

# The Impact of Mandatory Environmental Information Disclosure and the Green Innovation of Pollution-Intensive Companies? Evidence From China

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## Research Article

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# Abstract

Based on the Guidelines of the Shanghai Stock Exchange on Environmental Information Disclosure for Listed Companies issued in 2008, this paper constructs a quasi-natural experiment and uses the did method to study the impact of mandatory environmental information disclosure on the green innovation of pollution-intensive companies in China. The results show that mandatory environmental information disclosure can significantly promote the green innovation of pollution-intensive companies by strengthening the company's motivation and pressure to comply with the regulation; in addition, the positive effect is more obvious in state-owned companies, small companies and companies with poor information condition in pollution-intensive industries. This paper enriches the literature of mandatory environmental information disclosure and offers guidance for policymakers seeking to improve environmental information disclosure policies in emerging countries.

## Introduction

Since the reform and opening up for 40 years, China's economy has made remarkable achievements, and companies have also made great progress in transforming the traditional pattern of economic growth. However, the extensive economic growth mode is still obvious, which brings serious ecological and environmental problems. As the main producers of pollution, many companies just focus on short-term interests, blindly pursue the maximization of interests. The lack of environmental responsibility has seriously affected the life of people, and restricted the sustainable development of China's economy. In order to urge companies to fulfill their environmental responsibilities, the Chinese government has issued a series of laws and regulations in recent years. However, due to the different interest between the central and local governments, these policies have not achieved the expected effect and the proportion and quality of corporate environmental information disclosure is still poor. Control environmental pollution has become an important prerequisite for the sustainable development of China. In this context, the Shanghai Stock Exchange issued the guidelines on environmental information disclosure of listed companies on the Shanghai Stock Exchange (Guideline hereafter) in 2008, which requires companies listed in Shanghai Stock Exchange to disclose their environmental information.

Company transform through green innovation is an important way for the long-term economic development of the country, and also an effective way to promote the green development of the company. (Xiong et al. 2020) According to the institutional theory, the original driver of corporate innovation is institutional pressure (Bansal 2005), such as environmental regulation implemented by the government. As an important part of environmental regulation, although the mandatory environmental information disclosure (MEID hereafter) has been implemented in China for a period of time, can it promote the innovation of companies? It's still not clear. At present, there are two different views on the advantages and disadvantages of environmental information disclosure. On the one hand, based on the signaling theory, environmental information disclosure can alleviate the information asymmetry of companies (He et al. 2012), improve the social reputation of companies, and companies can obtain more financing opportunities and improve their economic performance (Li et al. 2013). On the other hand,

based on the agency theory, environmental information disclosure is the self-interest behavior of management to cover up the negative news of companies(Tian &Wang 2017). There are few literatures on the effectiveness of MEID from the perspective of corporate innovation. In addition, the extant articles mainly focus on the developed countries, such as the United States, less in the context of developing countries. In order to fill the above gaps, this paper studies the impact of MEID on corporate green innovation in the largest developing country, China.

In this paper, we aim to address the following two questions: will the MEID promote or hamper the green innovation of pollution-intensive companies? What factors affect the effect of MEID on corporate green innovation? Our sample are the companies in pollution-intensive industries listed on the A-shares of the Shanghai Stock Exchange and Shenzhen Stock Exchange between 2007and 2016. Specifically, we use the pollution-intensive companies listed in the Shanghai Stock Exchange as the treatment group while those listed on the Shenzhen Stock Exchange, which are not subject to similar disclosure regulations, as the control group. Employing a did model, we examine the impact of MEID on corporate green innovation based on manually collected patent data. The results show that: MEID significantly promote the green innovation of pollution-intensive companies; in addition, the positive impact of mandatory environmental information disclosure is more obvious in the poor information environment, state-owned companies and small companies in pollution-intensive industries. We also conduct various supplementary analyses to show our results are robust.

Our study makes several contributions to the literature. First, this paper focuses on the impact of MEID on pollution-intensive corporate innovation, provides empirical evidence for the effectiveness of MEID, and enriches the research on the MEID policy; Second, the extant literatures on the influence factors of corporate green innovation pay less attention to the mandatory environmental information disclosure. This paper explores the impact of MEID on corporate green innovation on the base of the implementation of the Guidelines, provides a new perspective for the research on the influence factors of corporate innovation; Third, this paper studies the heterogeneity of the impact of MEID from the aspects of information environment, property nature and company scale, which has a guidance for China and other countries to improve the environmental regulation to promote green innovation of different companies and protect environment; Fourthly, this paper takes China as the background to fill the gap that previous literatures mainly focus on the United States and other developed countries but lack of evidence from developing countries.

The reminder of this paper is arranged as follows. Section 2.1 looks at the institutional setting, Sect. 2.2 offers the literature reviews, followed by the research hypothesis in Sect. 2.3 ; Sect. 3 presents the research design, and describes the data and methods used in the paper; Sect. 4, tests the impact of MEID on the green innovation of pollution- intensive companies; then, analyzes the impact of MEID on the green innovation of pollution-intensive companies in the good information environment and the poor information environment, state-owned companies. Section5 is the robustness test. Conclusion and discussion are given in Sect. 6.

# Literature Review And Hypothesis Development

## Institutional background

Since the 1970s, China has promulgated a series of environmental protection laws and regulations, such as the environmental protection law of the people's Republic of China, in which there are few provisions on company environmental information disclosure. Until the beginning of this century, the Chinese government began to pay attention to the environmental information disclosure of listed companies. In 2001, the former State Environmental Protection Administration issued the Notice on environmental protection inspection of listed companies, which encouraged listed companies to actively disclose environmental information. In 2007, China issued the document Environmental Information Disclosure Measures, which is the first department regulation of environmental information disclosure. However, at that time, the environmental information disclosure was mainly voluntary, and the disclosure level was poor, which created opportunities for companies to hide environmental pollution information and increased the cost of government supervision.

With the increasing attention to economic and environmental sustainability in the world, companies are required to pay more attention to their environmental social responsibility. In China, the lack of environmental social responsibility has become a shocking problem (Chen et al. 2018). In order to cope with the public concern about environmental problems, the Chinese government has taken many measures to encourage companies to undertake their responsibility. For example, 1. China's Company Law 2006 requires companies to undertake social responsibility in the process of practical work; 2. The Green Credit Guide issued by China Banking Regulatory Commission links bank financing with CSR performance of companies; 3. Establish the blacklist of Environmental Protection Bureau in China's Ministry of environmental protection, and blacklist the companies with serious pollution ; 4. Use newspapers and other media to award a honorary titles to the companies that actively perform social responsibility. In addition, in order to ensure the openness and transparency of companies' environmental social responsibility, the Shanghai Stock Exchange issued the Guidelines on Environmental Information Disclosure of Listed Companies in Shanghai Stock Exchange in 2008, which requires all companies listed on the Shanghai Stock Exchange to disclose environmental information in their reports, including quantitative indicators such as environmental protection investment, technology development and environmental protection performance, as well as the information of the national standards, historical situation, environmental levels between industries and other aspects of the detailed requirements.

Due to the external nature of the MEID policy for a single company, we use the policy issued by Shanghai Stock Exchange in 2008 as a quasi-natural experiment to test the green innovation of experimental companies (mandatory environmental information disclosure companies) and control companies (other companies) before and after the policy.

## Literature review

China has experienced impressive economic growth since the economic reforms in the late 1970s. To speed up industrialization, economic development was prioritized, with all related social and environmental issues being pushed back. Ip (2009) describes the essence of Deng Xiaoping's economic reform in the 1990s as the 'culture of profit', where to pursue profit at any cost. Such a philosophy has inevitably caused unbalanced growth in China, resulting in significant social and environmental costs (Kolk et al. 2009). A heavily polluted environment has become alarming issues, which may even further threaten social stability, and companies are the main producers of environmental pollution. In this case, the Shanghai Stock Exchange issued a policy in 2008, requiring all pollution intensive companies listed here to release environmental information.

At present, scholars have carried out an intense discussion on the advantages and disadvantages of environmental information disclosure. Based on the signaling theory, some scholars believe that shareholders, investors and other stakeholders regard corporate environmental behavior as an indicator of risk management and financial responsibility, and environmental information disclosure can increase the transparency of companies in environmental protection, thus affecting their behavioral decision-making (Hamilton 1995). Inoue (2016) found that environmental information disclosure can improve the communication between companies and other stakeholders, stimulate companies to expand the scope of information disclosure, and increase their innovation activities. Plumlee et al. (2015) found that the quality of environmental information disclosure helps to enhance value of companies by improving the cash flow and reducing the cost of equity capital. They believe that environmental information disclosure can create indispensable conditions for companies to implement innovation strategy by improving the legitimacy of companies, passing information and enhancing the understanding, support and trust of stakeholders (Zhao & Meng 2016). Balla et al. (2018) studied the relationship between the legitimacy of environmental protection agencies and ecological innovation in the UK and Ireland, emphasizing that environmental protection agencies use incentive schemes and voluntary agreements to establish a trust relationship with regulated companies, so as to promote ecological innovation.

Other scholars hold different opinions. On the one hand, from the perspective of management self-interest, they believe that when the company discloses environmental information, managers may choose to provide private interests rather than social interests of corporate environmental social responsibility activities (Friedman 1970). In addition, environmental information disclosure also has the negative effect of improving the degree of information asymmetry. Corporate social responsibility information disclosure will divert the attention of information users to cover up negative information such as poor financial performance (Hemingway & Maclagan 2004). Taking A-share listed companies from 2008 to 2012 as samples, Quan et al. (2015) found that the disclosure of social responsibility information reduced the information transparency and increased the property hoarding of manager. On the other hand, they believe that the goal of the company is to create profits, so any activity to fulfill corporate social responsibility is an obstacle to achieve the goal of maximizing profits. Ren et al. (2020) found that environmental information disclosure will consume limited resources of companies, which will have a negative impact on the economic performance. However, Marshall et al showed that the relationship

between environmental information disclosure and company value is not significant (Marshall et al. 2009).

Therefore, if environmental information disclosure can increase information transparency and alleviate the problem of information asymmetry, MEID could also drive corporate innovation as an important environmental regulatory tool of information disclosure (Wang & Ning 2020). Yu et al. (2019) found that environmental regulation, taking environmental law enforcement and supervision as an example, drives the green transformation of company by increasing emission costs, reducing company operation efficiency and increasing punishment. Wang and Ning also support that mandatory social responsibility disclosure can drive company transformation. By studying resource-based companies in China, Li et al. (2020) found that environmental regulation can improve technological innovation of these companies. The research of Zhang and Ge suggest that the innovation level of companies undertaking the obligation of MEID has been significantly improved (Zhang & Ge 2021). On the contrary, if environmental information disclosure increases the degree of information asymmetry of company, then MEID cannot be regarded as an appropriate, strict and effective environmental regulation policy, so it cannot drive company innovation (Porter & Linda 1995).

In general, the extant research on the economic consequences of environmental information disclosure is scattered and uncoordinated. In addition, most of the existing research is from a macro perspective, and the research about the impact of MEID on green innovation is scarce, especially in developing countries. As an important part of environmental regulation, whether the MEID can drive the green innovation of pollution-intensive companies is not only related to the transformation of companies, but also helps to provide guidance for solving ecological problems, protecting environment and achieving sustainability. It is of great significance to study the impact of MEID on corporate green innovation.

## **Hypothesis development**

Companies is becoming the main maker of environmental pollution in China. To achieve sustainable development of environment, the key lies in promoting green innovation of companies, improving their production mode and emission mode, and realizing the transformation of companies. However, due to the uncertainty and long cycle of company innovation, the ability and willingness of enterprises to carry out green innovation actively are often insufficient (Jin et al. 2019). MEID can increase the transparency of information, enable the government, investors and other stakeholders to supervise the environmental behavior of companies more easily. That is to say, the environmental information of companies is subject to the dual supervision of the government law enforcement departments and the capital market at the same time, which makes the environmental externality of companies internalized, and forces companies to change their environmental governance strategies, from passive governance to active innovation and transformation (Guo 2019). According to legitimacy theory, legitimacy is crucial to the survival and development of companies, because it enables the company to obtain the support of various stakeholders (such as suppliers, distributors, customers and the government), so ensures the continuous flow of external resources into the company. As the main producers of pollution, the legitimacy of companies will be questioned. Therefore, they have reason and motivation to take positive strategies to

obtain legitimacy recognition (Shen et al. 2014). For this reason, in China, MEID promotes corporate green innovation through two ways:

On the one hand, MEID will affect corporate reputation and cost of capital, because this information will be concerned by investors in China's capital market. If a company cannot abide by the contract with stakeholders, but cause serious environmental pollution to the society, stakeholders (including public) will try to protect their own living environment. For example, for companies with poor environmental performance, investors often "vote with their feet" to deal with the punishment and litigation risk brought by environmental pollution through risk premium or investment reduction, which makes companies face higher financing cost (Doshi et al. 2013). Therefore, companies have the motivation to adopt a positive environmental governance strategy such as green innovation to prove the legitimacy of their business activities and obtain the trust of external stakeholders, so as to ensure that companies have sufficient resources for development.

On the other hand, the companies that are required to disclose environmental information may cause the local government and environmental protection departments to supervise more strictly, and impose more severe fines on their environmental pollution behaviors, which will increase the cost of environmental violations. In the Guidelines issued by Shanghai Stock Exchange, companies are required to disclose their environmental information, and the contents disclosed are specified and explained in detail. As a kind of government environmental regulation, MEID can form a strong institutional pressure on disclosure pollution intensive companies, restrain the opportunistic behavior of companies to evade environmental regulation, and promote them to obtain legitimacy by adapting to the environment and external institutional pressure (E 1999). Therefore, the companies have the motivation to carry out innovative activities, realize their own transformation and reduce environmental pollution so as to avoid high fines or litigation costs. Therefore, this paper proposes:

**Hypothesis 1a** MEID can promote the green innovation of pollution-intensive companies.

However, according to the principal-agent theory, managers may cover up corporate misconduct by undertaking environmental information disclosure for their own interests (Du & Wang 2021). Environmental information disclosure may have a "cover up effect" and become a means of self-interest for managers. In other words, managers may package companies as environmental protection companies and enhance their reputation through inefficient investment, which reduces the information transparency of the capital market. Specifically, MEID not only requires pollution intensive companies to disclose quantitative information such as pollution level and improvement effect, but also requires detailed disclosure of measures implemented by companies in environmental protection investment, technology development and environmental protection facilities construction. Some managers of pollution intensive enterprises may use inefficient green R&D investment, environmental protection facilities investment and other ways to "shape" the corporate image and enhance their personal reputation of managers. In this case, MEID becomes a tool for companies to whitewash themselves and cover up negative information. So, although companies have invested in environmental protection, it is

difficult to form new innovation products, because most of these are inefficient investments for the purpose of "tools", which wasting the resources to truly realize green innovation. Therefore, this paper proposes:

**Hypothesis 1b.** MEID cannot promote the green innovation of pollution-intensive companies.

The effect of MEID on company green innovation may be affected by the information condition of the company. When the company's information condition is poor, the degree of information asymmetry is high, so it is difficult for the market to supervise and guarantee the behavior related to environment of a company. In this case, the MEID can improve information transparency and form institutional pressure on enterprises. From the perspective of normative legitimacy, in order to respond to the external requirements of the environment protection, enterprises will be more motivated to take positive strategies. On the contrary, when the company information condition is better, its own behavior will be concerned by all walks of life. Therefore, the effect of using some mandatory policy to influence enterprise will be weakened. Therefore, this paper proposes:

**Hypothesis 2** Compared with the companies with better information condition, companies with poor information condition exhibit more increase in green innovation subsequent to the MEID.

The effect of MEID on corporate green innovation may be affected by the nature of property rights. At present, researches abroad and in China basically support a positive correlation between the nature of company ownership and environmental information disclosure. For example, Stephen (1998) studied 49 listed companies in Zimbabwe and found that ownership structure has a significant positive effect on MEID. From the perspective of Chinese situation, first of all, state-owned companies often bear the goal of government utility. When they are required to disclose company environmental information, they feel more pressure and need to realize their commitment to corporate social responsibility. Secondly, the performance evaluation of the managers in charge of the state-owned company is often linked with the implementation of national policies and social responsibility. At the same time, state-owned company's manager has their own pursuit of political interests, so they are more willing to take actions that meet the expectations of the government, such as fulfilling their environmental and social responsibilities (Lu et al. 2012). Therefore, the driving effect of MEID on company green innovation is more obvious. By contrast, it's not necessary for private companies to pursue political connections, so they will not actively carry out green innovation when facing the requirements of MEID. Therefore, this paper proposes:

**Hypothesis 3** Compared with non-state-owned companies, MEID has more obvious driving effect on green innovation of state-owned companies.

The effect of MEID on corporate green innovation may be affected by company scale. Based on the analysis of legitimacy theory, in the face of external pressure brought by compulsory environmental information disclosure, small companies will be more active in innovation than large enterprises with abundant resources. On the one hand, they need to obtain the recognition of government, so as to get the right to develop or use natural resources; on the other hand, active innovation for transformation can

transmit positive information to the market, get the trust of investors by catering to the widely accepted values and ethics of the society, and reduce the cost of capital. In contrast, large companies have enough resources and development opportunities, they may not be able to take the initiative to carry out green innovation when facing the pressure of environmental regulation. Therefore, this paper proposes:

**Hypothesis 4** Compared with large companies, the driving effect of MEID on green innovation is more obvious in small companies.

## Materials And Methods

### Sample and data sources

This paper selected the pollution-intensive companies listed on Shanghai Stock Exchange and Shenzhen Stock Exchange from 2007 to 2016 as the initial sample. According to the guidelines of Shanghai Stock Exchange, this paper takes the pollution-intensive companies listed on Shanghai Stock Exchange as the treatment group sample, and the pollution intensive companies listed on Shenzhen Stock Exchange as the control group sample (Yang et al. 2019). In order to ensure the timeliness and quality of the data, this paper conduct the following screening and pretreatments:

- a. exclude ST and \* ST companies to ensure the stability and effectiveness of the samples;
- b. exclude companies listed after 2007 or companies delisted during the sample period;
- c. exclude companies with incomplete or missing data.

Finally, this paper obtained 3560; observations from three companies, of which 2230 were in the treatment group and 1330 were in the control group.

For the identification of pollution intensive companies, referring to the classification in the second national pollution source survey plan of the State Council in 2017, this paper classified classifies 13 industries, including agricultural and sideline food processing industry, chemical raw materials and chemical products manufacturing industry, textile industry, automobile manufacturing industry, metal products industry, petroleum, coal and other fuel processing industry, ferrous metal smelting and rolling processing industry, and non-ferrous metal processing industry It belongs to 13 industries, including mining and dressing industry, non-ferrous metal smelting and rolling processing industry, electric power, heat production and supply industry, non-metallic mineral products industry, coal mining and washing industry, rubber and plastic products industry, which is defined as pollution intensive industry.

From the official website of the State Intellectual Property Office, this paper takes the IPC listed in the green list of International Patent Classification issued by the World Intellectual Property Organization (WIPO) as a keyword, using the natural logarithm of the number of green patents granted as a measure of the green innovation of company.

The data in this paper are mainly from Accounting Research (CSMAR) databases. To gain the list of companies with MEID, we collected according to the websites of Shanghai Stock Exchange and Shenzhen Stock Exchange manually. In addition, in order to avoid the impact of extreme value on the empirical results, this paper winsorizes all continuous variables at the top and bottom 1% of their distributions. Table 1 shows the distribution of samples by industry, in which the proportion of each industry in the treatment group and the control group is similar.

Table 1  
Distribution of treatment group and control group by industry sector.

Industry	Total	Treatment group	Treatment%	Control group	Control%
B06	196	143	6.41%	53	3.96%
B09	67	58	2.60%	9	0.67%
C13	109	45	2.02%	64	4.78%
C17	174	115	5.16%	59	4.40%
C25	114	66	2.96%	48	3.58%
C26	664	412	18.48%	252	18.81%
C27	624	404	18.12%	220	16.42%
C30	267	187	8.39%	80	5.97%
C31	227	147	6.59%	80	5.97%
C32	253	153	6.86%	100	7.46%
C33	94	45	2.02%	49	3.66%
C36	274	160	7.17%	114	8.51%
D44	507	295	13.23%	212	15.82%
Total	3560	2230	100.00%	1340	100.00%

## Models and variables

To investigate the impact of MEID on the green innovation of pollution-intensive companies, this paper constructs a did model as follow (Yu et al. 2020, Zeng et al. 2016):

$$NewP_{it} = \alpha_1 + \alpha_2 Treat_{it} + \alpha_3 After_{it} + \alpha_4 Treat * After_{it} + \gamma Control_{it} + \beta Year + \eta + \varepsilon_{it}$$

Where NEWP refers to the green innovation level of the company, which is measured by natural logarithm of the number of green patents granted. Treat refers to a dummy variable. If a company comes from Shanghai Stock Exchange, it is equal to 1, otherwise it is equal to 0. After is the time dummy variable. If the year is after 2008, it is equal to 1, otherwise it is equal to 0. Control refers to the control variable.

Referring to the existing literature, the model introduces the following control variables: Size, LEV, SOE, Board, Inboard, Growth, ROA and Cash. Year and industry represent the annual effect and industry effect respectively;  $e$  is random error term;  $i$  is company and  $t$  is year. Specific variables are defined as follows:

- a. Explained variable: green innovation level (NEWP): Referring to and Meng's method (Meng et al. 2019), this paper used the natural logarithm of the number of green patents granted to measure the green innovation level on the base of the existing research and data availability.
- b. Explained variable: mandatory environmental information disclosure (Treat, After): With the help of the Guidelines on environmental information disclosure of listed companies in Shanghai Stock Exchange issued in 2008, we take the pollution intensive companies listed in Shanghai Stock Exchange as the experimental group and the pollution intensive companies listed in Shenzhen Stock Exchange as the control group. Specifically, we constructs the spatial dummy variable (Treat), the time dummy variable (After) and the interaction between them (Treat  $\times$  After), where Treat represents the spatial dummy variable, if the company belongs to the pollution intensive company of Shanghai Stock Exchange, the value is 1, otherwise it is 0; After represents the time dummy variable, if the year is after the promulgation of the guidelines, that is, the year after 2008, the value is assigned to 1, otherwise it is 0; Treat  $\times$  After represents the interaction item, which is the intersection of the spatial dummy variable and the temporal dummy variable. This paper will focus on the coefficient of Treat  $\times$  After, if it is positive and significant, it means that MEID can significantly promote the innovation of pollution intensive companies.
- c. Controls: Based on the research of (Li et al. 2018) and (Shen & Zhou 2017), we control the following variables: (1) SIZE is the natural logarithm of total assets; (2) LEV is the proportion of total liabilities to total assets; (3) ROA is net income divided by total assets at the fiscal year end. (4) SOE is a dummy variable, if the state-owned companies is 1, otherwise 0; (5) BOARDS is the Board Size, which is measured by natural logarithm of the number of directors; (6) INBOARD is the proportion of Independent Directors, which is measured by the proportion of the number of independent directors in the number of directors; (7) GROWTH is the growth rate of operating revenue; (8) CASH is to the proportion of monetary capital in the total assets.
- d. Year is the annual dummy variable, and Industry is the industry dummy variable;  $e$  is the random error term.

## Results And Discussion

### Descriptive statistics

The descriptive statistical of the variables are presented in Table 2. In our sample, the mean of green innovation level (NEWP) is 1.617, the minimum of it is 0, the maximum of it is 8.915, the median of it is 1.386. There is a big difference between the minimum and the maximum, and the standard deviation is 1.735, which indicates that there is a certain difference in corporate green innovation. The mean of Treat is 0.625, which means 62.5% of companies require mandatory disclosure of environmental information;

the mean of After is 0.8, which means that the sample after the implementation year accounts for 80% of the total sample. The standard deviation of the spatial dummy variable (Treat) and the temporal dummy variable (After) is less than 1.000, and the fluctuation is small. In terms of control variables, except the standard deviation of Size is greater than 1.000, the standard deviations of other control variables are less than 1.000, and the fluctuation is small. All variables are in a reasonable range.

Table 2  
Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	1/4	Median	3/4	Max
NEWP	3560	1.639	1.737	0.000	0.000	1.386	2.890	8.915
Treat	3560	0.625	0.484	0.000	0.000	1.000	1.000	1.000
After	3560	0.800	0.400	0.000	1.000	1.000	1.000	1.000
LEV	3560	0.555	0.394	0.010	0.400	0.550	0.680	12.130
ROA	3560	0.033	0.088	-0.918	0.005	0.027	0.065	1.202
SIZE	3560	22.450	1.395	17.049	21.425	22.358	23.368	27.104
GROWTH	3560	0.149	0.417	-0.492	-0.052	0.091	0.240	2.771
CASH	3560	0.135	0.101	0.000	0.065	0.109	0.176	0.853
SOS	3560	0.704	0.456	0.000	0.000	1.000	1.000	1.000
BOARD	3560	2.189	0.257	0.000	2.197	2.197	2.197	2.890
INBOARD	3560	0.363	0.057	0.000	0.333	0.375	0.333	0.714
FOLLOW	3560	1.457	1.190	0.000	0.000	0.000	2.485	4.060

## Uni-variate analysis

Uni-variate test results are reported in Table 3. It shows that, firstly, on the whole, after the promulgation of the guidelines, the number of patents granted in pollution-intensive companies increased from 0.811 to 1.846. There was an increase of 1.035 units, and it was significant at the level of 1%; Secondly, the number of patents granted in the treatment group increased from 0.847 to 1.937, an increase of 1.13 units, while that in the control group increased from 0.751 to 1.628, an increase of 0.877 units. Especially after the promulgation of the guidelines, there is a significant difference in the number of patents granted between the treatment group and the control group.

Table 3  
Uni-variate test

Uni-variate test result(t value)					
Variables	Year	Average			Diff
		Full sample	Treatment group	Control group	
		(1)	(2)	(3)	(2)-(3)
NEWP_pre	2007–2008	0.811	0.847	0.751	0.101 (0.991)
NEWP_after	2009–2016	1.846	1.977	1.628	0.346*** (5.023)
NEWP_ave	2007–2016	1.035*** (14.662)	1.130*** (12.656)	0.877*** (7.682)	0.294*** (4.904)
Diff = the number of patents granted in the treatment group - the number of patents granted in the control group.					
* p < 0.1, ** p < 0.05, *** p < 0.01.					

It can be seen that the green innovation level of the treatment group has improved after being required to disclose environmental information, which provides preliminary evidence for hypothesis 1.

## Empirical regression results

Parallel trend is an important premise of double difference estimation. In this paper, parallel trend test is carried out first. The results are shown in Fig. 1. Before the Guidelines was issued, the number of patent authorization maintained the same level and trend between the treatment group and the control group; After the implementation of the Guidelines in 2008, the trend showed changes, and the increase of the number of patents granted in the treatment group was higher than that in the control group obviously. This result has passed the parallel trend test, which indicates that the did model is effective for this paper.

Based on the panel data of China's pollution intensive industries, this paper uses Stata 14.0 software to test the correlation among the variables of the (1) model. Table 4 reports the impact of mandatory environmental information disclosure on corporate green innovation. Without controlling other variables, the coefficient of the Treat \*After is 0.241, which is significant at the 5% level; with controlling other variables, the coefficient of Treat \* After is 0.223, which is also significant at the 5% level.

Table 4  
Test results of the impact of MEID on corporate green innovation

Explanatory variable	Explained variable: corporate green innovation (NEWP)	
	(1)	(2)
Treat	0.104 (1.03)	0.120 (1.39)
After	0.894 <sup>***</sup> (9.27)	0.828 <sup>***</sup> (7.31)
Treat*After	0.230 <sup>*</sup> (1.88)	0.216 <sup>**</sup> (2.15)
LEV		-0.628 <sup>***</sup> (-5.37)
ROA		1.070 <sup>***</sup> (3.05)
GROWTH		-0.210 <sup>***</sup> (-3.81)
SIZE		0.650 <sup>***</sup> (33.10)
CASH		-0.340 (-1.39)
SOE		-0.057 (-1.10)
BOARD		-0.044 (-0.50)
INBOARD		0.296 (0.78)
Year		Control
Robust standard errors in parentheses		
* p < 0.10, ** p < 0.05, *** p < 0.01		

Explanatory variable	Explained variable: corporate green innovation (NEWP)	
	(1)	(2)
Industry		Control
N	3560	3560
AdjR <sup>2</sup>	0.0643	0.4542
Robust standard errors in parentheses		
* p < 0.10, ** p < 0.05, *** p < 0.01		

The above results show that for pollution-intensive companies, MEID and the number of the patents granted is positive correlated, and the degree of impact is not significant. That is to say, MEID significantly promotes the green innovation of pollution-intensive companies. As the theoretical analysis, because the mandatory environmental information disclosure improves the transparency of company information and increase the cost of company environmental violations, pollution-intensive companies will take the initiative to carry out innovation in order to obtain a good social reputation and obtain resources for company development. Thus, the results support Hypothesis 1a instead of Hypothesis 1b.

## Heterogeneity analysis

### Information environment, MEID and corporate green innovation

The impact of MEID on corporate green innovation may be affected by the information condition (Follow). In order to verify whether there are differences of MEID on green innovation in different information environment conditions, this paper uses the natural logarithm of the sum of the number of analysts plus 1 to measure the quality of company information condition (Follow). Then, according to the quality of company information condition, the samples are divided into good information condition and bad information condition for grouping regression.

The results are shown in Table 5. Column (1) and Column (2) presents that the impacts of MEID on green innovation is different. The coefficient of Treat \* After is significantly positive at the statistical level of 5% in the group with poor information condition, but not significant in the sample with better information condition. It means that, MEID has a more significant driving effect on the green innovation in pollution-intensive companies with poor information environment. This paper argues that, under the poor information condition, MEID can play a better role in easing the degree of information asymmetry, forming institutional pressure to promote green innovation of pollution-intensive companies. The results verify hypothesis 2.

Table 5  
The heterogeneity test of MEID on innovation

Variable	Bad information condition	Good information condition	State-owned	Non-state-owned	large	small
	(1)	(2)	(3)	(4)	(5)	(6)
Treat	0.411 (0.44)	0.244 (1.59)	0.186* (1.88)	0.071 (0.42)	0.086 (0.53)	0.116 (1.21)
After	0.840*** (6.27)	0.843*** (4.33)	0.923*** (7.12)	0.641*** (2.93)	1.170*** (6.32)	0.614*** (4.33)
Treat*After	0.226** (2.02)	0.166 (0.96)	0.197** (1.99)	0.230 (1.16)	0.207 (1.14)	0.205* (1.79)
LEV	-0.079 (-0.74)	-1.326*** (-4.59)	-1.013*** (-6.19)	0.281 (1.59)	-1.322*** (-4.71)	-0.097 (-0.90)
ROA	0.549 (1.6)	0.738 (0.98)	0.389 (0.90)	1.340*** (2.58)	1.032 (1.29)	1.091*** (3.12)
GROWTH	-0.075 (-1.66)	-0.337*** (-2.79)	-0.178*** (-2.51)	-0.162** (-2.31)	-0.262** (-2.30)	-0.113** (-2.26)
SIZE	0.450*** (17.41)	0.754*** (21.81)	0.633*** (25.71)	0.712*** (20.22)		
CASH	-0.042 (-0.16)	-0.185 (-0.53)	-0.517*** (-11.77)	0.297 (0.67)	-1.812*** (-3.71)	0.482 (1.51)
SOE	0.143** (2.25)	-0.258*** (-2.97)			-0.298*** (-3.20)	0.114* (1.77)
BOARD	-0.09 (-0.09)	-0.169 (-1.12)	-0.100 (-0.99)	0.118 (0.65)	-0.114 (-0.87)	-0.268** (-2.55)

Robust standard errors in parentheses

\* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01.

Variable	Bad information	Good information	State-owned	Non-state-owned	large	small
	condition	condition				
	(1)	(2)	(3)	(4)	(5)	(6)
INBOARD	0.067 (0.14)	0.643 (0.11)	0.12 (0.28)	0.494 (0.64)	-0.284 (-0.50)	0.605 (1.24)
Year	Control	Control	Control	Control	Control	Control
Industry	Control	Control	Control	Control	Control	Control
N	1842	1718	2509	1051	1710	1850
AdjR <sup>2</sup>	0.3848	0.4460	0.4932	0.4596	0.4680	0.3385
Robust standard errors in parentheses						
* p < 0.10, ** p < 0.05, *** p < 0.01.						

### Property nature, MEID and corporate green innovation.

The impact of MEID on company green innovation may be influenced by the nature of property (SOE). In order to test whether there are differences in the impact of MEID on company green innovation under different property nature, this paper classifies the sample into state-owned companies and non-state-owned companies according to the property nature (SOE).

The results of group regression are shown in Column (3) and Column (4) of Table 5. The results presents that the coefficient of Treat \* After is positive in state-owned companies, and the significance is 10%, while in non-state-owned companies, the coefficient is positive, but not significant. Compared with non-state-owned companies, MEID has a more significant driving effect on the green innovation of state-owned pollution-intensive companies.

This paper suggests that state-owned companies are generally required to bear more social responsibility (Yang & Qiao 2013), and the performance of social responsibility is often regarded as a part of the evaluation of state-owned company managers. In addition, state-owned companies are easy to obtain government subsidies and loans, their funds and personnel are sufficient. Therefore, under the pressure of the Guidelines, state-owned companies have more motivation and ability to carry out green innovation. This results support hypothesis 3.

## Scale, MEID and corporate green innovation

The impact of MEID on corporate green innovation may be affected by company size. In order to verify whether there are differences in the impact of MEID on company innovation under different company scale, the samples are divided into small companies and large companies.

The results are shown in Column (5) and Column (6) of Table 5. The results present that the coefficient of Treat \* After of small companies is significantly positive at the level of 10%, which indicates that MEID can significantly promote the innovation of small pollution intensive companies; In contrast, the coefficient of Treat × After of large companies is positive, but not significant, which means that MEID cannot significantly promote the green innovation of large pollution intensive companies.

This shows that MEID can significantly drive the green innovation of small pollution-intensive companies. Through the analysis of this paper, it is found that compared with large companies with sufficient resources, small companies need to cater to the values and ethics of society for obtaining more resources and reducing the cost of capital for development. The results support Hypothesis 4.

## Robustness Test

### PSM-DID

To reduce the differences between the treatment group and control group and highlight the effects of Guidelines, we use the propensity-score-matched (PSM) radius matching method to match the treatment group with the control group. The steps are as follows: first, all the control variables are used as covariates to match the pollution intensive companies in Shanghai and Shenzhen stock markets. The nearest neighbor matching method is used to match the pollution intensive companies in Shanghai and Shenzhen stock markets. The matching ratio is 1:1, and the matched samples are retained; second, the DID model regression is performed on the matched samples. The test results are shown in column (1) of Table6. According to the results, MEID significantly promotes the green innovation of pollution-intensive companies, which is consistent with the research conclusion of this paper.

Table 6  
The result of robustness test

Variable	PSM-DID	Patent applications	More control variables
	(1)	(2)	(3)
Treat	0.122 <sup>***</sup> (1.40)	0.210 <sup>**</sup> (2.19)	0.123 (1.40)
After	0.823 <sup>***</sup> (7.25)	0.661 <sup>***</sup> (5.36)	0.793 <sup>***</sup> (6.99)
Treat*After	0.215 <sup>**</sup> (2.13)	0.192 <sup>*</sup> (1.77)	0.211 <sup>**</sup> (2.10)
CVs	Control	Control	Control
AdjR <sup>2</sup>	0.4543	0.4641	0.4570
N	3549	3560	3560
Robust standard errors in parentheses			
* p < 0.10, ** p < 0.05, *** p < 0.01.			

## Using different methods to measure company innovation

In the benchmark regression, we take the number of patents granted of listed companies as a proxy variable to measure the level of green innovation, and find that MEID can promote the green innovation of pollution-intensive companies. Furthermore, the number of patents applications of listed companies is used to re measure the innovation level of companies. Results are shown in column (2) of Table 6. It can be seen that the coefficient of After \* Treat is positive, and it is significant at the level of 10%, indicating that MEID can significantly promote corporate green innovation.

### More control variable

This paper further controls other variables, including: the proportion of the largest shareholder (Top1), which is measured by the proportion of the largest shareholder; the size of the board of supervisors (inspect), which is measured by the natural logarithm of the number of supervisors (Yu et al. 2020). The results are shown in column (3) of Table 6, from which it shows that the coefficient of After \* Treat is still significantly positive at the level of 5%. The result proves the robustness of the conclusion of this study once again.

## Conclusion And Implications

Exploring the impact of MEID on the green innovation is of great practical significance to promote the capital market to support the construction of ecological civilization. Based on the quasi-natural event of the Guidelines, this paper takes pollution-intensive companies listed in Shanghai and Shenzhen A-shares from 2007 to 2016 as research samples, uses did method and manually collected patent data to test whether MEID can drive corporate green innovation. This study shows that there is a positive relationship between the MEID and the green innovation of pollution intensive companies because MEID can enhance the motivation and pressure of companies to comply with the regulation.

According, this paper concludes that: compared with companies that are not required to disclose environmental information, the MEID significantly promotes the green innovation of pollution-intensive companies that are required to disclose environmental information; The impact of MEID on the green innovation of pollution-intensive companies is heterogeneous in information environment, property nature and company scale. Specifically, compared with the companies with better information environment, the role of MEID in promoting the green innovation of companies with poor information condition is more obvious; compared with non-state-owned companies, MEID can promote the green innovation of state-owned companies; MEID has a significant positive effect on the green innovation of small companies, but has a no effect in large-scale companies.

The conclusion is still robust after a series of robustness tests such as PSM-DID, changing the measure of corporate green innovation level and controlling more variables.

This paper enriches the research on the micro-economic consequences of MEID and the influencing factors of corporate green innovation, provides some implication for policymakers in emerging countries that seek to improve environmental information disclosure. The implications are as follows:

First, the government should continue to implement the MEID and improve the environmental monitoring system. Generally speaking, the obligation of environmental information disclosure helps to promote the green innovation of pollution-intensive companies, because mandatory environmental information disclosure can reduce the asymmetry of corporate environmental information, eliminate inefficient, outdated and polluting production mode through market competition mechanism. Effective information transmission can speed up the green innovation of companies. Therefore, from the perspective of the central government, we should further implement and improve environmental information disclosure to urge local companies to innovate effectively.

Second, the relevant departments should standardize the content of environmental information disclosure, increase audit efforts so as to improve the quality of environmental information disclosure. The quality of environmental information disclosure is directly related to whether stakeholders can obtain real and sufficient environmental information and make investment decisions consistent with expectations. At present, the disclosure level of qualitative information is higher than that of quantitative information, and the disclosure level of positive information is higher than that of negative information. This not only makes the environmental information disclosure a mere formality, but also increases the cost of company information disclosure, and increases the difficulty and cost of government supervision.

Therefore, it is necessary for the relevant departments to standardize the content, form and evaluation standard of environmental information disclosure, form a unified environmental performance index, and increase the audit of information disclosure, so as to improve the efficiency of public supervision and reduce the cost of government supervision.

Third, the government should effectively identify the characteristics of the disclosure subject to formulate differentiated environmental information disclosure policy. Implementing environmental regulation blindly means not only high cost, but also low regulation efficiency. Therefore, it is necessary to combine the development stages of different industries and regions to avoid "one size fits all". For example, in the implementation of mandatory environmental information disclosure policy, we need to focus on guiding the companies with non-state-owned companies and large companies to promote their innovation through environmental information disclosure.

The possible deficiency of this paper is that it only measures the corporate green innovation from the number of patents granted or the proportion of patent applications. It does not construct a comprehensive index to measure the green innovation, which may ignore such factors as green innovation investment, green innovation efficiency and so on. We will further improve this problem in the future.

## Declarations

**Author Contributions** Conceptualization: Qianghua G; Methodology: Qianghua G and Yidan W; Writing—original draft preparation: Yidan W; Writing—review and editing: Qianghua G and Yidan W; Supervision: Qianghua G.

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**Compliance with ethical standards**

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## References

1. Balla C, Burt G, De Vries F, MacEachern E (2018): How environmental protection agencies can promote eco-innovation: The prospect of voluntary reciprocal legitimacy. *Technol Forecast Soc.* 129, 242-253
2. Bansal P (2005): Evolving sustainably: A longitudinal study of corporate sustainable development. *Strategic Manage J* 26, 197-218
3. Chen Y, Hung M, Wang Y (2018): The effect of mandatory CSR disclosure on firm profitability and social externalities: Evidence from China. *Journal of Accounting and Economics* 65, 169-190 (in Chinese)
4. Doshi AR, Dowell GWS, Toffel MW (2013): How firms respond to mandatory information disclosure. *Strategic Manage J* 34, 1209-1231
5. Du S, Wang Z (2021): Corporate social responsibility disclosure, investment efficiency and corporate innovation. *Journal of Guizhou College of Finance and Economics*, 52-62 (in Chinese)
6. Friedman M (1970): The social responsibility of business is to increase its profits.
7. Guo, J (2019): The impact of environmental regulation on green technology innovation: Chinese evidence of "Porter effect". *Finance & Trade Economics* 40, 147-160 (in Chinese)
8. Hamilton JT (1995): Pollution as news Media and stock market reactions to the toxics release inventory data. *J Environ. Econ. Manage.*, 98-113
9. He X, Xiao T, Chen X (2012): Corporate social responsibility disclosure and corporate financing constraints. *Financial Research* 38, 60-83 (in Chinese)
10. Hemingway C A, Maclagan P W (2004): Managers' personal values as drivers of corporate social responsibility. *J Bus Ethics*, 33-44
11. Ip PK (2009): The challenge of developing a business ethics in China. *J Bus Ethics* 88, 211-224
12. Inoue E (2016): Environmental disclosure and innovation activity: Evidence from EU corporations, Kyoto University
13. Jin L, Zheng B, Hu X (2019): Patent licensing contract design and production outsourcing: From the perspective of corporate social responsibility. *Nankai Business Review* 22, 40-53 (in Chinese)
14. Kolk A, Hong P, van Dolen W (2009): Corporate social responsibility in china: an analysis of domestic and foreign retailers' sustainability dimensions. *Bus Strateg. Environ.*
15. Li D, Huang M, Ren S, Chen X, Ning L (2018): Environmental legitimacy, green innovation, and corporate Carbon Disclosure: Evidence from CDP China 100. *J Bus Ethics* 150, 1089-1104
16. Li W, Sun H, Tran DK, Taghizadeh-Hesary, F (2020): The impact of environmental regulation on technological innovation of resource: Based industries. *Sustainability Baesl* 12, 6837
17. L, Z, Zhao Y, Tong J (2013): Does social responsibility report reduce the cost of equity capital? Empirical evidence from China's capital market. *Accounting Research*, 64-70+97 (in Chinese)
18. Lu X, Lin W, Zhang M (2012): Ownership nature, political pressure and environmental information disclosure of listed companies Based on the empirical data of heavy pollution industry in China. *China Management Studies* 7, 114-136 (in Chinese)

19. Marshall S, Brown D, Plumlee M (2009): The impact of voluntary environmental disclosure quality on firm. *Academy of Management Annual Meeting Proceedings*
20. Meng Q, Li X, Zhang P (2019): Can ESOP promote enterprise innovation? Empirical Evidence from the perspective of employees. *Management World* 35, 209-228 (in Chinese)
21. Plumlee M, Brown D, Hayes RM, Marshall RS (2015): Voluntary environmental disclosure quality and firm value: Further evidence. *J Account Public Pol.* 34, 336-361
22. Porter ME, Claas VDL (1995): Toward a new conception of the environment: Competitiveness relationship. *The Journal of economic perspectives* 9, 97-118
23. Quan X, Wu S, Yin H (2015): Corporate social responsibility and stock price crash risk: "value weapon" or "self-interest tool"? *Economic Research Journal*, 49-64 (in Chinese)
24. Ren S, Wei W, Sun H, Xu Q, Hu Y, Chen X (2020): Can mandatory environmental information disclosure achieve a win-win for a firm's environmental and economic performance? *J Clean Prod.* 250, 119530
25. Shen H, Huang Z, Guo F (2014): Confession or defense: A Study on the relationship between corporate environmental performance and environmental information disclosure. *Nankai Business Review* 17, 56-63+73 (in Chinese)
26. Shen H, Zhou Y (2017): Environmental law enforcement supervision and corporate environmental performance: quasi natural experimental evidence from environmental interview. *Nankai Business Review* (in Chinese)
27. Tian L, Wang K (2017): The "cover up effect" of social responsibility information disclosure and the crash risk of listed companies: A Did-PSM analysis of Chinese stock market. *Management World*, 146-157 (in Chinese)
28. Wang X, Ning J (2020): Can mandatory social responsibility disclosure drive corporate Green transformation? Evidence based on green patent data of listed companies in China. *Auditing& Economic Research* 35, 69-77 (in Chinese)
29. Williamson OE (1999): Strategy research governance and competence perspective. *Strategic Manage J* 1087–1108
30. Xiong G, Luo Y, Zhao J (2020): An empirical test of the impact of corporate environmental responsibility on innovation performance. *Statistics and Decision Making.* 21,172-175 (in Chinese)
31. Yang J, Song J, Zhang J (2019): Compulsory social responsibility disclosure and underinvestment: Crowding out or pulling. *Journal of Shanxi Finance and Economics University* 41, 100-112 (in Chinese)
32. Yang Z, Qiao Y (2013): The relationship among the industrial competition attribute, company characteristics and social responsibility: Based on the empirical analysis of the listed company. *Science Research Management* 34, 58-67 (in Chinese)
33. Yu, C, Zhang W, Bi Q (2019): Does environmental law enforcement and supervision promote the green transformation of enterprises? *J Bus Econ. Manage.*, 61-73

- 34. Yu C, Zhang W, Bi Q, Dong, J (2020): Can government environmental audit improve enterprise environmental performance? *Audit & Economy Research* 35, 41-50 (in Chinese)
- 35. Zeng Y, Feng Z, Zhang, Q (2016): Geographical location, environmental regulation and enterprise innovation transformation. *Finance and Trade Research* 42, 87-98 (in Chinese)
- 36. Zhang Z, Ge, S (2021): Does environmental information disclosure have innovation promotion effect?. *Journal of Yunnan University of Finance and Economics* 37, 69-82 (in Chinese)
- 37. Zhao J, Meng, W (2016): The impact of official inspection on enterprise innovation: An empirical analysis Based on organizational legitimacy. *China Industrial Economics*, 109-126 (in Chinese)

## Figures

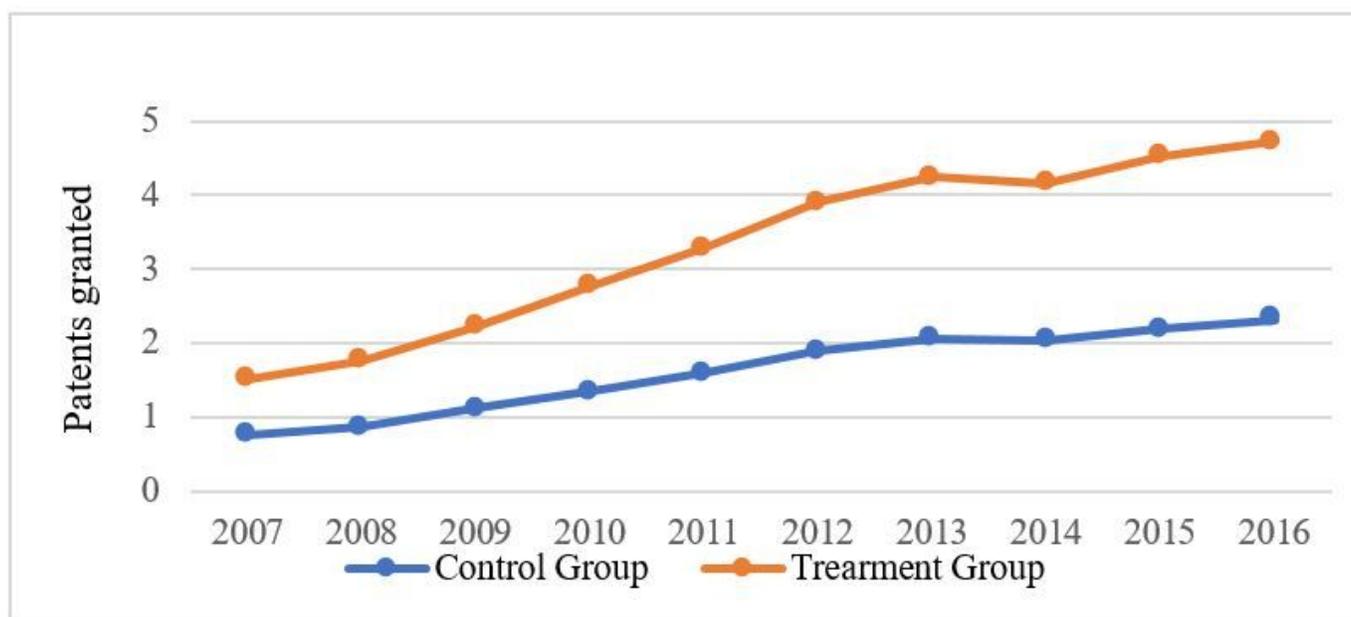


Figure 1

The number of patents granted trends of control group and treatment group during 2007–2016