Do Investors Care About Green Innovation?

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Abstract

Despite the importance of green innovation in fighting climate change, we find that green patent announcements do not have a positive effect on shareholder wealth. Even green patents that are granted to firms with a high climate risk exposure have no significant wealth impact. Similarly, neither the level of climate change concerns, nor the level of institutional investor ownership or attention make green patents more valuable. Moreover, the adoption of the Paris Agreement had no effect on the market valuation of green innovation. We also find no evidence that the number of green patents obtained by a company affects its environmental score, level of institutional investor ownership, or Tobin's Q. Despite all the talk that green innovation is key for climate change mitigation, investors seem to be indifferent to its impact on firm value.

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1. Introduction

We investigate whether investors care about green innovation by measuring their reaction to green patent announcements. Environmental (green) innovation can help firms capture climate-related opportunities and lower their exposure to climate risks. Green technologies are the key to decarbonizing the economy (Nordhaus, 2021) and climate change mitigation and adaptation (Government Office for Science et al., 2021; United Nations, 2021). Moreover, some institutional investors push companies to make more environmentally friendly decisions (Azar et al., 2021).

One of the most important corporate decisions is how to innovate. A key source of innovation is the private sector. For-profit companies own 85% of patents in the United States (National Science Board, 2018). Green innovation, commonly measured using green patents (Cohen et al., 2021; Aghion et al. 2016), could be important to investors who care about environmental issues and want to minimize their exposure to environmental risks (Ilhan et al., 2021). Moreover, the number of green patent announcements is surging. The annual number of green patents granted in the United States increased by 301% from 2009 to 2019, compared with an increase of 104% in the annual number of all patents. Since developing green technologies is risky and expensive, green patents can be a credible signal of a firm's environmental commitment (Spence, 1973). Therefore, we address the following question: Do investors reward companies for obtaining new green patents?

The evidence on the market reaction to sustainability-related news is mixed.[1] We differ from this literature by studying the announcements of green patents rather than general news articles. We know the market reacts positively to the announcement of new patents in general (Kogan et al., 2017) and that firm innovation is positively associated with profitability (Pandit et al.,

[1] Capelle-Blancard and Petit (2019) find that the average stock market reaction to positive news related to environmental, social, and governance (ESG) issues is insignificant. Flammer (2013) and Klassen and McLaughlin (1996) report a positive market valuation. In contrast, Krueger (2015) finds a negative reaction.

2011). Hence, we argue that investors should pay attention to green patents as they provide evidence of a firm's environmental progress (Amore and Bennedsen, 2016; EPO and IEA, 2021). Patents can be challenging to obtain for a company because innovation is path-dependent (Aghion et al., 2014), and innovating in green technologies requires a firm to redirect its research and development (R&D) efforts (Stern and Valero, 2021). Also, many funds now have a specific focus on environmental/sustainable investments and the amount of assets under management following sustainable investing strategies reached $51.4 trillion in 2020, a 42% increase from 2018 (US SIF, 2020). Therefore, green patents can help a firm attract a larger part of these funds (Cohen et al., 2021), reduce its cost of capital (Bolton and Kacperczyk, 2021; Chava, 2014), and help investors distinguish between firms that act on environmental issues and firms that only brand themselves as such.

We examine the value of green patents to investors by measuring the market reaction to patents granted to public firms in the United States during 1976-2019. Then we compare the market reaction to green patents against the market reaction to non-green (grey) patents. We find that the market does not reward companies for obtaining green patents. This is in contrast to the positive market valuation of non-green patents. This result holds regardless of whether a company is operating in a carbon-intensive industry, has a low environmental score, or has a high exposure to climate change risk.

Next, we assess whether the market valuation of patents is driven by investors' environmental concerns. Green patents may be seen as more valuable when investor concerns about climate change are higher. High levels of climate change concerns can make the climate-related risks faced by firms more important to investors and can increase investors' preference for green assets (Ardia et al., 2021). Moreover, green innovation may be particularly relevant to institutional investors, who can pressure companies to reduce their emissions (Azar et al., 2021).[2] We test whether the market valuation of green patents is affected by the amount of public attention to climate change, as measured by the Unexpected Media Climate Change Concerns index (Ardia et al., 2021). We find no evidence that the level of climate change concerns affects the market valuation of green patents, even if we focus specifically on heavy-polluting firms.

We also consider whether the market valuation of green patents is affected by institutional investor ownership and attention. Ben-Rephael et al. (2017) show that institutional investor attention matters. Stocks that receive low institutional investor attention are traded by the investors less frequently and less profitably (Schmidt, 2019). Therefore, the market reaction to green patent announcements may depend on whether institutional investors are paying attention to firms developing new green technologies. We find that neither the level of institutional investor ownership nor the amount of institutional investor attention is related to the market valuation of green patents. Also, we assess whether the market valuation of green patents changed following the 2015 Paris Agreement. Investor attention to climate change increased after the Paris Agreement (Kruse et al., 2020), while banks started charging companies a carbon risk premium (Ehlers et al., 2021). We find no evidence that the market valuation of green patents has increased after the adoption of the 2015 Paris Agreement.

We also explore some of the potential reasons why the market does not react to green patent announcements. We investigate whether the changes in a company's green patenting activity are related to the changes in the firm's environmental score, level of institutional investor ownership, and Tobin's Q. We find that there is no relation between these variables and green patenting activity. The results are consistent regardless of whether we measure green patenting

[2] As of March 2021, 575 institutional investors with a total of $50 trillion of assets under management have joined the Climate Action 100+ initiative, which aims to engage firms on climate change issues (The Economist, 2021). One example of shareholder activism is the battle between Engine No.1 and Exxon Mobil. In June 2021, the hedge fund won a proxy battle against the oil company gaining three seats on its board (Brower and Aliaj, 2021).

activity using the number of green patents obtained, the amount of green patent applications filed, or the amount of green patent citations received.

Our results imply that investors do not see green patent announcements as valuable. This is surprising since previous studies find that the stock market reacts positively to evidence of firms' environmentally-friendly actions such as implementing sustainability programs and issuing green bonds (Flammer, 2013; Klassen and McLaughlin, 1996; Flammer, 2021). But our results are consistent with Acemoglu et al. (2012) and Aghion et al. (2014) who argue that the returns to green technologies can be small compared to polluting technologies, because green technologies may be less developed. Also, investors may perceive investing in green innovation as riskier than in the non-green alternatives, because green technologies can spend a longer time in development and require more risk capital (Nanda et al., 2015; Gaddy et al., 2017). Our results are also consistent with Michaely et al. (2021), who find that institutional investors do not support environmental and social corporate proposals when their vote matters the most. Similarly, Gianfrate et al. (2021) find no evidence that institutional investors reduce the carbon emissions of an average company. Finally, our results also compliment von Schickfus (2021), who finds no evidence that firm engagement by institutional investors affects the amount of corporate green innovation.

The contribution of this paper is threefold. First, this is the first paper to our knowledge that investigates the market valuation of green patents. Second, we contribute to an emerging literature on the effects of investor attention to climate change (Choi et al., 2020; Ramelli et al., 2021; Huynh and Xia, 2021) by examining whether the magnitude of climate change concerns affects the market valuation of green patents. Third, we contribute to the literature on corporate green patenting (Cohen et al., 2021; Berrone et al., 2013; Kim et al., 2021) by using an objective measure of green patent value, the market valuation, and investigating whether the level of institutional investor ownership and attention affects it. We show that despite investors' calls for climate action and green innovation, they do not seem to value green patent announcements.

2. Hypotheses development

We apply the signaling theory (Spence, 1973; Connelly et al., 2011) to corporate green patent announcements. Patents can be valuable signals (Hsu and Ziedonis, 2013; Long, 2002). We argue that green patents can serve as signals that reduce the information asymmetry about a firm's environmental commitment. Also, green patents are valuable to the firm due to their impact on firm risk and cost of capital. For instance, firms can be subject to physical climate risks, and developing green technologies can help them mitigate these risks (Miao and Popp, 2014). Moreover, green innovation is negatively associated with pollution (Carrion-Flores and Innes, 2010), and the cost of complying with environmental regulations (Brunnermeier and Cohen, 2003). As investors demand higher returns for exposure to environmental regulation risk (Bolton and Kacperczyk, 2021; Chava, 2014), green patents can potentially lower a firm's cost of capital. Since patents can also provide other benefits to a firm beyond their signaling value, they are a productive signal (Conti et al., 2013).

A credible "signal" is costly to copy for firms that lack the sought-after characteristics (Spence, 1973; Riley, 1979). Green patents satisfy this condition (Berrone et al., 2013). To produce a new technology, a company has to increase its R&D spending or reallocate it from other projects.[3] This might be unsuccessful because investment in early-stage clean technologies is risky (Stern and Valero, 2021). Moreover, any green invention has to pass examination at the patent office in order to be patented, with only 56% of patent applications resulting in granted patents (Carley et al., 2015). If the process is successful and a patent is

[3] R&D expenditure is widely used to measure firms' innovative input (e.g., Brown et al., 2009; Hassan et al., 2021; Sunder et al., 2017), while patents are a common proxy of innovative output. A firm can also obtain patents by acquiring other innovative companies. However, this it is not a concern in our study, because the market reaction to a patent announcement is measured only once; at the time when the patent is granted to its first owner.

granted, it represents robust evidence of technical progress (EPO and IEA, 2021). This leads to the first hypothesis:

Hypothesis 1: The market reacts positively to green patent announcements.

We expect that there could be a differential market reaction based on differing firm characteristics. For example, since green patents can reduce firm pollution (Carrion-Flores and Innes, 2010), the market reaction could be stronger for green patents granted to companies that are seen as the highest polluters. Carbon emissions are negatively related to firm value (Matsumura et al., 2014), and lenders have started charging carbon-intensive borrowers a carbon risk premium since the Paris Agreement in 2015 (Ehlers et al., 2021; Delis et al., 2021).

The value of green assets can also be affected by investor preferences (Fama and French, 2007). This is a central point in the theoretical framework of Pástor et al. (2021a), where green (brown) firms produce positive (negative) externalities for society. In their model, investors care about Environmental, Social, and Governance (ESG) issues and they derive utility from holding green assets, which increases the price of green assets and lowers the expected returns. However, green companies can outperform brown firms when the environmental preferences of investors increase unexpectedly (Pástor et al., 2021a). For example, climate attention increased after the 2006 release of the Stern Review (Painter, 2020), and after the first Global Climate Strike of 2019 (Ramelli et al., 2021).

The level of concerns about climate change can proxy for the risk premium that is required by investors for bearing climate risk (Ardia et al., 2021). Higher levels of climate change concerns can increase investor preference for green assets and their demand for environmentally-friendly products (Pástor et al., 2021b; Bouman et al., 2020). Therefore, firms should be more rewarded for obtaining green patents when the levels of climate change concerns are high. This leads to the second hypothesis:

Hypothesis 2: The level of climate change concerns is positively related to the market valuation of green patents.

Institutional investor ownership is positively associated with overall firm innovation (Aghion et al., 2013; Rong et al., 2017). Green innovation can be even more important to institutional investors, who are becoming increasingly concerned by climate risk (Krueger et al., 2020). Successful engagements on environmental and social issues are positively related to firms' accounting performance and corporate governance (Dimson et al., 2015), and they are negatively associated with downside risk (Hoepner et al., 2021). Meanwhile, Dyck et al. (2019) show that the relation between institutional investor ownership and environmental performance is causal. Overall, the literature suggests that institutional investor ownership is positively associated with environmental performance. Therefore, the amount of attention paid by institutional investors to announcements of green patents may impact the magnitude of the market reaction.

But investor attention is a limited resource. Paying more attention to one company in their portfolio leaves institutional investors with fewer resources for monitoring other firms (Kempf et al., 2017). Companies that experience lower institutional investor attention produce fewer disclosures (Abramova et al., 2020), are subject to less board oversight (Liu et al., 2020), and have a higher stock price crash risk (Ni et al., 2020). Moreover, analyst recommendation changes and earnings announcements that receive high institutional investor attention lead to larger short-run abnormal returns (Ben-Rephael et al., 2017). Overall, the literature suggests that institutional investor attention affects stock market outcomes. Therefore, we argue that green patent grants accompanied by high levels of institutional investor attention should generate a more positive market reaction. This leads to the third hypothesis:

Hypothesis 3: The level of institutional investor attention is positively related to the market valuation of green patents.

3. Data and descriptive statistics

We obtain patent data from PatentsView, which is a publicly accessible service maintained by the United States Patent and Trademark Office (USPTO). We retrieved our PatentsView data in March 2021, and it includes information on over 7.6 million patents granted in the United States since 1976. We use PatentsView to obtain data on patent numbers, grant dates, citations, claims, and patent technology classes for all patents granted during 1976-2019. We do not include patents granted in 2020, because of the exceptional market circumstances created by the outbreak of COVID-19. Our initial sample includes 7,236,657 patents.

We identify green patents using the classification developed by the OECD (Haščič and Migotto, 2015) [4] that is commonly used in the literature (e.g., Cohen et al., 2021). Technology classification codes are assigned during the patent application process, and they depend on the inventions' technological content (Righi and Simcoe, 2019). The granular nature of patent classification systems allows for accurate identification of specific technologies, including "environmental" technologies (Haščič and Migotto, 2015). The green patent classification includes technologies related to climate change mitigation and adaptation, carbon capture and storage, renewable energy generation, pollution abatement, and waste management. Based on the green patent classification, the United States Trademark and Patent Office (USPTO) granted 7,054 green patents in 2009 and 28,320 green patents in 2019. The number of all patents granted by the USPTO was 191,927 in 2009 and 391,103 in 2019. Overall, using patents' IPC and CPC codes, we identify 351,066 green patents in our sample that were granted between 1976 and 2019.

Next, we identify which patents in our sample are owned by public firms in the United States. We use a patent-CRSP link created by Stoffman et al. (2021), who matched companies

[4] Our results are not sensitive to this particular green patent classification. Our results remain unchanged if we classify green patents using the Climate Change Mitigation Technologies classification scheme developed by the European Patent Office (Angelucci et al., 2018).

in CRSP to patents granted by the USPTO until 31 December 2020. We successfully match 2,578,327 patents, out of which 110,185 are classified as green patents, to publicly listed firms. We obtain firms' financial data from Compustat and their ESG scores from Refinitiv's Asset4. Our share price return data comes from CRSP.

For each company in our sample, we obtain earnings announcement dates from CRSP and dividend declaration dates from Compustat. To avoid contamination of the patent events by other closely occurring events (de Jong and Naumovska, 2016; Bowman, 1983), we drop all patent announcements which occur within two trading days of a firm's earnings or dividend announcements (Stickel, 1986; Hendricks et al., 2009). Moreover, we drop any patent announcements that have missing stock return data. In total we drop 397,354 patents from the sample, which leaves us with 2,180,973 patents in our sample, of which 98,140 are classified as green.

We obtain data on the level of climate change concerns from Ardia et al. (2021), who created the Unexpected Media Climate Change Concerns (UMC) index. The media index captures the daily level of negative attention about climate change during 2006 to 2018. We use the average value of the UMC index over a three-day window (0,+2) after a patent announcement to measure the level of climate change concerns. We also use alternative windows for robustness, and we obtain similar results.

Our institutional ownership data is from Ghaly et al. (2020).[5] The ownership data was obtained from Securities and Exchange Commission's Forms 13F that are filed by institutional investors every quarter. The forms contain information on all equity assets under the investors' management. Our data covers the period from 1981 to 2018.

[5] We are grateful to Kostas Stathopoulos for providing us with an updated dataset.

Our measure of institutional investor attention is based on the Bloomberg Heat Scores and is constructed following Ben-Rephael et al. (2017).[6] We assume that the Bloomberg Heat Scores follow a truncated normal distribution (Ben-Rephael et al., 2017), and we transform the scores of 0, 1, 2, 3, and 4 into their corresponding continuous values of -0.350, 1.045, 1.409, 1.647, and 2.154, respectively (Ben-Rephael et al., 2017). We use the total value of the continuous Bloomberg Heat Scores over a three-day window (0,+2) following a patent announcement to measure the level of institutional investor attention. We also measure institutional investor attention over alternative windows for robustness and our results remain unchanged. Our institutional investor attention data covers the period from 2010 to 2019.

Lastly, we obtain firm-level climate change exposure data from Sautner et al. (2020). Sautner et al. (2020) analyze the transcripts of quarterly earnings calls of over 10,000 publicly listed companies from 34 countries during 2002-2019. They measure firm-level exposure to climate change as the proportion of a firm's earnings call transcript that is centered around the topic of climate change (Sautner et al., 2020). All variables are defined in Table A1 in Appendix A.

Table 1 shows the descriptive statistics. We conduct our analysis and present the descriptive statistics on a patent announcement day level.[7] Our sample consists of 552,585 patent announcements, which include 2,180,973 patents granted during 1976-2019 to 7,968 different public companies. Panel A presents firm characteristics. The average company has a market capitalization of $21.8 billion, while the median firm has a capitalization of $3.6 billion. With a debt to assets ratio of 0.52, the average company in our sample is highly leveraged in comparison to the average nonfinancial corporation headquartered in the US (Palazzo and

[6] Bloomberg creates a daily attention score for stocks, called the Bloomberg Heat Score, which is based on the number of articles related to a specific stock that are read by the terminal users.

[7] Newly granted patents are announced by the United States Patent and Trademark Office (USPTO) every Tuesday. The USPTO can announce a grant of multiple patents to the same company on the same day. Since we observe one market reaction per announcement day, we treat each announcement as one observation.

Yang, 2019). The average firm in our sample has an R&D intensity of 8%. This is almost double the average R&D intensity of a typical US company of 4.1% (Wolfe, 2020). Moreover, 49.2% of the equity of an average company in our sample is owned by institutional investors.

/Table 1 here/

The characteristics of the patents granted to the firms are shown in Panel B of Table 1. After excluding examiner and self-citations, an average patent in our sample receives 10.6 citations, while the median patent receives 4.1.[8] To address the issue that older patents have had more time to accumulate citations than younger patents, we use the truncation-adjusted number of citations in our analysis.[9] Moreover, the average patent contains 1.1 independent claims. Panel C of Table 1 presents the characteristics of a typical patent announcement day in our sample. The average announcement includes 4.2 patents, with an average of 0.2 green patents per announcement. Lastly, panel D of Table 1 shows that green patents make up 3.6% of all patents granted to an average company in our sample every year.

4. Event study

We use a standard event study approach to measure the market valuation of patent announcements. We estimate abnormal returns (ARs) based on the difference between the security's return and the return on the market portfolio:

$$AR_{i,t} = R_{i,t} - R_{m,t} \qquad (1)$$

where $AR_{i,t}$ is the abnormal return of a security *i* on day *t*, and $R_{i,t}$ is the actual return of a security *i* on day *t*. $R_{m,t}$ is the risk-free rate adjusted market return[10] on day *t*. Following Kogan

[8] We exclude citations added by patent examiners and self-citations made by patent owners to their own patents, because they are unlikely to be useful in capturing the true patent quality (Alcácer et al., 2009; Dechezleprêtre et al., 2017).

[9] We calculate the truncation-adjusted patent citations by dividing the number of citations received by a patent by the number of citations received by an average patent granted in the same year. For example, if a patent that was granted in 2005 has accumulated 6 citations, but the average patent granted in 2005 has so far received only 3 citations, the truncation-adjusted number of patent citations is equal to 2.

[10] The risk-free rate adjusted market return for North America is from Kenneth French's website.

et al. (2017) we use the market adjusted model in equation 1, because many companies obtain patents every month or even every week. This approach mitigates the potential measurement error that is introduced when estimating a company's stock market beta by using asset pricing models that rely on non-overlapping pre-event estimation periods (MacKinlay, 1997; Brown and Warner, 1985).

We measure the patent announcement returns over a three-day event window (0,+2) (Kogan et al., 2017).[11] Our results are similar if we use alternative event windows. Table 2 shows the daily abnormal returns between day -1 and day +3 and the cumulative abnormal returns (CAR) over the (0,+1), (0,+2) and (0,+3) event windows. We compare patent announcements that do not include green patents (grey events) with patent announcements that do (green events). Panel A in Table 2 shows that grey events have an average CAR(0,+2) of 0.031%, which is statistically significant at the 1% level. This is similar to the results reported in the literature (Chemmanur et al., 2021; Marco, 2005). Moreover, this is a considerable market reaction. The average market capitalisation in our sample at the time of the patent announcement is $21.8 billion (see Table 1). Given an average CAR(0,+2) of 0.031%, the average patent announcement is associated with an increase in market value of $6.8 million (=0.031%*$21.8 bn). This is similar to Kogan et al. (2017), who find that a median patent owned by a publicly listed company is worth $3m, while an average patent is valued at $10.3m. Contrary to grey patent announcements, there is no statistically significant market reaction to green events. To alleviate concerns that our results are sensitive to how we define grey and green events, in panel B of Table 2 we restrict the sample to patent announcements that include a single patent. This enables a clearer comparison between green and grey patents, since the announcements of single patents are not confounded by the grants of other patents. An average announcement

[11] As shown by Kogan et al. (2017), the share turnover increases during the first three days around a patent announcement, which suggests that this is when the patent announcement is priced in by the market.

of a grey patent generates a CAR(0,+2) of 0.019% which is statistically significant, while there is no market reaction to an announcement of a green patent.

/Table 2 here/

To further compare green and grey patent announcements, in panel C of Table 2 we limit our sample to patents granted to firms operating in polluting industries (Berrone et al., 2013).[12] Surprisingly, we find a statistically significant reaction to grey patent announcements in polluting industries, and no market reaction to green patent announcements. Next, in panel D of Table 2 we limit our sample to patent announcements on days with a high level of climate change concerns. We define climate change concerns to be high when the value of the Unexpected Media Climate Change Concerns index measured over a three-day window (0,+2) is in the top 33% of its distribution. The market reacts positively to announcements including green patents when climate change concerns are high, as indicated by a CAR(0,+2) of 0.056% that is statistically significant at the 5% level. However, the market reaction to announcements that do not include green patents is even higher, as shown by a statistically significant CAR(0,+2) of 0.080%. This suggests that on days with high climate change concerns, investors do not reward green patent announcements any more than they reward grey patent announcements.

In panel E of Table 2, we restrict our sample to announcements with high institutional investor ownership. We define institutional investor ownership as high when its value is in the top tercile of its distribution. We find evidence that high institutional investor ownership is associated with a positive market reaction to grey patent announcements, as indicated by a statistically significant CAR(0,+2) of 0.048%. However, we find there is no market reaction to announcements with green patents over the same event window. Next, in panel F of Table 2,

[12] We follow Berrone et al. (2013) and classify polluting industries as the 20 most polluting US industry sectors according to the Toxic Release Inventory (TRI), which is a US government program measuring the management and emissions of toxic chemicals. The SIC codes of the 20 polluting industry sectors are: 10, 12, 13, 20, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 49, 50, 51.

we restrict our sample to announcements with high institutional investor attention. We define institutional investor attention as high when its value is in the top tercile of its distribution. We find evidence that high institutional investor attention is associated with a positive market reaction to grey patent announcements, as indicated by statistically significant CARs(0,+2) of 0.066%. However, there is no market reaction to announcements including green patents.

5. Regression analysis

Next, we test the value of green patents in a multivariate OLS regression setting. We estimate the following model:

$$CAR_{i,t} = \alpha + \beta_1 * green\ patent\ volume\ _{i,t} + \ \beta_n * X_{i,t-1} + \beta_n * Z_{i,t} + \gamma + \xi + u_{i,t} \quad (2)$$

$CAR_{i,t}$ is the average cumulative abnormal return over a three-day window (0,+2) following a patent announcement.[13] *Green patent volume* is a logarithm of one plus the number of green patents granted.[14] $X_{i,t-1}$ is a vector of firm specific control variables lagged by one year. In particular, we include *market capitalization*, as larger firms may produce more valuable patents (Kogan et al., 2017); *firm age*, as younger firms can produce innovation of higher technological quality (Balasubramanian and Lee, 2008), *return on assets*, as more profitable companies can produce more influential innovation (Geroski et al., 1993); *leverage*, as debt financing can influence firm innovation (Geelen et al., 2021); and *R&D*, as companies that invest more in R&D can have a higher innovation capability (Chen et al., 2018). $Z_{i,t}$ is a vector of patent-related control variables. In particular, we include *patent grants volume*, as the market can react more positively to announcements of multiple patents, *patent citations*, as patents with a higher

[13] In alternative specifications we use alternative dependent variables, including CAR(0,+1), CAR(0,+3), CAR(-1,+1), and CAR(-1,+3) and our results remain similar. For brevity we do not report these results, but they are available upon request.

[14] We obtain similar results if we use a simple count of the number of green patents granted without the log transformation, or if we measure the number of green patents granted as a proportion of all patents granted. We do not report these results for the sake of brevity, but they are available from the authors on request.

technological quality can be more valuable (Hall et al., 2005), and *patent claims*, as broader patents can be more valuable (Marco et al., 2019). Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

We expect green patents to be more valuable to firms that are more exposed to climate risks.[15] Therefore, we modify model (2) to include an interaction between *green patent volume* and a dummy variable that identifies firms with high exposure to climate risk. We estimate the following model:

$$
\begin{aligned}
CAR_{i,t} = \alpha + \beta_1 * green\ patent\ volume\ _{i,t} + \beta_2 * high\ climate\ risk\ firm_{i,t} \\
+ \beta_3 * high\ climate\ risk\ firm_{i,t}\ x\ green\ patent\ volume\ _{i,t} \\
+\ \beta_n * X_{i,t-1} + \beta_n * Z_{i,t} + \gamma + \xi + u_{i,t}
\end{aligned}
\tag{3}
$$

We identify high climate risk firms in three different ways. First, we identify high risk firms as firms operating in industries with high CO_2 emissions. We categorise carbon intensive industries using the list of heavy-emitting industries created by the Intergovernmental Panel on Climate Change (IPCC) (Krey et al., 2014; Choi et al., 2020). We manually match the most carbon intensive industries identified by the IPCC to the Fama-French 48 industry classification used in our sample. We create *CO_2 intensive industry*, which is a dummy variable equal to 1 if a firm is operating in a carbon intensive industry, and 0 otherwise. Second, we identify high climate risk firms as companies with a low Asset4 environmental score. We create *low environmental score*, which is a dummy variable that is equal to 1 when the firm's environmental score is in the bottom 33% of the variable's distribution, and 0 otherwise. [16] Third, we identify high climate risk firms by creating a dummy variable *high climate exposure*

[15] Climate risk can be divided into two parts; physical risk, which refers to a firm's exposure to more extreme weather events, and transition risk that refers to the potential costs of making the company more environmentally friendly in order to comply with climate regulations (von Schickfus, 2021).

[16] We obtain similar results if we use the median or the bottom 25% of the distribution as our cut-off points. For brevity we do not report these results, but they are available upon request.

$_{t-1}$, which is equal to 1 when the level of a firm's exposure to climate change (Sautner et al., 2020) is in the top 33% of the variable's distribution, and 0 otherwise.[17]

Regression results are shown in Table 3. In column (1) of Table 3, we regress CAR(0,+2) solely on *green patent volume,* and we include year, and firm fixed effects. The coefficient is statistically insignificant, which suggests that the number of green patents contained in an announcement does not affect the market reaction. In columns (3), (6), and (9) of Table 3, we interact *green patent volume* with *CO_2 intensive industry*, *low environmental score*, and *high climate risk exposure* $_{t-1}$, respectively. We find that in all specifications, the interactions are statistically insignificant. The results suggest that firms are not rewarded for obtaining green patents even if they have a high exposure to climate risks.

/Table 3 here/

Overall, investors do not reward firms for obtaining green patents. Therefore, we find no support for our first hypothesis (H1). This is in contrast to the positive market valuation of grey patent announcements shown in section (4). Arguably, green innovation can be seen as less valuable by the market than grey innovations because innovation is path dependent and green technologies have generally fewer past innovations to build upon (Aghion et al., 2014). Nanda et al. (2015) argue that early-stage renewable energy technologies spend more time in development and require significantly more investment than grey technologies. Similarly, Gaddy et al. (2017) show that venture capital investments in clean energy technologies yield low returns compared to investments in software or medical technologies, because clean technologies require more financing, return less capital to investors, and are more likely to fail.

The market valuation of green patents may be affected by how concerned investors are about the climate change problem. Therefore, we explore the relation between the level of climate

[17] We obtain similar results if we use the median or the top 25% of the distribution as our cut-off points. The firm-level measure of climate change exposure is from Sautner et al. (2020) (see: section 3). For brevity we do not report these results, but they are available upon request.

change concerns and the market valuation of green patent announcements. We estimate the following model:

$$CAR_{i,t} = \alpha + \beta_1 * climate\ concerns_{i,t} + \beta_2 * green\ patent\ volume_{\ i,t} + \beta_3 * climate\ concerns_{i,t}\ x\ green\ patent\ volume_{\ i,t} + \ \beta_n * X_{i,t-1} + \beta_n * Z_{i,t} + \gamma + \xi + u_{i,t} \quad (4)$$

CAR$_{i,t}$ is the average cumulative abnormal return over a three-day window (0,+2) following a patent announcement.[18] The independent variable of interest is *climate concerns*, which measures the average level of the Unexpected Media Climate Change Concerns (UMC) index (Ardia et al., 2021) over a three-day window (0,+2).[19] *Green patent volume* is a logarithm of one plus the number of green patents granted. [20] Our firm specific control variables include *market capitalization, firm age, return on assets, leverage,* and *R&D.* Our patent-related control variables include *patent grants volume, patent citations*, and *patent claims*. Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

Regression results are shown in Table 4. First, in column 1, we regress CAR(0,+2) solely on *climate concerns*, and we include year, and firm fixed effects. We find that the level of climate change concerns is not a statistically significant predictor of the market reaction to all patent announcements. Next, in column (3), we interact *climate concerns* with the number of green patents included in the announcement. The interaction term is statistically insignificant. Therefore, we find no evidence that the level of climate change concerns affects the market valuation of green patents.

[18] In alternative specifications we use alternative dependent variables, including CAR(0,+1), CAR(0,+3), CAR(-1,+1), and CAR(-1,+3) and our results remain similar. For brevity we do not report these results, but they are available upon request.
[19] We obtain similar results if we measure the average climate change concerns over alternative windows, including (-3,0), (-2,0), (0,+1), and (-1,+1). Furthermore, our results are similar if instead of using a continuous measure we use a dummy variable that is equal to 1 when the level of climate concerns is high. For brevity we do not report these results, but they are available upon request.
[20] We obtain similar results if we use a simple count of the number of green patents granted without the log transformation, or if we measure the number of green patents granted as a proportion of all patents granted to the same firm that day. For brevity we do not report these results, but they are available upon request.

/Table 4 here/

Climate concerns may only impact the market valuation of green patents granted to polluting companies, which face higher regulatory and transition risks with regards to climate change. Therefore, we modify model (4) to include *CO_2 intensive industry*, which is a dummy variable equal to 1 if a firm is operating in a carbon intensive industry, and 0 otherwise. We test the effect of climate change concerns on the value of green patents in carbon intensive industries using a triple interaction term between *CO_2 intensive industry*, *climate concerns* and *green patent volume*. The results are shown in Table I.A1 in the internet appendix.[21] Initially, in column (5) of Table I.A1, the triple interaction term is positive and significant at the 10% level, but the effect disappears after we add control variables in column (6). This suggests that climate concerns do not influence the market valuation of green patents granted to carbon intensive companies.

To test the robustness of this result, we modify model (4) to include *high climate exposure $_{t-1}$*, which is a dummy variable equal to 1 when the level of a firm's exposure to climate change (Sautner et al., 2020) is in the top 33% of the variable's distribution, and 0 otherwise.[22] We test the effect of climate change concerns on the value of green patents granted to firms with high climate change exposure by using a triple interaction term between *high climate exposure $_{t-1}$*, *climate concerns* and *green patent volume*. Our results are shown in Table I.A2 in the internet appendix. The triple interaction, which we add in column (5) of Table I.A2, is statistically insignificant.

We obtain similar results if we identify high climate risk firms based on their Asset4 environmental scores. We modify model (4) to include *low environmental score*, which is a dummy variable that is equal to 1 when the firm's environmental score is in the bottom 33%

[21] The internet appendix is available at https://www.dropbox.com/s/1apqmrkzaxbt9dd/IA.docx?dl=0.
[22] We obtain similar results if we use the median or the top 25% of the distribution as our cut-off points. The firm-level measure of climate change exposure is from Sautner et al. (2020) (see: section 3). For brevity we do not report these results, but they are available upon request.

of the variable's distribution, and 0 otherwise.[23] Our results are shown in Table I.A3 in the internet appendix. In Column (5) of Table I.A3 we interact *low environmental score* with *climate concerns*, and *green patent volume*, and we find that the triple interaction is statistically insignificant.

Overall, we find no effect of the level of climate change concerns on the market valuation of green patents. Therefore, we reject our second hypothesis (H2). Our results suggest that investors do not view green patents as effective solutions for addressing the climate-related risks faced by companies and the broader economy.

Next, we investigate whether institutional investors reward companies for obtaining green patents. We modify model (4) to include institutional investor ownership as our explanatory variable of interest:

$$\begin{aligned} CAR_{i,t} = \alpha + \beta_1 * IO_{i,t-1} + \beta_2 * green\ patent\ volume_{i,t} + \beta_3 \\ * IO_{i,t-1}\ x\ green\ patent\ volume_{i,t} + \ \beta_n * X_{i,t-1} + \beta_n * Z_{i,t} \\ + \gamma + \xi + u_{i,t} \end{aligned} \quad (5)$$

$CAR_{i,t}$ is the average cumulative abnormal return over a three-day window (0,+2) following a patent announcement.[24] $IO_{i,t-1}$ is the proportion of a company's shares owned by institutional investors measured one quarter before a patent announcement. For example, if a patent announcement occurred in Q3 2013, we use the level of institutional investor ownership as of Q2 2013. We do this to address potential reverse causality between institutional investor ownership and patent announcements. *Green patent volume* is a logarithm of one plus the number of green patents granted. [25] Our firm specific control variables include *market*

[23] We obtain similar results if we use the median or the bottom 25% of the distribution as our cut-off points. For brevity we do not report these results, but they are available upon request.
[24] In alternative specifications we use alternative dependent variables, including CAR(0,+1), CAR(0,+3), CAR(-1,+1), and CAR(-1,+3) and our results remain similar. For brevity we do not report these results, but they are available upon request.
[25] We obtain similar results if we use a simple count of the number of green patents granted without the log transformation, or if we measure the number of green patents granted as a proportion of all patents granted to the same firm that day. For brevity we do not report these results, but they are available upon request.

capitalization, firm age, return on assets, *leverage*, and *R&D.* Our patent-related control variables include *patent grants volume, patent citations,* and *patent claims*. Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

Regression results are shown in Table 5. First, in column (1) of Table 5, we regress CAR(0,+2) solely on institutional ownership, and we include year, and firm fixed effects. The coefficient on $IO_{i,t-1}$ is statistically insignificant, which suggests that the level of institutional investor ownership does not affect the market reaction to all patent announcements. Next, in column (3) of Table 5, we interact institutional investor ownership with the number of green patents granted. The interaction term is statistically insignificant.

/Table 5 here/

Institutional investors differ in their investment horizons which can affect how important corporate innovation is to them (Aghion et al., 2013; Bushee, 1998). Green patents could be especially valuable to institutional investors with long investment horizons since climate change is a long-run risk factor (Bansal et al., 2016). We obtain information on institutional investor classification from Brian Bushee's website, and we differentiate between the proportion of the company owned by transient, quasi-indexer, and dedicated institutional investors. Transient institutional investors are characterized by a short investment horizon, and a high portfolio turnover. Quasi-indexer and dedicated institutional investors are characterized by a long-term investment horizon and a low portfolio turnover (Bushee, 1998).

We use model (5) to test whether the proportion of a company's shares owned by different types of institutional investors affects the market reaction to green patents. Regression results using the ownership by transient, quasi-indexer, and dedicated institutional investors are shown in Tables I.A4, I.A5 and I.A6 in the internet appendix, respectively. The interaction between the number of green patents and the ownership level by the three different types of institutional investors are all statistically insignificant. We find no evidence that the level of institutional ownership impacts the market valuation of green patents, regardless of how the level of institutional investor ownership is classified.[26]

Institutional investors may not always be monitoring patent announcements since the amount of their attention is limited. Therefore, we test whether the amount of institutional investor attention affects the market valuation of green patents. We estimate the following model:

$$
\begin{aligned}
CAR_{i,t} = \alpha &+ \beta_1 * institutional\ attention_{i,t} + \beta_2 * green\ patent\ volume_{i,t} \\
&+ \beta_3 * institutional\ attention_{i,t}\ x\ green\ patent\ volume_{i,t} \\
&+ \beta_n * X_{i,t-1} + \beta_n * Z_{i,t} + \gamma + \xi + u_{i,t}
\end{aligned} \tag{6}
$$

$CAR_{i,t}$ is the average cumulative abnormal return over a three-day window (0,+2) following a patent announcement.[27] $Institutional\ attention_{i,t}$ measures the total level of institutional investor attention over a three-day window (0,+2) (Ben-Rephael et al., 2017).[28] *Green patent volume* is a logarithm of one plus the number of green patents granted.[29] Our firm specific control variables include *market capitalization, firm age, return on assets, leverage,* and *R&D.* Our patent-related control variables include *patent grants volume, patent citations*, and *patent claims*. Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

Regression results are shown in Table 6. First, in column 1 of Table 6, we regress CAR(0,+2) solely on *institutional attention*, and we include year, and firm fixed effects. Ceteris paribus, the positive and statistically significant coefficient on *institutional attention* indicates

[26] Our results are similar if instead of using a continuous measure of institutional investor ownership we use a dummy variable that equal to 1 when the level of institutional investor ownership is high. For brevity we do not report these results, but they are available upon request.
[27] In alternative specifications we use alternative dependent variables, including CAR(0,+1), CAR(0,+3), CAR(-1,+1), and CAR(-1,+3) and our results remain similar. For brevity we do not report these results, but they are available upon request.
[28] We use the three-day average of the continuous measure of institutional investor attention (Ben-Rephael et al., 2017). Our results are similar if we measure institutional investor attention over alternative windows, of if we use a dummy variable equal to 1 to identifies high levels of institutional investor attention. For brevity we do not report these results, but they are available upon request.
[29] We obtain similar results if we use a simple count of the number of green patents granted without the log transformation, or if we measure the number of green patents granted as a proportion of all patents granted to the same firm that day. For brevity we do not report these results, but they are available upon request.

that the market reaction to a patent announcement increases by 0.04% when institutional investor attention increases by 1. The standard deviation of institutional investor attention is 2.2 (see Table 1). Therefore, a one-standard deviation increase in institutional investor attention increases the market valuation of a patent announcement by 0.09% (=2.2*0.04%). In column 3 of Table 6, we interact institutional investor attention with the number of green patents announced. The interaction term in column (3) is statistically insignificant. This suggests that institutional investors do not react to announcements of green patents, even when they are paying attention to the company that is obtaining the patents.

/Table 6 here/

Institutional investor attention may only affect the market valuation of green patents when the level of institutional investor ownership is high. Therefore, we modify model (6) to include *high* IO_{t-1}, which is a dummy variable equal to 1 when the level of institutional ownership of a company is in the top 33% of the variable's distribution, and 0 otherwise.[30] Our results are shown in Table I.A7 in the internet appendix. In column (5) of Table I.A7, we interact *high* IO_{t-1} with institutional investor attention and the number of green patents, and we find that the interaction term is statistically insignificant. This result remains unchanged if we use a high level of transient, quasi-indexer, or dedicated level of institutional ownership instead.[31]

Institutional investor attention may affect the market valuation of green patents when the level of climate concerns is high. A high level of climate concerns can increase the perceived urgency of the climate change problem. This can make institutional investors react to green patents more positively. We test this proposition by modifying model (6) to include *high climate concerns*, which is a dummy variable equal to 1 when the level of climate concerns is

[30] We obtain similar results if we use the median or the top 25% of institutional ownership's distribution as our cut-off points. For brevity we do not report these results, but they are available upon request.
[31] For brevity we do not report these results, but they are available upon request.

in the top 33% of the variable's distribution, and 0 otherwise.[32] The results are presented in Table I.A8 in the internet appendix. The interaction between *high climate concerns, institutional attention*, and the *green patent volume* is added in column (5) of Table I.A8. The triple interaction term is statistically insignificant.

Next, we investigate whether institutional investor attention affects the market valuation of patents for firms with high climate exposure (Sautner et al., 2020). To test this, we modify model (6) to include *high climate exposure* $_{t-1}$, which is a dummy variable equal to 1 when the level of a firm's exposure to climate risk is in the top 33% of the variable's distribution, and 0 otherwise. [33] Our results are shown in Table I.A9 in the internet appendix. In column (5) we add the triple interaction between *high climate exposure* $_{t-1}$, *institutional attention*, and *green patent volume*. The triple interaction is statistically insignificant.

Overall, we find no evidence that the level of institutional investors' ownership or attention affects the value green patents, even when the companies that obtain the green patents face a high exposure to climate change. Therefore, we find no support for our third hypothesis (H3). This result is consistent with Michaely et al. (2021), who study the voting behavior of institutional investors on environmental and social (ES) corporate proposals. They find that institutional investors' ES funds tend not to support ES proposals when their vote is likely to affect a voting outcome that conflicts with the broader non-ES objectives of the institutional investors. Therefore, whilst institutional investors communicate their commitment to protecting the environment (Fink, 2020), they do not necessarily act accordingly. Moreover, our results are also consistent with von Schickfus (2021), who finds that institutional investor ownership is not related to a change in the direction of firm innovation towards green technologies.

[32] We obtain similar results if we use the median or the top 25% of institutional ownership's distribution as our cut-off points. For brevity we do not report these results, but they are available upon request.
[33] We obtain similar results if we use the median or the top 25% of institutional ownership's distribution as our cut-off points. For brevity we do not report these results, but they are available upon request.

The results so far suggest that the market does not value green technologies. However, it is possible that investors have only more recently started rewarding companies for obtaining green patents as governments have increasingly highlighted the vital importance of strategies to combat climate change. To test the robustness of our results, we exploit a major shock to the importance of green technologies caused by the adoption of the Paris Agreement during the 2015 United Nations Climate Change Conference. We present this analysis in Appendix B. Overall; we find no evidence that the market valuation of green patents has changed after the adoption of the Paris Agreement.

6. What happens after firms obtain green patents?

Overall, our results suggest that investors do not react to green patents at the time of their announcement. In this section, we investigate the possible reasons for this result. We start by testing whether changes in green patenting activity of a company are related to the firm's environmental score. If green patents improve environmental performance (Amore and Bennedsen, 2016), we expect to see a positive association between the two variables. We estimate the following model:

$$\begin{aligned} Environmental\ score_{i,t} \\ &= \alpha + \beta_1 * green\ patenting\ activity\ _{i,t-1} + \ \beta_n * X_{i,t-1} + \gamma \\ &+ \xi + u_{i,t} \end{aligned} \quad (7)$$

Environmental score measures a firm's environmental performance. We measure *green patenting activity* using six different firm-level metrics that are lagged by one year: (1) *green patents ratio$_{t-1}$*, (2) *green applications ratio$_{t-1}$*, (3) *green citations ratio$_{t-1}$*, (4) *green patent stock ratio$_{t-1}$*, (5) *green applications stock ratio$_{t-1}$*, and (6) *green citations stock ratio$_{t-1}$*.[34] We

[34] For robustness, in alternative model specifications we also include the second and the third lags of the green patent activity measures, and we obtain similar results. For brevity we do not report these results, but they are available upon request.

describe these metrics in Appendix C. $X_{i,t-1}$ is a vector of firm specific control variables, including *market capitalization*, *firm age*, *return on assets*, *leverage*, and *R&D*.[35] Moreover, γ denotes firm fixed effects and ξ denotes year fixed effects.

Our regression results are shown in Table 7. In column (1) of Table 7, we regress *environmental score* solely on *green patents ratio*$_{t-1}$. We find that there is no statistically significant relation between green patenting activity and environmental scores. In the remaining columns of Table 7, we test the other measures of green patenting activity, and we find very similar results. As shown in columns (5) and (11) of Table 7, only the green citation-related metrics are initially statistically significant, but the effect disappears after adding control variables. Overall, we find no evidence that green patenting activity affects environmental scores. Our results are at odds with Cohen et al. (2021), who find a positive correlation between green patenting and environmental scores. However, the difference lies in the fact that Cohen et al. (2021) rely only on year fixed effects as they are interested in the cross-sectional variation, whereas we include both firm- and year-fixed effects to examine whether new green patents obtained by firms are related to changes within firms.

/Table 7 here/

Next, we investigate whether the level of institutional investor ownership is related to a firm's green patenting activity. Since environmental performance can be important to institutional investors (Krueger et al., 2020), we expect a positive correlation between the two variables. We employ model (7) where all metrics of green patenting activity are lagged by one year. In alternative specifications we also include the second and the third lags of the green patent activity measures and our results (unreported) hold. Our dependent variable is $IO_{i,t}$, which is the proportion of a company's shares owned by institutional investors in a given year. Our results are presented in Table 8. In column (1) of Table 8, we regress the level of

[35] Our results are not sensitive to the choice of firm specific control variables.

institutional investor ownership on the green proportion of all patents granted to a company in a given year. We find no statistically significant relation between the two variables. Similarly, as shown in columns (3) to (12) of Table 8, when we use any of our other measures of green patenting activity, we also find that they have no effect on the level of institutional investor ownership.

/Table 8 here/

The importance of green patents to institutional investors may differ depending on their investment horizon. Therefore, we also use model (7) to test whether the proportion of a company's shares owned by different types of institutional investors is related to green patenting activity. Regression results using the ownership by transient, quasi-indexer, and dedicated institutional investors are shown in Tables I.A10, I.A11 and I.A12 in the internet appendix, respectively. We find that there is no relation between firms' green patenting activity and the level of ownership by the three different types of institutional investors. Overall, we find no evidence that institutional investors value green innovation, which is consistent with our previous results and the work of von Schickfus (2021).

Lastly, we test whether changes in green patenting intensity are related to changes in firm value, as measured by Tobin's Q. If green patents are valuable (Hao et al., 2021), we expect to find a positive correlation between the two variables. We estimate the following model:

$$\begin{aligned}\ln\,(Tobin's\ Q_{i,t}) \\ &= \alpha + \beta_1 * green\ patenting\ intensity_{\ i,t-1} + \ \beta_n * X_{i,t-1} \\ &+ \gamma + \xi + u_{i,t}\end{aligned} \tag{8}$$

Where *green patenting intensity* is measured using six different metrics that are lagged by one year[36] : (1) *green patents ratio*$_{t-1}$, (2) *green applications ratio*$_{t-1}$, (3) *green citations ratio* $_{t-}$

[36] In alternative model specifications we also include the second and the third lags of the green patent activity measures, and we obtain similar results. For brevity we do not report these results, but they are available upon request.

$_{1}$, (4) *green patent stock ratio$_{t-1}$*, (5) *green applications stock ratio$_{t-1}$*, and (6) *green citations stock ratio$_{t-1}$*. $X_{i,t-1}$ is a vector of firm specific control variables, including *market capitalization*, *firm age*, *return on assets*, *leverage*, and *R&D.*[37] Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

/Table 9 here/

Regression results are shown in Table 9. We find no statistically significant relation between any of our measures of green patenting intensity and Tobin's Q. As shown in column (5) of Table 9, the only metric that is initially statistically significant is *green citations ratio$_{t-1}$*, but the effect disappears after adding control variables. Overall, we find no evidence that green patenting activity is positively associated with firm value. Our results contrast with Hao et al. (2021), who find a positive correlation between green patenting and Tobin's Q. However, their study focuses on China during 2007-2018, while our sample covers the United States during 1976-2019.

7. Robustness: Climate Change Mitigation Technologies

To alleviate any concerns that our results are driven by how we classify patents on environmentally friendly technologies (see: section 3), in this section we focus specifically on patents covering Climate Change Mitigation Technologies (CCMTs). CCMT patents are identified by a dedicated patent classification scheme developed by the European Patent Office (Angelucci et al., 2018). CCMT patents are tagged using either an "Y02" or a "Y04" classification code. These codes are a part of the Cooperative Patent Classification (CPC) system (Grassano et al., 2020).[38]

[37] Our results are not sensitive to the choice of firm specific control variables.
[38] The CCMT classification scheme includes, among others, technologies on carbon capture storage of greenhouse gases, technologies related to adaptation to climate change, and technologies that aim to reduce greenhouse gas emissions (Grassano et al., 2020).

We repeat all of our analyses using CCMT patents (Angelucci et al., 2018) instead of green patents (Haščič and Migotto, 2015) and our results remain unchanged. We find no market reaction to CCMT patents granted to firms with a high exposure to climate change risks, as shown in Table I.A13 in the internet appendix. Moreover, as shown in Table I.A14 in the internet appendix, there is no statistically significant relation between the level of climate change concerns and the market valuation of CCMT patents. Furthermore, neither the level of institutional investor ownership, nor the amount of institutional investor attention affects the market valuation of CCMT patents, as shown in Tables I.A15 and I.A16 in the internet appendix, respectively. Lastly, we find no relation between CCMT patenting activity and firm's environmental score, level of institutional investor ownership, or Tobin's Q, as shown in Tables I.A17, I.A18, and I.A19 in the internet appendix, respectively. We conclude that it is unlikely for our results to be driven by how we identify patents on environmentally friendly technologies.

8. Conclusion

Motivated by the urgent call for more green innovation to fight climate change (Climate-KIC, 2021; Nordhaus, 2021; Gates, 2021; Kerry, 2021), we study the market valuation of green patent grants. Despite the potential of green innovation to lower environmental pollution (Haščič and Migotto, 2015; Carrion-Flores and Innes, 2010), we find no evidence that companies are rewarded for obtaining green patents. This is true for green patents obtained by companies operating in carbon-intensive industries as well as for firms with a high exposure to climate change.

We also find that climate concerns have no effect on the market reaction to green patent announcements. Despite the increasing pressure from institutional investors on companies to reduce their carbon footprint, we find no evidence that the environment is a priority for institutional investors. The level of institutional investor ownership or the amount of institutional investor attention does not affect the market valuation of green patents. Moreover, we find that the market valuation of green patents has not changed after the adoption of the Paris Agreement on 12 December 2015.

Lastly, we find no evidence that an increase in the number of green patents obtained by companies is related to higher environmental scores, level of institutional investor ownership, or firm value. Overall, we find that firms are not rewarded for engaging in green innovation. This is an unexpected result since green innovation is seen as the key to solving the climate change problem. Our results are consistent with green innovation being viewed as risky (Stern and Valero, 2021), and potentially less advanced than grey innovation (Acemoglu et al., 2012). Our findings support the argument that the government should be one of the main forces behind stimulating the development of green technologies (Aghion et al., 2014).

Table 1: Descriptive statistics

Panel A: Patent owner characteristics							
	Mean	Median	SD	25^{th}	75^{th}	Firms	Events
Market capitalization ($bn)	21.8	3.6	56.5	0.80	16.4	7,412	543,444
Firm age (years)	28.4	21.5	22.7	10.1	43.6	7,968	552,585
Return on assets (%)	10.8	13.3	16.3	8.2	18.2	7,422	542,860
Leverage (%)	52.0	52.2	21.8	38.1	65.1	7,440	542,610
R&D (%)	8.0	5.0	10.1	2.3	9.9	5,964	500,893
Tobin's Q	2.07	1.54	1.60	1.13	2.37	7,086	474,018
Marketing (%)	2.8	1.4	4.2	1.0	3.1	3,652	233,554
Institutional ownership (%)	50.2	54.8	28.0	27.3	71.4	7,024	471,809
Transient inst. ownership (%)	11.5	10.0	9.3	4.2	16.8	6,606	458,739
Quasi-indexer inst. ownership (%)	36.3	39.9	21.8	17.8	53.6	6,939	469,347
Dedicated inst. ownership (%)	3.2	1.3	5.0	0.1	4.2	5,268	375,520
Investor turnover (%)	19.3	18.9	5.6	16.2	21.9	6,700	426,327
ESG score	48.5	47.7	20.7	31.5	65.7	1,515	159,166
Environmental score	38.6	37.5	29.5	9.7	64.1	1,512	159,154
Climate exposure (%)	7.8	3.0	16.0	0.0	8.1	2,966	242,838

Table 1. Continued

Panel B: Patent characteristics							
Forward citations	10.6	4.1	27.7	0.6	11.8	7,968	552,585
Truncation adjusted forward citations	1.0	0.5	3.5	0.2	1.0	7,968	552,585
Independent claims	1.1	1.0	0.1	1.0	1.1	7,968	552,585
Panel C: Announcement day characteristics							
Patent grant volume	4.2	1.0	8.9	1.0	4.0	7,968	552,585
Green patent volume	0.2	0.0	0.9	0.0	0.0	7,968	552,585
Climate concerns (0,+2) (%)	9.9	6.2	23.0	-6.9	23.4	3,385	204,257
Institutional attention (0,+2)	0.6	-1.1	2.2	-1.1	2.1	1,960	142,409
Panel D: Yearly measures of green patenting activity							
Green patents ratio (%)	3.7	0.0	14.2	0.0	0.0	7,750	N/A
Green applications ratio (%)	1.8	0.0	6.8	0.0	0.0	7,750	N/A
Green citations ratio (%)	4.0	0.0	15.3	0.0	0.0	7,795	N/A

This table reports the descriptive statistics for the full sample of 2,180,973 patents granted during 1976-2019 to 7,968 different public companies. Events is the number of patent announcements. Panels A, B, and C present descriptive statistics on a patent announcement-level. Panel A reports patent owner characteristics. Panel B shows patent characteristics, Panel C shows announcement day characteristics and Panel D shows descriptive statistics of green patenting activity on a yearly level. See Table A1 in Appendix A for variable definitions.

Table 2: Event study results

	Mean AR (-1), %	Mean AR (0), %	Mean AR (+1), %	Mean AR (+2), %	Mean AR (+3), %	Mean CAR (0,+1), %	Mean CAR (0,+2), %	Mean CAR (0,+3), %	Events
Panel A: All patent announcements									
All events	-0.029***	-0.009***	0.020***	0.017***	0.011***	0.011***	0.028***	0.039***	552,585
Grey events	-0.031***	-0.011***	0.021***	0.021***	0.013***	0.010**	0.031***	0.045***	500,100
Green events	-0.004	0.004	0.011	-0.016**	-0.007	0.015	-0.001	-0.008	52,485
Panel B: Announcements of single patents only									
All events	-0.053***	-0.024***	0.012***	0.030***	0.030***	-0.012*	0.018**	0.048***	286,327
Grey events	-0.054***	-0.024***	0.012***	0.031***	0.030***	-0.012*	0.019**	0.048***	274,418
Green events	-0.027	-0.029	0.011	0.020	0.034	-0.018	0.003	0.036	11,909
Panel C: All announcements in polluting industries									
All events	-0.025***	-0.007**	0.025***	0.013***	0.007**	0.017***	0.031***	0.037***	387,035
Grey events	-0.029***	-0.009**	0.026***	0.017***	0.008**	0.018***	0.035***	0.043***	345,217
Green events	-0.008	-0.006	0.009	-0.021**	-0.003	0.016	-0.006	-0.009	41,818
Panel D: All announcements with high climate change concerns									
All events	-0.004	-0.007	0.046***	0.024***	0.028***	0.053***	0.078***	0.105***	118,341
Grey events	-0.006	-0.006	0.046***	0.028***	0.029***	0.052***	0.080***	0.109***	107,054
Green events	0.020	0.016	0.054***	-0.015	0.010	0.071***	0.056**	0.066**	11,287

Table 2. Continued

Panel E: All announcements with high institutional investor ownership									
All events	-0.014***	0.004	0.027***	0.012***	0.009**	0.031***	0.044***	0.052***	288,903
Grey events	-0.017***	0.002	0.029***	0.017***	0.010***	0.032***	0.048***	0.058***	262,288
Green events	0.021*	0.024**	0.007	-0.031***	-0.005	0.031**	0.000	-0.005	26,615
Panel F: All announcements with high institutional investor attention									
All events	-0.003	0.031***	0.022***	0.005	-0.007	0.053***	0.057***	0.050***	62,129
Grey events	-0.004	0.032***	0.026***	0.008	-0.004	0.058***	0.066***	0.061***	53,182
Green events	0.006	0.021	-0.001	-0.013	-0.025*	0.020	0.007	-0.018	8,947

This table presents the event study results computed using the market-adjusted model. All results are in %. "All events" refer to all patent announcements in our sample. "Grey events" refers to patent announcements that do not include a green patent. "Green events" are patent announcements where at least one patent is classified as green. Panel A presents full sample results. Panel B shows announcements of single patents only; when only one patent was granted to the same company on the same day. Panel C shows patent announcements in polluting industries only, as classified by Berrone (2013). Panel D shows patent announcements that are accompanied by high levels of climate change concerns. We define climate change concerns to be high when the value of the Unexpected Media Climate Change Concerns index measured over a three-day window (0,+2) is in the top 33% of its distribution. Panel E shows patent announcements to firms with a high level of institutional investor ownership. We define institutional investor ownership as high when the institutional ownership variable is in the top 33% of its distribution. Panel F shows patent announcements that are accompanied by high levels of institutional investor attention. We define institutional investor attention to be high when the sum of the continuous Bloomberg Heat Scores over a three-day window (0,+2) following a patent announcement is in the top 33% of its distribution. Panel G shows the patent announcements when both the institutional investor ownership and institutional investor attention are high. Panel H shows the patent announcements when both climate change concerns, and institutional investor ownership are high. Panel I shows the patent announcements when both climate change concerns, and institutional investor attention are high. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 3: Market reaction (CAR 0,+2) to green patents, and high climate risk firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Green patent volume	0.0001		0.0003	0.0003		0.0002	0.0002		0.0003	0.0004
	(0.0002)		(0.0002)	(0.0003)		(0.0003)	(0.0003)		(0.0003)	(0.0003)
CO_2 Intensive Industry		0.0004	0.0005	-0.0012						
		(0.0006)	(0.0006)	(0.0012)						
CO_2 Intensive Industry x green patent volume			-0.0003	-0.0002						
			(0.0004)	(0.0004)						
Low env. score					0.0008**	0.0008**	0.0006*			
					(0.0003)	(0.0003)	(0.0003)			
Low env. score x green patent volume						0.0007	0.0008			
						(0.0007)	(0.0008)			
High climate exposure $_{t-1}$								-0.0000	-0.0000	-0.0000
								(0.0002)	(0.0002)	(0.0002)
High climate exposure $_{t-1}$ x green patent volume									-0.0001	-0.0002
									(0.0003)	(0.0003)
Market capitalization $_{t-1}$				-0.0014**			-0.0026**			-0.0014**
				(0.0002)			(0.0005)			(0.0004)
Firm age $_{t-1}$				-0.0004			0.0007			-0.0006
				(0.0003)			(0.0005)			(0.0005)
Return on assets $_{t-1}$				0.0035**			0.0005			-0.0028
				(0.0014)			(0.0028)			(0.0019)

Table 3. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Leverage $_{t-1}$				-0.0014**			-0.0005			-0.0005
				(0.0006)			(0.0012)			(0.0009)
R&D $_{t-1}$				0.0012			-0.0009			-0.0021
				(0.0021)			(0.0056)			(0.0030)
Patent grant volume				0.0001			-0.0001			-0.0002
				(0.0001)			(0.0002)			(0.0002)
Patent citations				0.0003*			0.0000			0.0002
				(0.0001)			(0.0002)			(0.0002)
Patent claims				0.0002			0.0005			-0.0015
				(0.0008)			(0.0012)			(0.0011)
Constant	0.0003**	0.0002	0.0001	0.0132***	0.0002	0.0002	0.0231***	0.0002	0.0002	0.0162***
	(0.0001)	(0.0002)	(0.0002)	(0.0020)	(0.0002)	(0.0002)	(0.0049)	(0.0002)	(0.0002)	(0.0035)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	551,189	551,189	551,189	482,820	160,060	160,060	146,270	233,352	233,352	214,190
R-squared	0.0244	0.0244	0.0244	0.0230	0.0118	0.0118	0.0119	0.0194	0.0194	0.0190

The dependent variable is CAR (0,+2) calculated using the market-adjusted model. Standard errors are clustered at firm and grant date-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of patent announcements. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 4: Market reaction (CAR 0,+2) to green patents, and climate concerns (0,+2)

	(1)	(2)	(3)	(4)
Climate concerns	-0.0011 (0.0011)		-0.0013 (0.0011)	-0.0013 (0.0012)
Green patent volume		0.0001 (0.0002)	-0.0000 (0.0003)	0.0000 (0.0003)
Climate concerns x Green patent volume			0.0012 (0.0009)	0.0015* (0.0009)
Market capitalization $_{t-1}$				-0.0019*** (0.0004)
Firm age $_{t-1}$				-0.0006 (0.0006)
Return on assets $_{t-1}$				-0.0037** (0.0017)
Leverage $_{t-1}$				0.0002 (0.0010)
R&D $_{t-1}$				-0.0063* (0.0037)
Patent grant volume				0.0000 (0.0002)
Patent citations				0.0003 (0.0002)
Patent claims				-0.0030** (0.0011)
Constant	0.0003**	0.0004	0.0004	0.0220*** (0.0044)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	203,737	551,189	203,737	176,653
R-squared	0.0274	0.0244	0.0275	0.0263

The dependent variable is CAR (0,+2) calculated using the market-adjusted model. Standard errors are clustered at firm and grant date-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of patent announcements. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 5: Market reaction (CAR 0,+2) to green patents, and inst. investor ownership

	(1)	(2)	(3)	(4)
IO $_{t-1}$	-0.0009		-0.0010	0.0000
	(0.0006)		(0.0006)	(0.0007)
Green patent volume		0.0001	-0.0002	-0.0002
		(0.0002)	(0.0005)	(0.0005)
IO $_{t-1}$ x			0.0006	0.0007
Green patent volume			(0.0008)	(0.0008)
Market capitalization $_{t-1}$				-0.0016***
				(0.0003)
Firm age $_{t-1}$				-0.0004
				(0.0003)
Return on assets $_{t-1}$				0.0032**
				(0.0015)
Leverage $_{t-1}$				-0.0014**
				(0.0007)
R&D $_{t-1}$				-0.0003
				(0.0022)
Patent grant volume				0.0001
				(0.0001)
Patent citations				0.0003*
				(0.0002)
Patent claims				-0.0001
				(0.0009)
Constant	0.0009**	0.0003**	0.0009**	0.0148***
	(0.0004)	(0.0001)	(0.0004)	(0.0024)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	463,754	551,189	463,754	410,001
R-squared	0.0250	0.0244	0.0250	0.0239

The dependent variable is CAR (0,+2) calculated using the market-adjusted model. Standard errors are clustered at firm and grant date-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm and year fixed effects. All firm control variables are lagged by one year. Observations is the number of patent announcements. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 6: Market reaction (CAR 0,+2) to green patents, and inst. investor attention (0,+2)

	(1)	(2)	(3)	(4)
Institutional attention	0.0004***		0.0004***	0.0005***
	(0.0001)		(0.0001)	(0.0001)
Green patent volume		0.0001	0.0003	0.0003
		(0.0002)	(0.0003)	(0.0003)
Institutional attention x green patent volume			-0.0001	-0.0001*
			(0.0001)	(0.0001)
Market capitalization $_{t-1}$				-0.0011**
				(0.0005)
Firm age $_{t-1}$				-0.0008
				(0.0008)
Return on assets $_{t-1}$				-0.0030
				(0.0020)
Leverage $_{t-1}$				0.0029**
				(0.0013)
R&D $_{t-1}$				0.0026
				(0.0033)
Patent grant volume				-0.0002
				(0.0002)
Patent citations				0.0002
				(0.0002)
Patent claims				0.0011
				(0.0014)
Constant	-0.0003	0.0003**	-0.0002	0.0109**
	(0.0002)	(0.0001)	(0.0002)	(0.0049)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	131,070	551,189	131,070	115,126
R-squared	0.0243	0.0243	0.0243	0.0232

The dependent variable is CAR (0,+2) calculated using the market-adjusted model. Standard errors are clustered at firm and grant date-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of patent announcements. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 7: Green patenting activity and environmental score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Green patents ratio $_{t-1}$	-0.93	-1.64										
	(2.65)	(4.62)										
Green applications ratio $_{t-1}$			3.59	4.97								
			(3.20)	(3.73)								
Green citations ratio $_{t-1}$					8.25**	4.95						
					(3.11)	(3.83)						
Green patent stock ratio $_{t-1}$							-7.46	4.96				
							(4.90)	(7.16)				
Green applications stock ratio $_{t-1}$									1.56	-7.85		
									(3.68)	(7.65)		
Green citations stock ratio $_{t-1}$											15.63**	16.16
											(6.21)	(10.90)
Market capitalization $_{t-1}$		3.10***		3.09***		3.17***		3.09***		3.05***		3.17***
		(0.72)		(0.72)		(0.75)		(0.71)		(0.71)		(0.75)
Firm age $_{t-1}$		0.42		0.44		0.34		0.28		0.78		0.12
		(1.57)		(1.57)		(2.09)		(1.53)		(1.50)		(2.03)
Return on assets $_{t-1}$		-0.40		-0.37		-1.30		-1.46		-1.76		-1.34
		(2.52)		(2.50)		(2.60)		(2.20)		(2.20)		(2.55)
Leverage $_{t-1}$		0.72		0.72		1.08		0.54		0.07		0.95
		(3.40)		(3.40)		(3.49)		(3.31)		(3.25)		(3.48)
R&D $_{t-1}$		1.82		1.81		4.99		4.47		4.55		5.02
		(4.24)		(4.25)		(4.87)		(4.42)		(4.33)		(4.67)

Table 7. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	29.31***	1.06	29.65***	0.88	28.38***	0.25	27.79***	0.74	26.38***	0.14	27.39***	0.43
	(0.08)	(7.89)	(0.08)	(7.89)	(0.10)	(8.92)	(0.18)	(7.68)	(0.13)	(7.65)	(0.20)	(8.78)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,384	5,620	7,909	5,620	9,859	5,569	11,242	5,880	12,267	5,964	10,952	5,654
R-squared	0.84	0.85	0.84	0.85	0.84	0.85	0.84	0.85	0.83	0.85	0.84	0.85

The dependent variable is environmental score (out of 100). Standard errors are clustered at firm and year-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of firm-year observations. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 8: Green patenting activity and institutional investor ownership

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Green patents ratio $_{t-1}$	0.00 (0.01)	0.01 (0.01)										
Green applications ratio $_{t-1}$			0.01 (0.02)	-0.01 (0.02)								
Green citations ratio $_{t-1}$					0.02 (0.01)	0.01 (0.02)						
Green patent stock ratio $_{t-1}$							0.02 (0.02)	0.03 (0.03)				
Green applications stock ratio $_{t-1}$									-0.03* (0.02)	-0.01 (0.02)		
Green citations stock ratio $_{t-1}$											0.03 (0.03)	0.01 (0.03)
Market capitalization $_{t-1}$		0.05*** (0.00)		0.05*** (0.00)		0.05*** (0.00)		0.06*** (0.00)		0.06*** (0.00)		0.05*** (0.00)
Firm age $_{t-1}$		0.04*** (0.01)		0.04*** (0.01)		0.04*** (0.01)		0.04*** (0.01)		0.04*** (0.00)		0.04*** (0.01)
Return on assets $_{t-1}$		0.04*** (0.01)		0.04*** (0.01)		0.04*** (0.01)		0.03*** (0.01)		0.03*** (0.01)		0.03*** (0.01)
Leverage $_{t-1}$		-0.03*** (0.01)		-0.03*** (0.01)		-0.04*** (0.01)		-0.04*** (0.01)		-0.03*** (0.01)		-0.04*** (0.01)
R&D $_{t-1}$		-0.08*** (0.02)		-0.08*** (0.02)		-0.09*** (0.02)		-0.07*** (0.02)		-0.07*** (0.02)		-0.08*** (0.02)

Table 8. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	0.43***	0.02	0.45***	0.02	0.43***	0.05	0.40***	0.00	0.37***	-0.01	0.42***	0.04
	(0.00)	(0.02)	(0.00)	(0.02)	(0.00)	(0.03)	(0.00)	(0.02)	(0.00)	(0.02)	(0.00)	(0.03)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	47,918	27,108	40,473	27,108	57,627	26,534	75,316	30,781	98,952	32,843	65,463	27,299
R-squared	0.80	0.84	0.80	0.84	0.81	0.84	0.80	0.84	0.77	0.84	0.81	0.84

The dependent variable is the proportion of a company's shares owned by institutional investors. Standard errors are clustered at firm and year-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of firm-year observations. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Table 9: Green patenting activity and ln of Tobin's Q

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Green patents ratio $_{t-1}$	0.02 (0.03)	0.04 (0.04)										
Green applications ratio $_{t-1}$			0.01 (0.05)	-0.03 (0.05)								
Green citations ratio $_{t-1}$					0.05* (0.03)	0.04 (0.05)						
Green patent stock ratio $_{t-1}$							0.05 (0.05)	0.08 (0.07)				
Green applications stock ratio $_{t-1}$									0.02 (0.05)	0.10* (0.06)		
Green citations stock ratio $_{t-1}$											0.06 (0.06)	0.05 (0.07)
Market capitalization $_{t-1}$		0.13*** (0.01)		0.13*** (0.01)		0.13*** (0.01)		0.13*** (0.01)		0.13*** (0.01)		0.14*** (0.01)
Firm age $_{t-1}$		-0.15*** (0.02)		-0.15*** (0.02)		-0.17*** (0.03)		-0.15*** (0.02)		-0.16*** (0.02)		-0.18*** (0.03)
Return on assets $_{t-1}$		-0.00 (0.04)		-0.00 (0.04)		-0.01 (0.04)		-0.06* (0.03)		-0.07*** (0.03)		-0.05 (0.04)
Leverage $_{t-1}$		0.24*** (0.04)		0.24*** (0.04)		0.23*** (0.04)		0.25*** (0.04)		0.25*** (0.04)		0.24*** (0.03)
R&D $_{t-1}$		0.90*** (0.08)		0.90*** (0.08)		0.97*** (0.08)		0.87*** (0.08)		0.89*** (0.08)		0.94*** (0.09)

Table 9. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	0.58***	-0.03	0.59***	-0.03	0.53***	-0.01	0.52***	-0.04	0.56***	0.02	0.51***	0.00
	(0.00)	(0.07)	(0.00)	(0.07)	(0.00)	(0.08)	(0.00)	(0.07)	(0.00)	(0.06)	(0.00)	(0.08)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48,935	29,987	41,829	29,987	58,268	29,201	76,291	34,016	101,668	36,299	66,643	30,177
R-squared	0.64	0.68	0.65	0.68	0.63	0.68	0.62	0.67	0.57	0.67	0.63	0.68

The dependent variable is a natural logarithm of Tobin's Q. Standard errors are clustered at firm and year-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of firm-year observations. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Appendices

Appendix A. Variable definitions

Table A1: Variable definitions

Variable	Definition	Source
CCMT applications ratio	This variable is defined as the yearly number of patent applications covering climate change mitigation technologies divided by the yearly number of all patent applications filed during the same year.	N/A
CCMT applications stock ratio	This variable is defined as the cumulative number of patent applications covering climate change mitigation technologies divided by the cumulative number of all patent applications filed by a company. The variable has been adjusted for depreciation of applications stock at a yearly rate of 15%.	N/A
CCMT citations ratio	This variable is the yearly number of citations received by patents covering climate change mitigation technologies divided by the yearly number of citations received by all patents during the same year.	N/A
CCMT citations stock ratio	This variable is the cumulative number of citations received by patents covering climate change mitigation technologies divided by the cumulative number of citations received by all patents. The variable has been adjusted for depreciation of citations stock at a yearly rate of 15%.	N/A
CCMT patent stock ratio	This variable is defined as the cumulative number of patents covering climate change mitigation technologies divided by the cumulative number of all patents obtained by a company. The variable has been adjusted for depreciation of patent stock at a yearly rate of 15%.	N/A
CCMT patent volume	This variable is a natural logarithm of one plus the number of patents covering climate change mitigation technologies granted to the same company on the same day. We classify CCMT patents based on the classification developed by the European Patent Office (Angelucci et al., 2018).	N/A
CCMT patents ratio	CCMT patents ratio is the yearly number of patents covering climate change mitigation technologies divided by the yearly number of all patents obtained during the same year.	N/A

Table A1. Continued

Climate concerns	Climate concerns is the average level of the Unexpected Media Climate Change Concerns (UMC) index (Ardia et al., 2021) over a three-day window (0,+2).	Ardia et al. (2021)
CO_2 Intensive Industry	CO2 Intensive Industry is a dummy variable equal to 1 if a firm is operating in a carbon intensive industry, and 0 otherwise.	Krey et al. (2014)
Firm age	Firm age is the number of years since the firm first appearance in CRSP.	CRSP
Green applications ratio	Green applications ratio is defined as the yearly number of green patent applications divided by the yearly number of all patent applications filed during the same year.	N/A
Green applications stock ratio	This variable is defined as the cumulative number of green patent applications divided by the cumulative number of all patent applications filed by a company. The variable has been adjusted for depreciation of applications stock at a yearly rate of 15%.	N/A
Green citations ratio	Green citations ratio is the yearly number of citations received by green patents divided by the yearly number of citations received by all patents during the same year.	N/A
Green citations stock ratio	Green citations stock ratio is the cumulative number of citations received by green patents divided by the cumulative number of citations received by all patents. The variable has been adjusted for depreciation of citations stock at a yearly rate of 15%.	N/A
Green patent stock ratio	Green patent stock ratio is defined as the cumulative number of green patents divided by the cumulative number of all patents obtained by a company. The variable has been adjusted for depreciation of patent stock at a yearly rate of 15%.	N/A
Green patent volume	Green patent volume is a natural logarithm of one plus the number of green patents granted to the same company on the same day. We classify green patents using the classification developed by Haščič and Migotto (2015).	N/A
Green patents ratio	Green patents ratio is defined as the yearly number of green patents divided by the yearly number of all patents obtained by a company that year.	N/A
High climate exposure	High climate exposure is a dummy variable that is equal to 1 when the level of a firm's exposure to climate change (Sautner et al., 2020) is in the top 33% of the variable's distribution, and 0 otherwise.	Sautner et al. (2020)

Table A1. Continued

Institutional attention	Institutional attention is the total level of institutional investor attention over a three-day window (0,+2). This variable was calculated using the continuous values of the Bloomberg Heat Score (Ben-Rephael et al., 2017).	Bloomberg
IO	IO is the proportion of a company's shares owned by institutional investors.	Ghaly et al. (2020)
IO dedicated	IO dedicated is the proportion of a company's shares owned by dedicated institutional investors.	Ghaly et al. (2020)
IO quasi-indexer	IO quasi-indexer is the proportion of a company's shares owned by quasi-indexer investors.	Ghaly et al. (2020)
IO transient	IO transient is the proportion of a company's shares owned by transient institutional investors.	Ghaly et al. (2020)
Leverage	Leverage is defined as total liabilities (Compustat item: lt) divided by total assets (Fang et al., 2014).	Compustat
Low environmental score	Low environmental score is a dummy variable that is equal to 1 when the firm's Asset4 environmental score is in the bottom 33% of the variable's distribution, and 0 otherwise.	Asset4
Market capitalization	Market capitalization is the number of shares outstanding multiplied by the share price.	CRSP
Marketing	Marketing is defined as total marketing expenditures (Compustat item: xrd) divided by total assets.	Compustat
Paris Agreement	Paris Agreement is a dummy variable equal to 1 if a patent announcement takes place after 12 December 2015, and 0 otherwise.	N/A
Patent citations	Patent citations is the number of citations received by a patent, excluding examiner citations and self-citations, divided by the number of citations received by an average patent granted in the same year.	PatentsView
Patent claims	Patent claims is a simple count of the number of independent claims of a patent (Marco et al., 2019).	PatentsView
Patent grant volume	Patent grants volume is a logarithm of one plus the number of patents that a particular company obtained from the USPTO on the same trading day.	PatentsView
R&D	R&D is defined as research and development expense (Compustat item: xrd) divided by total assets (Hirshleifer et al., 2012).	Compustat
Return on assets	Return on assets is defined as operating income before depreciation (Compustat item: oibdp) divided by total assets (Fang et al., 2014),	Compustat
Tobin's Q	Tobin's Q is the ratio of market value to book value of assets (Hirshleifer et al., 2012).	Compustat and CRSP

Appendix B. Paris Agreement

This appendix examines the impact of the adoption of the Paris Agreement on the market valuation of green patents. The Paris Agreement, signed on 12 December 2015, is a legally binding international treaty which aims to tackle the problem of climate change and limit global warming to 1.5°C above pre-industrial levels (Kruse et al., 2020). The scope of the agreement and its ambitious goal of limiting the temperature increase to 1.5°C was seen as unexpected (Kruse et al., 2020). We observe that the number of green patents obtained by firms, as a proportion of all patents, increased from 3.7% to 5.1% after the adoption of Paris Agreement (see Table B1 in this appendix).[39] [40]

Since the Paris Agreement reflected a worldwide commitment to protecting the environment, we expect the agreement to have a positive effect on the market valuation of green patents. We test this using the following model:

$$\begin{aligned} CAR_{i,t} = \alpha + \beta_1 * green\,patent\,volume_{i,t} + \beta_2 * Paris\,Agreement + \beta_3 \\ * Paris\,Agreement\ x\ green\,patent\,volume_{i,t} + \beta_n * X_{i,t-1} \\ + \beta_n * Z_{i,t} + \gamma + \xi + u_{i,t} \end{aligned} \tag{9}$$

$CAR_{i,t}$ is the average cumulative abnormal return over a three-day window (0,+2) following a patent announcement.[41] *Green patent volume* is a logarithm of one plus the number of green patents granted.[42] *Paris Agreement* is a dummy variable equal to 1 if a patent announcement takes place after 12 December 2015, and 0 otherwise. Our firm specific control variables include *market capitalization, firm age, return on assets, leverage,* and *R&D.* Our patent-

[39] In our sample, 3.7% of all patents obtained by an average company every year are green patents (see: Table 1)
[40] We use a multivariate OLS model to test this. The dependent variable is the green proportion of all patents granted to a company in a year. Our independent variable of interest equals 1 for all patents granted after December 2015, and 0 otherwise. We include firm fixed effects and the same set of firm controls as in model (9).
[41] In alternative specifications we use alternative dependent variables, including CAR(0,+1), CAR(0,+3), CAR(-1,+1), and CAR(-1,+3) and our results remain similar. For brevity we do not report these results, but they are available upon request.
[42] We obtain similar results if we use a simple count of the number of green patents granted without the log transformation, or if we measure the number of green patents granted as a proportion of all patents granted to the same firm that day. For brevity we do not report these results, but they are available upon request.

related control variables include *patent grants volume*, *patent citations*, and *patent claims*. Lastly, γ denotes firm fixed effects and ξ denotes year fixed effects.

Table B1: The Paris Agreement and the number of green patents

	(1)	(2)
Paris Agreement	0.014*** (0.003)	0.009*** (0.003)
Market capitalisation $_{t-1}$		0.000 (0.001)
Firm age $_{t-1}$		0.005*** (0.002)
Return on assets $_{t-1}$		-0.001 (0.002)
Leverage $_{t-1}$		0.000 (0.004)
R&D $_{t-1}$		-0.006 (0.006)
Constant	0.035*** (0.001)	0.022*** (0.006)
Firm FE	YES	YES
Year FE	NO	NO
Observations	56,791	36,299
R-squared	0.521	0.564

The dependent variable is the number of green patents divided by the number of all patents obtained by a company in a year. Standard errors are clustered at firm and year-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects. We do not include year fixed effects, because they are highly collinear with *Paris Agreement*. All firm control variables are lagged by one year. Observations is the number of firm-year observations. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

The regression results are shown in Table B2. We interact *Paris Agreement* and *green patent volume* in column (3) of Table B2. The interaction term is statistically insignificant, which suggests that the market valuation of green patents did not change after the adoption of the Paris Agreement. We add control variables in column (4) and our results remain unchanged.

Table B2: Market reaction (CAR 0,+2) to green patents, and the Paris Agreement

	(1)	(2)	(3)	(4)
Green patent volume	0.0001 (0.0002)		0.0001 (0.0002)	0.0002 (0.0002)
Paris Agreement		0.0006 (0.0014)	0.0006 (0.0014)	0.0010 (0.0016)
Paris Agreement x Green patent volume			-0.0000 (0.0003)	-0.0003 (0.0004)
Market capitalization $_{t-1}$				-0.0014*** (0.0002)
Firm age $_{t-1}$				-0.0006 (0.0006)
Return on assets $_{t-1}$				0.0035** (0.0014)
Leverage $_{t-1}$				-0.0014** (0.006)
R&D $_{t-1}$				0.0012 (0.0021)
Patent grant volume				0.0001 (0.0001)
Patent citations				0.0003* (0.0001)
Patent claims				0.0002 (0.0008)
Constant	0.0003** (0.0001)	0.0002 (0.0002)	0.0002 (0.0002)	0.0127*** (0.0020)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	551,189	551,189	551,189	482,820
R-squared	0.0244	0.0244	0.0244	0.0230

The dependent variable is CAR (0,+2) calculated using the market-adjusted model. Standard errors are clustered at firm and grant date-level and are reported in parentheses. All control variables are winsorized at the 1% and 99% tails. All regressions include firm fixed effects and year fixed effects. All firm control variables are lagged by one year. Observations is the number of patent announcements. See Table A1 in Appendix A for variable definitions. Significance at 10%, 5%, and 1% level is represented by *, **, and ***, respectively.

Next, we test whether the relation between climate concerns and the market valuation of green patents has changed after the adoption of the Paris Agreement. The agreement is described as a historic achievement in the fight against global warming (Pham et al., 2019), and the promise by global leaders to address the climate change problem should have a negative effect on the level of climate change concerns. We modify model (9) to include an interaction between *Paris Agreement*, *green patent volume,* and *climate concerns,* which measures the average level of climate change concerns over a three-day window (0,+2).[43] The regression results are presented in Table I.A20 in the internet appendix. The triple interaction term is statistically insignificant, which suggests that the adoption of the Paris Agreement did not have an effect on the relation between the level of climate concerns and the market valuation of green patents.

Arguably, the adoption of the Paris Agreement has increased the risk of environmental regulations faced by companies (Degryse et al., 2021). Since green technologies can help firms mitigate these risks, companies that obtain green patents may be seen as more valuable to institutional investors after the adoption of the agreement. We test this by modifying model (9) to include an interaction between *Paris Agreement, green patent volume* and $IO_{i,t-1}$, which is the proportion of shares owned by institutional investors. The regression results are shown in Table I.A21 in the internet appendix. The triple interaction is statistically insignificant.[44]

Lastly, we test whether the adoption of the Paris Agreement had an effect on the relation between institutional investor attention and the market valuation of green patents. We modify model (9) to include an interaction between *Paris Agreement*, *green patent volume* and $institutional\ attention_{i,t}$, which measures the total level of institutional investor attention over a three-day window (0,+2). Our regression results are shown in Table I.A22 in the internet

[43] We obtain similar results if we measure the average climate change concerns over alternative windows. For brevity we do not report these results, but they are available upon request.
[44] We obtain similar results if we use the proportion of shares owned by transient, quasi-indexer, or dedicated institutional investors. For brevity we do not report these results, but they are available upon request.

appendix. The triple interaction is statistically insignificant, which suggests that the adoption of the agreement did not have an effect on institutional investors' valuation of green patents. Overall, we find no evidence that the market valuation of green patents has changed after the adoption of the Paris Agreement.

Appendix C. Measures of green patenting activity

To gain a comprehensive view of corporate green innovation, we use six firm-level metrics to measure *green patenting activity*. All metrics are lagged by one year. They include: (1) *green patents ratio*$_{t-1}$, which is the green proportion of all patents granted in a given year (Cohen et al., 2021; Amore and Bennedsen, 2016), (2) *green applications ratio*$_{t-1}$, which is the green proportion of all patent applications filed in a given year (Hao et al., 2021), (3) *green citations ratio*$_{t-1}$, which is the number of citations received by green patents in a year as a proportion of all patent citations received in a given year (Amore and Bennedsen, 2016; Cohen et al., 2021), (4) *green patent stock ratio*$_{t-1}$, which is the green proportion of a firm's patent stock, (5) *green applications stock ratio*$_{t-1}$, which is the green proportion of a firm's patent applications stock, and (6) *green citations stock ratio*$_{t-1}$, which is the green proportion of all patent citations received by a company.

The first three measures capture a firm's green patenting behavior in a particular year. In contrast, the last three measures are calculated using a company's patent stock, which is a cumulative measure of innovation (Porter and Stern, 2000). Patent stock counts the total number of patents granted to a company until a specific point in time, and it is calculated as follows:

$$patent\ stock_{i,t} = patents_{i,t} + (1 - \delta) * patent\ stock_{i,t-1} \qquad (10)$$

Where *patents*$_{i,t}$ is the number of patents granted to a firm in a given year. δ is a depreciation rate set to 15% (Hall et al., 2005; Balasubramanian and Sivadasan, 2011; Bertoni and Tykova, 2015), which accounts for the depreciation in the value of ideas over time (Porter and Stern, 2000). For example, if a company received its first patent two years ago, received three patents last year, and obtained four patents this year, its current patent stock equals 7.27.[45] We calculate the green proportion of a firm's patent stock by dividing a company's green patent stock by its total patent stock. We follow the same process to calculate the green proportion of the patent applications stock and the green proportion of the patent citations stock.

[45] This is calculated as follows: 1*0.85*0.85+3*0.85+4=7.27.

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