The Green Tobin's q: Theory and Evidence

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Abstract: This paper demonstrates how a firm's green efforts impact a firm's value. We derive from a dynamic stochastic model a "Green Tobin's q" as a function of a firm's pollution abatement efforts, green stockholder pressure, R&D expenditures, stocks of green knowledge, as well as traditional capital stocks and investments. Our evidence focuses on the oil industry which is inextricably bound to the debate on climate change. Our regression results indicate a negative impact on Tobin's q from green technologies and a positive impact on Tobin's q from green stockholder pressure. In addition to adding a theoretical model that addresses firm-level green effort, we provide practical guidance to managers regarding pressing issues in the energy transition.

Keywords: Pollution, R&D, green technologies, firm investments, climate change

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1. Introduction

This paper addresses increased environmental concerns as recently summed up by *The Economist*: "For all the cynicism that oil firms are 'greenwashing' their way through the energy transition, [their] efforts should be taken seriously. But how seriously?" (Ryder, 2019). During the keynote address at the Financial Management Association's 2020 annual meeting, Laura Starks discussed "a call for action for us as researchers to be providing evidence, to be gathering more information and most importantly to be seeing what are the effects of climate risk and what can be done to mitigate the negative effects and highlight the positive effects" (37:24-37:49).

This paper provides theory and evidence to answer that simple question and respond to the call for action. The theory behind the Green Tobin's q is straight-forward: a firm owes a duty to owners that agents wisely invest each dollar. At some point, a firm's investments must generate positive returns, or should be redirected toward alternatives. The evidence applied to the derived Green Tobin's q is taken from the two main oil firms in the United States and United Kingdom: ExxonMobil ("Exxon") and Chevron, and Royal Dutch Shell ("Shell") and British Petroleum ("BP"). We find that the market values the firms' efforts differently, and thus firms should take some of their green efforts more seriously than other green activities. Tobin's q captures how *serious* (or market relevant) green efforts are, following prior "pays to be green" literature (Dowell, Hart, & Yeung, 2000; King & Lenox, 2002). Our proxies of firm-level green effort capture two perspectives: (1) climate change patents filed by agents, and (2) shareholder proposals related to climate change brought up by owners at annual meetings. We follow prior literature in measuring patents by patent counts (Johnstone, Haščič, & Popp, 2010), and stockholder pressure by the number of shareholder proposals per year (Chen, T., Dong, & Lin, 2020). These ex ante actions consider the twin perspectives of owners and agents, and shed light on how seriously the stock market values a firm's green efforts.

When evaluating firm *effort*, accumulating a stock of knowledge may be more important than a breakthrough achievement, and the resurfacing of an issue at an annual meeting better captures stockholder pressure than the popularity of any single proposal. Effort is better captured by these collective actions, as opposed to which patent ended up being the most important or which proposal gathered the most votes. Further, these two proxies for green effort would be difficult for firms to artificially manufacture or greenwash. As opposed to marketing campaigns, media connections, and even investor relations, agents must face the scrutiny of a patenting office to protect green technologies, and owners must satisfy securities regulators in order to make green proposals at annual meetings. Our focus on these particular green efforts occur in highly formal settings in which federal agents vet the appropriateness, and thus somewhat inhibit firms' proclivities to greenwash.

We find that these climate change patents are negatively correlated with q, and climate-related shareholder proposals are positively correlated with q. These correlations hold with the inclusion of established controls, time and firm invariant factors, and causation exercises.[1] Our robustness checks include an alternative database, an expanded sample to other major oil firms around the world, and a sample limited to the United States.

2. Literature Review and Motivation

A growing literature descries increased political and public pressure on companies to improve their green record (Cahan, Chen, Chen, & Nguyen, 2015). Some studies find this pressure to be value destructive for political inclinations (Di Giuli & Kostovetsky, 2014), agency conflicts (Krüger, 2015), or entrenchment considerations (Surroca & Tribó, 2008), while other research reports that the pressure for "goodness" commands higher acquisition premiums (Deng, Kang, & Low, 2013), provides a strategic choice (Wu &

[1] Following Laura Stark's keynote address, during the Q&A portion, Stu Gillan asked, "how do you see the tradeoff in term of climate research that's largely descriptive verses the desire for work that allows for causal interpretations?" Her response was that, "particularly in a new area, we need to see what we can learn from the descriptive research that just shows correlation" (48:13-49:03). For this reason, we characterize causation survivals more as exercises than as definitive identifications.

Shen, 2013), and generates positive abnormal returns for environmental and social engagement (Dimson, Karakaş, & Li, 2015). Firms' stockholders are also influenced by public opinion and place additional pressure on corporations to improve their environmental performance (Flammer, 2015). Other prior literature discovers mixed evidence on the relationship between environmental and financial performance (Buonanno, Carraro, & Galeotti, 2003; Elsayed & Paton, 2005; Konar & Cohen, 2001; Nordhaus, 2010). This mixed evidence is due to a lack of theoretical guidance on how to apply ad hoc measures. As Buchanan et al. (2018) note, "existing theoretical research remains inconclusive on the effect of CSR on firm value or financial performance." (p. 1) Further, as Li and Wu (2020) point out, "the paucity of empirical research in this area can be partially attributed to the scarcity of firm-level data on the outcomes of CSR engagements." (p. 1) To our knowledge, only a few papers (Albuquerque, Koskinen, & Zhang, 2019; Fatemi, Fooladi, & Tehranian, 2015; Wu, Zhang, & Xie, 2020) derive theoretical models for green effort expectations, i.e. where the measures fit into a framework. We aim to fill this void in the theoretical literature, while providing an empirical context for our model.

Essentially, q-theory says that a growth opportunity exists when the market values the collection of firm investments more than the component costs to reproduce them (Brainard & Tobin, 1968). Any examination of Tobin's q, green or otherwise, compares market value to replacement costs, a comparison of accounting data to financial valuation, as stressed by Lindenberg and Ross (1981). Ideally, Tobin's q would represent the marginal contribution of the next investment dollar, but practical measures capture an average Tobin's q as the ratio of the market value of a firm's assets to their replacement costs (Tobin & Brainard, 1977). Calculations of Tobin's q vary, but we settle on conservative ones by Chung and Pruitt (1994). With q in mind, we review the literature on green technologies and stockholder pressure to address climate change.

2.1. Green Technologies

New green technologies have two market failures: environmental externalities and the public goods nature of new knowledge. The consequence is underinvestment in the research to develop greener technologies. To address these shortcomings, government subsidies to greener R&D projects are often proposed as part of a policy solution (Newell, 2007), in which R&D subsidies lead to significant increases in climate-friendliness (Popp, 2006). At times, solutions to polices do not owe to the ones intended but to the spillover effects from the effort to address an externality, and firm value is rewarded by such knowledge spillovers (Dechezleprêtre, Martin, & Mohnen, 2013). This spillover effect on value serves as the basis for examining green effort, instead of the subsequent outcome of the effort.

As is well-established in the innovation literature, firms that invent do not always reap the benefits (Nelson, 1959), thus a distinction between socially desirable and privately profitable (Aghion & Howitt, 1992), almost an inherent consequence of incomplete contracts (Grossman & Hart, 1986). Consequently, a negative association of green effort and market value may merely reflect political will to subsidize what the market judges to be more socially desirable than privately profitable. Over time, however, all firm investments and expenditures are expected to produce profits. At some point, the market renders a verdict: green effort either finds market support as an investment or proves to be a social subsidy.

The difference between investment and subsidy is not always obvious, as sometimes only time can tell. To make the distinction, the R&D literature analyzes whether environmental R&D crowds out other R&D investments. Nordhaus (2010) shows that new energy R&D completely crowds out other R&D; his result, however, hinges on the assumption of a fixed supply of R&D labor. If energy R&D complements other R&D, crowding out does not occur (Buonanno et al., 2003). Popp and Newell (2012) find no evidence at the industry level of crowding out across sectors but do discover that increases in alternative energy patents leads to fewer patents of other types. This begs fundamental questions that Hicks (1932) hypothesized of factors of production that become relatively more expensive: "induced innovation" explains governmental efforts to affect input prices. Given constraints on R&D budgets, are green technologies developed at the expense of other technologies? No matter how vast a firm's internal markets, tournaments for resources within the firm keep the competition lively. Whether or not the prize is charity, investment, or signal (Lys, Naughton, & Wang, 2015), the Green Tobin's q provides a theoretical roadmap for empirical application.

The empirical literature on the relationships between environmental and financial performance finds ambiguous results, much like the empirical ambiguity of value created by broader measures of ESG and CSR (Margolis, Elfenbein, & Walsh, 2009). Some studies show a neutral impact between environmental and financial performance (Elsayed & Paton, 2005); other studies find a negative relationship (Cordeiro & Sarkis, 1997; Rassier & Earnhart, 2010; Sarkis & Cordeiro, 2001), while yet others report a positive relationship (King & Lenox, 2002; Konar & Cohen, 2001). For instance, Konar and Cohen (2001) indicate that a decrease in emissions enhances Tobin's $q - 1$ (or the intangible portion of q) in S&P 500 firms, and King and Lenox (2002) find evidence that waste prevention can improve financial performance. Ambec and Lanoie (2008) suggest that better environmental performance can improve financial performance: reduced costs and risk along with enhanced revenues through market access and differentiated products. Chava (2014) finds material reductions in a firm's cost of capital when screened according to their environmental profile. There appears to be a slight edge for a positive relationship between environmental and financial performance in more recent studies.

The measures and samples of financial and environmental performance are many and varied. Iwata and Okada (2011) study the financial performance of Japanese manufacturing firms responding to different environmental issues, finding that waste emissions have no effect while greenhouse gas reductions enhance financial performance, at least for clean industries. Other studies discover more dynamic relationships between environmental and financial performance (Lioui & Sharma, 2012), where the direct relationship is negative but indirect ones are positive: firm value benefits from R&D effort spurred by environmental performance. The proxies employed, sample construction, and decomposition influence the sign, size and strength of the relationship between environment and financial performance.

The time period and length of time also exerts an influence. When environmental regulation is considered, Delmas et al. (2015) confirm Cordeiro and Sarkis (1997) who find a negative short-run impact on accounting returns but positive long-term value indicated by Tobin's q. Horváthová (2010), through meta-analysis, finds a more consistent, negative link between environmental performance and financial performance with simple correlation coefficients and portfolio studies, than with more sophisticated econometric techniques which fail to provide consistent evidence. A positive link is found in her meta-analysis of 37 empirical studies, but these win-wins for environmental performance and financial performance are found more frequently in common law countries where investors are afforded more protection than in civil law countries. Over extended horizons, a consistent signal between environmental and financial performance is difficult to find.

Consistency between financial and environmental performance for the oil industry, likewise, has its challenges. Despite a legacy of "low R&D intensity" (Moncada-Paternò-Castello, Ciupagea, Smith, Tübke, & Tubbs, 2010; Von Tunzelmann & Acha, 2005), the industry seems to be changing. Technology appears as an increasingly important strategic priority for several international oil companies (Chazan, 2013; Kulkarni, 2011; Parshall, 2011). Spending on innovation and R&D by oil companies has increased to reflect the industry's strategic shift (Thuriaux-Aleman, Salisbury, & Dutto, 2010). Many companies have adopted the concept of "open innovation" (Chesbrough, 2003) and more collaborative models of R&D embracing ideas from other industries and technical domains (Ramirez, Roodhart, & Manders, 2011; Verloop, 2006). Given the potential for spillover effects to find market support, the oil industry is a timely sector of the economy to examine.

The literature on the financial performance of environmental (green) technologies lacks theory to clarify when crowding out can be expected or when spillover will be rewarded, why more recent studies increasingly find positive correlations between environmental and financial performance and what is prompting more intense innovation efforts in the oil industry. As explained next, the investing public and firms' existing investors have become more vocal in their concerns with the environment. Climate change is often at the center of the debate on how to invest wisely moving forward.

2.2. Green Stockholder Pressure

The CEO of Royal Dutch Shell, Ben van Beurden, recently emphasized some "hard truths" about climate change that shareholders, in particular, need to come to terms with. Confronting climate change, according to him, "needs shareholders' support to move in the right direction" (Ryder, 2019). Such owner support can be viewed as the green light for oil firms to pursue green technologies. The literature informs us of innovation's tolerance for loss (Chen, Leung, & Evans, 2016; Manso, 2011). Thus, if firms are to innovate ways to abate pollution or create clean technologies, a greater lenience for research that "fails" to develop is requisite to the creative process. In other words, owners leaning less on agents for immediate profits and relaxing their aversion to loss is conducive to innovation.

The literature on shareholder proposals has struggled to identify definitive purpose for the governance mechanism, most of which is centered on the United States where proposals make regular appearances at annual meetings (Gillan & Starks, 2007; Karpoff, Malatesta, & Walkling, 1996; Levit & Malenko, 2011; Renneboog & Szilagyi, 2011). Though proposal identification is elusive, Buchanan, Netter and Yang (2010) find stronger influence on management behavior for precatory US proposals than for compulsory UK proposals. By exploiting discontinuities in market reactions around "close call" votes at annual meetings, Cuñat, Gine and Guadalupe (2012) find positive market responses to increased governance, which greatly enhance the identification of proposal effect. Such an approach to discontinuity is also employed by Flammer (2015) who discovers positive announcement returns for CSR proposals that pass when vote outcome is too close to call prior to the annual meeting. As supplemental evidence, she investigates the impact on Tobin's q several years after a CSR proposal gathers majority support, and finds a significant positive association four years hence. The inquiry on the relationship between Tobin's q and

ESG proposals continues with Grewal, Serafeim and Yoon (2016) who are careful to distinguish between material and immaterial ESG issues. The authors find that ESG proposals concerning immaterial issues display a slight decline in q, while material issues show subsequent increases in q. More recently, Chen, Dong and Lin (2020) exploit discontinuities around the Russell 1000/2000 threshold to demonstrate the value relevance of shareholder "voice" expressed by proposals. With guidance from the literature, the following model theorizes how shareholders are able to influence their investments when expressing climate concerns through their proposals.

As demonstrated in the next section, shareholder proposals exert their influences on an integral of profits by allowing for failure or the probability that an innovation does not occur. This influence may be the "shareholder support" that Mr. van Beurden hopes to secure.

3. The Model: Green Tobin's q

The industry has N identical firms, the representative firm's real profits, neglecting all costs, are proportional to its capital stock, k, and decreasing in the industry-wide capital stock, K; thus taking the form $\pi(K)k$, where $\pi'(K) < 0$.[2]

The representative firm also invests M in the innovative activity, which is the rate of expenditure in R&D of cleaner technologies that help abate pollution. Assuming zero depreciation rate, the firm's investment, I, equals the rate of change of the firm's capital stock, $\dot{k}$, and R&D expenditures, M:[3]

$$I = \dot{k} + M \tag{1}$$

[2] See Romer (2006)

[3] Considering externalities and the public good nature of the R&D activity, the firm may receive a subsidy s from the government (e.g., Acemoglu et al., 2012) so instead of (1) we have: (1') $I = \dot{k} + (1 - s)M$

The variable *V* represents the stock of knowledge, which is accumulated as an increasing function of R&D expenditures:

$$\dot{V} = h(M) \tag{2}$$

There are adjustment costs associated with the rate of change of the firm's capital stock and pollution abatement *A*, $Z(\dot{k}, A) = aAC(\dot{k})$, where a is a parameter representing stockholder pressure for green effort[4], and $C(\dot{k})$ is a convex function of the rate of change of the firm's capital stock satisfying, $C(0) = C'(0) = 0, C'(\dot{k}) > 0, C''(\dot{k}) > 0$.

R&D may be fruitless, as it is a risky activity. Therefore, firm's profits overtime are impacted by the uncertainty of innovative activity. The representative firm's intertemporal profits are given by:

$$\int_0^\infty e^{-rt}\{\aleph(V)[\pi(K)k - I - aA\,C(\dot{k})] + w(V)h(M)\beth(k, A)\}dt \tag{3}$$

The term $w(V)$is the subjective probability density function that the innovation will occur at the state of knowledge, *V*, so the probability density that the innovation will occur at time *t* is $w(V)h(M)$. $\aleph(V)$ is the probability that the innovation will never occur. The term $\beth(k, A)$ denotes the maximized value of the integral of the profits after the innovation happens.[5]

Pollution abatement efforts, *A*, reduce the amount of pollution, *P*, in the environment:

$$P_t = P_0 - \int_0^\infty A dt \ \geq 0 \tag{4}$$

It is assumed that the initial level of abatement efforts is normalized to 1: A_0=1/a

The representative firm's problem is to choose intertemporal paths of the control variables *I*, *A*, and *M* with a view to maximizing (3) subject to Eqs. (1), (2) and (4). The Hamiltonian of the problem is:

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[4] An additional or alternative way to introduce stockholder pressure in this model is to assume that the firm has to use the current cleaning technology, as such it has to divert resources form R&D of new technologies to satisfy this demand, impacting the accumulation of knowledge, so, instead of (2) we have: (2') $\dot{V} = h(M) - aA$

[5] See Dasgupta (1982) for a discussion.

$$H = e^{-rt}\{\aleph(V)[\pi(K)k - I - aAC(I-M)] + w(V)h(M)\beth(k,A) + q(I-M) + \gamma h(M)\} - \mu A$$

(5)

Where q and γ are the co-state variables for the dynamic constraints (1) and (2), respectively.

From the first order conditions for investment *I*, we derive the Green Tobin's q:

$$H_I = 0 \rightarrow q = \aleph(V)[1 + aAC'(I-M)] \quad (6)$$

Note that in the absence of R&D in green technologies, *M*=0, we have no uncertainty and pollution abatement efforts are set at the initial level: A_0=1/a. As a consequence, Eq.(6) yields the well-known Tobin's q:

$$q = [1 + C'(I)] \quad (7)$$

According to Eq. (7) the cost of acquiring a unit of capital equals the purchase price (fixed at 1) plus the marginal adjustment cost. Note that in the steady state, *I*=0 and *q*=1.

Comparison of Eqs. (6) and (7) shows that the Green Tobin's q depends on the stock of knowledge *V*, pollution abatement efforts *A* and R&D expenditures *M*. However, in order to fully examine the determination of the Green Tobin's q, we must consider the remaining first order conditions of the problem:

$$H_A = 0 \rightarrow e^{-rt}\{\aleph(V)[-aC(I-M)] + w(V)h(M)\beth_A(k,A)\} = \mu > 0 \quad (8)$$

$$H_M = 0 \rightarrow \aleph(V)[aAC'(I-M)] + w(V)h'(M)\beth(k,A) = q(I-M) - \gamma h'(M) \quad (9)$$

$$\dot{q} - rq = -\{\aleph(V)\pi(K) + w(V)h(M)\beth_k(k,A)\} \quad (10)$$

$$\dot{\gamma} - r\gamma = -\{\aleph'(V)[\pi(K)k - I - aAC(I-M)] + w'(V)h(M)\beth(k,A)\} \quad (11)$$

Equations (8) and (9) equal marginal costs to marginal benefits of pollution abatement efforts and R&D expenditures, respectively. Eq.(10) equals the marginal revenue product of capital to the opportunity cost of a unit of capital, given by the difference between foregoing interest rate and capital gains $rq - \dot{q}$. Eq.(11) equals the marginal revenue product of knowledge with the opportunity cost of a unit of knowledge.

Consider the steady state, where $\dot{k} = \dot{V} = \dot{q} = \dot{\gamma} = 0$, in the system of equations (1), (3), (4), (6), (8)-(11) which determines the optimal values of 8 endogenous variables *I*, *A*, *M*, *V*, *q*, *k*, γ, and μ. The system is block recursive causal. Equation (3) determines the equilibrium value of *M*, and Eq. (4) the equilibrium value of *A*, then, given *A*, Eq.(1) determines the equilibrium value of *I*. Given *A*, *M*, and *I*, the sub-system (6) and (9)-(11) determine simultaneously the optimal values of *V*, *q*, *k* and γ. Finally, the last endogenous variable determined by the model is μ.

In accordance with the model's block recursive structure, one can write the Green Tobin's q as a function of pollution abatement efforts [proxied by environmental expenses] *A*, stockholder proposals for green effort *a*, R&D expenditures *M*, stock of knowledge [given by patents] *V*, firm's capital stock [given by assets] *k* and investments *I* [given by capital expenditures].

In Appendix 1, solving the model in the steady-state and assuming that a greater stock of knowledge *V* reduces the probability that the innovation will never occur, $\aleph'(V) < 0, \aleph''(V) > 0$; and that *V* increases the probability density that the innovation will occur at time t, *w'(V)>0*. In addition, taking into account that $\beth_k(k, A) > 0, \beth_A(k, A) < 0,$ yields the following expression for green Tobin's q:

$$q = \aleph(V^*(I^*, k^*, A^*, N, s, r, a)) \quad (12)$$

The green Tobin's q is impacted negatively by pollution abatement efforts, *A*. The influence of capital *k*, and industry *N*, on green Tobin's *q* are ambiguous. However, it grows with stakeholder pressure *a*, government subsidies *s* to R&D in cleaner technologies, the discount rate *r*, and more investments *I*.

The next sections comprise the empirical tests of the model's main predictions, in particular the impact of the agent's green efforts (the stock of knowledge, *V*, in climate change patents) and the exogenous owner's green efforts (the climate-related proposals, *a*).

4. Sample

We gather fundamental accounting and year-end stock price data from Compustat and Datastream, patent information from Patstat, and shareholder proposal data from SeekEdgar[6] developed by Raj Srivastava and supplemented with text searches from the SEC Edgar site, as well as reviewing firm websites. Table 1 provides data calculations and sources.

[Insert Table 1]

The literature offers several versions of Tobin's q. We follow the literature (King & Lenox, 2002) and opt for the simple version of Tobin's q developed by Chung and Pruitt (1994), which is calculated as the market value of equity plus the book value of preferred stock, long term debt, and current liabilities net of current assets, all scaled by book value of total assets. As derived in our model, the Green Tobin's q is a function of stock of knowledge *V*, stockholder proposals *a*, R&D expenditures *M*, capital stock *k*, investments *I*, and abatement costs *A*.

$$q = q(V, a, M, k, I, A) \quad (12)$$

The proxies for the green variables of interest are a firm's Green Patents (*V*) and Green Proposals (*a*). We employ Patstat, the database for "green patents" previously used to investigate the impacts of green bonds (Flammer, 2018), carbon taxes in the auto industry (Aghion et al., 2016), and the effect of regulation and research networks on green patents (Fabrizi et al., 2018). The Cooperative Patent Classification (CPC) is an international system jointly developed by the US and European Patent Offices and adopted throughout

[6] https://www.seekedgar.com/

the world.[7] We follow Flammer (2018) and explore the Y02 series (technologies or applications for mitigation or adaptation against climate change) with subclassifications (A, B, C, D, E, P, T, and W) providing granularity on the type of climate change patent. We follow Aghion et al. (2016) and Fabrizi et al., (2018) to focus on the triadic patents filed in the United States, Europe, and Japan. We focus on the Y02E (Energy-related) patents as most applicable to the energy transition. Similar to Flammer, we compare the number of green patents (classified as Y02E) to total patents, and use this ratio as *V*, one of our two green variables of interest. The other green variable of interest, Stockholder Pressure, *a*, is the number of shareholder proposals submitted at annual meetings which specifically reference "climate change." The other (control) variables are: R&D (*M*) is scaled by assets, Capital stock (*k*) as the natural log of assets, and Investments (*I*) as capital expenditures scaled by sales.

[Insert Table 2]

Table 2 contains descriptive information about the four major oil firms in the US and UK from 1998 to 2017. Tobin's q ranges from well below unity (min .46) to more than double (max 2.26) with a mean just above unity (1.19). On average over time, the market views these four oil firms with declining growth opportunities. The average oil firm's Y02E patents comprise 4% of its total patents filed, ranging from 0 to 19% over the time period. Shell and BP received their first proposals related to climate change in 2015, while Exxon received six climate change proposals in 2016. Table 3 presents pairwise correlations.

[Insert Table 3]

The correlations of interest are those between Tobin's q and firm green effort: the agent's green technology and the owner's green proposals. A strong, negative correlation exists between the percent Y02E patents and Tobin's q with an economic significance of -0.546 and statistically significant at the 1% level. Green pressure has a weaker, positive correlation with Tobin's q of 0.257, significant at the 5% level. Other correlations with Tobin's q are similar to the literature.

[7] See https://www.uspto.gov/patents-application-process/patent-search/classification-standards-and-development.

[Insert Figure 1 (Panel A: Tobin's q, Panel B: Green Technology and Panel C Green Pressure)]

To expand the above pair-wise correlations, Figure 1 presents time trends by firm. As Tobin's q is the focus of our theoretical derivation and empirical application, understanding how q has trended over time for these four firms is critical to distilling the green influences on it. As shown in Panel A of Figure 1, Tobin's q is declining over time for all four firms, and only Exxon retains a q above unity by 2017. To smooth the time trend, a lowess fit is offered, which indicates a slight uptick in Tobin's q from 2014 to 2017 for Chevron, BP, and Shell, while Exxon's q continues to decline. Panel B of Figure 1 presents the how green technology has trended over time for these four firms. While a linear fit indicates an upward trend, the locally weighted smoothing of a lowess fit displays something more dynamic. BP began to place much more emphasis on green patents starting in the early 2000s and continued to outpace the other three competitors through 2009. There appears to be an inflection point or high mark for each firm in their percentage of Y02E patents: 2009 for BP, 2010 for Shell, 2011 for Chevron, and 2014 for Exxon. Panel C of Figure 1 shows the time trends for shareholder proposals related to climate change, where Exxon experiences the most stockholder pressure.

[Insert Figure 2 (Tobin's q and Green Effort)]

Figure 2 relates Tobin's q to both forms of green effort: technology and pressure, and indicates a negative relationship for all four firms between Tobin's q and green effort. Taken together, the various time trends and differences in emphasis on green technology and stockholder pressure among highly comparable firms in well-developed capital markets provides an excellent opportunity to examine the variation in Tobin's q.

While agents initially placed more emphasis on green technologies and then eased off them, owners intensified their green pressure. Although the proxy for stockholder pressure is promising, it is difficult to quantify. Consequently, we caution any interpretations of the associations between Tobin's q and shareholder proposals that follow. The correlations between q and a are largely descriptive.

As Buchanan, Netter, and Yang (2010) point out, shareholder proposals are quite different in the two countries. In the US, shareholder proposals are advisory only, regardless of vote outcome. In the UK, shareholder resolutions are binding when they gather majority support. Proposals are common in the US, rare in the UK. Generalizing, shareholder proposals are persuasive in the US and coercive in the UK. Despite the differences, proposals in either country are explicit expressions of owner concerns. Such concern expressed by shareholding investors helps to attribute the pressure toward value-relevance (Deng et al., 2013; Renneboog, Ter Horst, & Zhang, 2008). While the intensity of this exogenous pressure varies over time and between countries, there are some interesting dynamics at these four firms' most recent annual meetings.

While Exxon received its first proposal related to climate change in 1996, it would not be until 2017 that a majority of shareholders would support such a resolution. (No board or management in the US has ever supported a proposal related to climate change.) Subsequent proposals have fallen far short of majority support. Even though outside the sample, a proposal to create a climate change board committee gathered only 7.4% of the vote at Exxon's 2019 annual meeting. Similar pressures have mounted and released at Chevron over the years. In 2018, "Chevron shareholders rejected two climate change resolutions at the oil giant's annual meeting, upsetting activists who are pressuring fossil fuel companies to curb crude oil production and reduce greenhouse gas emissions" (Siegal, 2018). In 2019 at Chevron's annual meeting, shareholders rejected two proposals related to climate change: a proposal for a report on reducing carbon footprint gathered 33.2% of the vote, while a proposal to create a climate change board obtained only 7.6% of shareholder support.

In 2015, both UK oil firms received their first shareholder proposals related to climate change and, surprisingly, the management of both firms supported these proposals. Both 2015 proposals received near unanimous shareholder approval: 98.91% of the vote for Shell's Resolution 21, and 98.28% for BP's Resolution 25. Every year since 2015, Shell has received a similar shareholder resolution, but without management support these resolutions gathered only 2.78%, 6.34% and 5.54% of the vote from 2016 to 2018, respectively. Again, though subsequent to the sample period, some interesting developments have taken place at recent annual meetings. In 2019, the sponsoring shareholder withdrew such a resolution from

Shell's annual meeting. At BP's annual meeting in 2019, however, shareholders introduced two resolutions on climate change. Management supported Resolution 22 which received 99.14% of the vote, while Resolution 23 gathered only 8.4% support from other shareholders without management's approval. Clearly, voter support displays not only wide variation among these four firms, but also wildly divergent support for the same firm in the same year. As a firm-years observation, vote outcome can have opposite indications. Taken together, however, the *number* of proposals filed (like patents filed) is believed to provide the best indication of pressure being exerted on management to address climate change.

If explanatory, the wide variation of green efforts – technology and pressure – over two decades for these four direct competitors should be priced in the market. As the largest firm with vast access to capital markets, Exxon has only recently intensified its relative green technology, so have their shareholders pressured them to address climate change. Our theoretical model explains how Green Tobin's q is a function of these green efforts, but it remains to be seen if these additional green technologies gain firms a valuable advantage and whether incremental shareholder pressure is beneficial to shareholder wealth.

5. Results

To distill the preceding associations for relevance to Tobin's q, ordinary least squared regressions provide guidance. Table 4 addresses the impact on q that green technology and shareholder pressures have. The first two regressions reflect the correlations established above: a negative one between V and q, and a positive correlation between a and q. When controls are added to the regression, the coefficients on both owner and agent green efforts retain significance at the 1% level, a level maintained when year dummies are added to control for time trends, while the magnitude of the coefficients of interest increase. When only firm dummies are introduced in model 5, the negative relationship between q and V retains significance at the 1% level but that between q and a becomes indistinguishable from zero. When both time and firm dummies are added to the regression, high levels of significance are bestowed on both variables of interest. The correlations displayed in pairwise continue be negative for V and positive for a, even when estimated by ordinary least square regressions with a full set of control variable, time and firm invariant factors.[8]

Insert Table 4

Moving through the interquartile range, the coefficient on the percent of Y02E (the reduction of greenhouse gases through renewable energy sources) reduces the mean Tobin's q of 1.154 by -0.109 (or almost to unity), all else held constant. When an oil firm receives a shareholder proposal related to climate change, the regression results suggest that Tobin's q increases by 0.065 (Although the mean number of proposals received is 0.825, a firm cannot receive a fraction of a proposal. A firm at the 75th percentile receives one such proposal.)

To evaluate multi-collinearity, variance inflation factors (VIF) are calculated in Table 4 as well, for regressors in model 6, i.e. the variance of an independent variable unrelated to the other independent variables. In regression 6 of Table 4, 93.1% of the variation is explained. Only Capital Stock, *k*, raises concerns of multi-collinearity with a VIF of 19.161, which exceeds the generally held level of 10 being an unacceptable inflation of variance. Further, all variables are tested for their stationarity using the Levin-Lin-Chu test, as there is a balanced panel and the sample is limited to the four US/UK firms over a sufficient time, i.e. satisfying their assumption that N number of firms be small relative to T, time. Again, when Capital Stock is tested for stationarity, we fail to reject the hypothesis that *k* contains unit roots and conclude that the variable is non-stationary. To allow for the possibility of cross-sectional correlations, we also specify the demean option for the Levin-Lin-Chu test, which fails to reject the null for Capital Stock. These tests confirm the need to remove the time trends from the variables. To address multi-collinearity and omitted variable bias, several econometric techniques are employed in Table 5.

[Insert Table 5]

First, fixed effects are added to the regression to remove time invariant factors in model 1. The aforementioned effects of *V* and *a* hold. Next, model 2 introduces a squared term for *V*, given the inflection points for emphasis on green technologies noted above in the lowess graph in figure 1B. The significance

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[8] In unreported results, adding either *V* or *a* to a base model (of controls, time and firm invariant factors) increases explanatory power by approximately 1.5%.

level for *V* drops to the 10% level, however the squared term is indistinguishable from zero, indicating that our interpretations of linear trends is not negated by the dynamic nature of the trend in *V*. All independent variables are lagged in Model 3 to allow some time for their influence on Tobin's q to surface. In this specification, *V* is significant at the 5% level, while *a* becomes indistinguishable from zero. In model 4, the natural log of both dependent and independent variables are taken, and results are qualitatively similar. To address the time trends, the independent variables are orthogonalized and detrended. Since Capital Stock displays the undesirable variance inflation factor, it is orthogonalized first, with the other independent variables orthogonalized in the order shown. The results are similar to prior ones. In column 6, all variables, including the dependent, are detrended according to the procedures outlined by Büthe and Milner (2008).[9] Here, the negative coefficient on *V* retains its significance at the 1% level and the positive one on *a* at the 5% level, once all time trends are removed from the variables, including q.

In the last two specification, GMM estimators are employed in models 8 and 9. Elsayed and Patton (2005) evaluate environmental performance and financial performance by a method introduced by the Arellano and Bond (1991). This procedure uses a generalized method of moments (GMM) approach which takes lagged differences of the independent variables and uses them as lagged instruments of Tobin's q. The model is validated by the presence of first order serial correlation but an absence of it in the second order, as well as the Sargan test for over-identification in the choice of instruments. While the results in model 8 support prior claims of a significant negative effect of *V* and a positive one of *a*, as well as assist identification, this GMM estimator can provide misleading interpretations when the number of firms is small relative to the number of time periods. To compensate for this shortcoming, Bruno (2005) proposes a correction to the bias introduced by instrument proliferation in small samples like ours. His least squares-dummy variable corrected (LSDVC) method accommodates small samples using the GMM estimators in the line of Anderson and Hsiao (1982), Arellano and Bond (1991) and Blundell and Bond (1998). In a

[9] Briefly, the dependent variable is tested for a time trend by regressing it univariately against time and checking for significance. If significant (at the 5% level), the de-trending process transforms the variables to have a firm-mean of zero to reduce multi-collinearity concerns. See footnote 16 in Buthe and Milner (2008) for a full discussion.

review of different econometric techniques designed to allow for causal inference, Flannery and Hankins (2013) determine that LSDVC method with the Blundell-Bond option produces the most reliable interpretations, which we employ in Model 9 where standard errors are bootstrapped in 50 iterations, following Bogliacino and Vivarelli (2012). The LSDVC method, however, imposes strict exogeneity, which Flannery and Hankins (2013) suggest using Wooldridge's (2009) test of adding future values (t + 1) that should have no predictive power. We use leading values of the independent variables and find no predictive power. Along with tests for first and second order serial correlations, Sargan test for overidentification and Difference-in-Sargan test for exogeneity, the results in Model 9 provide strong evidence of the negative effect that increasing these Green Patents have a negative effect on Tobin's q for these oil companies, while Green Pressure does not appear to have a unique effect on *q*. Wintoki, et al. (2012) also find compelling evidence by employing these bias-corrected GMM estimators in a different corporate finance setting.

6. Robustness

The Y02E is but one of several classifications of technologies for adaptation to climate change. To explore the broad classification (Y02) and other sub-classifications (A, B, C, D, P, T and W), Figure 3 follows the collective green technologies of all four firms. The Y02P classification contains the most patents, followed by Y02E (the variable of interest in our main results above), while the other sub-classifications are negligible in number.

Insert Table 6

Table 6 explores the granularity of the Patstat data, employing the specification of column 6 in Table 4, the main OLS regressions with controls and time and firm dummies. While the broader Y02 classification approaches a marginal level of significance and a negative effect on Tobin's q, the granularity exposes not only that this result is driven by the strength of Y02E subclassification's effect but also that the other subclassifications have a negative impact on *q* (except Y02A). Broadening the view of Green

Technologies lends credence to our claim of these four firms detract from value by pursuing climate change technologies. In unreported results, we also conduct a search for "carbon emission" patents in Google Patents for these for firms and discover similar evidence. To further bolster our claim that *green* technologies are value destructive, we also employ Noah Stoffman's database on firm-level patent counts and values (Stoffman et al. (2019)). Our unreported results indicate a *positive* correlation between Tobin's q and patent counts and values. Thus, the market views the overall contributions to stocks of knowledge (proxied by all patents, not just green ones) that these four firms gain each year to enhance their values proxied by *q*.

[Insert Table 7]

In another attempt to broaden our lens, we expand the sample to include more oil firms around the world by including Eni (Italy), Petroleo Brasileiro (Brazil), Repsol (Spain), Sinopec Shanghai (China) and Total (France), along with the US and UK firms above. Table 7 reports results in a manner similar to Table 4, excluding *a*, as shareholder proposals for the additional firms around the world could not be located. While the results in Table 7 diminish in significance, they are consistently negative, lending credence to our claim that green technologies destroy value for oil firms.

[Insert Table 8]

Finally, we compare Exxon to Chevron and find that the negative effect of green technologies persists when 97.7% of the variation between the two firms over time is explained. Results are displayed in Table 8. To see if an "Exxon" effect is taking place (in unreported results), the firm is removed from the four firm comparison to discover that Exxon does, indeed, have an effect but only on the level of significance but not on the negative interpretation of green technologies.

Clearly, climate change is a material issue to oil firms. Owner pressure to address it finds fairly weak evidence of market support. Efforts to address the issue through green technologies are a substantial portion of oil firm innovation policies, yet subsequent value reflected in Tobin's q discourages further investment in green technologies. At some point this may change, but in the confines of our sample it holds. All of these major oil firm have made large in investments in carbon capture as a potentially lucrative line of business (McFarlane, 2021), but the stock market has yet to reward such initiatives, at least according to what we can ascertain from the econometrics.

7. Concluding Remarks

Our main purpose is to derive the Green Tobin's q for the literature at the intersection of environmental and financial performance. To this end, we put forward a dynamic stochastic model of firm investment in which a representative firm invests in pollution abatement and R&D in green technologies, investments to address the pressure stockholders exert concerning environmental issues. Optimality conditions indicate that Tobin's q must reflect green efforts, if substantial. The derived Tobin's q is a function of pollution abatement efforts, stockholder proposals for green effort, R&D expenditures, stocks of knowledge in green technologies, firm's capital stock, and investments. Using data from the oil industry, this paper tests the derived model. Our empirical application of the Green Tobin's q highlights the effects of the efforts exerted by agents in green patents and the pressure by owners to address climate change in their shareholder proposals.

As theorized, the Green Tobin's q is a function of firm green efforts. Our results survive causality exercises and are robust to alternative data sources and to broadening and narrowing the sample. Regression results indicate that green technology patents have a significant, negative effect on Tobin's q, while stockholder pressure has a positive correlation but an ambiguous effect. Given the tailored sample but one over a lengthy period on firms at the center of the energy transition, it may appear surprising that the green patents for these oil firms deter investment, while stockholder proposals encourage it. However, this finding makes sense once we consider what the Green Tobin's q functions as: an integral of maximized profits based on dynamic constraints and the chances of success or failure. Our theoretical model and empirical evidence align with Manso's (2011, p. 1824) suggestion to encourage innovation: "shareholders may want to motivate a CEO to pursue more innovative business strategies…[or] regulators may want to stimulate entrepreneurship, say, through the design of…" clean energy subsidies and carbon taxes. Such motivation requires tolerance for loss or the chance taken on innovation. Indeed, these green firm efforts – abatement, clean R&D, and knowledge – are some hard truths about climate change that Ben van Beurden must also balance, while the exogenous pressure from shareholders finds some market support. Besides filling a theoretical void in the literature, the Green Tobin's q hopes to answer very practical and pressing questions such as how seriously green effort should be taken. Our evidence suggests that the oil firms taking green patents too seriously are being penalized, while firms would be wise to heed green stockholder proposals. Our evidence validates recent claims by the oil firm examined, as recently reported in the *Wall Street Journal*. "Both [BP and Shell] have said they would invest heavily in renewable energy—a strategy that their investors so far haven't rewarded." (Matthews, 2021)

We leave for further studies different applications of CSR and ESG components, e.g. a Labor Rights Tobin's q, by substituting into equation 3 a social component competes in the integral of profits. Subsequent research might discover additional model parameters and expanded samples to allow for more general statements to be made. For our purposes, focusing on the four largest direct competitors in the oil industry enables an assessment of not only how seriously these firms are taking efforts to combat climate change, but also how seriously the market values their efforts.

Appendix 1: The Comparative Statics Analysis

The model in the steady-state [considering Eqs. (1') and (2') [see footnotes 3 and 4] determines implicitly the equilibrium stock of knowledge, *V**:

$$[r^{-1}\aleph'(V)[\pi(K)k - I] + w(V)\beth(k,A)]h'(M) = \aleph(V)\,(1-s) \quad \text{(A.1)}$$

Note that *V** is a function of *k**, *I**, *A**, *r* and *s*. Substituting *V** into (6) yields the equilibrium green Tobin's *q*:

$$q = \aleph(V^*(I^*, A^*, k^*, s, r, a, N))$$

Total derivation of (A.1) allows us to determine the impacts of *k**, *I**, *A**, r, and *s* on V*, assuming that *h'(M*)* = 1, and *w(V)* > 0, *w'(V)* > 0, $\aleph'(V) < 0, \aleph"(V) > 0$, $\beth_k(k,A) > 0, \beth_A(k,A) < 0$. This yields

$$\frac{dq}{ds} = \aleph'(V)\frac{dV}{ds} = \frac{-\aleph(V)\aleph'(V)}{Q} > 0$$

$$\frac{dq}{dk} = \aleph'(V)\left[\frac{-\aleph'(V) - w(V)\beth_k(k,A)}{Q}\right] \gtrless 0$$

$$\frac{dq}{dr} = \aleph'(V)\frac{dV}{dr} = \frac{\left(\aleph'(V)\right)^2[\pi(K)k - I]}{r^2 Q} > 0$$

$$\frac{dq}{dA} = \frac{-w(V)\beth_A(k,A)\aleph'(V)}{Q} < 0$$

$$\frac{dq}{dN} = \aleph'(V)\left[\frac{-\aleph'(V) - w(V)\beth_k(k,A)}{Q}\right]\left(\frac{-k}{N}\right) \gtrless 0$$

$$\frac{dq}{dI} = \frac{\left(\aleph'(V)\right)^2}{Q} > 0$$

Where $Q = \aleph''(V)r^{-1}[\pi(K)k - I] + w'(V)\beth(k,A) - \aleph'(V)(1-s) > 0$

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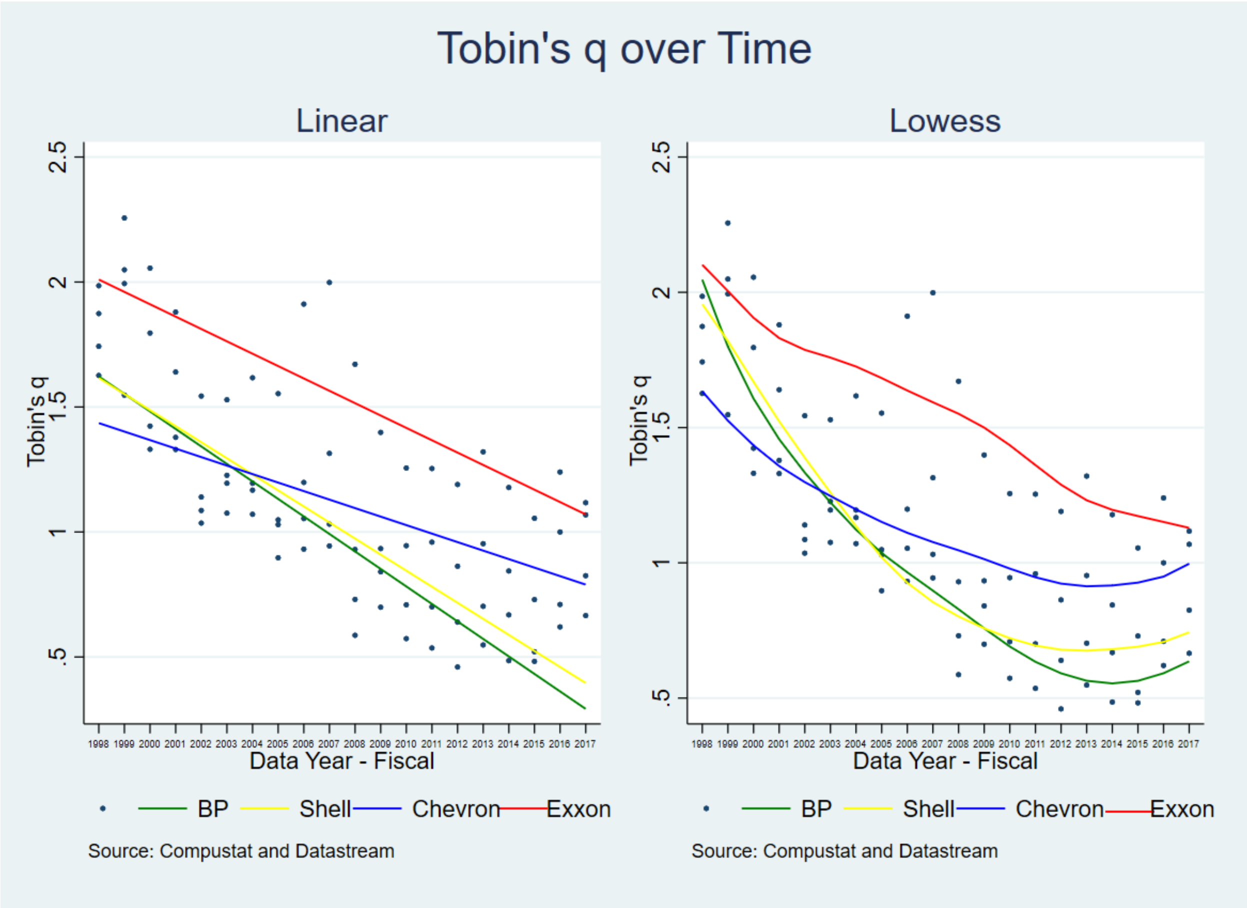
Figures

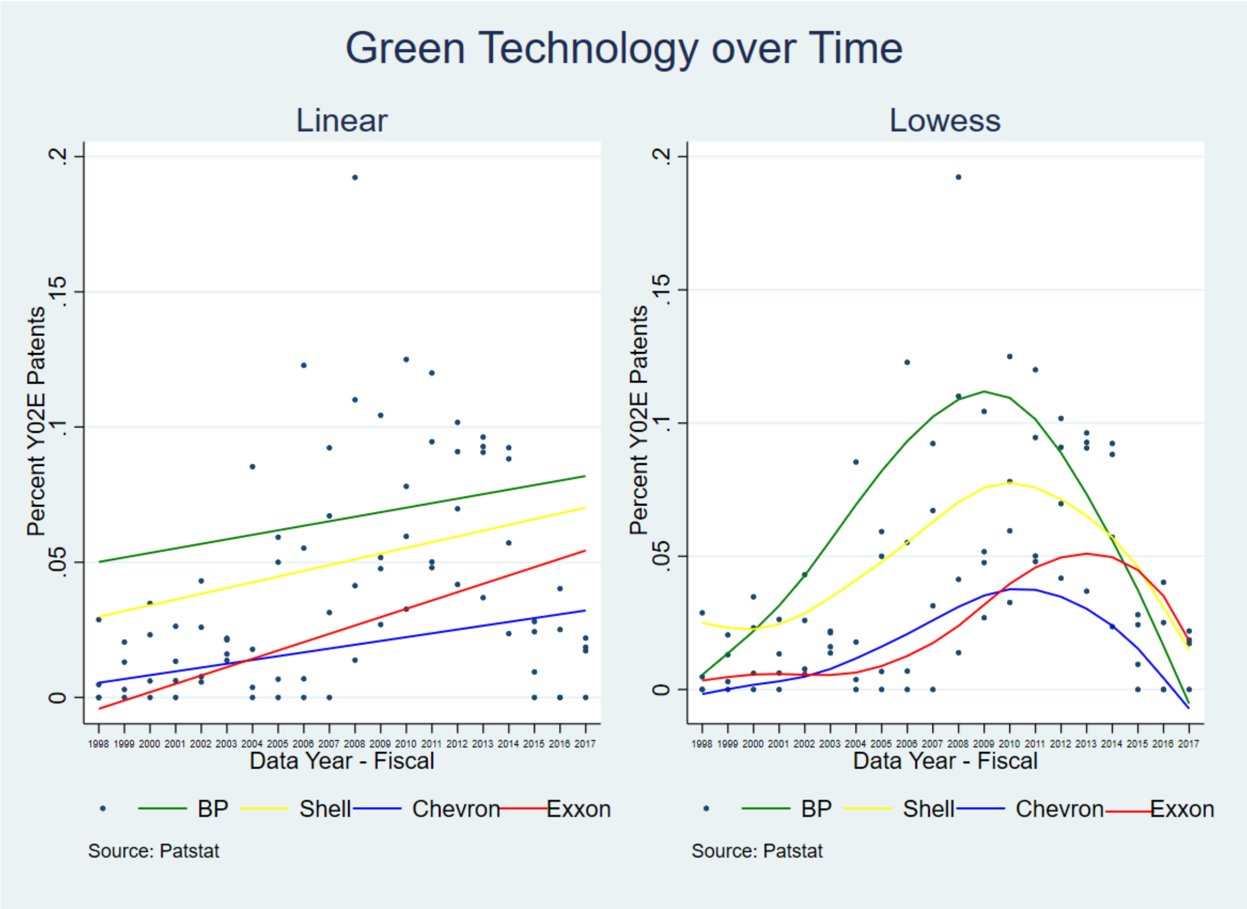
Figure 1 Time trends for Tobin's q and Green Effort: Technology and Pressure

This figure focuses on the two major oil firms in the United States and United Kingdom – Exxon and Chevron, Shell and BP – from 1998 to 2017. The lines represent both a linear and lowess fit. Tobin's q is calculated as the market value of equity plus book value of preferred stock, long-term debt and short-term debt net of short-term assets, all divided by total assets. Green Technology is each firm's percent of patents filed with the Y02E classification relative to total patents filed by a firm in the same year. Green Pressure is the number of shareholder proposal that mention "climate change" in the resolution.

Panel A



Panel B


Green Technology over Time
Linear
Lowess
Percent Y02E Patents
0
.05
.1
.15
.2
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Data Year - Fiscal
BP
Shell
Chevron
Exxon
Source: Patstat

Panel C

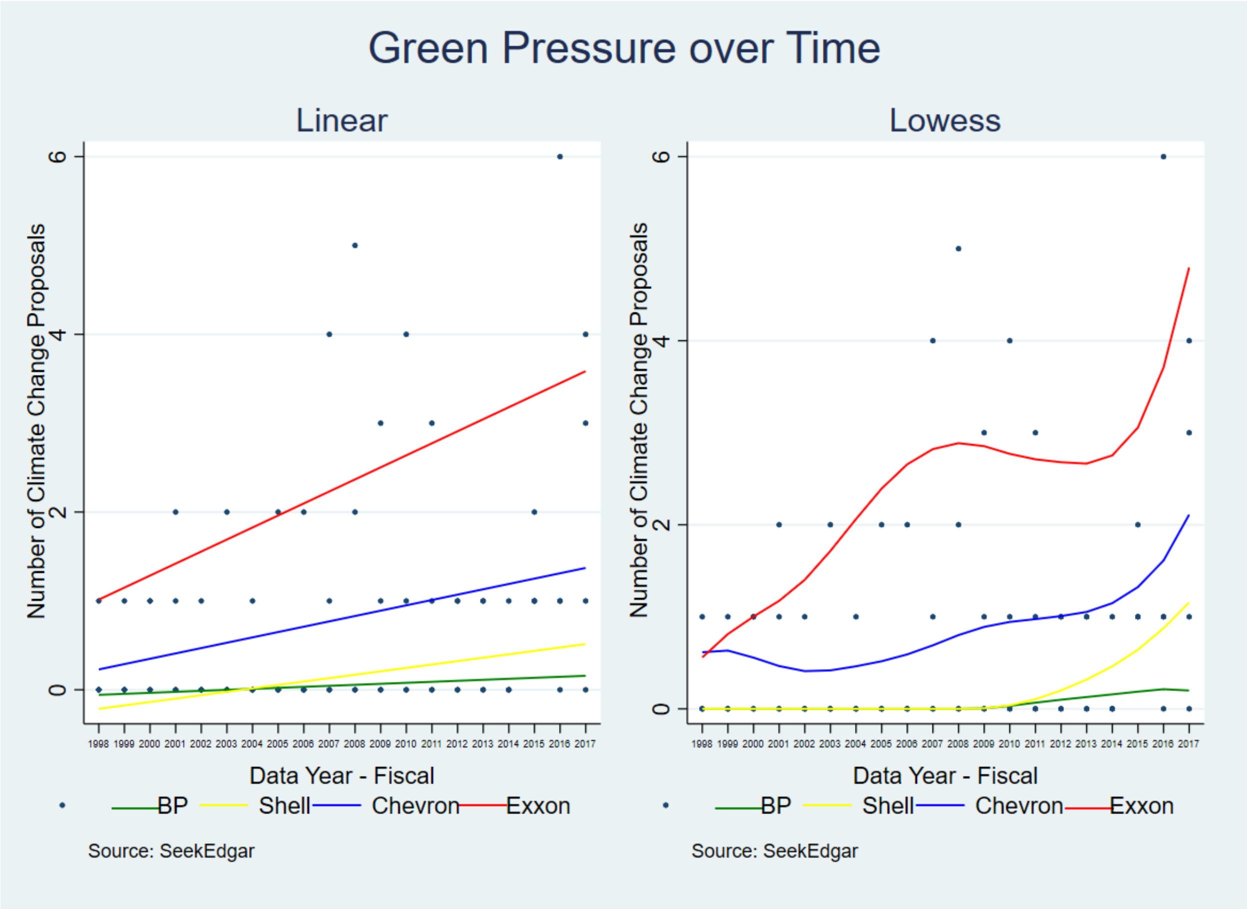

Green Pressure over Time
Linear
Lowess
Number of Climate Change Proposals
0
2
4
6
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Data Year - Fiscal
BP
Shell
Chevron
Exxon
Source: SeekEdgar

Figure 2 Tobin's q and Green Effort: Technology and Pressure

This figure displays the relationship of Tobin's q with Green Effort: the percent of Y02E Patents and stockholder proposal that reference climate change. Tobin's q is calculated as the market value of equity plus book value of preferred stock, long-term debt and short-term debt net of short-term assets, all divided by total assets.

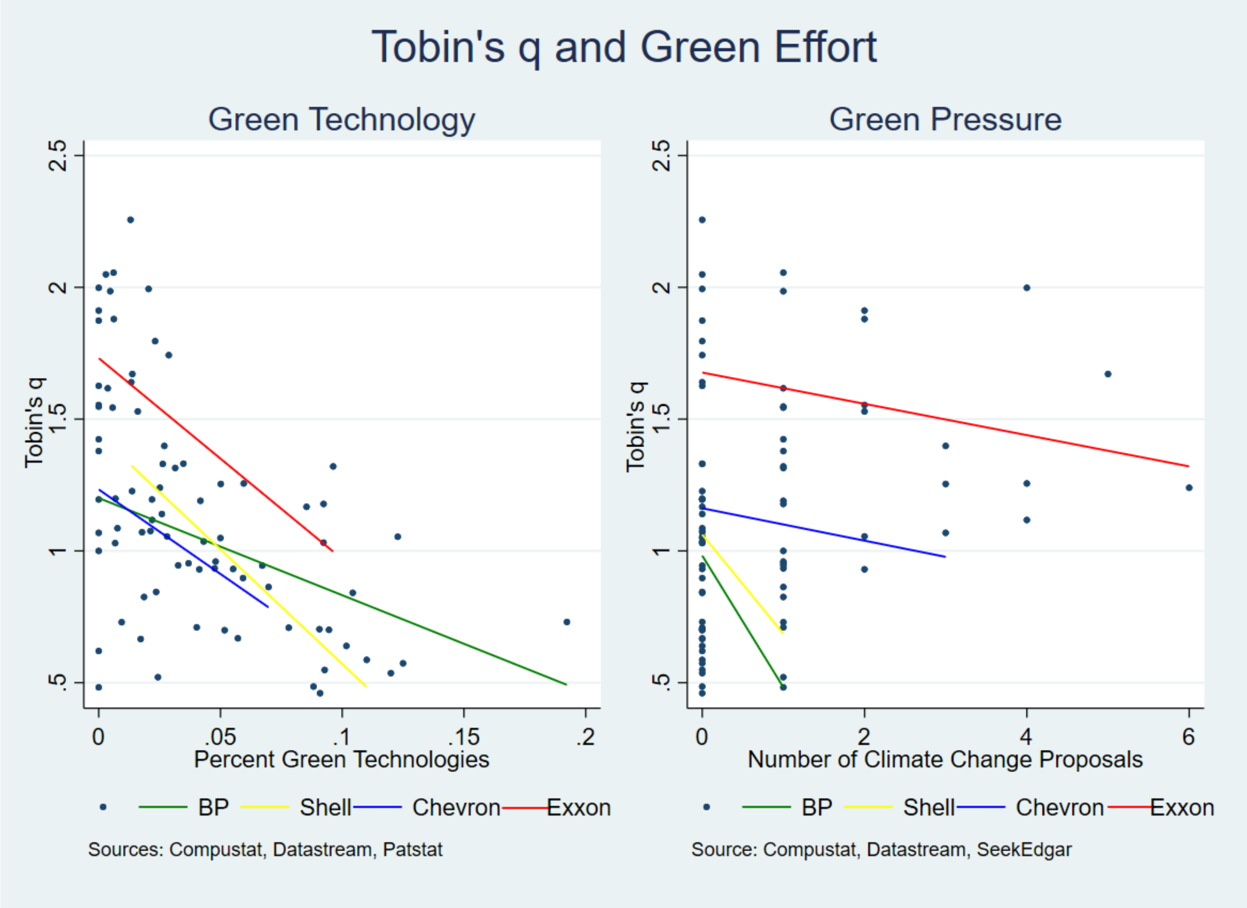
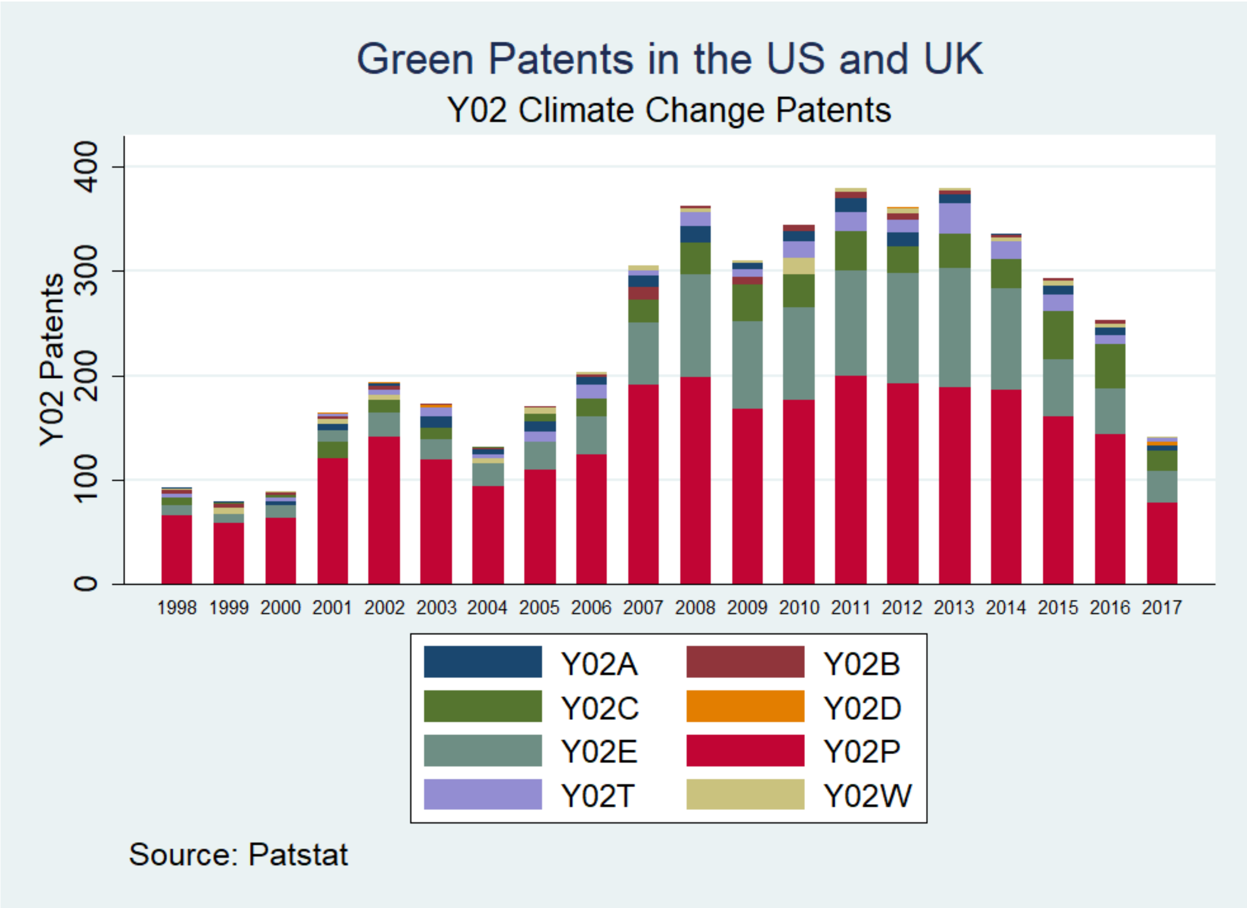


Figure 3 Collective Green Technology Effort by US and UK firms

This figure aggregates the number of climate change patents according to the Cooperative Patent Classification (CPC) Y02. The subclassifications are as follows:

Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE
Y02B CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS
Y02C CAPTURE, STORAGE, SEQUESTRATION OR DISPOSAL OF GREENHOUSE GASES
Y02D CLIMATE CHANGE MITIGATION TECHNOLOGIES IN INFORMATION AND COMMUNICATION TECHNOLOGIES
Y02E REDUCTION OF GREENHOUSE GAS [GHG] EMISSIONS, RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION
Y02P CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS
Y02T CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION
Y02W CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT



Tables

Table 1

Description of Variables: This tables describes the variables used in regressions, how they are calculated and their source.

Variable	**Calculation/Description**	**Source**
Dependent Variable		
q: Tobin's q	Market value of equity plus book value of preferred stock, long-term debt and short-term debt net of short-term assets, all divided by total assets.	Chung and Pruitt (1994)
Market value of Equity	Shares outstanding * year-end closing price	Compustat, Datastream
Green Variables of Interest		
V: Green Patents	The number of Y02E patents divided by the total number of patents per firm per year.	Patstat
a: Green Proposals	Number of "Climate Change" Proposal per year per firm	DEF 14A, Notice of Meetings
Control Variables		
M: R&D	R&D Expense/Assets	Compustat: xrd, at
k: Capital Stock	Natural log (Assets)	Compustat: at
I: Investment	Capital Expenditures/Sales	Compustat: capx, revt

Table 2 Descriptive Statistics:

This table provides descriptive information for the variables defined in Table 1 of the four major oil firms in the US and UK from 1998 to 2017: Exxon, Chevron, Shell and BP.

	N	Mean	Median	Std. Dev.	min	max	p25	p75
q: Tobin's q	80.000	1.154	1.073	0.445	0.460	2.256	0.833	1.411
V: Green Patents	80.000	0.040	0.026	0.040	0.000	0.192	0.007	0.059
a: Green Proposals	80.000	0.825	0.000	1.271	0.000	6.000	0.000	1.000
M: R&D	80.000	0.003	0.003	0.001	0.001	0.007	0.003	0.004
K: Capital Stock	80.000	12.179	12.318	0.534	10.506	12.927	11.896	12.571
I: Investment	80.000	0.081	0.071	0.037	0.041	0.241	0.061	0.090

Table 3 Pairwise Correlations

This tables provides the pairwise correlations among variables for the major oil firms in the US and UK.

Variables	q	V	a	M	k	I	A
q: Tobin's q	1.000						
V: Green Patents	-0.546***	1.000					
a: Green Proposals	0.257**	-0.226**	1.000				
M: R&D/Assets	0.532***	-0.191*	0.086	1.000			
k: Capital Stock	-0.584***	0.482***	0.215*	-0.422***	1.000		
I: Investments	-0.147	-0.149	-0.002	0.078	-0.038	1.000	

***, ** and * shows significance at the 1%, 5% and 10% levels, respectively

Table 4 Main OLS regressions and Variance Inflation Factors

The following table contains ordinary least square regressions for the two major oil firms in the US (Exxon and Chevron) and UK (Shell and BP) from 1998 to 2017. The dependent variable is *Tobin's q*, calculated as market value of equity plus book value of preferred stock, long-term debt and short-term debt net of short-term assets, all divided by total assets. *V: Green Patents* calculated as each firm's patents filed in a year which contain "carbon emission" in the filing divided by total patents. *a: Green Proposals* is the number for shareholder proposals per year which contain "climate change" is the resolution. M: *R&D/Assets* is research and development expense scaled by assets. *k: Capital Stock* is the natural log of total assets. *I: Investment* is capital expenditures scaled by sales. Robust standard errors are calculated for the t-statistics reported in parentheses.

	(1) Tobin's_q	(2) Tobin's_q	(3) Tobin's_q	(4) Tobin's_q	(5) Tobin's_q	(6) Tobin's_q
V: Green Patents	-6.098***		-3.066***	-3.127***	-1.933**	-2.104***
	(-5.554)		(-3.009)	(-3.002)	(-2.142)	(-3.127)
a: Green Proposals		.09***	.083***	.158***	.012	.065***
		(2.752)	(3.389)	(7.469)	(.438)	(2.996)
M: R&D			141.227***	-49.5	38.916	-122.456***
			(4.116)	(-1.438)	(1.201)	(-2.999)
K: Capital Stock			-.314***	.291***	-.552***	.226
			(-3.496)	(3.205)	(-5.241)	(1.176)
I: Investment			-2.762***	.086	.346	.065
			(-3.994)	(.105)	(.438)	(.056)
_cons	1.398***	1.08***	4.809***	-1.197	7.724***	-.221
	(19.956)	(18.07)	(4.278)	(-1.22)	(6.004)	(-.108)
Observations	80	80	80	80	80	80
R-squared	.299	.066	.633	.886	.777	.931
Year Dummy	No	No	Yes	Yes	No	Yes
Firm Dummy	No	No	Yes	No	Yes	Yes

t-values are in parentheses
**** p<.01, ** p<.05, * p<.1*

	VIF	1/VIF
V: Green Patents	3.697	.271
a: Green Proposals	3.787	.264
M: R&D	7.338	.136
K: Capital Stock	19.161	.052
I: Investment	4.643	.215
Mean VIF	9.384	.

Table 5 Endogeneity Concerns

The dependent variable is Tobin's q. Column 5, the independent variables are orthogonalized in sequence. k, Capital stock, is orthogonalized first, as it displays a VIF that exceeds a generally acceptable level. The other the independent variables are orthogonalized in the order shown. In column 6, all variables, including the dependent, are detrended according to the procedures outlined by Büthe and Milner (2008). Column 7 employs a GMM estimator introduced by Arellano and Bond (1991). Column 8 employs a GMM estimator proposed by Bruno (2005) and invokes the Blundell and Bond (1998) specification with bias corrected up to order 0(1/NT) and standard errors bootstrapped in 50 iterations. Robust standard errors are calculated for the t-statistics reported in parentheses.

	(1) Tobin's_q	(2) V_Squared	(3) Lagged	(4) Logged	(5) Orthogonalized	(6) Detrended	(7) ABond_GMM	(8) LSDVC_GMM
V: Green Patents	-2.104***	-3.6*		-.779*	-.11***	-2.24***	-1.131**	-1.141*
	(-2.686)	(-2)		(-1.999)	(-4.113)	(-3.123)	(-2.507)	(-1.802)
a: Green Proposals	.065**	.071***		.093***	.047*	.056**	.021	.013
	(2.624)	(2.762)		(2.973)	(1.829)	(2.402)	(1.423)	(.454)
M: R&D	-122.456***	-110.392**		-57.62***	-.107***	-.427	-132.899***	-113.014**
	(-2.782)	(-2.401)		(-2.8)	(-2.873)	(-.014)	(-6.653)	(-2.554)
K: Capital Stock	.226*	.257*		.084	.149	-.05	-.392***	.08
	(1.693)	(1.868)		(1.367)	(1.439)	(-.462)	(-2.92)	(.619)
I: Investment	.065	.055		.356	.002	1.39**	-.4	-1.132
	(.068)	(.058)		(.704)	(.056)	(2.095)	(-.556)	(-1.151)
V-squared		10.017						
		(.924)						
L. V: Green Patents			-1.834**				-.029	
			(-2.18)				(-.238)	
L. a: Green Proposals			.027				-.025***	
			(.954)				(-5.764)	
L. M: R&D			-59.41				24.562	
			(-1.263)				(1.482)	
L. K: Capital Stock			.361**				.485***	
			(2.449)				(3.456)	
L I: Investment			.463				.096	
			(.455)				(.202)	
L. Tobin's q							.467***	.616***
							(6.985)	(4.989)
L2. Tobin's q							.012	
							(.174)	
_cons	-.021	-.438	-1.788	.372	2.108***	0	60.322***	
	(-.015)	(-.285)	(-1.116)	(.55)	(8.708)	(0)	(4.742)	
Observations	80	80	76	80	80	80	68	76
R-squared	0.9307	0.9318	0.9202	0.9288	0.9307	0.2646		
Year Dummy	Yes	Yes	Yes	Yes	Yes	No	No	No
Firm Dummy	No	No	No	No	Yes	No	No	No
Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
AR(1) (p-value)							0.059	0.000
AR(2) (p-value)							0.236	0.882
Sargan test of overidentification (p-value)							0.197	0.034
Difference-in-Sargan test of exogeneity (p-value)								0.195

*t-values are in parentheses, *** p<.01, ** p<.05, * p<.1*

Table 6 Granularity

This table has the same specifications as column 6 in Table 4, the main regression, but with different Y02 classifications for V: Green Patents. The dependent variable is *Tobin's q*. Robust standard errors are calculated for the t-statistics reported in parentheses.

	(1) Tobin's_q	(2) Tobin's_q	(3) Tobin's_q	(4) Tobin's_q	(5) Tobin's_q	(6) Tobin's_q	(7) Tobin's_q	(8) Tobin's_q
a: Green Proposals	.078***	.081***	.08***	.08***	.082***	.065***	.08***	.078***
	(2.92)	(2.903)	(3.028)	(3.086)	(2.998)	(2.996)	(2.95)	(2.861)
M: R&D	-122.905***	-118.111***	-119.418**	-129.949***	-118.958***	-122.456***	-119.548**	-119.158**
	(-2.828)	(-2.677)	(-2.657)	(-2.785)	(-2.679)	(-2.999)	(-2.656)	(-2.646)
K: Capital Stock	.248	.223	.236	.223	.241	.226	.223	.223
	(1.2)	(1.082)	(1.136)	(1.081)	(1.153)	(1.176)	(1.073)	(1.083)
I: Investment	-.176	-.085	-.032	-.013	-.087	.065	-.092	-.134
	(-.14)	(-.068)	(-.026)	(-.01)	(-.07)	(.056)	(-.073)	(-.106)
V: Y02	-.281							
	(-1.232)							
V: Y02A		1.19						
		(.392)						
V: Y02B			-2.12					
			(-.682)					
V: Y02C				-1.421				
				(-1.181)				
V: Y02D					-4.374			
					(-1.243)			
V: Y02E						-2.104***		
						(-3.127)		
V: Y02P							-.011	
							(-.031)	
V: Y02T								-1.028
								(-.65)
_cons	-.482	-.267	-.394	-.207	-.449	-.221	-.257	-.245
	(-.22)	(-.122)	(-.178)	(-.094)	(-.202)	(-.108)	(-.117)	(-.112)
Observations	80	80	80	80	80	80	80	80
R-squared	.923	.921	.922	.922	.922	.931	.921	.921
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

t-values are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 7 Ordinary Least Square regressions for Major Oil Firms around the World

The following table contains ordinary least square regressions for oil firms around the world from 1998 to 2017. The dependent variable is *Tobin's q*. The firms (countries) include: Exxon, Chevron (US), Shell and BP (UK), Eni (Italy), Petroleo Brasileiro (Brazil), Repsol (Spain), Sinopec Shanghai (China) and Total (France). M: *R&D/Assets* is research and development expense scaled by assets. *k: Capital Stock* is the natural log of total assets. *I: Investment* is capital expenditures scaled by sales. Robust standard errors are calculated for the t-statistics reported in parentheses.

	(1) Tobin's_q	(2) Tobin's_q	(3) Tobin's_q	(4) Tobin's_q	(5) Tobin's_q	(6) Tobin's_q
V: Green Patents	-2.582***	-2.624***	-1.468***	-.896**	-.208	-.208
	(-4.769)	(-4.56)	(-2.936)	(-2.177)	(-.57)	(-.516)
M: R&D		119.438***	57.63***	84.451**	42.267	42.267
		(5.563)	(3.277)	(2.6)	(1.289)	(1.074)
K: Capital Stock		.049**	.089***	-.292***	.11	.11
		(2.282)	(3.805)	(-4.408)	(1.256)	(1.442)
I: Investment		-1.634***	-1.333***	-.358	-1.139	-1.139
		(-3.051)	(-2.792)	(-.521)	(-1.496)	(-.709)
_cons	1.061***	.276	.482*	4.411***	.208	.316
	(24.445)	(1.302)	(1.947)	(5.116)	(.196)	(.312)
Observations	168	168	168	168	168	168
R-squared	.088	.321	.594	.662	.793	.668
Year Dummy	No	No	Yes	No	Yes	Yes
Firm Dummy	No	No	No	Yes	Yes	No
Fixed Effects	No	No	No	No	No	Yes

t-values are in parentheses

**** p<.01, ** p<.05, * p<.1*

Table 8 Ordinary Least Square regressions for US only: Exxon and Chevron

The following table contains ordinary least square regressions for oil firms in the US only 1998 to 2017. The dependent variable is *Tobin's q*, calculated as market value of equity plus book value of preferred stock, long-term debt and short-term debt net of short-term assets, all divided by total assets. *V: Green Patents* is the percentage of each firm's patents filed in a year which contain carbon emission in the filing of total patents. *a: Green Proposals* is the number for shareholder proposals which contain "climate change" is the resolution. *M: R&D/Assets* is research and development expense scaled by assets. *k: Capital Stock is the natural log of total assets*. *I: Investment* is capital expenditures scaled by sales. Robust standard errors are calculated for the t-statistics reported in parentheses.

	(1) Tobin's_q	(2) Tobin's_q	(3) Tobin's_q	(4) Tobin's_q	(5) Tobin's_q	(6) Tobin's_q
V: Green Patents	-6.024***		-5.557**	-2.336	-3.9***	-2.209*
	(-2.836)		(-2.587)	(-1.734)	(-3.068)	(-2.047)
a: Green Proposals		.035	-.004	.077**	-.017	.013
		(.981)	(-.123)	(2.876)	(-.686)	(.589)
M: R&D			207.184***	-94.955*	56.774	-126.07***
			(3.074)	(-1.918)	(1.348)	(-3.124)
K: Capital Stock			.11	.463***	-.235***	.121
			(1.251)	(6.456)	(-3.089)	(1.191)
I: Investment			-3.155***	-1.899**	-.702	.131
			(-4.525)	(-2.863)	(-1.121)	(.176)
_cons	1.459***	1.272***	-.293	-2.571***	3.866***	.951
	(18.599)	(15.043)	(-.259)	(-3.157)	(4.02)	(.911)
Observations	40	40	40	40	40	40
R-squared	.177	.019	.62	.96	.799	.977
Year Dummy	No	No	No	Yes	No	Yes
Firm Dummy	No	No	No	No	Yes	Yes

t-values are in parentheses

**** p<.01, ** p<.05, * p<.1*