



Research article

The impact of mandatory CSR disclosure on green innovation: evidence from China

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Abstract: This paper examines how mandatory CSR information disclosure affects corporate green innovation. The analysis exploits China's mandate in 2008 which requires firms to disclose CSR activities, and uses a difference-in-difference method to do the empirical analysis. The results reveal that the treated firms exhibit an increase in green innovation subsequent to the mandate which supports Porter's hypothesis with the positive role of environmental regulations. On average, after the policy implementation, the firms in the list generate 2.193–2.244 more green invention patents than those if not in the list. In addition, the impact of mandatory CSR disclosure is heterogeneous on different types of firms. Firms with large size, state-owned firms and firms in pollution-intensive industries are more likely to be affected by mandate, which suggests that these firms are more sensitive to the mandatory information disclosure.

Keywords: corporate social responsibility; green innovation; mandatory information disclosure

JEL Codes: G38, M14, M41, O32, Q56

1. Introduction

The famous Berle-Dodd debate has aroused people's attention to corporate social responsibility (hereafter called CSR). They discussed who the firms should be responsible for. Berle's view is that

firms should be seen only as the maximizers of shareholders' value. Dodd's view supports the notion that firms should be accountable to stakeholders and the general public. Nowadays, it is generally believed that CSR includes responsibilities to employees, creditors, consumers, social welfare, environment and resources. In other words, CSR is the responsibility to stakeholders, not just to shareholders. Most scholars have focused on the responsibility of firms to shareholders, and they have studied the relationship between CSR and corporate performance (El Ghouli et al., 2011; McWilliams and Siegel, 2000; Deng et al., 2013). This paper focuses on the responsibility for the environment and resources and tries to determine the impact of CSR on green innovation.

Is it necessary to implement the policy of mandatory CSR information disclosure? Research shows that CSR information disclosure can reduce financing costs and ease information symmetry (Xu et al., 2019). For firms with high capital cost, voluntary CSR information disclosure will be carried out to reduce capital cost. CSR information disclosure can also attract institutional investors' investment by attracting analysts' attention and reducing the analysis forecast error (Dhaliwal et al., 2012; Dhaliwal et al., 2011), CSR information disclosure is conducive to improving firm value (Plumlee et al., 2015; Dai et al., 2019). However, also scholars have found that CSR information disclosure may reduce corporate profits, reduce industrial wastewater and sulfur dioxide emissions, and improve corporate environmental performance (Chen et al., 2018; Ren et al., 2020). The reason for these controversial issues may be that the samples are different. The former mainly studies the effect of CSR information disclosure which may be faced with self-selection problems, that firms with more CSR information disclosure are usually faced with higher financing cost. While the latter studies the effect of mandatory CSR information disclosure, which is exogenous and can avoid the endogenous problems caused by self-selection.

In 2008, Shanghai Stock Exchange, along with Shenzhen Stock Exchange, issued a notice on mandatory CSR information disclosure. Based on this quasi natural experiment, this paper adopts the difference-in-difference method, and concludes that CSR information disclosure can promote green innovation. On average, after the implementation of the policy, the firms on the list have 1.912–1.956 more green development patent applications than those not on the list. Furthermore, this paper studies the impact of heterogeneity on different types of firms. State owned firms and large-scale firms are more likely to be affected by policies. On average, the number of green invention patent applications of state-owned firms in the list is 2.44 more than that of state-owned firms if not in the list, and the number of green invention patent applications of large-scale firms in the list is 2.81 more than that of large-scale firms if not in the list. In addition, this paper also found that pollution intensive firms are more likely to be affected by the policy. The pollution intensive firms in the list have 6.98 green invention patent applications than those if not in the list.

The main contributions of this paper are as follows. Firstly, we examine the impact of mandatory CSR information disclosure on green innovation. Since the Berle-Dodd debate, there have been a large number of studies on the effect of CSR information disclosure. Research shows that CSR information disclosure can reduce financing costs and also produce social effects, such as reducing environmental pollution (Chen et al., 2018). However, few scholars have studied the impact of CSR information disclosure on corporate micro behavior, especially on corporate innovation behavior. Our paper complements contemporaneous research by Chen et al. (2018). The authors use the DID method to analyze the how mandatory CSR disclosure impacts firm performance and social externalities. This

paper also adopts the DID method to study how mandatory CSR information disclosure affect corporate green innovation behavior. Secondly, we also supplement the research about the impact of environmental regulation on green innovation. Guo et al. (2018) argue that there is an inverted U-shaped relationship between environmental regulation and green technology innovation, and China is on the left side of the inflection point, that is, China's environmental regulation is conducive to technological innovation. This paper supports the conclusion of Guo et al. (2018), and concludes that as an environmental regulation policy, the introduction of mandatory CSR information disclosure policy is conducive to promoting firms' green innovation. It also verifies Porter's hypothesis: environmental regulation can affect the level of firms' performance by strengthening the degree of innovation and competition (Porter and Vanderlinde, 1995). Finally, we examine the heterogeneous effect of mandatory CSR information disclosure on green innovation. Schumpeter hypothesis holds that the innovation level of large firms is higher than small and medium-sized firms. This paper supports this conclusion. Compared with small and medium-sized firms, the green innovation level of large-scale firms is significantly improved after the introduction of the policy, while the green innovation level of small and medium-sized firms has no significant change. State-owned firms are more likely to attract investors' attention, so they should be sensitive to the mandatory CSR information disclosure policy.

The remainder of the paper is organized as follows. Section 2 reviews the literature, and put up with our hypotheses. Section 3 is the research design, and describes the data and methods. Section 4 firstly investigates the effect of mandatory CSR information disclosure on green innovation, then analyzes the heterogeneous effects between state-owned firms with non-state-owned firms, large firms with small and medium-sized firm. Section 5 uses the PSM-DID method to do the robust tests. Section 6 concludes.

2. Literature review and hypotheses

2.1. Literature review

2.1.1. CSR, techonogical innovation and performance

The Berle-Dodd debate has attracted scholars' attention to CSR (Aguinis and Glavas, 2012; Tapver, 2019). Earlier studies focused on whether CSR can increase firm performance. However, there is no consensus about the the effect of CSR information disclosure on firm's performance. The positive view argue that CSR information disclosure can provide incremental information, so it has a positive impact on the firm's economic performance (Reverte et al., 2016; Al-Tuwaijri et al., 2004; Clarkson et al., 2013; Fan et al., 2020; Haque et al., 2019). While the opposing view suggests that firms' objective functions are to generate profits and any managerial involvement in CSR activities is rather a barrier to the accomplishment of the profit maximizing purpose. Investing in CSR activities is likely to reduce a firm's capital and other critical resouces, so CSR distorts capital allocation efficiency (Bhandari and Javakhadze, 2017). Environmental information disclosure consumes the firm's limited resources so that it has a negative impact on the firm's economic performance (Ren et al., 2020). Furthermore, Denis & Michel concludes that there is insignificant relation between environmental information disclosure and firm value (Marshall et al., 2009).

Later studies argue that CSR may have an indirect effect on firm's performance through innovation. Several studies contend that CSR and R&D are highly correlated (McWilliams and Siegel, 2000, 2011) and that the indirect effect of CSR activities on firms' performance comes through the enhancement of firms' R&D efforts (Broadstock et al., 2019; Lioui and Sharma, 2012). Simpson and Tamayo (2020) documents that increased disclosure and better financial reporting can foster innovation. Li et al. (2019) argues that corporate environmental responsibility can affect firm value with innovation as a mediating role. Furthermore, CSR information disclosure can alleviate the information asymmetry between managers and investors, controlling shareholders and minority shareholders, and alleviate the financing constraint problems, thereby improving innovation sustainability (Hu et al., 2020). However, Bocquet et al. explores the relationship between CSR and innovation from a firm strategic perspective, they conclude that firms with strategic CSR profiles are more likely to innovate in both products and processes. In contrast, adopting responsive CSR practices may create barriers to innovation (Bocquet et al., 2013).

2.1.2. The heterogeneous effects of mandatory CSR information disclosure

Firms have also become increasingly willing to voluntarily issue standalone CSR reports in recent years. Large numbers of studies have proved that greater CSR information disclosure could reduce the capital cost (El Ghouli et al., 2011; Dhaliwal et al., 2012; Diamond and Verrecchia, 1991; Botosan, 1997; Botosan and Plumlee, 2002). Firms with a high cost of capital in the previous year tend to initiate disclosure of CSR activities in the current year (Dhaliwal et al., 2011). But these results may not apply to the mandatory CSR information disclosure.

To our knowledge, there is little evidence investigating the heterogeneous effects of mandatory CSR information disclosure. One exception is the research of Chen et al. (2018), who argues that after the mandatory CSR disclosure the firms experience a decrease in sales revenue and an increase in operating costs, leading to a decrease in profitability. A second exception is the study by Grewal et al. (2019), who investigates the equity market reaction to events associated with the adoption of mandatory nonfinancial disclosure. To explore the impact of mandatory CSR information disclosure on green innovation can supplement the research in this area.

2.1.3. Environmental regulation and green innovation

This paper also aligns with Porter's hypothesis which suggests that environmental regulation has a positive effect on firms' performance levels through the enhancement of innovation and competitiveness (Porter and Vanderlinde, 1995; Porter, 1991; Adjei Kwakwa et al., 2018). Restricting to environmental innovation, a series of literature find a positive relationship with environmental regulation (Lanjouw and Mody, 1996; Lanoie et al., 2011; Popp, 2003, 2006), even Li et al. (2018) construct a model to prove the effectiveness of green loan and government subsidy on promoting green innovation (Li et al., 2018). Furthermore, Johnstone et al. examine not only the impact of the stringency of environmental policies, but also the impact of their stability and flexibility, and find that both stability and flexibility have distinct effects on innovation (Johnstone et al., 2009). In order to explore the applicability of Porter hypothesis in China, Zhao and Sun do an empirical study to explore this

mechanism by using Chinese pollution-intensive, and results show that environmental regulation has significant positive effects on corporation's innovation (Zhao and Sun, 2016).

But the results of many studies still cannot be explained by the Porter hypothesis. For example, Jaffe and Palmer document that environmental regulation have a significant positive effect on R&D expenditures, but is not significantly related to inventive output (Jaffe and Palmer, 1997). Brunnermeier and Cohen study how environmental innovations responds to changes in pollution-reduction expenditures and the enforcement of environmental regulation, they find that environmental innovation responds to increases in pollution abatement expenditures, but increased monitoring and enforcement activities related to existing regulations do not provide any additional incentive to innovate (Brunnermeier and Cohen, 2003). One reason for this is that environmental regulation may have little impact on the technological innovation of some firms, but it has a significant impact on technology adoption and diffusion (Shao et al., 2020). Gray and Shadbegian (1998) show that environmental regulation enables firms to achieve cleaner production standards by purchasing new pollution control equipment and production equipment, rather than by engaging in R&D activities and innovation (Gray and Shadbegian, 2003).

2.2. Hypotheses

According to Porter's hypothesis, strict and appropriate environmental regulations will force firms to carry out green innovation in energy conservation and environmental protection. Subsequently a number of scholars have come to conclusions that environmental regulation can drive corporate green innovation (Lanjouw and Mody, 1996; Brunnermeier and Cohen, 2003; Rehfeld et al., 2007). CSR activities encompass corporate social and environmental behavior that goes beyond the legal or regulatory requirement of the relevant market and/or economy (Kitzmueller and Shimshack, 2012). We posit that mandatory CSR disclosure is an environmental regulation policy, so as to expect that mandatory CSR disclosure will restrain pollutant emissions and foster green innovation. That is because once firms disclose their CSR activities, the government and interest groups may find it easier to "shame" polluting firms into reducing their pollutant emissions (Thaler and Sunstein, 2008).

Specifically, mandatory CSR information disclosure mainly affects green innovation through two channels. Firstly, CSR information disclosure can alleviate the agency problem, which arises from the separation of ownership (shareholders) and control (managers). Information asymmetry further aggravates the agency problem. As a nonfinancial disclosure, mandatory CSR information disclosure can alleviate information asymmetry and increase monitoring (Wang et al., 2016). According to the career concern model, managers may dislike the risk innovation involves, and increased monitoring can improve incentives to innovate (Aghion et al., 2013). Secondly, as a means of environmental regulation, CSR information disclosure can stimulate firms' green innovation. Porter hypothesis believes that when firms try to improve the environmental efficiency of resource utilization, innovation may occur, which helps improve production processes and product quality. Based on this argumentation, we propose the following hypothesis:

Hypothesis 1A. Firms experience an increase in green innovation subsequent to the mandatory CSR disclosure.

However, there are also some studies indicating that environmental regulation would have adverse effects on technological innovations. Gray and Shadbeigian (2003) found that environmental investment would crowd out productive investment under strict environmental regulations, leading to a decline in production technology. Wagner found that the more emphasis on environmental regulations, the less innovative patent firms produced (Wagner, 2007). Thus, we propose the opposing hypothesis:

Hypothesis 1B. Firms experience a decrease in green innovation subsequent to the mandatory CSR disclosure.

The Schumpeter hypothesis suggests large firms can produce more innovations than small and medium-sized firms. One reason is that larger firms have enough output over which they can apply the results, then they can spread the cost of innovation (Cohen and Klepper, 1996). Another reason is that small and medium-sized firms face greater financing constraints, that is, small and medium-sized firms may not have enough funds for R&D investment, while large firms even can directly use cash flow and commercial credit as the main sources of R&D investment (Sasidharan et al., 2015). Thus we postulate the following hypothesis:

Hypothesis 2. Large Firms exhibit more increase in green innovation than small and medium-sized firms subsequent to the mandatory CSR disclosure.

In addition, unlike private firms, when required to disclose their CSR activities, state-owned firms feel larger pressure to increase their commitment to CSR, so they are more susceptible to the influence of policies and tend to carry out more green innovation activities. We hypothesize this prediction as follows:

Hypothesis 3. State-owned firms exhibit a different increase in green innovation from non-state-owned firms subsequent to the mandatory CSR disclosure.

Furthermore, once the mandatory CSR disclosure comes out, the impact on firms in Pollution-intensive industries (PIIs) is the largest. Pollution-intensive industries have to disclose more information about the environmental protection and resource conservation. And if the disclosure is not ideal, investors will vote with their feet, which will force firms to carry out more innovation activities. Based on this argumentation, we form the following hypothesis:

Hypothesis 4. Firms in Pollution-intensive industries (PIIs) are more affected by mandatory CSR disclosure than Non- Pollution-intensive industries (NPIIS).

Finally, we show the influence mechanism of mandatory CSR information disclosure on green innovation in Figure 1.

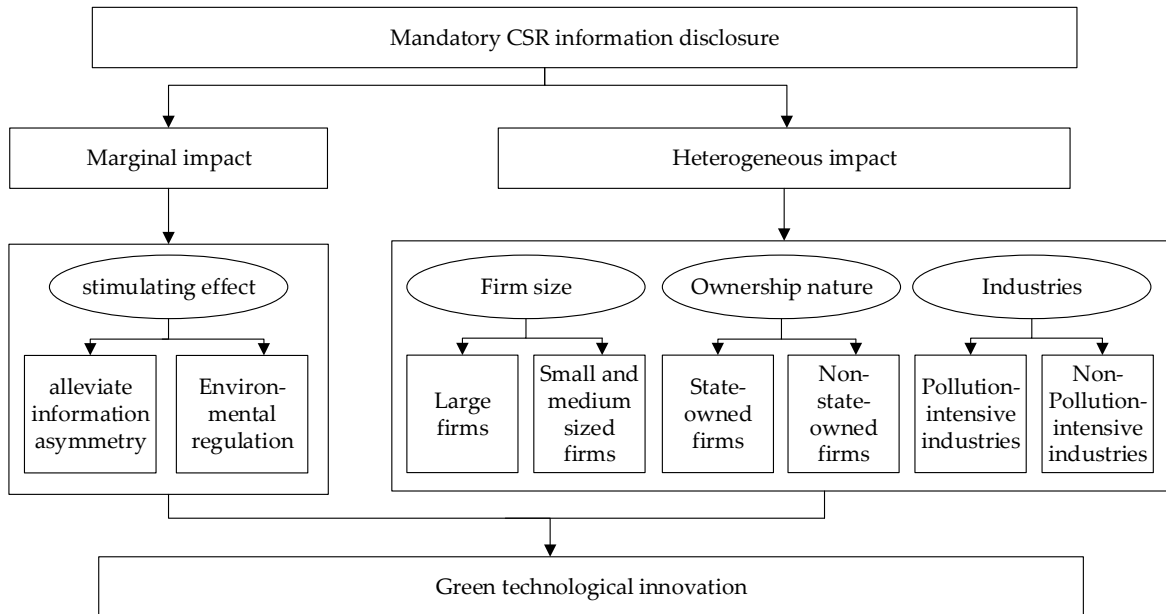


Figure 1. The influence mechanism of mandatory CSR information disclosure on green innovation.

3. Research design

3.1. Basic models

At the end of December 2008, Shanghai Stock Exchange release a notice that require the companies issuing foreign shares listed overseas and financial companies shall disclose the report on the fulfillment of social responsibility of the company (hereinafter referred to as “social responsibility report”) at the same time as the annual report of 2008. And listed companies included in the “Shenzhen Stock Exchange 100 index” shall disclose their social responsibility reports in accordance with the provisions of the guidelines on social responsibility. Due to this exogenous policy, it is possible to use a differences-in-differences (DID) strategy to identify the impact of compulsory CSR information disclosure on green innovation:

$$\begin{aligned}
 & greeninnovation_{it} \\
 & = \alpha + \beta \cdot treat_i + \gamma \cdot post_t + \delta \cdot treat_i \cdot post_t + \lambda \cdot controlvariables_{it} + \varepsilon_{it}
 \end{aligned} \quad (1)$$

where $greeninnovation_{it}$ represents the green innovation; $treat_i$ is a dummy variable, which equals 1 if the corporate is in experience group, otherwise equals 0; $post_t$ is a time dummy variable, which equals 1 if the year is after 2007, otherwise equals 0. So the coefficient of the interactions δ can be used to measure the impact of compulsory CSR information disclosure on green innovation.

3.2. Data

This paper mainly collects the data of Chinese Shanghai and Shenzhen stock markets from 2005 to 2011. As the mandatory information disclosure policy is released at the end of December 2008, we

select the samples three years before 2008 and three years after 2008 respectively. On the one hand this sample interval is long enough to form a panel data. On the other hand, other policies implemented in this interval may confound the effect when longer interval is included. The financial information of listed companies are from China Security Market and Accounting Research (CSMAR) database. To ensure the reliability of the results, we conduct the following screening and pretreatments: (1) eliminating samples with missing variable data; (2) eliminating special treatment (ST) companies; (3) excluding financial companies; (4) deleting firm-year observations with many missing values.

To obtain the green innovation information, we first collect invention patents by company and year from the State Intellectual Property Office in China. Secondly, we identify the green invention patents according to the IPC Green Inventory, which is an online tool launched by the World Intellectual Property Organization (WIPO). They aim to facilitate searches for patent information relating to Environmentally Sound Technologies (ESTs). The inventory classifies green innovation into seven categories: transportation, alternative energy production, energy conservation, transportation, waste management, agriculture and forestry, and nuclear power generation according to the United Nations Framework Convention on climate change. And finally, we count the numbers of green invention patents.

3.3. Variable definition

3.3.1. Dependent variables

We define the green innovation by the numbers of green invention patent applications. Different from utility model, invention patents have the highest technical content. Therefore, invention patents are generally used to measure the degree of technological innovation.

3.3.2. Key explanatory variables

As mentioned above, $treat_i$ and $post_t$ are both dummy variables. The interaction of $treat_i$ and $post_t$ is our key explanatory variable, and its coefficient measures the impact of mandatory CSR information disclosure on green innovation.

3.3.3. Control variables

The models employed in our analyses include a number of firm-level control variables. In order to test the “Schumpeterian hypothesis”, we add to variable “Firm size” in our model. In order to test the impact of ownership nature on green innovation, we add to dummy variable “State-owned firms or not” in our model. In order to test the impact of financial performance, we add to variables “Profitability” and “Debt-paying ability”. Also we add to variable “Proportion of the largest shareholder” to test the impact of ownership structure on green innovation. Specially, Table 1 shows the definition of the main variables, for example, $lnasset$ is the natural log of total assets. $largesthold$ is the total percentage of shares owned by the largest shareholder. $isstateown$ is an indicator denoting whether firms are not state-owned firms.

Table 1. Definitions of the main variables used in this study.

Variable Name	Symbol	Definition
Green innovation	greeninnovation	Numbers of green invention patent applications
Debt-paying ability	liability	Liabilities/Asset
Firm size	lnasset	LN (year-end total assets)
Proportion of the largest shareholder	largesthold	Total percentage of shares owned by the largest shareholder
State-owned firms or not	isstateown	The variable equals 1 if the corporate is state-owned firms, otherwise equals 0
Proportion of the state shareholder	state	Total percentage of shares owned by the state shareholder
Cashflow	cashflow	Net increase in cash and cash equivalents

4. Empirical results

4.1. The impact of mandatory CSR Disclosure on green innovation

Firstly, we compare the samples between treat groups with control groups. Table 2 presents the descriptive statistics. In our sample, the mean of roa is 0.06 (0.6) for our treat groups and 0.05 (0.09) for our control groups. We use the variables (lnasset, largesthold, isstateown) to measure the sizes of the firms, the shareholding proportion of the controlling shareholder and the nature of the firms respectively. All variables in treat groups are close to the control groups.

Table 2. Descriptive statistics.

	Treat group					Control group				
	N	mean	sd	min	max	N	mean	sd	min	max
roa	1233	0.06	0.6	-0.41	20.79	9966	0.05	0.09	-0.81	2.93
liability	1233	0.52	0.19	0.01	1	9966	0.47	0.21	0	1
lnasset	1233	22.62	1.64	16.69	28.28	9966	21.41	1.12	13.08	27.1
largesthold	1233	40.53	15.68	6.47	100	9966	37.08	15.67	2.2	99
isstateown	1233	0.8	0.4	0	1	9966	0.53	0.5	0	1

As Bertrand and Mullainathan point out, the premise for the application of DID model is that the treat group and the control group should satisfy the parallel trend hypothesis before being treated (Bertrand and Mullainathan 2003). Then the difference between the treat group and the control group can be considered as the treatment effect. Therefore we add two variables, year - 3, year - 2, for the pre-period and three variables, year + 1, year + 2 and year + 3 for the post-period. We next interact these five variables with the dummy variable treat. The results reported in Figure 2 show that the coefficient of (year - 3)*treat and (year - 2)*treat and (year + 1)*treat are insignificant and that the coefficient of (year + 2)*treat and (year + 3)*treat are significantly positive. It may be due to lag effect that the coefficient of (year + 1)*treat

is insignificant. These result support the parallel trend assumption and suggest increased innovation after the mandatory CSR information disclosure. Therefore, it is suitable to use DID model to test the impact of mandatory CSR information disclosure on green innovation.

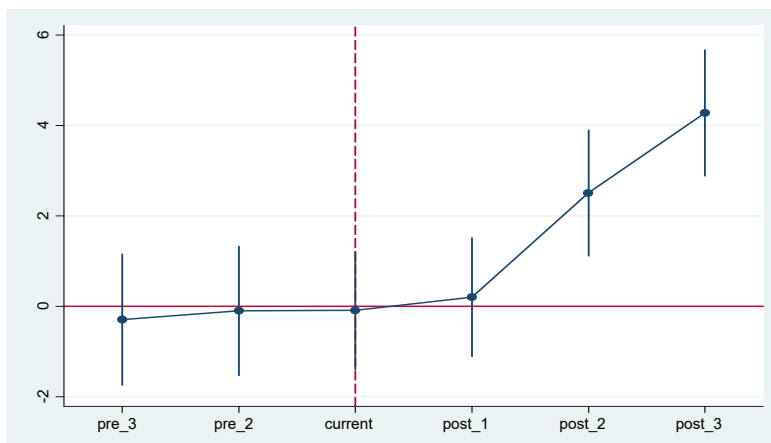


Figure 2. Parallel trend test. Note: Vertical bands represent $+1.98$ times the standard error of each point estimate; pre_3, pre_2, post_1, post_2 and post_3 represent year - 3, year - 2, year + 1, year + 2 and year + 3 respectively.

Table 3 reports the DID results of mandatory CSR information disclosure on green innovation. Column (1) is the basic model, and column (2) and (3) adds to year dummy variables and other control variables, respectively. In column (1)–(3), the coefficient of the interaction between post and treat (post*treat) are always significantly positive, which indicates that mandatory CSR information disclosures have significant effect on corporate green innovation. On average, after the introduction of the policy, the firms in the list generate 2.193–2.244 more green invention patents than those not in the list. The results support the hypothesis 1A, namely firms experience an increase in green innovation subsequent to the mandatory CSR disclosure. But we cannot determine which channel (alleviate the information asymmetry or environmental regulation) plays a role in the process.

Table 3. The impact of mandatory CSR disclosure on green innovation.

	(1)	(2)	(3)
post*treat	2.215*** (0.480)	2.244*** (0.480)	2.193*** (0.479)
post	0.300** (0.145)	0.680*** (0.248)	-1.432 (1.146)
treat	-2.420*** (0.600)	-2.077*** (0.611)	-2.011*** (0.610)
lnasset			0.155 (0.179)
largesthold			0.006 (0.012)
state			-0.019*** (0.005)
cashflow			0.000*** (0.000)
age			0.001 (0.001)
_cons	0.478*** (0.117)	0.408** (0.195)	-4.991 (3.796)
Year FE	Not Included	Included	Included
N	9732	9732	9725
R2	0.004	0.006	0.015

Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2. The heterogeneous impact of mandatory CSR disclosure on green innovation

In order to prove the hypothesis 2 and hypothesis 3, we further distinguishes the firms into different groups according to the ownership nature and the size of firms, and tests the impact of mandatory CSR information disclosure on green innovation. Table 4 reports the results. In column 1 and column 2, we show the results of state-owned firms and non-state-owned firms respectively. In column 3 and column 4, we show the results of the small and medium firms and large firms respectively (According to the median size of e firms, firms are divided into large firms group and small and medium-sized firms group). The coefficient of the interaction between post and treat is significantly positive in the sample of state-owned firms, but it is not significant in non-state-owned firms, which indicates that mandatory CSR information disclosure has a positive effect on state-owned firms. It supports the hypothesis 3, which assumes state-owned firms exhibit a different increase in green innovation from non-state-owned firms subsequent to the mandatory CSR disclosure. This may be due to the fact that state-owned firms feel more pressure to increase their commitment to CSR.

Compared with small and medium-size firms, the coefficient of the interaction is significant and positive in large firms. It supports the hypothesis 2, which assumes large firms exhibit more increase in green innovation than small and medium-sized firms subsequent to the mandatory CSR disclosure.

And the Schumpeterian hypothesis holds. This may be due to the fact that larger firms have enough output to spread the cost of innovation or the fact that large firms have enough funds for R&D investment compared with small and medium-sized firms.

Also, in order to test hypothesis 4. First, we draw on the definitions of Pollution-intensive industries (PIIs) to divide different industries. According to Liu et al., based on the median of the emission intensity the industries are divided into Pollution-intensive industries (PIIs) and non-Pollution-intensive industries (NPIIs), which is reported in Table 5, and the division standard of industrial sectors is in accordance with “China Industry Economy Statistical Yearbook” (Liu et al., 2016). Traditional manufacturing industries such as Manufacture of paper and paper products, Manufacture of textiles, Beverage manufacturing and Production and supply of gas are included into the Pollution-intensive industries. Then we make regression based on these two groups of samples, whose results are shown in columns 5 and 6 of Table 4. In column 5, the coefficient of the interaction is significant at the 1% level, while in column 6, the coefficient is not significant. This shows that in the pollution intensive industries, the mandatory information disclosure policy can promote the innovation behavior of firms. On average, after the introduction of the policy, the number of green invention patent applications of firms in the list is 6.98 more than those if not in the list.

Table 4. The heterogeneous impact of mandatory CSR disclosure.

	SOE (1)	NSE (2)	SMEs (3)	Large (4)	PIIs (5)	NPIIs (6)
post*treat	2.77*** (0.64)	-0.19 (0.81)	-0.19 (0.59)	3.12*** (0.75)	3.14*** (0.61)	-0.26 (0.66)
post	-2.24 (1.96)	0.23 (1.05)	-0.00 (1.00)	-2.18 (2.06)	-1.96 (1.41)	-0.07 (1.73)
treat	-2.27*** (0.82)	-0.12 (0.94)	0.13 (0.73)	-2.75*** (0.95)	-2.94*** (0.77)	0.27 (0.85)
lnasset	0.09 (0.30)	0.31* (0.19)			0.11 (0.21)	0.42 (0.31)
largesthold	0.00 (0.02)	-0.02 (0.01)	-0.01 (0.01)	0.02 (0.02)	0.02 (0.01)	-0.02 (0.02)
cashflow	0.00*** (0.00)	-0.00 (0.00)	-0.00 (0.00)	0.00*** (0.00)	0.00*** (0.00)	-0.00 (0.00)
age	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
state			0.00 (0.00)	-0.03*** (0.01)	-0.03*** (0.01)	
_cons	-6.56 (6.68)	-5.15 (3.65)	0.39 (1.58)	-3.55 (3.59)	-5.12 (4.50)	0.00 (0.01)
Year FE	Included	Included	Included	Included	Included	Included
N	5597	4128	4746	4979	2464	7261
R2	0.017	0.005	0.003	0.022	0.022	0.006

Note: Standard errors in parentheses,* p < 0.1, ** p < 0.05, *** p < 0.01.

Table 5. The definition of pollution-intensive industries.

Pollution-intensive industries	
Manufacture of paper and paper products	Manufacture of textiles
Beverage manufacturing	Production and supply of gas
Processing of food from agricultural products	Smelting and pressing of ferrous metals
Manufacture of chemical fibers	Production and supply of electric power and heat power
Foodstuff manufacturing	Petroleum processing, coking, and nuclear fuel processing
Manufacture of raw chemical materials and chemical products	Smelting and pressing of nonferrous metals
Production and supply of water	Manufacture of non-metallic mineral products

Note: Definitions of PIIs come from the results of Liu et al. (2016).

5. Robust tests

5.1. PSM-DID method

Furthermore, we use the propensity score matching and difference-in-difference (PSM-DID) method to do the robust tests. Before using propensity score matching method, the two tests (balance assumption and common support assumption) are required. On the one hand, the balance assumption (also called ignorability or selection on observables) require the two groups in observables should be as similar as possible so that the possibility of firms entering the control group was similar to the treat group. Therefore, firstly we select the variables (roa, liability and whether state-owned firms) as the covariant and use logit model to compute the propensity score. Table 6 shows the results of balance test. In this table, the t-test results show that, there are significant differences between the two groups in several variables (roa, liability and whether state-owned firms) before matching. But after matching, the significance decreases obviously. There is no significant difference between the two groups in terms of roa, liability and whether state-owned firms. Moreover, the average deviation between the control group and the processing group is within 5%, and the deviation reduction range is more than 70%. This shows that the balance hypothesis is satisfied. On the other hand, the common support hypothesis requires the propensity scores of treat group and control group have common support. Figure 3 shows that before matching, the kernel density of the control group and the treat group are significant different. But after matching the kernel density of the two groups are very close, which indicates that after matching, the two groups have common support (meet the common support hypothesis). In addition, it indicates that the characteristics of the variables in the two groups are similar, after matching.

Table 6. Balance test.

Variable	Unmatched	Mean		% reduct		t-test		V(T)/
	Matched	Treated	Control	%bias	bias	t	p > t	V(C)
roa	U	0.06177	0.04603	3.7		2.44	0.015	47.62*
	M	0.06177	0.04675	3.5	4.6	0.88	0.380	53.52*
lnasset	U	22.616	21.406	86		33.66	0.000	2.15*
	M	22.616	22.623	-0.5	99.4	-0.10	0.918	1.01
largestholder	U	40.529	37.077	22		7.29	0.000	1
	M	40.529	40.178	2.2	89.8	0.53	0.599	0.81*
isstateown	U	0.79968	0.5294	59.7		18.30	0.000	
	M	0.79968	0.79157	1.8	97	0.50	0.618	

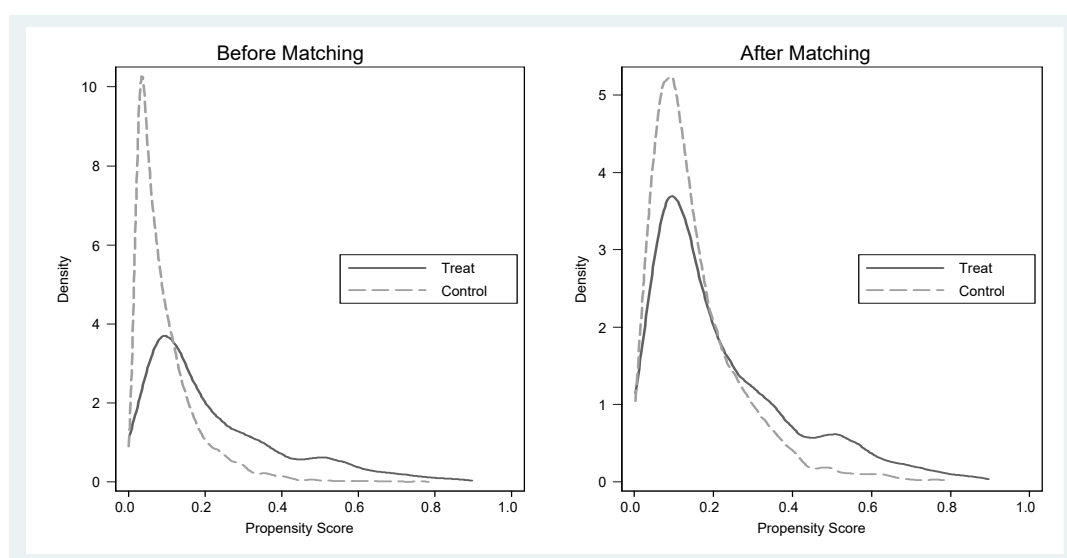
**Figure 3.** The kernel density of the treat and control group before and after matching.

Table 7 reports the descriptive Statistics of the sample after the matching. The treat groups are the same as mentioned before (Table 2), while the control groups are composed of the PSM samples. After matching, the differences between treat groups and control groups are narrowed to a comparable range, for example, the mean of liability with control groups is 0.52, which is the same as treat groups.

Table 7. Descriptive statistics, PSM samples.

	treat					control				
	N	mean	sd	min	max	N	mean	sd	min	max
roa	1233	0.06	0.6	-0.41	20.79	2484	0.05	0.09	-0.81	1.76
liability	1233	0.52	0.19	0.01	1	2484	0.52	0.2	0.02	1
lnasset	1233	22.62	1.64	16.69	28.28	2484	22.05	1.28	15.47	27.1
largesthold	1233	40.53	15.68	6.47	100	2484	38.53	16.57	2.2	95
isstateown	1233	0.8	0.4	0	1	2484	0.74	0.44	0	1

Then based on the PSM samples, we again utilize the DID model to test the hypothesis 1. Table 8 reports the results of PSM-DID method. Column (1) is the basic model, and column (2) adds to the year dummy variables. The results show that the coefficient of the interactions are both significant and positive, which suggest that firms generate 1.729–1.907 more green invention patents on average after the mandatory CSR information disclosure.

Table 8. The impact of mandatory CSR disclosure, PSM sample.

	(1)	(2)
post*treat	1.729* (0.891)	1.907** (0.893)
post	0.463 (0.530)	1.583* (0.845)
treat	-2.005* (1.113)	-0.938 (1.170)
_cons	1.029** (0.448)	0.637 (0.694)
Year FE	Not Included	Included
N	3717	3717
R2	0.004	0.009

Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.2. Placebo effect

In Table 9, we use two placebo tests to support the results. First, we assign 2007 as a pseudo mandatory disclosure adoption year, classifying our firm-year observations as post-period if the year falls in 2007. We assume that the coefficient should be significant if there were other factors which affected the green innovation. But the fact is that the coefficient of the interaction reported in column (1) is not significant again, which proves that there is no firm green innovation subsequent to the pseudo mandatory disclosure adoption year.

Then, we repeat our analysis after deleting 2008 from our sample to do another robustness test. As we understand, if the mandatory information disclosure has effect on green innovation, deleting the sample of one year should not change the results. The results reported in column (2) show that the coefficient on the interaction term post*treat continues to be significantly positive.

These results support the parallel trend assumption. They also suggest that our observed increase in firm green innovation for our treatment firms occurs after the disclosure mandate become effective. Taken together, the results suggest that mandatory CSR disclosure can foster firm green innovation.

Table 9. Additional robustness tests with the dependent variable being green innovation.

	Placebo test (1)	Deleting 2008 (2)
post*treat	-0.0398 (0.0704)	2.745*** (0.466)
post	0.0557 (0.0357)	0.365 (0.282)
treat	0.236** (0.0925)	-2.713*** (0.669)
roa	-0.0592 (0.170)	-0.161 (0.966)
lnasset	0.0459 (0.0396)	0.205 (0.164)
largesthold	0.000313 (0.00204)	-0.00251 (0.0108)
Year FE	Included	Included
_cons	-0.768 (0.828)	-3.769 (3.390)
N	5484	9710
R2	0.006	0.008

Note: Standard errors in parentheses,* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3. Other control variables

Furthermore, we also add to other control variables. According to the research of Aghion et al. (2013), greater institutional ownership can promote corporate innovation, we add to variable “Proportion of shares owned by institutional investors” to test the impact of institutional investors. In order to test the impact of ownership structure, we also add to variable “Proportion of the top ten largest shareholder”. In order to test the impact of corporate governance structure, we add to variable “Separation degree between chairman and CEO”. Specially, table 10 shows the definition of the other control variables, for example, *ins* is defined as the percentage of shares owned by all kinds of institutional investors. *separation* is defined as a dummy variable which equals 1 if chairman and CEO are the same person, otherwise equals 0.

Table 10. Definitions of other control variables used in this study.

Variable Name	Symbol	Definition
Proportion of shares owned by institutional investors	<i>ins</i>	Total percentage of shares owned by all kinds of institutional investors
Separation degree between chairman and CEO	<i>separation</i>	A dummy variable which equals 1 if chairman and CEO are the same person, otherwise equals 0
Proportion of the top ten largest shareholder	<i>topten</i>	Total percentage of shares owned by the top ten largest shareholder

Table 11 show the results of additional robustness tests with other control variables. In column (1), the coefficient of the interaction is still significant and positive. On average, after the introduction of the policy, the firms in the list generate 2.341 more green invention patents than those if not in the list. In column (2)–(5), we can still conclude that state-owned firms and large firms are more sensitive to the mandatory information disclosure policy, and that they generate more invention patents than did they if not in the list.

Table 11. Additional robustness tests with the dependent variable being green innovation.

	All (1)	SOE (2)	NSE (3)	Large (4)	SMEs (5)
post*treat	2.341*** (0.504)	2.845*** (0.680)	-0.170 (0.820)	3.169*** (0.809)	-0.154 (0.615)
post	0.064 (0.190)	0.007 (0.302)	0.116 (0.194)	0.354 (0.337)	0.067 (0.146)
treat	-2.471*** (0.626)	-2.930*** (0.852)	-0.085 (0.942)	-3.587*** (0.985)	0.151 (0.747)
roa	0.067 (1.344)	-0.048 (2.400)	0.252 (1.201)	-0.167 (3.481)	0.045 (0.937)
liability	0.057 (0.804)	-0.597 (1.391)	0.639 (0.775)	0.776 (1.829)	0.264 (0.646)
largesthold	-0.001 (0.015)	0.006 (0.023)	-0.008 (0.017)	0.003 (0.031)	0.004 (0.014)
topten	-0.009 (0.013)	-0.011 (0.022)	-0.011 (0.012)	-0.005 (0.028)	-0.012 (0.011)
lnasset	0.368** (0.176)	0.589* (0.307)	0.173 (0.174)		
isstateown	0.137 (0.468)			0.583 (1.102)	0.099 (0.352)
ins	0.354 (0.603)	0.270 (0.913)	0.763 (0.668)	0.667 (1.163)	0.863 (0.545)
seperation	-0.001 (0.019)	-0.006 (0.034)	-0.000 (0.020)	-0.003 (0.039)	0.003 (0.016)
_cons	-6.913* (3.645)	-11.289* (6.331)	-2.849 (3.631)	0.232 (1.839)	0.474 (0.615)
Year FE	included	included	included	included	included
N	9331	5254	4077	4665	4666
R2	0.005	0.007	0.003	0.007	0.002

Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Conclusions

Since the Berle-Dodd debate, more and more scholars pay attention to CSR. The initial research focuses on the relationship between CSR and firm value, and the results are inconclusive. CSR can reduce firm's financing cost, but also spends too much resources on unproductive activities. Later research also begins to focus on CSR from the perspective of stakeholders, for example the impact of CSR on environmental performance, the indirect effect of CSR on firm value through innovation. And as people pay more attention to information disclosure, many countries begin to implement mandatory CSR information disclosure, which require firms to issue stand-alone CSR reports along with the annual report. The same is true of China. Although the original intention of policy makers is good, but frankly the effectiveness of policies needs to be judged through research. Unfortunately, few scholars have done research. Under this incentive, a quasi-natural experiment is designed in this paper to study the impact of mandatory CSR on green innovation.

The DID results show that mandatory CSR information disclosure can indeed promote firms' green innovation. On average, after the introduction of the policy, the firms in the list generate 1.912–1.956 more green invention patents than those if not in the list. Moreover, the influence is heterogeneous among different types of firms. Larger firms, state-owned firms and firms in pollution-intensive industries are more likely to be affected by mandatory disclosure. And the results are robust to the different samples or methods. In sum, our findings support the "Porter Hypothesis" that the environmental regulation could promote corporate green innovation. Also, our findings show that state-owned firms and larger firms are more sensitive to policy, thus are more influenced by the environmental regulation.

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Conflicts of interest

The authors declare no conflict of interest.

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