

## Article

# Mandatory Environmental Regulation and Green Technology Innovation: Evidence from China

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**Abstract:** Faced with the severe situation of high energy consumption and major pollutant emissions, the Chinese government has adopted various mandatory environmental regulations (MERs) to improve the binding force of environmental protection policy implementation. In 2006, the environmental protection target responsibility system was implemented, and the energy conservation and emission reduction targets were linked to the performance assessment of government officials as a binding indicator. What is the impact of this policy on green technology innovation activities? Based on this, this paper identifies the relevant indicators of green technology innovation activities. It uses the difference-in-differences (DID) method to investigate the impact of mandatory environmental regulation on the quantity and quality of green technology innovation activities. The conclusions are as follows: (1) The implementation of MERs promoted the expansion of the number of green patent applications. (2) MERs also led to the decline of the quality and the emergence of the foaming phenomenon. (3) Enterprises with weak innovation ability are the main group causing the decline of green technology innovation quality, and they are concentrated in independent innovation and low-level pollution industries. The conclusion of this paper helps provide a theoretical basis and countermeasures for deepening the reform of the MER policy, strengthening the coordination of different environmental regulation tools, and establishing a market-oriented green technology innovation system and environmental protection science and technology policy.

**Keywords:** mandatory environmental regulations; environmental protection; green technology innovation; green patent; sustainable development



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## 1. Introduction

With the global low-carbon transition, the accelerated consumption of resources and people's increasing attention to environmental protection issues, green technologies focusing on reducing resource consumption, developing renewable resources, and reducing environmental pollution have become a hot topic worldwide [1–3]. China is also facing the grim situation of high energy consumption and major pollutant emissions. The Chinese government has decided to take such tough measures as mandatory environmental regulation (MER) to achieve the goal of green development. MER, also known as command-control environmental regulation, refers to the laws, regulations, and policies on environmental protection formulated by government departments or environmental protection agencies. Mandatory is its main feature. In 2006, in the “Outline of the 11th Five Year Plan for National Economic and Social Development of the People's Republic of China”, for the first time, environmental protection indicators such as the total emission of major pollutants and the energy consumption per unit of GDP were determined as binding indicators for the performance evaluation of local officials. Local officials are the actual implementation subjects of environmental policies. They are responsible for their jurisdiction's energy conservation and emission reduction indicators. The superior competent unit will assess the completion of the indicators and announce it to the public. The assessment results will serve as an important basis for the superior government to decide on local officials'

promotion and performance assessment at all levels. Implementing this policy has made government officials pursue GDP growth and has an important impact on environmental protection. Generally, reasonably designed environmental regulations are important in promoting technological innovation. The data calculation of the BVD (Bureau van Dijk) patent database shows that China's green technology innovation activities have become more active, and the number of green patent applications has exploded. The number of green patents granted yearly has increased from 19,000 in 2008 to 184,000 in 2021. Therefore, it is necessary to explore whether the MER represented by the environmental protection target responsibility system in China will lead to the foaming of green patent applications; that is, the number of patents will increase while the quality of patents will decline.

## 2. Literature Review

The impact of environmental regulation on green technology innovation has always been a hot issue in the field of green innovation. According to the traditional neoclassical theory, increasing environmental regulation intensity will increase the overall social welfare. This will still be at the cost of increasing production costs, thus reducing the technological innovation ability of enterprises [4]. Environmental regulation can force enterprises with high energy consumption and pollution to innovate production technology, thereby improving production efficiency and reducing pollution emissions [5]. Through case analysis, it is pointed out that appropriate environmental regulation policies can stimulate enterprise innovation and enhance enterprise competitiveness [6]. Previous literature has deeply discussed the mechanism of environmental regulation affecting technological innovation. It is still worth noting that there are conflicting conclusions on whether environmental regulation can induce technological innovation.

Some studies show a significant positive correlation between environmental regulation and environmental patents [7–9]. Properly designed environmental regulations can effectively promote green technology innovation [10–15]. Some empirical studies show that environmental regulation promotes enterprise technological innovation to a certain extent [16–18]. The number of patents was used to measure technological innovation, showing that environmental regulation positively impacts technological innovation [19,20]. Environmental regulation significantly promotes the technological innovation of enterprises based on the test of the sample of Listed Companies in emerging industries [21]. The stricter the environmental regulation policy, the greater the incentive effect on the technological innovation of enterprises [22]. Higher emission tax and emission standards can promote green innovation capability improvement [23]. Environmental control measures such as subsidies and constraints can effectively stimulate enterprises to strengthen green innovation investment [24]. A reasonable level of government environmental regulation can effectively improve the overall green production level [25].

Some scholars put forward the opposite viewpoint, believing that environmental regulation will inhibit enterprises' technological innovation by increasing enterprises' cost [26–28]. A significant negative correlation exists between environmental regulation and green innovation patent production [29]. The negative impact of environmental regulation on green innovation mainly occurs in western China [30]. Some scholars also believe there is no significant relationship between environmental regulation and enterprise technological innovation [31]. The correlation between pollution reduction expenditure and environmental patents is insignificant. There was no significant correlation between environmental regulation and green technology innovation after examining the patent value data of the United States and Germany [32]. An empirical test using the data of Chinese industrial enterprises shows no evidence that implementing cleaner production standards can promote enterprise technological innovation [33]. There is no obvious correlation between environmental regulation and green innovation [34]. The impact of MER on green technology innovation is not significant [35].

These inconsistent conclusions provide two important inspirations for this paper: First, we should reasonably distinguish the types of environmental regulation, and there are

obvious differences in the impact of MER and market-oriented environmental regulation on green technology innovation. In terms of stimulating the technological innovation of enterprises, mandatory measures are inferior to market-oriented measures [36]. Although, compared with the MER, market-oriented environmental regulation can provide more flexible innovation incentives [4,37,38]. However, China's current environmental regulation policy is still dominated by command control, and local officials are the executors of the MER policy [39]. The relationship between environmental regulation policies and technological innovation of enterprises is affected by the degree of policy compulsion, and only mandatory policies have a significant relationship [40]. Second, we should identify green technological innovation from innovation activities and scientifically measure the quantity and quality of green technological innovation. Due to the data availability limitation, identifying green technology innovation is a difficult problem. The measurement indicators in the existing literature focus on indirect indicators such as R&D expenditure [41] and green productivity [42–44]. With the improvement of the availability of patent data, patent data have become a key indicator to measure innovation. Information such as the category of the technical field displayed by the patent is also conducive to identifying green patents. Therefore, more and more researchers have begun to use patent data to measure green technology innovation [11,13,14,45,46].

From the above studies, we can find that there is no unified conclusion on verifying the "Porter Hypothesis", but many scholars have tested the existence of the "Porter Hypothesis", that is, environmental regulation can induce green technology innovation. The previous literature focused on the impact of environmental regulation on the number of green patents, but there are few studies related to the quality of green patents, and there is a lack in-depth research on the impact of heterogeneous factors on green innovation induced by environmental regulation. Based on this, this paper examines the impact of MER on green technology innovation by distinguishing the quantity and quality of green patent applications. It discusses the heterogeneity of this impact on the types of application subjects, patent cooperation methods, and industrial pollution levels.

The contribution of this paper is mainly reflected in two aspects: on the one hand, it identifies the invention patents with the characteristics of green technology innovation to build relevant indicators for analyzing the quantity and quality of green technology innovation activities, measuring green technology innovation activities more scientifically, and mitigating the errors caused by data measurement. On the other hand, different from the existing studies that pay more attention to the impact of environmental policies on the quantity of green technology innovation, this paper examines the dual impact on the quantity and quality of green technology innovation. By distinguishing the quantity and quality of green patent applications, this paper examines the impact of MER, especially the target responsibility system of environmental protection implemented in 2006, on green technology innovation and discusses the heterogeneity of this impact on the type of application subject, patent cooperation mode, and industrial pollution degree. It is found that although MER significantly promotes an increase in the number of green patents, it leads to the decline of the quality of the green patents. Therefore, there is a foaming phenomenon, and the expected technical value and market value have not been generated, so there can be a patent bubble. The data are further analyzed from the perspectives of profit nature, organization mode, and industrial pollution degree and provide micro evidence and multiple explanations for the decline in the quality of green technology innovation caused by MER. The results not only provide new evidence for the phenomenon of green patent foaming in China but also help to enrich the relevant research on the evaluation of the effect of environmental regulation policies.

### 3. Research Design

#### 3.1. Data Source and Indicator Selection

The research perspectives of different studies are diverse, leading to various indicators to measure innovation activities in empirical research. This paper mainly studies the impact

of MER policies on green technology innovation. Due to the data availability limitation, identifying green technological innovation is a difficult problem. Many existing studies measure green technological innovation using indirect indicators such as R&D expenditure and green productivity. With the improvement of the availability of patent data and the in-depth mining of patent information by researchers, the advantages of patent data make it a key indicator to measure innovation. The patent documents list the categories of technical fields conducive to identifying green patents aimed at green technology. Therefore, this study also uses green patent indicators to measure green technological innovation. The database is referenced from the BVD (Bureau van Dijk: [www.bvdinfo.com](http://www.bvdinfo.com)) patent database, and more than 5.1 million invention patent applications were screened from 2002 to 2016. The IPC (International Patent Classification) information of the patent can accurately distinguish the technical field characteristics of the innovation activities and then build the experimental group and the control group, creating conditions for the use of the double difference method (DID) estimation. Moreover, by using patent data, we can measure the quantity of green technology innovation activities and the quality of green technology innovation activities by constructing the patent knowledge width index. Generally, the wider the knowledge field involved in the patent, the higher the complexity, the more difficult it is to be imitated and replaced, and the greater the market value [47].

Construction of experimental groups and control groups. Most existing studies on the environmental policy-induced innovation effect are based on the industry or regional level [45]. This paper refers to the practices of [46,48] at the level of IPC, and [49] adopted a weighted method to sum patent data into panel data. Due to the difference in the degree of the impact of the target responsibility system of environmental protection on green patents and non-green patents, the green patents are used as the experimental group, and other types of patents are used as the control group [50]. Finally, 100 experimental groups and 530 control groups were obtained. The difference test was carried out. After implementation of the policy, the number of invention patent applications in the experimental and control groups increased significantly, and the number of invention patent applications in the experimental group increased much more than that in the control group. However, the quality of invention patent applications in the experimental group decreased significantly after implementing the policy, while that in the control group increased. This difference was also statistically significant.

### 3.2. Regression Function

To effectively identify the impact of MER on green technology innovation, this paper uses DID to build the following model:

$$Patent_{i,t} = \alpha_0 + \alpha_1 green_i \times post_t + \alpha_2 green_i + \alpha_3 post_t + \delta X_{it} + \gamma_i + d_t + \varepsilon_{it} \quad (1)$$

where  $Patent_{i,t}$  indicates the quantity and quality of invention patents, subscripts  $i$  and  $t$  and correspond to the patent technology category and a year, respectively. The grouping variable  $green_i$  is a dummy variable to distinguish whether it belongs to the experimental group. If it belongs to the green technology, then  $green_i = 1$ , otherwise  $green_i = 0$ .  $post_t$  is the dummy variable before and after the implementation of the policy. If  $t$  is 2006 and later years,  $post_t = 1$ ; otherwise  $post_t = 0$ .  $X_{it}$  represents a collection of control variables, and,  $\gamma_i$  and  $d_t$  are the individual fixed effect and year fixed effect, respectively. The estimation coefficient of the cross-term  $green_i \times post_t$ ,  $\alpha_1$  is the policy effect that this paper focuses on.  $\alpha_1 > 0$  indicates that the policy promotes the growth of the quantity and quality of green patents.  $\alpha_1 < 0$  indicates that the policy suppresses the growth of the quantity and quality of green patents.  $\alpha_1 = 0$  indicates that the policy effect is not obvious.  $\varepsilon$  represents the error term, and it is assumed to be normally distributed at zero mean value and constant variance [51,52].

For testing, we selected variables that may affect green technology innovation as control variables at the enterprise level. The scale of scientific researchers (Inresearcher) is measured by the natural logarithm of the number of R&D scientific researchers. The

duration of an enterprise ( $\ln age$ ) is measured by the logarithm of its establishment years. The ownership type of an enterprise ( $owner$ ) is divided into state-owned and non-state-owned enterprises according to the nature of the enterprise. The value assigned is 1 with the ownership variable of a state-owned enterprise, otherwise 0.

To observe how the impact of MER on green technology innovation changes over time, referring to the practices of [46,50], this paper further expands model (1) to

$$Patent_{i,t} = \alpha_0 + \beta_t \sum_{t=2002,t \neq 2005}^{2016} green_i \times year_t + \gamma_i + d_t + \varepsilon_{it} \quad (2)$$

where  $year_t$  is the dummy variable of the year,  $green_i \times year_t$  is the cross-term of the grouping variable  $green_i$  and the dummy variable of the year before and after the implementation of the policy,  $\beta_t$  which indicates the policy effect of the target responsibility system of environmental protection on the quantity and quality of green patents in that year.  $\varepsilon$  represents the error term which is normally to be distributed at zero mean value and constant variance. Here, the year before the implementation of the policy (2005) is taken as the reference group.

Table 1 shows the descriptive statistical results of each variable.

**Table 1.** Descriptive statistics.

Variables	Observed Value	Mean	Standard Deviation	Minimum	Maximum
Quantity of application for invention patent	9300	2.086	1.612	0	8.080
Quality of application for invention patent	9300	0.336	0.177	0	0.668
$\ln researcher$	9300	7.275	1.298	3.971	10.872
$\ln age$	9300	2.651	0.336	1.617	3.296
Owner	9300	0.426	0.472	0	1

## 4. Results and Discussion

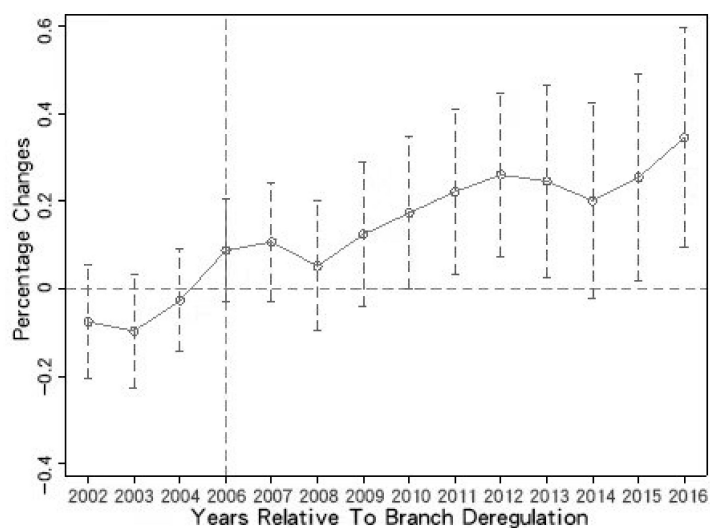
### 4.1. Benchmark Regression

The benchmark regression results are shown in Table 2. First, this paper examines the impact of the MER represented by the target responsibility system of environmental protection on the quantity of green technology innovation. The results in column (1) show that under the bidirectional fixed effect of individual and year, the estimated coefficient of  $green_i \times post_t$  is significantly positive at the level of 1%. Further, Figure 1 shows the dynamic effect of MER on the number of green innovation activities. It can be seen that the estimated coefficient of  $\beta_t$  the three years before the implementation of the target responsibility system of environmental protection, is not significant, which means that the parallel trend assumption of DID estimation is satisfied. After implementation of the target responsibility system of environmental protection, the quantity of green patent applications has increased significantly, indicating that implementing the target responsibility system of environmental protection has increased the quantity of green innovation. Secondly, the impact of the target responsibility system of environmental protection on the quality of green technology innovation is investigated. The results show that the coefficients of  $green_i \times post_t$  are significantly negative, indicating that the implementation of the target responsibility system of environmental protection inhibits the improvement of the quality of green technology innovation. The results in Figure 2 show that the estimated coefficients of  $\beta_t$  the three years before the implementation of the target responsibility system of environmental protection are not significant, meeting the parallel trend assumption, and the quality of green patents has significantly decreased since 2010.

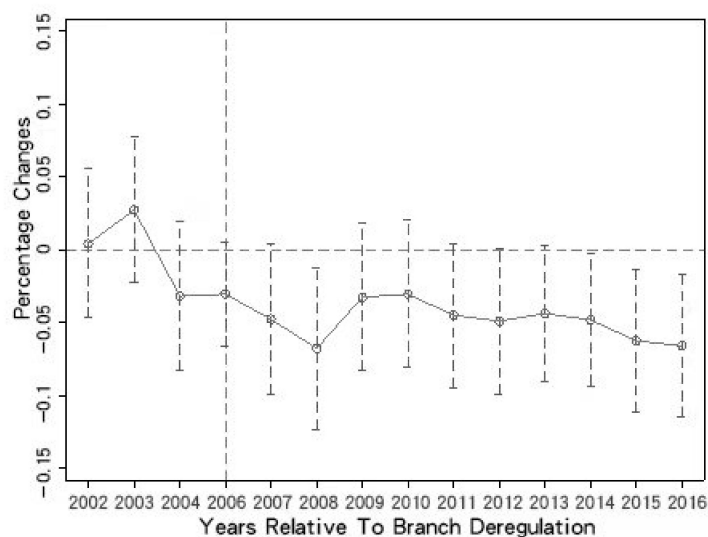
**Table 2.** Results of benchmark regression.

	Quantity of Patents	Quality of Patents
	(1)	(2)
$green_i \times post_t$	0.137 *** (1.652)	−0.042 *** (−4.128)
Inresearcher	0.043 *** (0.006)	0.039 *** (0.005)
Inage	0.215 *** (0.021)	0.352 *** (0.067)
Owner	−0.019 (0.024)	−0.023 (0.027)
Individual FE	Yes	Yes
Year FE	Yes	Yes
N	9300	9300
R <sup>2</sup>	0.581	0.015

\*\*\* represents level of significance of parameter at 10%.



**Figure 1.** The dynamic effect of the MER on the number of green patents.



**Figure 2.** The dynamic effect of the MER on the quality of green patents.



The estimation results of control variables in Table 2 showed that the coefficient of Inresearcher is positive and has passed the significance level test of 1%. The results showed that the number of R&D scientific researchers is significant and positively correlated with the quantity and quality of green patents, and the increase in R&D workers in enterprises is conducive to improving their green innovation capabilities. The increase in the age of enterprises also significantly improved their green innovation capabilities. The estimated results showed that for every 1% increase in the age of enterprises, the number and quality of green patents of enterprises increased by 0.215% and 0.352%, respectively. Although the estimated coefficient of enterprise ownership structure is negative, it is insignificant. It indicates that there is no significant difference in the number and quality of green patents between state-owned enterprises and non-state-owned enterprises.

In general, there is a time lag in the impact of MER on the quantity and quality of green innovation. In response to the assessment of the superior government on the completion of energy conservation and emission reduction indicators, local officials will take some administrative intervention measures that can achieve quick results in a short time. These administrative measures bring relatively limited environmental governance benefits, and it is difficult to achieve the environmental protection responsibility objectives. Therefore, on the one hand, local officials abide by the emission standards with the characteristics of MER, and on the other hand, try to use incentive measures to encourage green technology innovation. Enterprises facing the pressure of government environmental regulation may choose to relocate or pay fines to control pollution in the short term. They will still also be forced to carry out green technology innovations long-term.

To verify the reliability of the estimation results, this paper conducts a robustness test around the construction of patent quality indicators and other important policy impacts. To a certain extent, it can prove the reliability and non-randomness of the empirical research results.

The quality of patents is measured by the number of individuals from a country applying for a patent. A series of patents formed by applying for the same patent in different countries constitute a patent family. The higher the patent value, the more likely the inventor is to apply for patent protection in multiple countries [53]. Therefore, it can be understood that the more frequently the same patent family appears in different countries, the higher the value of the patent. This paper refers to the practice of [46] and measures the patent quality by measuring the number of patent application countries. It is found that the regression results in column (1) of Table 3 are consistent with the benchmark results.

**Table 3.** Robustness test 1.

	Patent Family	IPC Subclasses	Median
	(1)	(2)	(3)
$green_t \times post_t$	−0.109 (−2.307)	−0.083 *** (−2.717)	−0.066 *** (−4.119)
Individual FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R <sup>2</sup>	0.276	0.12	0.138
N	9300	9300	9300

\*\*\* represents level of significance of parameter at 10%.

The quality of the patent can also be measured by the scope of the technical field involved in the patent because the wider the technical field involved in the patent, the more complex the knowledge involved, and the more difficult it is to be replaced and imitated, and the higher its value [54]. Therefore, the number of IPC subclasses involved in the patent can be calculated to measure the width of its technical field. The regression results in column (2) are consistent with the benchmark results. In addition, how patent quality is aggregated may also impact the estimation results. Here, the median method is used

to replace the mean method, and the median method is used to sum the patent data for regression. The regression results in column (3) are consistent with the benchmark results.

Impact of other policies. China's central and local governments have issued various policies to encourage and subsidize patent applications. For example, the 'Outline of national intellectual property strategy' was promulgated in 2008, and the new 'Environmental protection law' was implemented in 2015. To exclude the impact of these policies on green patent applications, in Table 4. This paper adds the cross-term of grouping variables and time dummy variables in 2008 and 2015, respectively, based on model (1), and the results are still stable.

**Table 4.** Robustness test 2.

	Quantity of Patents	Quality of Patents
	(1)	(2)
$green_i \times post_t$	0.252 *** (3.142)	−0.045 *** (−3.564)
$green_i \times post_{2008}$	−0.150 ** (−2.052)	−0.023 (−1.395)
$green_i \times post_{2015}$	−0.001 (−0.023)	−0.003 (−0.264)
Individual FE	Yes	Yes
Year FE	Yes	Yes
N	9300	9300
R <sup>2</sup>	0.673	0.135

\*\* and \*\*\* represents level of significance of parameters at 5%, and 10%, respectively.

## 4.2. Heterogeneity Analysis

### 4.2.1. Profit and Non-Profit Organizations

Enterprises, colleges, and scientific research institutions are the main technological innovation groups, but their innovation activities show significant differences in many aspects. Unlike colleges and scientific research institutes, profit-making is the main purpose for enterprises to carry out technological innovation. Enterprises are the main implementation targets, whether mandatory pollutant emission standards or the incentive tax relief. This paper divides the main body of technological innovation into enterprises, colleges, and scientific research institutes and then tests the heterogeneous impact of the MER on green technological innovation. In columns (1) and (3) of Table 5, the quantity of patent applications is taken as the dependent variable, and the coefficients of  $green_i \times post_t$  are significantly positive; in columns (2) and (4), the quality of the patent application is taken as the dependent variable, and the coefficient of  $green_i \times post_t$  is only significantly negative in the regression result in column (2). This shows that the MER has played a significant role in increasing the number of green patent applications, but it has reduced the quality of green patent applications of enterprises and has no significant impact on the quality of green patents of colleges.

**Table 5.** Profit and non-profit organizations.

	Enterprises		Colleges and Scientific Research Institutions	
	Quantity of Patents (1)	Quality of Patents (2)	Quantity of Patents (3)	Quality of Patents (4)
$green_i \times post_t$	0.178 *** (2.720)	−0.035 ** (−2.283)	0.304 *** (3.847)	−0.017 (−1.012)
FE	Yes	Yes	Yes	Yes
N	9300	9300	9300	9300
R <sup>2</sup>	0.448	0.1	0.538	0.209

\*\* and \*\*\* represents level of significance of parameters at 5%, and 10%, respectively.



#### 4.2.2. Cooperative Innovation and Independent Innovation

Cooperation and independence are two common forms of innovation activities. Independent innovation is obviously a better choice when enterprises implement innovation activities to obtain more benefits, such as subsidies and tax cuts. Because the enterprise entirely decides the investment in technological innovation, the enterprise also enjoys income. For cooperation, implementing innovation activities will face many uncertainties brought by cooperation and the distribution of potential benefits. According to the information of patent applicants, this paper compares the patent construction sub-samples of individual applicants and joint applicants (two or more) to investigate further the heterogeneity of the organizational form of the impact of MER on the quality of green technology innovation activities.

As shown, for the coefficients of  $green_i \times post_t$  in columns (2) and (4) of Table 6, the former is not significant, while the latter is significantly negative. This means that the MER has a significant negative impact on the quality of green patents applied individually but has no significant impact on the quality of green patents applied jointly. In addition, the promotion effect of the MER on the number of green patents is supported in the samples of cooperative applications and individual applications.

**Table 6.** Cooperative innovation and independent innovation.

	Cooperative Innovation		Independent Innovation	
	Quantity of Patents (1)	Quality of Patents (2)	Quantity of Patents (3)	Quality of Patents (4)
$green_i \times post_t$	0.315 *** (3.284)	0.014 (0.914)	0.236 *** (3.012)	−0.048 *** (−3.766)
FE	Yes	Yes	Yes	Yes
N	9300	9300	9300	9300
R <sup>2</sup>	0.576	0.369	0.656	0.133

\*\*\* represents level of significance of parameter at 10%.

#### 4.2.3. High-Level Pollution Industry and Low-Level Pollution Industry

The implementation of MER has greater cost pressure on high-level pollution industries. The motivation of green technology innovation is mostly to improve the efficiency of green technology products and reduce pollution emissions. The low-level pollution industry has less pressure on emission reduction and carries out green innovation to create an environmental protection image. This paper identifies the patents included in different industries. It divides them into high-level pollution industries and low-level pollution industries according to the pollution intensity of the industries to investigate the heterogeneity of the impact of the MER on green technology innovation in industries with different pollution densities. Table 7 reports the corresponding regression results. From the number of patent applications, the coefficient of  $green_i \times post_t$  is significantly positive; from the quality of patent application, the coefficient of  $green_i \times post_t$  is significantly negative only in the low-level pollution industry. This indicates that the MER promotes an increase in green patent applications in industries with different pollution intensities, but only has a significant negative impact on the quality of green patent applications in industries with low-level pollution.

**Table 7.** Industries with different pollution intensities.

	High-Level Pollution Industry		Low-Level Pollution Industry	
	Quantity of Patents (1)	Quality of Patents (2)	Quantity of Patents (3)	Quality of Patents (4)
$green_i \times post_t$	0.193 *** (2.827)	−0.026 (−2.034)	0.187 *** (2.837)	−0.036 *** (−2.915)
FE	Yes	Yes	Yes	Yes
N	9300	9300	9300	9300
R <sup>2</sup>	0.608	0.156	0.647	0.107

\*\*\* represents level of significance of parameter at 10%.

## 5. Conclusions and Policy Implications

This paper constructs the quantity and quality indicators of green innovation activities based on patent data. It empirically tests the impact of the MER represented by the target responsibility system of environmental protection on green technology innovation. The results show that the MER significantly promotes the quantity of green patent applications, but to a certain extent, it negatively impacts the quality of green innovation activities. There is a certain time lag in the impact of the MER on green patents. In the short term, it does not significantly impact the quantity and quality of green patents. In the long term, it promotes an increase in the number of green patents and reduces the quality of green patents. The policy effect of the MER on green patents is heterogeneous according to the profit-making nature, innovation ability, organization mode of innovation activities, and industrial pollution intensity of patent applicants. Based on the above research conclusions, the policy implications of this paper are as follows:

- The MER includes environmental protection performance in the performance assessment of local officials, which has a strong binding force on local officials, thus providing political incentives for them to control environmental pollution. The results also show that the MER promotes an increase in the number of green patents in the whole society and has a positive impact. Therefore, in the future, the proportion of environmental protection performance in the performance assessment of local officials should be increased, and the lifelong tracking system of environmental protection responsibility should be implemented. In addition, it is suggested to increase the assessment proportion of research and development and the promotion of green technologies and encourage local governments to control environmental pollution actively.
- Local governments should formulate reasonable environmental protection science and technology policies. On the one hand, we should give full play to the supporting role of financial subsidies, tax relief and other incentives, stimulate the enthusiasm of the whole society for green technology innovation, and achieve an increase in the quantity of green technology innovation; On the other hand, we should strengthen the evaluation of the quality of green patents, identify high-value green technologies, take the quality of green patents as an important standard for policy support and provide financial support, and give full play to the positive role of green technology innovation in environmental protection.
- We should promote the coordination of different environmental regulation tools and establish various environmental regulation systems. Unlike the MER, market-oriented environmental regulation emphasizes the autonomy of enterprises and encourages enterprises to choose emission reduction tools voluntarily and flexibly. However, when Chinese enterprises still lack green development awareness, they should focus on the MER, with step-wise promotion of the application of market-oriented environmental regulation, and give full play to the role of different environmental regulation tools in inducing green technology innovation.
- We should formulate differentiated environmental regulation policies according to different enterprises to achieve accurate positioning of policies. The results of this

study show that the impact of the MER on green technology innovation is different due to different factors such as innovation capacity, profit-making nature, and industrial pollution intensity. Therefore, when formulating specific environmental regulation policies, local governments should fully consider the heterogeneity of enterprises and put forward regulation policies according to the different characteristics of enterprises instead of adopting a “one size fits all” approach.

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