Corporate governance and the environment: evidence from clean innovations

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Abstract

This paper presents causal evidence on the importance of corporate governance for the environmental performance of firms. Using changes in takeover legislation to establish exogenous variations in the quality of corporate governance, we show that worse-governed firms patent fewer clean innovations relative to their total innovation effort. We also find that worse-governed firms patent more non-green innovations, suggesting that the governance shock affects the composition of innovative activities by inducing a substitution from green to dirty projects. Our findings are more pronounced for firms with limited stock of clean innovations, industries with lower energy dependence, firms operating in states with lower pollution abatement costs and for firms with a lower share of institutional ownership. Overall, our results suggest that green activities increase shareholder value but that myopic CEO behavior tends to bias towards dirty projects. Thus external pressure from (stronger) shareholder interests improves environmental performance as well as shareholder value.

Keywords: corporate governance, environment, patents
JEL: G34, O31, Q20

1. Introduction

Global climate change is the greatest economic and social challenge that humanity faces in the foreseen future. Although some important determinants of environmental efficiency, such as public policies (Jaffe et al. 2002; Johnston et al. 2010), energy prices and technology (Popp 2002; Martin 2010), and other firm-specific factors (Cole et al. 2007; De Canio and Watkins 1998) have been studied, there is still much variation across firms that remains unexplained. Academic scholars are thus paying increasing attention to the effect of corporate governance on environmental policies. Existing works examine, for instance, the effect of managerial quality on energy efficiency (Bloom et al. 2010) and pollution outcomes (Kock et al. 2011). The prevailing view of this recent research is that good corporate governance is positive correlated with firms' environmental efficiency. However, as acknowledged in existing works (e.g. Bloom et al. 2010), the literature has not found firm evidence on the direction of causality in the nexus between corporate governance and environmental outcomes.

We contribute to this literature by providing causal evidence for how corporate governance shapes firms' environmental innovation policy, measured by the number of patents related to energy-saving and environmental technologies. As documented in existing works, environmental patents represent a key driver to reduce toxic emissions (Carrion-Flores and Innes 2010). Our contribution is thus twofold. First, by investigating the effect of corporate governance on green patents, we illustrate a specific channel that explains how good governance can effectively reduce pollution outcomes. Second, we adopt an empirical identification based on changes in the U.S. takeover legislation that allows us to discern the causal effect of corporate governance on firms' environmental policies.

Using data on U.S. manufacturing companies from the Compustat and NBER patent datasets, we exploit information on patents' technological class to identify environmental-related innovations. We then adopt a difference-in-differences approach based on the passage of business combination (BC) laws in the U.S. states during the second half of the

1980s. BC laws had a negative effect on corporate governance because firms incorporated in the legislating states improved their ability to defend from uninvited takeovers, which in turn increased managerial slack (Bertrand and Mullainathan 2003). The staggered passage of BC laws across U.S. states provides geographic and time variations in the quality of corporate governance. Moreover, given that BC laws affected firms in their state of incorporation, we can exploit the discrepancy between state of headquarter and incorporation to carefully control for geographic effects.

Our main result indicates that the exogenous worsening of corporate governance generated by the passage of the BC laws led to a statistically significant and economically relevant reduction in firms' green innovation activity. Following the passage of BC laws, firms experienced, on average, a 7 percent reduction of environmental-related patents in their patent portfolio. The reduction in green innovation was matched by an increase in non-green innovation with no significant impact on research and development activities. Our results are robust to the exclusion of Delaware, where many U.S. firms are incorporated, firms headquartered in California, and firms incorporated in states that never implemented the BC laws.

We show that the economic size of the impact of corporate governance on firms' green innovation activities is shaped by the opportunity costs of substituting from green towards non-green innovation: First, the larger a firm's stock of clean innovation, the smaller reduction in green innovation following BC laws. Second, the negative effect of BC law passages on green innovations is more pronounced in sectors with lower energy dependence. Finally, the substitution in innovation activities is larger for firms operating in states with lower cost of pollution abatement. In addition to these economic factors we also show that the substitution effect is negatively related to the size of institutional ownership. Taken together, our results suggest that there are both economic and governance determinants of firms' green innovation activity. When the internal governance incentives (measured by size of institutional ownership) and/or the economic incentives (measured by marginal opportunity costs) are strong, a change in state-level corporate governance has a lower impact on firms green innovation activities.

Finally, we ask what are the market value implications of changing environmental performance as a result of BC laws. While it is known that the implication of the BC laws was to reduce firm value (Bertrand and Mullainathan 2003), we show that there is a positive correlation between firm value reduction and the reduction in green innovation activity after the introduction of the BC laws.

To our knowledge there is no formal theoretical models analyzing how changes in corporate governance affect firms' green patenting. We believe there are at least three channels through which green innovation activity can be affected by the improvement in take over protection that was the main consequence of the BC laws. First, there is a *quiet life* argument. Since managers are less exposed to the disciplining role of takeovers, they will focus less on shareholder value and more on private rent extraction. This would imply that managers are tempted to engage less in cognitively difficult activities such as innovation. Hence, according to this argument, improved take over protection should lead to less innovation and thus a decline in both green and non-green research projects.

Second, there is a *career concern* argument. Managers working under strong shareholder pressure may on average face a larger chance of being removed from their job in cases where there shareholder cannot extract clear information about managers effort and talent. Assuming that green projects requires a longer time span but in expectation have higher NPV. Since managers under strong shareholder pressure faces a higher risk of being fired, they may have higher incentive to favor projects with a relative short time horizon compared to more risky long term projects. By reducing shareholder pressure, the BC laws can induce higher incentives to engage in long term projects and, hence, induce a substitution from non-green to green research projects.

Third, there is an *institutional monitoring* argument. In the realistic case where ownership is dispersed and that institutional shareholders are the main block holders of the firms, the BC laws lower the ability of institutional shareholder to affect the behavior of firm management. The reduction in institutional shareholders' power will provide more leverage for risk averse managers to choose less risky projects against the shareholders' interest. Assuming that green innovation projects are more risky but also potentially more

rewarding, the institutional monitoring argument predict that the BC laws may induce a substitution from green to non-green projects.

Our empirical results are consistent with the institutional monitoring argument and inconsistent with the first two arguments above: we find that the BC laws imply a substitution from green to non-green innovation, and that the size of the substitution effect is correlated with a reduction in shareholder value. Furthermore, the effect is mostly present when the share of institutional ownership is small, suggesting that large institutional owners have power to efficiently monitor management beyond the impact of the BC laws. By contrast, the reduction of green innovation activity is inconsistent with the career concern argument that predicted an increase in green innovation activity. Further more, our findings are also inconsistent with a quiet life argument, because we find an increase in non-green innovation activity.

Section 2 describes the data and provides summary statistics. Section 3 illustrates the empirical strategy. Section 4 presents the main empirical findings and a number of robustness checks. Section 5 illustrates how our result varies depending on firm and industry characteristics, whereas Section 6 discusses the market value effect of fewer clean patents. Section 7 concludes.

2. Data and summary statistics

2.1 Financial data

We use firm-level data from the Compustat dataset, which contains comprehensive financial information on U.S. publicly traded firms. We restrict the dataset to firms with positive sales and book value of assets that are incorporated and headquartered in the U.S. Also, similar to other studies in this field (Bloom et al. 2010; Carrion-Flores and Innes 2010; Kock et al. 2011; Konar and Cohen 2001), we restrict the dataset primarily to the manufacturing sector (SIC codes up to 4000), which is considered the main source of toxic

emissions[1] and also account for most of the patenting activity (Scherer 1983; Balasubramanian and Sivadasan 2011).

We construct a set of firm-level variables such as firm sales, capital to labor ratio, firm age, market to book value, and R&D to assets ratio. We also construct such an industry-level control as the Herfindahl-Hirschman Index (HHI), to account for the potential effect of market structures on environmental activities (Fernandez-Kranz and Santalo 2010). We compute the HHI using the distribution of firms' revenues in a particular three-digit SIC industry, and we correct for potential misclassifications due to the presence of a single firm in a given industry by dropping 2.5% of the firm-year observations at the right tail of the HHI distribution (Giroud and Mueller 2010). Table A2 offers a complete description of how each variable was constructed. Table 1, Panel A, presents the summary statistics.

2.2 Environmental innovation

We measure firms' environmental innovation using clean patents (Aghion et al. 2011; Jaffe and Palmer 1997; Brunnermeier and Cohen 2003; Carrion-Flores and Innes 2010). Patent data come from the dataset assembled at the National Bureau of Economic Research (NBER), which contains information on more than three million patents granted by the U.S. Patent and Trademark Office (USPTO) and all citations made to these patents starting from 1976 (Hall et al. 2001; Bessen 2009). Using patents, as opposite to e.g. R&D expenses, allows us to classify innovations according to their technological content. Our classification of clean patents follow closely Carrion-Flores and Innes (2010) and is based on the primary three-digit patent classification provided by the USPTO. The main technological categories considered are broadly related to: air or water pollution; hazardous waste prevention; disposal and control; recycling; and alternative energy defined. A detailed description of the technology classes used to identify clean patents is provided in

[1] Manufacturing activities are, however, highly heterogeneous in terms of pollution emissions and contain sectors with relatively high (e.g. chemicals) and low (e.g. apparel) emission levels. In unreported analyses, we find that our results are present in the subsample of the most pollution-intensive industries as well as in all other industries. Following existing studies (e.g. Keller and Levinson 2002), pollution-intensive industries are classified as pulp and paper (SIC 26), chemicals (SIC 28), petroleum (SIC 29), stone clay and glass (SIC 32), primary metals (SIC 33), fabricated metals (SIC 34), and transportation equipment (SIC 37).

Table A1, while Table 1, Panel B, provides summary statistics for the main innovation variables used in the empirical analysis.

We adopt finer classifications of clean innovations in a number of robustness checks. First, we use the classification of energy patents in (Popp 2002; Popp and Newell 2011).[2] This classification, which is based both on patents' main classifications and subclassifications, is apt to define renewable technologies as well as new sources that may use fossil fuels, such as fuel cells and coal liquefaction; hence, it captures technological efforts in both improving the use of existing energy supplies and in developing entirely new sources. Second, we adopt the classification of renewable energy technologies provided by Johnstone et al. (2010). Using the International Patent Classification (IPC), Johnstone et al. (2010) provide a list of appropriate IPC codes related directly to such renewable technologies as wind, solar, geothermal, ocean, biomass, and waste.

2.3 Corporate governance measures

Our main corporate governance variable is the adoption of BC laws by thirty U.S. states in the late 1980s. BC laws were the most stringent statutes of a wave of laws enacted in the 1980s and aimed at limiting the takeover activity among firms incorporated in the legislating states. Specifically, BC laws increased the cost of hostile takeovers by imposing a moratorium on the transfer of assets from the target to the acquirer company, thus limiting the ability to pay down acquisition debt. Because these laws made much harder to realize the benefits of takeovers, the consequence was a drastic weakening of the market for corporate control. Given that the market for corporate control is a powerful mechanism to discipline managers (Shleifer and Vishny 1997), several empirical works have exploited the passage of BC laws and other changes in takeover legislation to establish exogenous worsening in the quality of corporate governance.[3]

Table 2 shows the staggered passage of BC laws in the period 1985-1991. We use a time window that spans from 1976 to 1995, thus including a few years before and after the passage of BC laws. Table 3 shows the number of states and firm-year observations subject

[2] See Appendix A in Popp and Newell (2011) for a detailed description of energy patents

[3] See e.g. Bertrand and Mullainathan (1999; 2003), Francis et al. (2011), and Giroud and Mueller (2010).

to BC laws in our sample. Thirty U.S. states (68.2% of states in the sample, representing 87.8% of firm-year observations) passed BC laws, while fourteen states (13.3% of states in the sample, representing 12.2% of firm-year observations) never passed a BC law.

3. Empirical strategy

Our main goal is to establish whether corporate governance matters for firms' environmental innovation. One common approach to address this question is to compare the environmental performance of firms with different corporate governance quality. However, provided that such approach reveals a positive association, its causal interpretation (i.e. better corporate governance causes better environmental performance) is

last state of incorporation, and therefore we cannot tackle this issue directly. However, the literature has provided some evidence that changes of incorporation during the period considered were quite rare (Romano 1993). Bertrand and Mullainathan (2003) randomly sampled 200 firms from their dataset and manually checked how many firms changed state of incorporation; they found only three changes, all of them to Delaware and several years prior to the passage of the BC law in that state.

Another important advantage of BC laws is that they affected firms at their state of incorporation, which often differs from the state of operation.[4] This discrepancy allows us to compare, within the same state and industry, the environmental activities of firms that were affected by worse governance (i.e. incorporated in a BC-passing state) using as control group firms that were not exposed to governance changes (i.e. incorporated in a state that did not pass a BC law, or that passed it later in time).

An illustration of our difference-in-differences methodology is presented in Graph 1, which compares the average clean patenting activity of firms incorporated in Massachusetts and California. While the former (treatment group) experienced a worsening in corporate governance due to the passage of a BC law in 1989, the latter (control group) did not experience such change as California did not pass a BC law. Focusing on the pre-BC years, we observe that though Massachusetts incorporations patented more clean innovations on average, the slightly upward trend did not drastically differ from California incorporations. However, focusing on post-BC law years, we observe a sharp decline in the clean patenting activity of Massachusetts incorporations, which were exposed to the law passage, while California incorporations seem to follow the existing trends. Our identification generalizes this example to all states and BC passages over the years. Specifically, we estimate the following difference-in-differences model:

$$Y_{ikt} = \alpha_i + \alpha_t + \beta BC_{kt} + \gamma' X_{ikt-1} + e_{ikt} \qquad (1)$$

where Y_{ijkt} measures at time t the clean patenting activity of firm i incorporated in state k. BC_{kt} is a dummy equal to one if a firm is incorporated in a state that has passed a BC law

[4] In our sample, 64.5% of firms are incorporated outside their state of operations.

by time t (treatment group), and zero otherwise (control group). Hence, the coefficient β measures the effect of BC law passages on firms' clean patenting activity relative to firms incorporated in states that passed BC laws later in time or that never passed a BC law.

Given that firms incorporated in BC passing states are different from those incorporated in states that never passed BC laws (Giroud and Mueller 2010), it is important to include a comprehensive set of controls. α_i and α_t represent, respectively, firm and year fixed effects, which are included to absorb common shocks potentially affecting environmental activities, e.g. the energy crises of the 1970s, and unobserved heterogeneity across firms that is invariant over time. X_{ijkt-1} is a vector of controls which, depending on the specification, includes firm sales, capital-to-labor ratio, R&D stock, HHI, and firm age. Controls are lagged by one year to prevent potential simultaneous effects of BC laws. Finally, we include headquarters' state and three-digit industry linear trends, computed as year averages of the dependent variable excluding the firm in question.

e_{ijkt} are the residuals, which we estimate by clustering at the state of incorporation. This procedure accounts for arbitrary correlations of residuals across different firms in a given year and state of incorporation, across different firms in a given state of incorporation over time as well as over different years for a given firm (Giroud and Mueller 2010).

4. Results

4.1 Main results

We begin by analyzing our benchmark effect of worse governance on the probability of patenting a clean innovation. In particular, we estimate a linear probability model in which the dependent variable is an indicator equal to one if, conditional on being a patenting firm, a firm in a given year reports at least one environmental-related patent.

Table 4 show that firms exposed to BC law passages experienced a drop in the frequency of patenting clean innovation. In Column 1 we present the basic difference in difference regression without controls. We notice that the BC laws induced a drop in green innovation of 7,23 pct point and this effect is significant on a 5 pct level. Introducing a set

of controls in Column 2 only marginally reduces the economic size of the effect which is still statistically significant at a 5 pct level.[5]

Columns 3 and 4 presents further evidence for the reduction in green innovation using as dependent variable the count of clean patents divided by the overall number of patents of a firm.[6] As shown, the coefficient of BC laws is negative and statistically significant at 1%. The most comprehensive specification (Column 4) indicates that following BC laws, firms incorporated in legislating states reduced their clean patenting activity by 3.9 percentage points. Given that the average ratio of clean patents to total patents is 25.7%, the decrease can be quantified in approximately 15% of the average clean innovation, and is therefore economically relevant.

4.2 Substitution between innovation projects

So far our results indicate that firms patented less clean innovations. We next address the question if this is a general reduction in innovation activities (as predicted by the *quite life* argument) or if there is a substitution from green to non-green activities (as predicted by the *institutional* monitoring argument). We do this in two steps.

First, we investigate if the reduction in green patenting was followed by an increase in non-green patenting. In Panel A of Table 5, we focus on the patenting of clean innovations, using as dependent variable the logarithm of one plus clean patent counts (Column 1). Consistent with our previous results, we find that worse-governed firms experienced a drop in environmental innovation. In Column (2), we use as dependent variable the logarithm of one plus non-clean patent counts. Opposite to the case of clean patents, our results indicate that worse-governed firms experienced an increase in environmental-unrelated patents. Taken together, this evidence indicates that worse corporate governance caused a drop in clean projects and a simultaneous increase in non-clean projects.

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[5] The endogenous variable is a discrete number. Thus, in unreported analyses, we further confirm this result using a conditional fixed-effects logit model

[6] By construction, this variable is missing when the firm reports zero patents. However, results are robust to replacing these missing values with zeros.

Second, given the observed substitution from green to non-green projects, we ask if there was an overall effect on research and development in the affected firms. We test this notion in Table 5, Panel B. First, we use R&D expenses to total assets as dependent variable. If lower clean projects are due to a change in the composition of innovation projects, aggregate R&D expenses should not exhibit any change. By contrast, if firms are decreasing clean investment due to a drop in innovation inputs, aggregate R&D expenditures should decline following BC laws passages. As shown in Column (1), BC laws had no significant impact on R&D expenditures. Similarly, consistent with the notion that the decrease in clean patents was offset by an increase in non-clean patents, we do not find any significant change in the total number of patents (Column 2).

To sum up our benchmark results we conclude that the introduction of BC laws implied a substitution from green innovation to non-green innovation without any overall impact on the research and development activities. The substitution effect was significant in both economic and statistical sense. Thus our results so far is consistent with the *institutional monitoring* argument above but not consistent with neither the *quiet life* argument nor the *career concern* argument. The quiet life argument predicted a general reduction in research and development activities that we did not see in data. The career concern argument predicted an increase in green innovation which is the opposite of what we find in data. We will provide further evidence for the *institutional monitoring* argument below.

4.3 Robustness checks

Table 4 and 5 above showed out main finding, that following the introduction of the BC law firms substitute from clean to non-clean innovation projects. Our simple difference in difference setup raises a number of questions about the validity of our identification. We address a number of these issues in Table 6 that present a battery of robustness exercises. Given that Table 4 and 5 established the substitution from clean to non-clean patenting we will to save space in the following focus on the ratio of clean innovation as our dependent variable.

First, we take into account the fact that OLS may be inappropriate because the dependent variable is a proportion, which also contains several zeros due to firms that do not patent any clean innovation. Table 6, Column (1) shows results obtained using a fixed effect- Tobit model, computed using bootstrapped standard errors.[7] We observe that the substitution effect is statistically significant at a 1 pct level and large in economic terms. Column (2) shows the results obtained using a pooled fractional non-linear procedure estimated using Quasi-Maximum Likelihood (QML), as proposed in Papke and Wooldridge (1996), including states and three-digit SIC industry dummies.[8] We notice that the effect is smaller using the pooled estimation method but still statistically significant at a 10 pct level.

Second, clean projects can be defined in several ways and we it may be a concern that we focus on one particular categorisation of patents. To cater to this, we use a host of alternative dependent variables. In Column (3), we use the ratio of cite-weighted clean patents to firms' total cite-weighted patents, to take into account not just the number of patents but also their technological importance as reflected by future citations received. It is interesting to notice that the BC law dummy is negative and significant at a 1 pct level. In Column (4), we adopt the ratio of patents for new energy technologies (Popp 2002; Popp and Newell 2011) to a firm's total patents.[9] In Column (5), we adopt we adopt the ratio of patents for renewable technologies (Johnstone et al. 2010) to a firm's total patents.[10] Both of these specifications also provide a significant impact effect of BC laws on the ratio of clean projects. Thus, Column 3 to 5 confirm that the substitution effect is robust to alternative definitions of clean patenting.

Third, we can be concerned that the implementation of the BC laws contain a signal that state policy is less favourable to green innovation. Now the key in this argument is that

[7] Specifically, we use the pantob procedure developed by Bo Honoré.

[8] We also extend this model to the longitudinal setting by using a fractional probit model with heteroskedasticity-robust standard errors as in Papke and Wooldridge (2008). While our result are largely robust to the adoption of this procedure, it should be noticed that there are some difficulties in using this model with unbalanced data (Papke and Wooldridge 2008).

[9] While we only report OLS estimates, this result is robust to the use of the alternative models as done in Table 5, Columns (1) and (2).

10 One common problem when using these classifications to compute the ratio of clean patents is the high presence of zeros. For this reason, we have confirmed our finding using as well the fixed-effect Tobit and the pooled fractional procedure which we introduce in Column (1) and (2) for our main classification.

the BC law could be correlated with some other information release about how states in general provide incentives to engage in clean innovation. It is important to notice that this argument validity is limited because of the structure of the firm governance. The BC laws affect the headquarter of the firm through the state of incorporation. Now general state policy towards green innovation is likely to be important for a firm's production plants, which in many cases are located in different states than the state of incorporation. For instance, 55.4 pct of our sample are incorporated in Delaware and most of these firms do have their production facilities in other states. Thus, if the introduction of the BC law is correlated with a signal that states put less emphasize on green corporate behaviour, then the substitution effect should mainly be present in firms which have headquarter in states where they also have their production facilities. However, to cater to this argument directly we adopt the G-index as an alternative measure of corporate governance. The GIM index is assembled by Gompers et al. (2003) using data from the Investor Responsibility Research Center (IRRC) and it assigns a score based on the number of firm and state-level provisions that restrict shareholder rights. The key element for our analysis is that a significant part of the variation in this index is due to variation on firm and industry level, not on state level. Since the GIM index is available from 1990 to 2006, we conduct this check on a subsample that covers this period, rather than the period 1976-1995 used in our main analyses.[11] Moreover, we replace the BC passage dummy with a dummy equal to one if the firm displays a number of provisions above the median value (i.e. worse governance) and zero otherwise. Table 5, Column (6) yields a economically and statistically significant negative effect on the ratio of clean patenting for firms that have worse corporate governance according to the Gompers index. Hence, Column (6) confirms our finding that worse governance is associated with a substitution from clean to non-clean innovation activities.

Fourth, we are concerned that the results may be driven by specific states. Thus, to make sure that the results are not driven by influential states that report the highest innovation activity, we exclude firms headquartered in California (Column 7). Given that the majority of firms are incorporated in Delaware, we are also concerned that the average effect of BC laws may simply be driven by Delaware incorporated firms. To test whether

[11] Missing values of the G-index are replaced with the last value available.

this is the case, we exclude firms incorporated in in Delaware in Column (8). Finally, In Column (9) we exclude states that never passed a BC law, thus employing only the staggered passage of BC laws in the construction of the control group. None of these exclusions affect the robustness of our main findings, that the introduction of the BC laws implied a substitution from clean to non-clean innovation activities.

Fifth, it is theoretically possible that the correlation between BC laws and substitution of clean innovation project were driven by the general performance of the firms. Struggling firms may in general have difficulties in being successful in clean innovation. However, the managers of struggling firms have higher incentive to protect their jobs through lobbying states for increased managerial protection. According to this argument the observed correlation between introduction of BC laws and substitution towards more non-green innovation activities could be driven by a omitted variable measuring the general performance of the firm. If this is the case states that introduced BC laws should have many struggling firms before the introduction and thus the substitution from clean to non-clean innovation activities should start before the introduction of the BC laws. We check whether the effect of BC laws was anticipated by firms, e.g. due to the fact that firms in states with given characteristics lobbied for the passage of BC laws. We do so by creating a placebo BC law passage two years before its real implementation. Column (10) shows that the placebo BC laws did not have any significant effect on firms' environmental policy; as such, this result strengthens the argument that BC laws had a causal effect on corporate environmental policies.

In unreported analyses, we further confirm our results in several ways. For example, we restrict the analysis to firms that remain in the dataset for at least 4 years (or 8, or 12 years) in order to mitigate the effects of entry and exit. Another concern arises because we cannot identify the month when a BC law were passed. Hence, it may be inappropriate to consider as post-BC period observations in states that passed a BC law at the end of the year. To avoid this concern, we drop firm-year observations corresponding to the year of the BC passage. We also deal with outliers, i.e. firms that report a very high number of clean patents, by dropping 1% (or 5%) of observations in the right tail of the distribution of the clean patent counts. We also allow for heterogeneous time and state effects by

interacting all the covariates with year and treatment-state dummies. While equation (1) contains one-year lagged controls, we replicate our results using two-year lags or contemporaneous controls. We further confirm that our results are robust to alternative procedures to estimate the standard errors, e.g. clustering at the firm level or adopting block-bootstrap (as proposed in Bertrand et al. 2004) using 100 replications. Finally, we also test for dynamic effects by replace the dummy indicating the passage of BC laws with a set of dummies indicating each two-year increment from two years prior to the BC passage up to six years or more after the BC passage. The omitted group is hence formed by observations in the third year or earlier prior to the BC passage, as well as observations in never-BC states. Results (untabulated) show that the negative effect of BC laws is largest from three years after the reform onwards, possibly because it takes time before the managerial slack translates into fewer environmental projects selected. Moreover, the negative effect of BC laws is rather persistent and remains significant until the fifth year since the reform passage.

To sum up, we have in this section shown that the main finding that the introduction of BC laws implied a change in firms innovation activities towards more non-clean projects is vary robust. In particular, we have shown that the findings are robust to a number of alternative estimation methods, to various ways of defining what is clean innovation, to replacing the BC law with an alternative governance measure, to alternative composition of treatment and control states and that it is not driven by that struggling firms reduced their clean innovation activities and lobbied for the introduction of the BC law.

5. Economic and governance variations

In this section, we investigate how and why the BC laws caused a substitution in firms innovation activity. We follow two steps. We begin by documenting that the substitution from clean to non-clean patenting was shaped by economic factors. Broadly defined, we show that the effect was larger when the economic incentives were favoring clean patenting. In the second part, we provide specific evidence for the *institutional monitoring* argument as discussed in the introduction.

5.1 Economic incentives

A recent literature on innovation (see e.g. Acemoglu et al. (2011), Aghion et al. (2011)) has documented that innovation activities often exhibit path dependency. When firms have a large stock of innovation projects the marginal cost of new products is reduced by using lasting resources such as knowledge or technology from previous projects. The idea is that "firms build on their existing stock of technology-specific knowledge to develop new innovations, which in turn can lead to technological lock-in" (Aghion et al. 2011). Thus, according to the path dependency theory we should observe that the existing stock of clean patents has a positive effect on the propensity to patent new clean innovations.

Applying this argument, we claim that it is relatively easier for worse-governed managers to reduce clean innovations when the firm is not subject to heavy technological lock-in induced by past innovation decisions. To investigate this claim, we construct the stock of clean patents using the perpetual inventory method (Peri 2005; Cockburn and Griliches 1988) and a 15% depreciation rate.[12] We interact the indicator of worse governance with a dummy equal to one if the firm has a large (above-median) or small (below-median) stock of clean patents. Consistent with the notion of technological lock-in, results presented in Table 8, Column (1), indicate that, compared to firms with small clean patents stock, firms with large clean patents stock respond less to the passage BC laws. The difference between the coefficients are close to 25 pct. Even if the difference is not statistically significant, results suggests that firms are partly locked in the technologies acquired in the past, which influences the response to exogenous variations in corporate governance.

Next, we argue that the opportunity cost of switching from clean to non-clean innovation activities is higher for a firm operating in an industry highly dependent on

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[12] To account for the heterogeneity in the value of patent stock, in an unreported check we use the stock of clean patents weighted by citations received in subsequent patents.

energy resources. For such industries we therefor predict a lower substitution effect from introducing the BC laws. To test this claim, we compute an industry-level measure of energy dependence using data from the NBER manufacturing dataset. In particular, we take the ratio of energy expenses (cost of electrics and fuels) to the total value added. Then we classify industries as highly (above-median) or low (below-median) dependent on energy and interact this indicator with the BC law dummy. Results, reported in Column (2), show that introduction of BC laws reduces the ratio of environmental related patents to all patent with 4,67 pct points in industries with low energy dependence and with 3,39 pct points in industries with high energy dependence.[13] The 25 pct difference is suggestive (even if the difference is not statistical significant) that the BC laws induced more substitution in firms innovation activities in industries where energy dependence were lower.

Another source of variation in firms opportunity costs of substituting towards more non-clean innovation project is the stringency of environmental regulations in the state where the firm is headquartered. We expect that the cost of lowering environmental innovation is higher in states with stringent pollution regulations. To test this argument, we adopt the index computed by Levinson (2001) and Keller and Levinson (2002), who use data from the Pollution Abatement Costs and Expenditures Survey to quantify industry-adjusted pollution abatement costs in 48 U.S. states. A higher value indicates a more stringent state environmental regulation. For our purpose, we interact the BC law dummy with an indicator equal to one if a firm's state of headquarter has high (above-median) or low (below-median) pollution abatement cost index.[14] As shown in Column (3) the negative effect of worse governance is significant and economically larger when the firm operates in a state where pollution abatement costs are low. In other words, a higher cost of complying with pollution regulations deter the drop in environmental innovation caused by the managerial slack following the passage of BC laws.

To sum up, Table 8 provides suggestive evidence, that variation in opportunity cost of reducing clean innovation activity impacts the degree of substitution from clean to non-clean projects induced by the introduction of the BC laws.

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[13] This analysis is limited to firms in the SIC codes 2000-4000, as the NBER manufacturing dataset only covers industries in these SIC codes.
[14] We also exclude 1987 due to missing data in the original survey.

5.2 Institutional ownership

In the introduction we outlined three theoretical arguments for why more manger protection reduce firms clean innovation: *the quiet life* argument, *the career concern* argument and the *institutional monitoring* argument. We have already concluded that evidence is against the first two arguments. The quiet life argument predicts a general reduction in R&D projects and is not consistent with the documented substitution from clean to non-clean projects. The career concern argument predicts that the added managerial protection should induce a substitution towards more risky and longer running [illegible]

statistically significant on a 5 pct level. Hence, our findings support the institutional monitoring argument and is consistent with that large institutional owners have power to efficiently monitor management beyond the impact of the BC laws. and thus mitigate the negative effect of BC laws on clean patenting.

6. The value of green innovation

Results so far have established that the introduction of BC laws caused a substitution from environmental to non-environmental innovation projects, that the size of the substitution is driven by variation in opportunity costs and that the effect is related to institutional owners ability to implement their preferred policy on firm management.

It is important to emphasize that it is conceptually not clear whether this substitution in innovation activities is harmful or beneficial to companies. On the one hand, it may be that before the passage of BC laws managers were subject to institutional owners and other stakeholders' demand for costly environmental initiatives with unclear real benefits; following a weakening of the market for corporate control, managers became more insulated from these pressures (Kock et al. 2011) and thus were able to reallocate investment from clean projects to other projects yielding higher returns. Under such circumstances, we expect the drop in firms' environmental innovation to be associated with higher market value.

On the other hand, a weaker market for corporate control may have reduced environmental effort because a greater entrenchment led managers focus on projects with lower risk and reduced activities that were difficult to pursue, such as clean innovation, even if these activities were potentially valuable for the company at large[16]. Under such alternative circumstances, we expect the drop in environmental innovation to be associated with a decline in market value.

We shed light into these issues by first analyzing the association between changes in clean patenting and market to book ratios around the passage of BC laws.

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[16] This view is broadly consistent with Liou and Sharma (2011), who report a positive association between firms' energy-related patents and Tobin's Q, as well as with Dowell et al. (2000) who find a positive association between firms' environmental standards and market value.

In Table 9, we use as dependent variable the change in market to book around the BC law passage (computed as the average of post-BC period minus the average of the pre-BC period). We compute in a similar way the change in the ratio of clean patents, which is used as explanatory variable together with year fixed effects and industry intercepts. Column (1) indicates a positive association between changes in market to book and clean patenting, i.e. lowering the clean patent ratio around the BC passages is associated with lower market value. We know from existing works that BC laws affected other aspects of firm operations which may correlate with both environmental innovation and market value. To reduce this concern, in Column (2) we include changes in other key variables that are often used in market value regressions, such as ROA, tangibility, leverage and total assets. Although the effect displays a smaller economic magnitude, it remains statistically significant at the 10% level.

These findings provides little support to the idea that firms reallocated investment from unproductive clean projects to more productive expenditures. By contrast, our findings suggest that while being green is positively associated with financial performance (King and Lenox 2001, 2002) entrenched managers reduces effort in complicated tasks as required to pursue a clean innovation policy.

7. Concluding remarks

However, we since innovation may have significant externalities we are not able to conclude what is the social welfare consequences of the reduction in environmental innovation. If environmental unrelated projects have a higher social return, even after taking into account the negative private return on firms, we cannot conclude that the drop in clean innovation due to worse governance was harmful for the society. Yet, Popp and Newell (2011) offer two arguments suggesting that alternative energy innovations are among the projects with highest social return. First, there is comparatively less amount of research available on alternative energy than in other fields, which makes the potential for generating positive knowledge spillovers higher. Second, alternative energy innovations may affect a broader array of industries than traditional innovations, and thus have a better potential to constitute General Purpose Technologies. These arguments offer some indication that cutting environmental innovation due to worse governance may be detrimental for the society at large.

References

Acemoglu D., Aghion P., Bursztyn L. and Hemous D. (2011) "The Environment and Directed Technical Change", *American Economic Review*, forthcoming.

Aghion P., Dechezleoretre A., Hemous D., Martin R. and Van Reenen J. (2011) "Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry", Working Paper.

Albert M.B., Avery D., Narin F. and McAllister P. (1991) "Direct Validation of Citation Counts as Indicators of Industrially Important Patents", *Research Policy* 20, 251-259.

Atanassov J. (2009) "Do Hostile Takeovers Stifle Innovations? Evidence from Anti-Takeover Legislation and Corporate Patenting", Working Paper.

Balasubramanian N. and Sivadasan J. (2011) "What Happens when Firms Patent: New Evidence from US Economic Census Data", *Review of Economics and Statistics*, forthcoming.

Bessen J. (2009) "NBER PDP Project User Documentation: Matching Patent Data to Compustat Firms", available at: http://www.nber.org/~jbessen/matchdoc.pdf

Bertrand M., Duflo E. and Mullainathan S. (2004) “How Much Should we Trust Difference-in-Differences Estimates?”, *Quarterly Journal of Economics* 119, 249-275.

Bertrand M. and Mullainathan S. (1999) “Is There Discretion in Wage Setting? A Test Using Takeover Legislation”, *Rand Journal of Economics* 30, 535-554.

Bertrand M. and Mullainathan S. (2003) “Enjoying the Quiet Life? Corporate Governance and Managerial Preferences”, *Journal of Political Economy* 111, 1043-1075.

Bloom N., Genakos C., Martin R. and Sadun R. (2010) “Modern Management: Good for the Environment or Just Hot Air?”, *Economic Journal* 120, 551-572.

Bloom N. and Van Reenen J. (2007) “Measuring and Explaining Management Practices Across Firms and Countries”, *Quarterly Journal of Economics* 122, 1351-1408.

Bloom N. and Van Reenen J. (2010) “New Approaches to Measuring Management and Firm Organization”, *American Economic Review, Papers & Proceedings* 100, 105-109.

Brunnermeier S. and Cohen M (2003) “Determinants of Environmental Innovation in U.S. Manufacturing Industries”, *Journal of Environmental Economics and Management* 45, 278-293.

Carrion-Flores C. and Innes R. (2010) “Environmental Innovation and Environmental Performance”, *Journal of Environmental Economics and Management* 59, 27-42.

Chemmanur T.J. and Tian X. (2011) “Do Anti-Takeover Provisions Spur Corporate Innovation?”, Working Paper.

Cockburn I. and Griliches Z. (1988) “Industry Effects and Appropriability Measures in the Stock Market’s Valuation of R&D and Patents”, *American Economic Review* 78, 419-23.

Cole M.A., Elliot R.J.R. and Strobl E. (2007) “The Environmental Performance of Firms: The Role of Foreign Ownership, Training, and Experience”, *Ecological Economics* 65, 538-546.

De Canio S. and Watkins W. (1998) “Investment in Energy Efficiency: Do the Characteristics of Firms Matter?”, *Review of Economics and Statistics* 80, 95-107.

Dowell G., Hart S. and Yeung B. (2000) “Do Corporate Global Environmental Standards Create or Destroy Value?”, *Management Science* 46, 1059-1064.

Fernandez-Kranz D. and Santalo J. (2010) “When Necessity Becomes a Virtue: The Effect of Product Market Competition on Corporate Social Responsibility”, *Journal of Economics & Management Strategy* 19, 453-487.

Francis B.B., Hasan I., Kose J. and Song L. (2011) “Corporate Governance and Dividend Payout Policy: A Test Using Antitakeover Legislation”, *Financial Management* 40, 83-112.

Giroud X. and Mueller H. (2010) “Does Corporate Governance Matter in Competitive Industries?”, *Journal of Financial Economics* 95, 312-331.

Gompers P., Ishii J. and Metrick A. (2003) “Corporate Governance and Equity Prices”, *Quarterly Journal of Economics* 118, 107-155.

Hall B.H., Jaffe A. and Trajtenberg M. (2001) “The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools”, Working Paper 8498, *National Bureau of Economic Research.*

Hall B.H., Jaffe A. and Trajtenberg M. (2005) “Market Value and Patent Citations”, *RAND Journal of Economics* 36, 16-38.

Hong H., Kubik J.D. and Scheinkman J.A. (2011) “Financial Constraints *on* Corporate Goodness”, Working Paper.

Jaffe A. and Palmer K. “Environmental Regulation and Innovation: A Panel Data Study”, *Review of Economics and Statistics* 4, 610-619.

Jaffe A., Fogarty M.S. and Trajtenberg M. (2000) ”Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors”, *American Economic Review* 90, 215-218.

Jaffe A., Newell R. and Stavins R.N. (2002) “Technological Change and the Environment”, *Environmental and Resource Economics* 22, 41-69.

Johnstone N., Hascic I. and Popp D. (2010) “Renewable Energy Policy and Technological Innovation: Evidence from Patent Counts”, *Environmental and Resource Economics* 45, 133-155.

Keller W. and Levinson A. (2002) “Pollution Abatement Costs and Foreign Direct Investment Inflows to U.S. States”, *Review of Economics and Statistics* 84, 691-703.

King A. and Lenox M. (2001) “Does it Really Pay to be Green? An Empirical Study on Firm Environmental and Financial Performance”, *Journal of Industrial Ecology* 5, 105-116.

King A. and Lenox M. (2002) “Exploring the Locus of Profitable Pollution Reduction”, *Management Science* 48, 289-299.

Kock C.J., Santalo J. and Diestre L. (2011) “Corporate Governance and the Environment: What Type of Governance Creates Greener Companies?”, *Journal of Management Studies*, forthcoming.

Konar S. and Cohen M.A. (2001) “Does the Market Value Environmental Performance?”, *Review of Economics and Statistics* 83, 281-289.

Levinson A. (2001) “An Industry-Adjusted Index of State Environmental Compliance Costs”, in Metcalf G. and Carraro C. (eds.), *Behavioral and Distributional Effects of Environmental Policy*, University of Chicago Press.

Lioui A. and Sharma Z. (2011) “Environmental Corporate Social Responsibility and Firm Value”, Working Paper.

Martin R. (2010) “Why is the U.S. so Energy Intensive? Evidence from US Multinationals in the UK”, *CEP Discussion Paper* 965.

Papke L.E. and Wooldridge J. (1996) “Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates”, *Journal of Applied Econometrics* 11, 619-632.

Papke L.E. and Wooldridge J. (2008) “Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates”, *Journal of Econometrics* 145, 121-133.

Peri G. (2005) “Determinants of Knowledge Flows and their Effects on Innovation”, *Review of Economics and Statistics* 87, 308-322.

Popp D. (2002) “Induced Innovation and Energy Prices”, *American Economic Review* 92, 160-180.

Popp D. and Newell R. (2011) “Where Does Energy R&D Come From? Examining Crowding Out from Energy R&D”, *Energy Economics*, forthcoming.

Romano R. (1987) “The Political Economy of Takeover Statutes”, *Virginia Law Review* 73, 111-199.

Romano R. (1993) “Competition for Corporate Charters and the Lesson of Takeover Statutes”, *Fordham Law Review* 61, 843–64.

Sapra H., Subramanian A. and Subramanian K. (2011) “Corporate Governance and Innovation: Theory and Evidence”, Working Paper.

Scherer F.M. (1983)” The Propensity to Patent”, *International Journal of Industrial Organization* 1, 226-237.

Shleifer A. and Vishny R.W. (1997) “A Survey on Corporate Governance”, *Journal of Finance* 52, 737-783.

Stein J.C. (1988) “Takeover Threats and Managerial Myopia”, *Journal of Political Economy* 96, 61-80.

Graph 1.
Example of identification using BC laws

This graph illustrates the average logarithm of one plus clean patents for firms incorporated in California and Massachusetts in the years before and after 1989. In 1989, Massachusetts passed a BC law, California never passed a BC law.

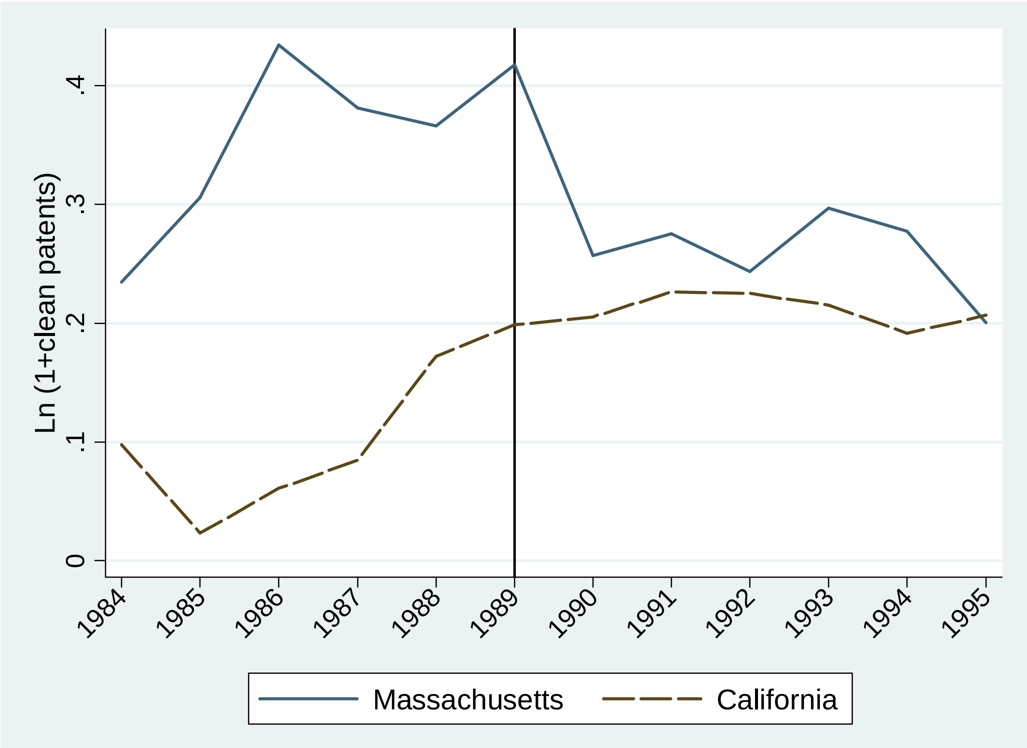

Table 1.
Summary statistics

This table provides summary statistics for the firm characteristics. A complete description of each variable is provided in Table A2.

	Number of observations	Mean	Standard deviation	Median
	(1)	(2)	(3)	(4)
Panel A. Firm characteristics				
Firm sales	18876	4.457	2.341	4.396
Capital/Labor	18876	2.861	0.935	2.834
Firm age	18876	2.441	0.925	2.565
HHI	18876	0.162	0.101	0.136
Panel B. Innovation measures				
R&D/Assets	18876	0.063	0.082	0.037
Patent counts	18876	12.104	45.667	1
Environment-related patent counts	18876	2.843	10.635	0
Environment-related patents/All patents	10298	0.257	0.320	0.115

Table 2.
Business combination laws by state

This table illustrates the passage of business combination (BC) laws in the U.S. states. States that never passed a BC law are listed at the bottom of the table.

State	BC law passage

Table 4.
Changes in clean patenting activity

This table presents results obtained from OLS regressions. The dependent variable in Columns (1) and (2) is an indicator equal to one if a patenting firm reports at least one clean patent in a given year, and zero otherwise. The dependent variable in Columns (3) and (4) is the ratio of environmental-related patents to all patents. Each regression includes firm fixed effects, year dummies, and headquarters' state and industry linear trends, computed as annual averages of the dependent variable after excluding the firm in question. Furthermore, Columns (2) and (4) include the 1-year lagged logarithm of sales, capital to labor ratio, R&D stock, firm age. The construction of each variable is described in Table A2. Standard errors, clustered by the state of incorporation, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Dependent variable:	At least one environmental-related patent		Ratio of environmental-related patents/All patents	
	(1)	(2)	(3)	(4)
BC	-0.0723**	-0.0639**	-0.0393***	-0.0405***
	(0.0293)	(0.0253)	(0.0142)	(0.0143)
Firm sales		0.0414**		-0.0026
		(0.0178)		(0.0080)
Capital/Labor		-0.0023		0.0078
		(0.0112)		(0.0069)
R&D stock		0.0735***		-0.0014
		(0.0121)		(0.0071)
HHI		0.1220		-0.0988**
		(0.0998)		(0.0407)
Firm age		-0.0153		-0.0101
		(0.0199)		(0.0122)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
State and industry trends	Yes	Yes	Yes	Yes
Number of observations	10030	10030	10296	10296

Table 5.
Substitution between innovation projects

This table presents results obtained from OLS regressions. Panel A illustrates results obtained using environmental-related and unrelated cite weighted patent counts as dependent variables. Each regression in Panel A includes the 1-year lagged logarithm of sales, capital to labor ratio, R&D stock, HHI, firm age, logarithm of one plus patent counts, firm fixed effects, year dummies, and headquarters' state and industry linear trends, computed as annual averages of the dependent variable after excluding the firm in question. Panel B illustrates results obtained using measures of overall innovation as dependent variables. Specifically, Column (1) uses the logarithm of one plus patent counts, Column (2) uses the ratio of R&D expenditures to the book value of assets. Each regression in Panel B includes the 1-year lagged logarithm of sales, capital to labor ratio, R&D stock, HHI, firm age, firm fixed effects, year dummies, and headquarters' state and industry linear trends, computed as annual averages of the dependent variable after excluding the firm in question. The construction of each variable is described in Table A2. Standard errors, clustered by the state of incorporation, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Panel A. Environment-related and unrelated innovations

Dependent variable:	Environment-related patent counts	Environment-unrelated patent counts
	(1)	(2)
BC	-0.0210**	0.0115*
	(0.0085)	(0.0058)
Firm sales	0.4409***	0.8734***
	(0.0108)	(0.0143)
Capital/Labor	0.0067	0.0060**
	(0.0055)	(0.0026)
R&D stock	0.0016	-0.0045
	(0.0066)	(0.0031)
HHI	-0.0010	0.0276***
	(0.0093)	(0.0048)
Firm age	0.0142	0.1017***
	(0.0745)	(0.0372)
Patent counts	-0.0529***	-0.0025
	(0.0145)	(0.0076)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
State and industry trends	Yes	Yes
Number of observations	18868	18868

Panel B. Aggregate innovation

Dependent variable:	All patents	R&D/Assets
	(1)	(2)
BC	0.0216	0.0014
	(0.0289)	(0.0017)
Firm sales	0.1110***	-0.0153***
	(0.0141)	(0.0011)
Capital/Labor	-0.0110	-0.0024**
	(0.0099)	(0.0011)
R&D stock	0.3434***	0.0294***
	(0.0244)	(0.0020)
HHI	0.1493	0.0106
	(0.1783)	(0.0075)
Firm age	-0.0769***	0.0103***
	(0.0208)	(0.0021)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
State and industry trends	Yes	Yes
Number of observations	18868	18868

Table 6.
Robustness checks

This table present results from various specifications. In Columns (1)-(2), we re-estimate Table 5, Column (6) using a variety of estimation methods. In Column (1), we estimate a fixed-effect Tobit model with bootstrapped standard errors, using the *pantob* Stata code developed by Bo Honoré. In Column (2), we estimate a pooled fractional logit model which includes state and three-digit SIC industry fixed effects instead of firm fixed effects. In Columns (3)-(7), we use a variety of dependent variables and subsamples. In Column (3), we provide OLS estimates using the ratio of cite-weighted environmental-related patents to the total of cite-weighted patents. In Column (4), we adopt the ratio of firms' energy-related patents to the total number of patents. In Column (5), we adopt the ratio of renewable-related patents. In Column (6), we use a sample of firms between 1990 and 2006 and adopt the G-index as measure of corporate governance. In particular, BC is replaced with a dummy equal to one if the firm has worse governance (above the median G-index) or not (equal or below the median G-index). In Column (7), we exclude firms headquartered in California. In Column (8), we exclude firms incorporated in Delaware. In Column (9), we exclude firms incorporated in states that never passed a BC law. In Column (10), we use a placebo BC law passage two years its real implementation. Unless differently specified, each regression includes the controls of Table 5, Column (6). The construction of each variable is described in Table A2. Standard errors, which are clustered by the state of incorporation unless differently specified, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Dependent variable: Environmental-related patents/All patents

	Alternative estimation methods		Alternative dependent variables			Alternative governance measure	Alternative subsamples			Reverse causality
	Fixed-effect Tobit	Pooled fractional logit	Ratio of cite-weighted counts	Ratio of energy patents	Ratio of renewable patents	G-index	Excluding California HQ	Excluding Delaware incorp.	Excluding never BC states	Placebo BC passage *t* = -2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
BC	-0.2763***	-0.0279*	-0.0475***	-0.0126***	-0.0024*	-0.0470**	-0.0296**	-0.0378**	-0.0310***	-0.0152
	(0.0789)	(0.0146)	(0.0161)	(0.0038)	(0.0013)	(0.0184)	(0.0111)	(0.0185)	(0.0109)	(0.0165)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State and industry trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	10296	10296	10211	10296	10296	4099	8721	4826	9596	10296

Table 7.
Economic costs

This table presents results obtained from OLS regressions. The dependent variable is the ratio of firms' environmental-related patents to the total number of patents. Small and large stock of environmental-related patents are computed using the median threshold of a firms' stock of environmental-related patents. Low and high abatement costs are computed using the median threshold of the abatement cost index, constructed in Levinson (2001) and Keller and Levinson (2002). Low and high energy dependence are computed using the median threshold of an energy dependence index. The index is computed at the industry-level from the NBER Manufacturing Dataset as the ratio of energy expenses (cost of electric and fuels) to the total value added. Each regression includes the controls of Table 5, Column (6). The construction of each variable is described in Table A2. Standard errors, clustered by the state of incorporation, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Dependent variable: Environmental-related patents/All patents

Table 8.
Institutional ownership variations

This table presents results obtained from OLS regressions. The dependent variable is the ratio of firms' environmental-related patents to the total number of patents. Low and high shares of institutional ownership are computed using the median threshold. Each regression includes the controls of Table 5, Column (6). The construction of each variable is described in Table A2. Standard errors, clustered by the state of incorporation, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Dependent variable: Environmental-related patents/All patents	
	(1)
BC×Low institutional ownership	-0.0525**
	(0.0211)
BC×High institutional ownership	-0.0392*
	(0.0221)
High institutional ownership	-0.0101
	(0.0143)
Year fixed effects	Yes
Firm fixed effects	Yes
State and industry trends	Yes
Controls	Yes
Number of observations	6392

Table 9.
Clean patenting and market value

This table presents results obtained from OLS regressions. The dependent variable is the change in the market to book ratio around the passage of BC laws. In particular, it is computed as the difference of the average of market to book in the post-BC period minus the average of the pre-BC period. The main explanatory variable is the change in environment-related patent ratio around the passage of BC laws, computed similar to the change of market to book. Column (1) also includes year and industry dummies. Column (2) further controls for the changes in ROA (EBITDA to total assets), leverage, tangibility and logarithm of book value of assets. Standard errors, clustered by the state of incorporation, are reported in parenthesis. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Dependent variable: Market to book changes around BC passages

	(1)	(2)
Changes in clean patents ratio	0.0152***	0.0078*
	(0.0050)	(0.0039)
Year fixed effects	Yes	Yes
Industry dummies	Yes	Yes
Controls	No	Yes
Number of observations	913	804

Table A1.
Environmental patents

This table illustrates the patent utility classes, provided by the U.S. patent classification system, that were used to classify environmental-related patents. The grouping and definition of each class follows Carrion-Flores and Innes (2010).

Wind energy	242, 073, 180, 440, 340, 343, 422, 280, 104, 374
Solid waste prevention	137, 435, 165, 119, 210, 205, 405, 065
Water Pollution	405, 203, 210
Recycling	264, 201, 229, 460, 536, 106, 205, 425, 060, 075, 099, 100, 162, 164, 198, 210, 216, 266, 422, 431, 432, 502, 523, 525, 902
Alternative energy	204, 062, 228, 248, 425, 049, 428, 242, 222, 708, 976
Alternative energy sources	062, 425, 222
Geothermal energy	060, 436
Air pollution control	123, 060, 110, 422, 015, 044, 423
Solid waste disposal	241, 239, 523, 588, 137, 122, 976, 405
Solid waste control	060, 137, 976, 239, 165, 241, 075, 422, 266, 118, 119, 435, 210, 405, 034, 122, 423, 205, 209, 065, 099, 162, 106, 203, 431

Table A2.
List of variables

Name	Description	Source
Innovation variables		
Patent counts	Count of a firm's number of patents	NBER
Cite-weighted patent counts	Count a firm's number of patents weighed by future citations received and adjusted for truncation (as described in Hall et al. 2001; Hall et al. 2005)	NBER
R&D/Assets	R&D expenses to the book value of total assets, dropping observations with values smaller than zero or greater than 1	Compustat
Environmental-related patent counts	Count of a firm's number of clean patents	NBER
Cite-weighted environmental-related patent counts	Count a firm's number of environmental-related patents weighed by future citations received and adjusted for truncation (as described in Hall et al. 2001; Hall et al. 2005)	NBER
Small, medium and large stock of environmental-related patents	Tertiles of a firm's stock of environmental-related patents, computed using a perpetual inventory method assuming a 15% annual depreciation rate	NBER
Environmental-related patents/Total patents	Ratio of a firm's environmental patent counts to the total patent counts. The definition of environmental-related patents is provided in Table A1	NBER
Energy patents/Total patents	Ratio of a firm's energy patent counts to the total patent counts. The definition of energy patents is provided in Popp and Newell (2011)	NBER
Renewable patents/Total patents	Ratio of a firm's renewable patent counts to the total patent counts. The definition of energy patents is provided in Johnstone et al. (2010)	NBER
Firm characteristics		
Firm sales	Logarithm of a firm's sales	Compustat
Capital/labor	Logarithm of capital (property, plants and equipment) to labor (employees) ratio	Compustat
Firm age	Logarithm of (1+age), where age are the years a firm has been in Compustat	Compustat
Market to book ratio	(prcc_f ×cshtr_f)/ceq, where prcc_f is the market price of a common share at the end of the fiscal year, cshtr_f is the number of common shares outstanding and ceq is the book value of equity. Following Baker and Wurgler (2002), we exclude observations with values lower than zero or greater than ten	Compustat
Industry and state characteristics		
HHI	Herfindahl-Hirschman Index, computed as the sum of squared market shares of all firms, based on sales, in a given three-digit SIC industry in each year. We drop 2.5% of observations at the right tail of the distribution to mitigate potential misclassifications (Giroud and Mueller 2010)	Compustat
Industry linear trends	Average of the dependent variable across all firms in the same three-digit SIC industry, where averages are computed excluding the firm in question	Compustat
State linear trends	Average of the dependent variable across all firms in the same state of location of the firm, where averages are computed excluding the firm in question	Compustat
Pollution abatement cost index	Computed by Levinson (2001) and Keller and Levinson (2002) using data on abatement costs from the Pollution Abatement Costs and Expenditures survey by the U.S. Census Bureau. The index is computed at the state level after adjusting for industrial composition at the two-digit SIC level (20-39)	Levinson (2001); Keller and Levinson (2002)
Energy dependence	Computed at the 3-digit SIC level from the NBER Manufacturing Dataset as the ratio of energy expenses (cost of electric and fuels) to the total value added	NBER
Governance Characteristics		
BC	Dummy variable, set equal to 1 starting from the year when the BC law was passed	

	by the state where the firm is incorporated (and to 0 otherwise); see Table 1 for the listing of passage dates	
Institutional ownership	Fraction of firm's outstanding shares that are held by institutional investors	Thompson Financial CDA Spectrum
G-index	Index developed in Gompers et al. (2003) based on governance provisions from the Institute of Responsibility Research Center (IRRC). The index is available for the years 1990, 1993, 1995, 1998, 2000, 2003, and 2006. Missing years are replaced using the last data available.	IRRC