakistan. *Land Use Policy* 90, 104324. doi:10.1016/j.landusepol.2019.104324

Elahi, E., Khalid, Z., and Zhang, Z. (2022a). Understanding Farmers' Intention and Willingness to Install Renewable Energy Technology: A Solution to Reduce the Environmental Emissions of Agriculture. *Appl. Energy* 309, 118459.

Elahi, E., Weijun, C., Jha, S. K., and Zhang, H. (2019a). Estimation of Realistic Renewable and Non-renewable Energy Use Targets for Livestock Production Systems Utilising an Artificial Neural Network Method: A Step towards Livestock Sustainability. *Energy* 183, 191–204. doi:10.1016/j.energy.2019.06.084

Elahi, E., Weijun, C., Zhang, H., and Abid, M. (2019b). Use of Artificial Neural Networks to Rescue Agrochemical-Based Health Hazards: A Resource Optimisation Method for Cleaner Crop Production. *J. Clean. Prod.* 238, 117900. doi:10.1016/j.jclepro.2019.117900

Elahi, E., Weijun, C., Zhang, H., and Nazeer, M. (2019c). Agricultural Intensification and Damages to Human Health in Relation to Agrochemicals: Application of Artificial Intelligence. *Land Use Policy* 83, 461–474. doi:10.1016/j.landusepol.2019.02.023

Elahi, E., Zhang, H., Lirong, X., Khalid, Z., and Xu, H. (2021b). Understanding Cognitive and Socio-Psychological Factors Determining Farmers' Intentions to Use Improved Grassland: Implications of Land Use Policy for Sustainable Pasture Production. *Land Use Policy* 102, 105250. doi:10.1016/j.landusepol.2020.105250

Elahi, E., Zhang, Z., Khalid, Z., and Xu, H. (2022b). Application of an Artificial Neural Network to Optimise Energy Inputs: An Energy- and Cost-Saving Strategy for Commercial Poultry Farms. *Energy* 244, 123169. doi:10.1016/j.energy.2022.123169

Endres, A., and Friehe, T. (2011). Incentives to Diffuse Advanced Abatement Technology Under Environmental Liability Law. *J. Environ. Econ. Manage.* 62 (1), 30–40. doi:10.1016/j.jeem.2010.12.001

Fowlie, M., Holland, S. P., and Mansur, E. T. (2012). What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program. *Am. Econ. Rev.* 102 (2), 965–993. doi:10.1257/aer.102.2.965

Fussier, C. (1996). *Driving Eco-Innovation: A Breakthrough Discipline for Innovation and Sustainability*. London: Pitman Publishing. doi:10.1002/(SICI)1099-0836(199711)6:53.0.CO

Gu, H., Bian, F., and Elahi, E. (2020). Effect of Air Pollution on Female Labor Supply: An Empirical Analysis Based on Data of Labor Force Dynamic Survey of China. *Soc. Work Public Health* 35, 187–196. doi:10.1080/19371918.2020.1764433

Gu, H., Cao, Y., Elahi, E., and Jha, S. K. (2019). Human Health Damages Related to Air Pollution in China. *Environ. Sci. Pollut. Res.* 26, 13115–13125. doi:10.1007/s11356-019-04708-y

Hamamoto, M. (2006). Environmental Regulation and the Productivity of Japanese Manufacturing Industries. *Resour. Energy Econ.* 28 (4), 299–312. doi:10.1016/j.reseneeco.2005.11.001

Hancevic, P. I. (2016). Environmental Regulation and Productivity: The Case of Electricity Generation under the CAAA-1990. *Energy Econ.* 60, 131–143. doi:10.1016/j.eneco.2016.09.022

Hering, L., and Poncet, S. (2014). Environmental Policy and Exports: Evidence from Chinese Cities. *J. Environ. Econ. Manag.* 68 (2), 296–318. doi:10.1016/j.jeem.2014.06.005

Huang, Q., Peng, B., Elahi, E., and Wan, A. (2021). Evolution and Driving Mechanism of Ecological Security Pattern: A Case Study of Yangtze River Urban Agglomeration. *Integr. Environ. Assess. Manag.* 17, 573–583. doi:10.1002/ieam.4358

Jaffe, A. B., and Palmer, K. (1997). Environmental Regulation and Innovation: A Panel Data Study. *Rev. Econ. statistics* 79 (4), 610–619. doi:10.1162/003465397557196

Kesidou, E., and Wu, L. (2020). Stringency of Environmental Regulation and Eco-Innovation: Evidence from the Eleventh Five-Year Plan and Green Patents. *Econ. Lett.* 190, 109090. doi:10.1016/j.econlet.2020.109090

Kneller, R., and Manderson, E. (2012). Environmental Regulations and Innovation Activity in UK Manufacturing Industries. *Resour. Energy Econ.* 34 (2), 211–235. doi:10.1016/j.reseneeco.2011.12.001

Lange, I., and Redlinger, M. (2019). Effects of Stricter Environmental Regulations on Resource Development. *J. Environ. Econ. Manage.* 96, 60–87. doi:10.1016/j.jeem.2019.04.006

Lanoie, P., Patry, M., and Lajeunesse, R. (2008). Environmental Regulation and Productivity: Testing the Porter Hypothesis. *J. Prod. Anal.* 30 (2), 121–128. doi:10.1007/s11123-008-0108-4

Levinson, A., and Taylor, M. S. (2008). Unmasking the Pollution Haven Effect. *Int. Econ. Rev.* 49 (1), 223–254. doi:10.1111/j.1468-2354.2008.00478.x

Li, X., Qiao, Y., and Shi, L. (2019). Has China's War on Pollution Slowed the Growth of its Manufacturing and by How Much? Evidence from the Clean Air Action. *China Econ. Rev.* 53, 271–289. doi:10.1016/j.chieco.2018.08.015

Milani, S. (2017). The Impact of Environmental Policy Stringency on Industrial R&D Conditional on Pollution Intensity and Relocation Costs. *Environ. Resour. Econ.* 68 (3), 595–620. doi:10.1007/s10640-016-0034-2

Peng, B., Chen, H., Elahi, E., and Wei, G. (2020a). Study on the Spatial Differentiation of Environmental Governance Performance of Yangtze River Urban Agglomeration in Jiangsu Province of China. *Land Use Policy* 99, 105063. doi:10.1016/j.landusepol.2020.105063

Peng, B., Chen, S., Elahi, E., and Wan, A. (2021a). Can Corporate Environmental Responsibility Improve Environmental Performance? an Inter-temporal Analysis of Chinese Chemical Companies. *Environ. Sci. Pollut. Res.* 28, 12190–12201. doi:10.1007/s11356-020-11636-9

Peng, B., Huang, Q., Elahi, E., and Wei, G. (2019a). Ecological Environment Vulnerability and Driving Force of Yangtze River Urban Agglomeration. *Sustainability* 11, 6623. doi:10.3390/su11236623

Peng, B., Li, Y., Elahi, E., and Wei, G. (2019b). Dynamic Evolution of Ecological Carrying Capacity Based on the Ecological Footprint Theory: A Case Study of Jiangsu Province. *Ecol. Indic.* 99, 19–26. doi:10.1016/j.ecolind.2018.12.009

Peng, B., Wang, Y., Elahi, E., and Wei, G. (2019c). Behavioral Game and Simulation Analysis of Extended Producer Responsibility System's Implementation under Environmental Regulations. *Environ. Sci. Pollut. Res.* 2019, 1–11. doi:10.1007/s11356-019-05215-w

Peng, B., Wang, Y., Elahi, E., and Wei, G. (2018). Evaluation and Prediction of the Ecological Footprint and Ecological Carrying Capacity for Yangtze River Urban Agglomeration Based on the Grey Model. *Ijerph* 15, 2543. doi:10.3390/ijerph15112543

Peng, B., Yan, W., Elahi, E., and Wan, A. (2021b). Does the Green Credit Policy Affect the Scale of Corporate Debt Financing? Evidence from Listed Companies in Heavy Pollution Industries in China. *Environ. Sci. Pollut. Res.* 2021, 1–13.

Peng, B., Zhang, X., Elahi, E., and Wan, A. (2022a). Evolution of Spatial-Temporal Characteristics and Financial Development as an Influencing Factor of Green Ecology. *Environ. Dev. Sustain* 24, 789–809. doi:10.1007/s10668-021-01469-y

Peng, B., Zhao, Y., Elahi, E., and Wan, A. (2022b). Does the Business Environment Improve the Competitiveness of Start-Ups? the Moderating Effect of Cross-Border Ability and the Mediating Effect of Entrepreneurship. *Corp. Soc. Responsib. Environ. Manag.* doi:10.1002/csr.2262

Peng, B., Zhao, Y., Elahi, E., and Wan, A. (2021c). Investment in Environmental Protection, Green Innovation, and Solid Waste Governance Capacity: Empirical Evidence Based on Panel Data from China. *J. Environ. Plan. Manag.* 2021, 1–24.

Peng, B., Zheng, C., Wei, G., and Elahi, E. (2020b). The Cultivation Mechanism of Green Technology Innovation in Manufacturing Industry: From the Perspective of Ecological Niche. *J. Clean. Prod.* 252, 119711. doi:10.1016/j.jclepro.2019.119711

Pessoa, A. (2005). "Ideas" Driven Growth: the OECD Evidence. *Pej* 4 (1), 46–67. doi:10.1007/s10258-005-0040-8

Porter, M. E. (1991). Essay. *Sci. Am.* 264, 168. doi:10.1038/scientificamerican0491-168

Porter, M. E., and Linde, C. v. d. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *J. Econ. Perspect.* 9 (4), 97–118. doi:10.1257/jep.9.4.97

Qiu, L. D., Zhou, M., and Wei, X. (2018). Regulation, Innovation, and Firm Selection: The Porter Hypothesis under Monopolistic Competition. *J. Environ. Econ. Manag.* 92, 638–658. doi:10.1016/j.jeem.2017.08.012

Rassier, D. G., and Earnhart, D. (2015). Effects of Environmental Regulation on Actual and Expected Profitability. *Ecol. Econ.* 112, 129–140. doi:10.1016/j.ecolecon.2015.02.011

Rubashkina, Y., Galeotti, M., and Verdolini, E. (2015). Environmental Regulation and Competitiveness: Empirical Evidence on the Porter Hypothesis from European Manufacturing Sectors. *Energy Policy* 83, 288–300. doi:10.1016/j.enpol.2015.02.014

Shaw, S.-L., Fang, Z., Lu, S., and Tao, R. (2014). Impacts of High Speed Rail on Railroad Network Accessibility in China. *J. Transp. Geogr.* 40, 112–122. doi:10.1016/j.jtrangeo.2014.03.010

Shen, D., Xia, M., Zhang, Q., Elahi, E., Zhou, Y., and Zhang, H. (2019). The Impact of Public Appeals on the Performance of Environmental Governance in China: A Perspective of Provincial Panel Data. *J. Clean. Prod.* 231, 290–296. doi:10.1016/j.jclepro.2019.05.089

Sheng, X., Peng, B., Elahi, E., and Wei, G. (2019). Regional Convergence of Energy-Environmental Efficiency: From the Perspective of Environmental Constraints. *Environ. Sci. Pollut. Res.* 26, 25467–25475. doi:10.1007/s11356-019-05749-z

Shi, B., Feng, C., Qiu, M., and Ekeland, A. (2018). Innovation Suppression and Migration Effect: The Unintentional Consequences of Environmental Regulation. *China Econ. Rev.* 49, 1–23. doi:10.1016/j.chieco.2017.12.007

Song, M., Du, J., and Tan, K. H. (2018). Impact of Fiscal Decentralization on Green Total Factor Productivity. *Int. J. Prod. Econ.* 205, 359–367. doi:10.1016/j.ijpe.2018.09.019

Testa, F., Iraldo, F., and Frey, M. (2011). The Effect of Environmental Regulation on Firms' Competitive Performance: The Case of the Building & Construction Sector in Some EU Regions. *J. Environ. Manag.* 92 (9), 2136–2144. doi:10.1016/j.jenvman.2011.03.039

Tombe, T., and Winter, J. (2015). Environmental Policy and Misallocation: The Productivity Effect of Intensity Standards. *J. Environ. Econ. Manag.* 72, 137–163. doi:10.1016/j.jeem.2015.06.002

Tu, Y., Peng, B., Elahi, E., and Wu, W. (2020). Initiator or Intermediary? A Case Study on Network Relation of Environmental Regulatory Capture in China. *Ijerph* 17, 9152. doi:10.3390/ijerph17249152

Tu, Y., Peng, B., Wei, G., Elahi, E., and Yu, T. (2019). Regional Environmental Regulation Efficiency: Spatiotemporal Characteristics and Influencing Factors. *Environ. Sci. Pollut. Res.* 26, 37152–37161. doi:10.1007/s11356-019-06837-w

Wang, C., Wu, J., and Zhang, B. (2018). Environmental Regulation, Emissions and Productivity: Evidence from Chinese COD-Emitting Manufacturers. *J. Environ. Econ. Manag.* 92, 54–73. doi:10.1016/j.jeem.2018.08.004

Wang, F., Cai, W., and Elahi, E. (2021). Do Green Finance and Environmental Regulation Play a Crucial Role in the Reduction of CO2 Emissions? an Empirical Analysis of 126 Chinese Cities. *Sustainability* 13, 13014. doi:10.3390/su132313014

Wang, Y., Elahi, E., and Xu, L. (2019a). Selective Maintenance Optimization Modelling for Multi-State Deterioration Systems Considering Imperfect Maintenance. *IEEE Access* 7, 62759–62768. doi:10.1109/access.2019.2916624

Wang, Y., Peng, B., Wei, G., and Elahi, E. (2019b). Comprehensive Evaluation and Spatial Difference Analysis of Regional Ecological Carrying Capacity: A Case Study of the Yangtze River Urban Agglomeration. *Ijerph* 16, 3499. doi:10.3390/ijerph16183499

Wu, B., Peng, B., Wei, W., and Ehsan, E. (2021). A Comparative Analysis on the International Discourse Power Evaluation of Global Climate Governance. *Environ. Dev. Sustain.* 2021, 1–22. doi:10.1007/s10668-020-01180-4

Xie, R.-h., Yuan, Y.-j., and Huang, J.-j. (2017). Different Types of Environmental Regulations and Heterogeneous Influence on "Green" Productivity: Evidence from China. *Ecol. Econ.* 132, 104–112. doi:10.1016/j.ecolecon.2016.10.019

Yang, C.-H., Tseng, Y.-H., and Chen, C.-P. (2012). Environmental Regulations, Induced R&D, and Productivity: Evidence from Taiwan's Manufacturing Industries. *Resour. Energy Econ.* 34 (4), 514–532. doi:10.1016/j.reseneeco.2012.05.001

Yuan, B., and Xiang, Q. (2018). Environmental Regulation, Industrial Innovation and Green Development of Chinese Manufacturing: Based on an Extended CDM Model. *J. Clean. Prod.* 176, 895–908. doi:10.1016/j.jclepro.2017.12.034

Zhang, D., Rong, Z., and Ji, Q. (2019). Green Innovation and Firm Performance: Evidence from Listed Companies in China. *Resour. Conservation Recycl.* 144, 48–55. doi:10.1016/j.resconrec.2019.01.023

Zhang, H., Yang, J., Ren, X., Wu, Q., Zhou, D., and Elahi, E. (2020). How to Accommodate Curtailed Wind Power: A Comparative Analysis between the US, Germany, India and China. *Energy Strategy Rev.* 32, 100538. doi:10.1016/j.esr.2020.100538

Zhao, H., Zhao, X., Elahi, E., and Wang, F. (2022). Policy Evaluation of Drama-Related Intangible Cultural Heritage Tourism for Boosting Green Industry: An Empirical Analysis Based on Quasi-Natural Experiment. *Sustainability* 14, 5380. doi:10.3390/su14095380

Zhao, X., Peng, B., Elahi, E., Zheng, C., and Wan, A. (2020). Optimization of Chinese Coal-Fired Power Plants for Cleaner Production Using Bayesian Network. *J. Clean. Prod.* 273, 122837. doi:10.1016/j.jclepro.2020.122837

Zhao, Y., Peng, B., Elahi, E., and Wan, A. (2021). Does the Extended Producer Responsibility System Promote the Green Technological Innovation of Enterprises? an Empirical Study Based on the Difference-In-Differences Model. *J. Clean. Prod.* 319, 128631. doi:10.1016/j.jclepro.2021.128631

Zheng, C., Peng, B., Elahi, E., and Wan, A. (2020). Strategies of Haze Risk Reduction Using the Tripartite Game Model. *Complexity* 2020. doi:10.1155/2020/6474363

Zhong, Z., Peng, B., and Elahi, E. (2021). Spatial and Temporal Pattern Evolution and Influencing Factors of Energy-Environmental Efficiency: A Case Study of Yangtze River Urban Agglomeration in China. *Energy & Environ.* 32, 242–261. doi:10.1177/0958305x20923114

Zhong, Z., Peng, B., Xu, L., Andrews, A., and Elahi, E. (2020). Analysis of Regional Energy Economic Efficiency and its Influencing Factors: A Case Study of Yangtze River Urban Agglomeration. *Sustain. Energy Technol. Assessments* 41, 100784. doi:10.1016/j.seta.2020.100784

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