Corporate Environmental Proactivity: Evidence from the European Union's Emissions Trading System

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Abstract

In the presence of environmental policy, how do regulated firms respond? The answer is crucial for the design and effectiveness of policy regimes intended to mitigate environmental damage. We investigate whether particular types of firms are more likely to be proactive; in other words, which firms tend to behave in a manner most consistent with the desired policy outcomes. Using data on per-firm 'verified' and 'allocated' emissions from the European Union's Emissions Trading System (EU ETS) from 2005 till 2016, and given some firms exceed or undershoot the allocated allowances by a large margin, we posit that this and related measures are useful proxies for a firm's proactiveness in responding to environmental policy. We find that public firms are less likely than private firms to be proactive, whilst the same is found for firms in common rather than civil law countries and for state-owned firms. Strikingly, proactiveness is associated both with greater reductions in greenhouse gas emissions and poorer firm performance suggesting there is an economic cost to good environmental behaviour. Whilst the EU ETS is reducing emissions, it is not yet adequately compensating proactive firms or penalising those who pollute - better system design could aid this further.

Keywords: Environmental policy; Proactiveness; EU ETS; Greenhouse gas emissions; Firm performance.

Introduction

A major question for firms is how to respond when government or other non-market actors seek to alter industry behaviour (see Backman *et al.*, 2017; Verbeke *et al.*, 2017). Whether firms change their behaviour, and the degree of this change, is likely related to a number of both internal (e.g., the effect on firm performance and relevant technical knowledge) and external factors (e.g., the regulatory costs of non-compliance). Likewise, a vital question for non-market actors is how to ensure the desired firm-level response from the design and implementation of policy. In particular, this may consist of a compliance threshold for firms plus an encouragement to behave below the regulatory enforced level.

Perhaps the most important contemporary policy space ─ where answers to these two above questions are required ─ is that of the environment, related concerns about climate change and the desire of many to move the global economy from reliance on hydrocarbons to renewable sources of energy. For example, consider the Kyoto Protocol, which agreed to reduce atmospheric greenhouse gas concentrations to 'a level that would prevent dangerous anthropogenic interference with the climate system' (see UNFCCC, Art. 2). Since the Protocol was agreed in December 1997 and came into force in February 2005, countries and regions have sought to limit carbon dioxide and other greenhouse gas emissions (GGE) using a variety of approaches. In particular, the European Union's Emissions Trading System (EU ETS), employs a cap and trade principle where, given a maximum EU wide cap on emissions, participating organisations must purchase additional allowances if they exceed their individual target and conversely, can sell allowances if they undershoot.

Our study uses annual data from 2005 to 2016 on the EU per-firm 'allocated allowances' and crucially, the 'verified emissions.' Interestingly, some firms exceed or undershoot the allocated allowanced by a (large) margin and we posit that this and related measures are useful proxies for a firm's *proactiveness* in responding to environmental policy. Our first research question is therefore to ask which factors explain movements in these proxies, including measures of firm type, legal environment and state ownership. To derive appropriate hypotheses, we draw together several strands of relevant literature including work on comparative capitalisms that specifies how different types of firm governance imply whether managers can make investment choices, including those related to the environment, over shorter or longer-term horizons (see, *inter alia*, Whitley, 2008 and Hall and Soskice, 2001).

Subsequently, our second research question examines how corporate environmental proactivity in the EU ETS affects both the environment, in terms of reducing GGE, and firm performance, after allowing for several control variables. These are two key areas of investigation to assess the effectiveness of the emissions trading system and inform any policy debate around the design of the mechanism itself. Of course, one might assume *a priori* that emissions reduction and firm performance are also linked: for example, if reducing GGE inhibits firm performance, the average firm is likely to be less environmentally proactive and this will reduce the overall effectiveness of the policy.

The remaining parts of the paper are divided into six sections: Section 2 considers the extant literature and theoretical underpinnings of our work; describing in detail the EU ETS mechanism and developing a definition of corporate environmental proactivity and related hypotheses. Section 3 provides an overview of the data and methodology whilst section 4 presents the empirical results. Finally, section 5 provides the related discussion and conclusion.

Literature and theoretical underpinnings

European Union's Emissions Trading System (EU ETS)

The EU has targeted a reduction in GGE[1], relative to 1990 levels, of 20 percent by 2020 and 'by at least' 40 percent by 2030 (see European Commission report, 2017).[2] The main vehicle for achieving these objectives is the European Union's Emissions Trading System (EU ETS) established by directive 2003/87/CE of 13 October 2003 and officially started on 1 January 2005, aiming to limit emissions for about 12,000 heavy energy-using installations. Since then, GGE in Europe are capped, traded and priced. This cap-and-trade scheme is the world's

[1] GGE includes carbon dioxide (CO_2) emissions, perfluorocarbons (PFC) emissions from aluminium production and nitrous oxide (N_2O) emissions from all nitric, adipic, glyoxylic acid and glyoxal production.
[2] The same report noted that by 2015, GGE were already reduced by 22 percent of 1990 levels.

first and largest multinational program for emissions reduction and covers around 45 percent of the EU's GGE. In a nutshell, the EU ETS works as follows: Firms receive (at the installation level) emission allowances, which in total do not exceed a predetermined annual cap set by the scheme. A cap is also set on the total amount of certain greenhouse gases that can be emitted by all installations covered by the system. Within their individual cap, if firms chose to pollute more than the allowances they received, then they must purchase extra allowances in the open market from firms who used less from the allocated quantities, and vice versa. This system, combined with the fact that the total cap is reduced over time so that total emissions fall, creates incentives to polluters to reduce emissions (e.g., switching to less carbon-intensive production technologies) so they can sell the surplus for profit.

The EU ETS is presently in its third phase of operation; accordingly, in Phase I (2005-2007) and II (2008-2012) allowances were given free of charge, whereby in Phase III (2013-2020) some allowances are purchased through auctions. Given the importance of the EU ETS mechanism, work such as Laing *et al*. (2013) have surveyed the extant literature evaluating its efficacy. They suggest that some abatement in GGE has occurred and that the phased design has led to improvements (e.g., dealing with the initial over-allocation of allowances) in the mechanism. Certainly, the system, based on the latest data[3], has coincided with reduced emissions overall within participating installations as shown in Figure 1. Between 2005 and 2017, GGE have fallen by approximately 26 percent.[4] Interestingly, the price of the allowances has fluctuated considerably across the three phases, as shown in Figure 2.

[Insert Figures 1 and 2 around here]

Considering the EU ETS objectives, framework and operation to date, several interesting research questions present themselves. Given the mechanism appears broadly successful in reducing emissions, how have different types of firms responded to the policy?

[3] See https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1
[4] Phase IV (2021-2030) aims to reduce the emissions of participating installations by 43 percent of 2005 values.

Specifically, which firms might be classified as most or least responsive? Moreover, how has this ‘responsiveness’ affected the performance of firms?[5] To answer these questions we first need to explore how the extant literature has categorized firm behaviour in the context of environmental strategy more generally and specifically, the degree of compliance with related legislation.

Corporate environmental proactiveness

When discussing the behaviour of firms in relation to strategy often the extant literature refers to whether firms are proactive or not, but the characterizations of ‘proactiveness’ vary. For example, Lumpkin and Dess (1996) suggest that proactiveness is one of the five components of a firm’s entrepreneurial orientation, arguing in later work that “Proactiveness is an opportunity-seeking, forward-looking perspective involving introducing new products or services ahead of the competition and acting in anticipation of future demand to create change and shape the environment” (Lumpkin and Dess, 2001: p.431).

Of course, in the specific context of a firm’s environmental impact, a forward-looking perspective will also involve consideration of mitigating harmful processes as well as products and future demand.[6] There have been several attempts in the literature to present a more holistic view. Employing a resource-based theoretical approach, Hart (1995) differentiates between four types of environmental perspectives at the firm level, including pollution prevention.[7] Developing this idea, Buysse and Verbeke (2003) propose five resource domains representing environmental competencies in employee skills, strategic planning, management systems, functional area (e.g., research and design, finance,

[5] Although there is some analysis on the carbon market operation from a finance perspective (e.g., Oestreich and Tsiakas, 2015), we are not aware of any work that links policy responsiveness to firm performance. They show, using a sample of German firms, that those allocated free allowances significantly outperformed those that did not (in terms of stock returns) over approximately the period 2004 to early 2009.

[6] Note however, there is some evidence of a positive correlation between a firm’s general strategic position and its environmental proactivity (Aragón-Correa, 1998).

[7] The others are an end-of-pipe approach, product stewardship and sustainable development.

production *et cetera*) involvement in greening the firm and green technology investment; with a firm's activity in these domains determining its environmental proactiveness (see Backman *et al*., 2017).

The literature has suggested that a firm's action in the green technology resource domain can be the clearest indication of its degree of environmental proactivity (Rugman and Verbeke, 1998). Such investments can often be in response to regulatory requirements (see Verbeke *et al*., 2017) and in this sense, proactive environmental strategies have been commonly defined as practices *that go further* than legal compliance with environmental legislation (see *inter alia*, Buysse and Verbeke, 2003). Developing this framing, proactiveness can be assessed on a continuum (Aragón-Correa and Rubio-López, 2007; Aragón-Correa and Sharma, 2003), whereby the level of environmental proactiveness equates to the degree of compliance with regulation, and three discrete regions of the continuum can be identified signifying firm behaviour from *most advanced* (i.e., proactive behaviour beyond compliance), *reactive* (i.e., behaviour equivalent to legal compliance only) and *active resistance* (i.e., lobbying authorities to reduce environmental requirements or delay introduction – see Verbeke *et al*., 2017).

For cap-and-trade schemes, such as the EU ETS, we posit that an analogous typology can be developed. In particular, the allowances provided to each firm provide an anchor around which to assess environmental credentials and again provide three distinct regions of environmental behaviour: firms in the scheme that pollute less than their allowances can be denoted environmentally proactive, those that pollute an equivalent amount to their allowance can be considered reactive or environmentally neutral and finally, firms that produce more GGE than allowances can be regarded environmentally resistant.[8] Given unused allowances

[8] Our definition of 'environmentally resistant' within the EU ETS is necessarily different from the 'active resistance' of Verbeke *et al*., 2017. Whilst active resistance may involve lobbying to reduce or delay standards (information which can perhaps only be gleaned by survey) our environmental resistance involves producing more GGE than allowances.

can be sold on a carbon exchange, the ETS mechanism is designed to encourage firms to be environmentally proactive in the manner defined.

Measuring environmental proactiveness

To judge a company's environmental practice, the extant literature has typically employed Environmental, Social and Governance (ESG) criteria such as the popular Kinder Lydenberg Domini (KLD) ratings (see Kim, 2018). However, Mattingly and Berman (2006) advise caution when using these ratings as a proxy for firm practice. Whether or not KLD/ESG measures are reasonable proxies for firm practices, one might argue that environmental performance (which can be measured by emissions release data – see Färe *et al*., 2010) is a more appropriate measure about whether firms are environmentally proactive.[9] Moreover, from our discussion in the previous section, it could be argued for the EU ETS that the distance quantity:

$$EEP_{it} = (e_{it} - \tilde{e}_{it})/\tilde{e}_{it}, \tag{1}$$

where e_{it} are the verified emissions of firm *i* in year *t*, $\tilde{e}_{it}$ are the allocated allowances and therefore EEP_{it}, represents the proportionate excess emissions, captures the continuum of environmental responses and therefore nests the discrete regions of environmental proaction, reaction and resistance. Specifically, if $EEP_{it} \approx 0$, then firm *i* is merely complying with regulation and could therefore be considered reactive. If $EEP_{it} \gg 0$, then firm *i* has overshot its target allowances, is not responding to policy and is environmentally resistant. Finally, if $EEP_{it} \ll 0$, then firm *i* has undershot target, and is thus can be regarded as environmentally proactive. In our later empirical work, we classify firms as included in this latter category

[9] For example, Aragón-Correa and Rubio-López (2007) noted that surveys on firms' attitudes to environmental issues may reflect social bias.

(i.e., environmentally proactive) if their EEP_{it} is less than or equal to –20 percent. This seemed an appropriate threshold, given approximately a third of our firm-year observations fall into this category (see our later Data section) and ensuring the grouping has enough degrees of freedom whilst still capturing good environmental behaviour.[10]

Of course, in the case of the EU ETS and as noted above, if a company produces more GGE than allowed, then they must provide 'compensation' by purchasing extra allowances. Likewise, a company that pollutes below allocation, can sell its unused allowances in the open market. Hence, an economic version of (1) would be:

$$EEE_{it} = (e_{it} - \tilde{e}_{it})f_t, \tag{2}$$

where f_t is the appropriate futures price for GGE allowances. In the later analysis, we employ a standardized version of (2), namely $zEEE_{it}$. Below we expand on these ideas to develop hypotheses related to the characteristics of firms that are more likely to be environmentally proactive.

Ownership and environmental proactiveness

Environmental proactiveness, where firms behave beyond compliance, has been viewed in the literature as an attempt to satisfy the values of various (market and non-market) stakeholders aside from regulators (Hart, 1995; Garrod, 1997). These other interested stakeholders could include shareholders, customers, environmentally-orientated NGOs and local community-focused groups. Notably, there is empirical evidence of a positive association between proactiveness and stakeholder interest. For example, using survey data from 197 Belgian firms, Buysee and Verbeke (2003) show that firms classified as practicing

[10] We also check later whether our empirical findings remain robust for different thresholds of proactiveness (i.e., <=-15% or <=-25%).

environmental leadership are more likely than reactive firms to consider stakeholders in decision making.

Of course, not all stakeholders will be perceived as equally important by managers when formulating environmental strategy. Henriques and Sadorsky (1999), examining Canadian firms, suggested shareholders and customers amongst others as key influences on firm practice. Somewhat contrastingly, Buysee and Verbeke (2003) showed that while proactive firms considered internal primary stakeholders (i.e., shareholders, employees and financial institutions), there was little evidence to support consideration of external primary stakeholders (i.e., customer and suppliers) or secondary stakeholders (i.e., media, competitors, NGOs and international agreements). From an EU ETS perspective, given regulated firms will typically be power or industrial/manufacturing firms involved in intermediate goods production[11], this *a priori* suggests that internal primary stakeholders are likely significant determinants of a firm's degree of environmental proactiveness.

Of the internal primary stakeholders of EU ETS firms, we focus on the owners. These can be considered the most important and therefore influential of such stakeholders (see Buysee and Verbeke, 2003). Taking a high-level approach, Whitley (2008) notes that given that governance differs across firms, consequently so does their dominant logics of action. In particular, to explore these linkages he suggests that the influence of ownership on managers' strategic choice, can divided into four main 'situations'. The first situation is the *archetypal owner-controlled* firm, whereby majority owners oversee daily operations and therefore managers have little autonomy. The second situation corresponds to where ownership is more dispersed but concentrated enough (i.e., control over large blocks of shareholders' votes) to affect the overall strategic direction of the firm. The third situation encompasses some *market-based forms of owner control*, where ownership is highly dispersed amongst many

[11] Buysee and Verbeke (2003) note that firms that produce intermediate goods are less likely to engage with external primary stakeholders due to the lack of direct contact with the final consumer.

investors, each more interested in the performance of their own portfolio; consequently, managers' should have a large degree of autonomy over firm-specific strategic choice. Finally, the fourth situation recognises that within a market-based form, share ownership can become dominated by short-term performance orientated fund managers. In this latter context, managers can once again become highly constrained.

Broadly speaking the four ownership types represent private (i.e., situation 1 and 2) and public firms (i.e., situation 3 and 4). Using the classifications above, private ownership at the very least, has a significance influence on strategic direction. As a corollary, if owners are committed to long-term development plans, including in the environmental sphere, such plans are likely to be implemented with relatively little interference from outside control given private firms typically have less obligation to release their firms' details, report finances or answer to the public or media. By contrast, the managers of public firms are likely to be under pressure to generate short-term financial returns for shareholders; pressures which Whitley (2008) stresses have grown over the latter years of the 20th century and restricted long-term planning.

Whether firms have long or short time horizon for strategy and investment has been shown as integral to their degree of environmental proactivity. Particularly, Verbeke *et al*. (2017) in a study of imposed carbon capture and storage (CCS) technology, found that firms facing short-term performance requirements often adopted a reactive compliance strategy. On the other hand, firms with a longer horizon could be more proactive, "*The longer-term view they embraced allowed management to conceive early adoption of the imposed innovation in project terms and drove the establishment of unique capabilities that might well support future competitive advantage*" (p.692).

Conflating the notions that firms with short-term strategy horizons are likely to be relatively less environmentally proactive, and that public firms are more likely to present a short-term strategy horizon, leads to our initial hypothesis:

H1: *Publicly listed companies are less environmentally proactive on average than their private analogues.*

Of course, shareholders are not limited to private citizens, other companies or investment funds. The state can take full or partial ownership of a firm. Indeed, a recent EU Commission (2016) institutional paper noted that, "*State-owned enterprises (SOEs) account for a large share of output and employment in many EU member states*" (p.6) and that, for example, SOEs share of total energy sector turnover was 40 percent.[12] A typical view in the literature is that SOEs are economically inefficient (see Boycko *et al*., 1996). Adopting an agency cost perspective, managers are often politically appointed and have little incentive to improve performance by allocating resources or investing optimally (Krueger, 1990). Moreover, board level appointments provide lax monitoring and may attempt to extract rents (Hsu *et al*., 2018), with an overall picture of weak financial performance and corporate governance (Bortolotti and Faccio, 2009).

An alternative view also exists which suggests that state ownership may confer functionality to usefully mitigate externalities such as pollution, particularly given a government's greater ability (compared to the private sector) to fund long-term investment in technologies such as carbon capture. Recently Hsu *et al*. (2018), using a sample of publicly listed firms across 45 countries from 2004 to 2014, showed that SOEs in emerging countries have greater involvement in environmental issues than other firms. Interestingly this

[12] The sample period was 2008-2012 and SOEs were defined as firms where the state holds at least 20 percent of the equity.

difference was not maintained for SOEs in developed countries which may have a greater availability of capital financing outside government sources.

Given these competing perspectives, the role of state ownership in EU ETS firm proactivity is clearly an empirical question. However, *a priori*, we note that since 2004 a number of new member states have joined the EU with a relatively high proportion of SOEs (e.g., Poland, Romania, Croatia and Slovenia). As a whole, these new member state firms have lagged substantially behind other firms in terms of performance measures such as return on equity (European Commission, 2016). Moreover, given the transitional nature of their economies, many SOEs may not give sufficient priority to longer-term objectives such as environmental reform. At an EU wide level therefore, we might expect the following:

H2: *State owned firms are less environmentally proactive on average than other companies.*

Of course, states can have indirect, non-ownership effects, on firms within their jurisdiction. Amongst other things, Allen *et al*. (2018) stress the role states have in producing sources of advanced knowledge generation and as Laffont and Tirole (1993) discuss, states can legislate to mandate particular types of firm behaviour or provide incentives via subsidies. Indeed, it is important to recognise that different legal settings may well affect the environmental proactivity of firms. Work by La Porta *et al*. (1998, 1999) stress that differences in states *legal origin* partially determine contemporary differences in corporate governance. In other words, common law countries (e.g., U.S, most of the U.K, Ireland) present a liberal market shareholder-orientated approach, whilst civil law countries (e.g., Scandinavia, France, Germany) provide a coordinated market system with multi-stakeholder types of governance (Ahlering and Deakin, 2006). This distinction between liberal and coordinated markets in the ‘varieties of capitalism’ literature (see Hall and Soskice, 2001) is often seen to correspond to governance systems based on either arms-length/outsider control or direct/insider control (Berglöf, 1997). Common law countries are associated with governance mechanisms in which outsiders require relatively high rates of return over short-time horizons, whilst in civil law countries, insider control governance allows for longer time frames for decision-making and investment. Assuming as before that firms with short term strategy horizons are likely to be relatively less environmentally proactive, leads to our third hypothesis:

> H3: *Firms within civil law countries are more likely to be environmentally proactive as compared to firms embedded in common law frameworks.*

Such an approach is quite broad and whilst useful, it is important to bear in mind that a more nuanced picture can exist at national level. For example, whilst most of the U.K predominantly follows a common law approach, Scotland largely has a civil law framework. Moreover, firms in the same country will not all be affected uniformly by the typical governance frame. Clearly, although this might not be the case for the average firm, some firms in civil law countries will be under short-term pressure for high returns; likewise, there will be those in common law countries who can adopt a longer-term perspective (Ahlering and Deakin, 2006).

Environmental proactiveness, volume of emissions and firm performance

What is the effect of corporate environmental proactivity in the EU ETS on both the environment and firm performance? These are the two key questions to inform any policy debate around the design of the mechanism itself. To begin, it seems straightforward to hypothesise:

H4: *GGE will be reduced further by firms that are environmentally proactive.*

Of course, the amount of GGE reduction associated with a particular degree of proactiveness will be important and is an empirical question. A more involved discussion is required for the relation between environmental proactiveness and firm performance. From the Corporate Social Responsibility (CSR) literature, it appears there may be a negative association between high CSR expenditure and firm value/performance at least over the short-term (see, *inter alia*, Gregory *et al*., 2014). In particular, companies that invest heavily in pollution reducing technology may suffer a diminution in short-term cash flows. Within the EU ETS itself, a firm's performance will be affected, *ceteris paribus*, by whether (i) they have to buy extra allowances or can sell excess allowances, and the prevailing futures price (ii) the amount of investment in pollution-reducing processes and (iii) the ability to pass-through any additional input cost to the consumer. Given the GGE futures price was considered low for much of our sample period[13], that investment in technology typically takes several years to realize and pass-through can often be limited by regulatory authorities, our final hypothesis is:

H5: *Environmental proactiveness has a negative effect on firm performance in the short-term*.

Data and methodology

Data

Our study exploits the EU ETS Company Database that consolidates information as reported by the European Union Transaction Log, which is a source of verified GGE information, set

[13] For example, in phase III, the futures price was typically below €10 and sometimes even below €5 per tonne.

up by the European Commission. The raw dataset includes 1,018 publicly listed and private companies from 31 European countries (i.e., the EU-28 zone, Norway, Iceland and Liechtenstein), accounting for more than 90% of GGE from EU ETS companies and featuring 12,210 firm-year observations.

The sample spans the period 2005-2016 and covers all three different EU ETS phases; accordingly, in Phase I (2005-2007) and II (2008-2012) allowances were given free of charge, whereby in Phase III (2013-2020) some allowances are purchased through auctions. The database includes information about the per firm number of facilities/installations, as well as the per firm allocated and verified emissions, covering different industries such as Oil and Gas, Power and Heat, Motor, Chemicals, Metals, *et cetera*. After eliminating observations with missing information about the sector that firms operate in, firms' headquarters location or allocated/verified emissions, the sample includes 887 firms featuring 9,645 firm-year observations.

About 89% of the observations relate to firms headquartered in EU-28 countries, 2.5% relate to firms headquartered in other European countries (i.e., Norway, Switzerland and Ukraine) and rest relate to firms headquartered in non-European countries. Further, there are 16 distinct industries in this sample, with some industries representing a sizeable proportion of the firm-year observations (e.g., Power and Heat is approximately 29 percent) while some others cover a negligible proportion (e.g., Coke, Education, Mining, Pharmaceutical, Water Utilities are less than 1 percent per case). For conducting the analysis, two more filtering criteria have been applied:

i. industries with less than 1 percent representation in the sample are eliminated; we imposed this filter to minimize the impact of sectors that are underrepresented in the sample (however, this exclusion is based on the number of observations not the volume of emissions relating to these observations);

ii. observations with EEP_{it} as per *Eq.* (1) greater than 300% are also eliminated; we have imposed this filter to minimize the impact of outliers evidenced by the large difference between the "mean" and "median" values of this variable before the imposition of filtering.

The final sample therefore includes 856 firms featuring 8,942 firm-year observations originating from 11 industries. The summary statistics for firm-level emissions and related variables used to test H1 to H4, following the above filtering procedure, are provided in Table 1, whilst detailed variable definitions are provided in the Appendix.[14]

[Insert Table 1 around here]

In section 2, it was noted that an economic measure of excess emissions following *Eq.* (2) would require an appropriate futures price for GGE allowances and this price is plotted in Figure 2. The variable f_t that we construct, is the monthly average value (within a calendar year) using the monthly settlement prices of EUA futures contracts obtained through Thomson Reuters DataStream. Such futures contracts are traded on the European Climate Exchange (ECX) which is owned by the Intercontinental Exchange (ICE). In line with Oestreich and Tsiakas (2015), we construct a continuous price series combining a series of futures contracts as follows: During Phase I (2005-2007) our series is equal to the price of the December 2008 contract. During Phase II (2008-2012) the series is equal to the price of the December 2009 contract until its last trading day, and then switches to December 2010 until its last trading day and so on until December 2012. During Phase III (2013-2016) we follow the same procedure and set the series equal to the futures contract with maturity in December of each year for all the trading days of the year.

[14] Data items like the country of origin for each firm, percentage of state ownership, and macro variables are hand collected from various sources such as Thomson Reuters DataStream, World Bank Open Data, Web searches, *et cetera*.

Based on mean values in Table 1 featuring 8,942 observations for all variables tabulated, firms appear to overshoot (*EE*) by 87,779 units their allocated allowances, in terms of percentage excess emissions (*EEP*) they undershoot by 2 percent, whilst in terms of euro excess emissions (*EEE*) they incur a cost equal to €994,319 for overshooting their allocated allowances. Further, 33.5 percent of the firms appear to undershoot by more than 20 percent their allocated allowances, hence these are the firms which we account as being environmentally proactive (*PR020*); a per year-industry adjusted version of this variable (*PR20_IA*) labels 20.9 percent of the sample firm-observations as being environmentally proactive. Other statistics indicate that: firms employ 9.707 facilities/installations (*INSTALLATIONS*) that produce CO_2 equivalent emissions; 30.6 percent of the observations feature publicly-listed (*PUBLIC*) firms, 5.7 percent of the observations refer to state-owned (*STATE*) firms, 89.2 percent of the observations feature firms headquartered in the EU-28 zone (*EU28*) and 14.5 percent of the observation regard firms that operate within common law legal systems (*COMMON*). Lastly, 26.1 percent of the observations originate from Phase I, 44.3 percent from Phase II and 29.6 from Phase III.

Finally, in Table 2 we report summary statistics for the firm-level performance variables and various controls used for testing H5 (detailed variable definitions are provided in the Appendix). The financial data are primarily from Compustat Global but we also checked for all companies manually and hand collected further information to increase the sample size. All continuous variables are winsorized at 1 percent from the top and bottom of their distribution.

[Insert Table 2 around here]

Based on mean values in Table 2, firms in our sample show a return on equity (*ROE*) equal to 20.6 percent, annual cumulative market return performance (*RET*) equal to 3.4 percent, whilst their operating performance as captured by return on assets (*ROA*) is equal to

6.1 percent. Their operating profitability is 29.4 percent of the beginning of the fiscal period sales (*EARN*), operating cash flow is 53.3 percent of the beginning of the fiscal period stockholders' equity (*CASH FLOW*), asset growth (*ASSET GROWTH*) stands at 50.5 percent[15], capital expenditures are 9.4 percent of the beginning of the fiscal period assets (*CAPEX*), total debt is 96 percent of stockholders' equity (*LEV*), and research and development expense is 0.9 percent of sales (*R&D*). Further, industry competition as measured by the Herfindahl index is 0.133 (*HERFINDAHL*), the GDP growth in the sample countries is 1.2 percent, whilst the short-term interest rate stands at 2.1 percent.

Methodology

To begin, we note that hypotheses *H1*, *H2* and *H3* posit that publicly-listed, state-owned and firms headquartered in common law legal systems, respectively, are less environmentally proactive compared to their peers. Initially, we therefore estimate variants of the following panel regression:

$$y_{it} = \gamma_0 + \gamma_1 PUBLIC_{it} + \gamma_2 STATE_{it} + \gamma_3 COMMON_{it} + \gamma_4 PROx_{it} + \gamma_5 PROx_{it} PUBLIC_{it} + \gamma_6 PROx_{it} STATE_{it} + \gamma_7 PROx_{it} COMMON_{it} + \sum_{i=1}^{n} \beta_i X_{it} + \varepsilon_{it}, \quad (3)$$

where y_{it} is either of our two measures of excess emissions in *Eq*. (1) and (2) for firm *i* in year *t*, namely *EEP* and *EEE*, *PUBLIC* is a dummy variable indicating publicly-listed firms (i.e., it takes the value 1 for a publicly-listed firm, and 0 otherwise), *STATE* is a dummy variable representing when the national government has a stake in the firm (i.e., it takes the value 1 when the government has a stake of 5 percent or more, and 0 otherwise), *COMMON* is a dummy variable representing whether a firm's headquarters are located in a common law

[15] This mean value seems rather high because it is affected by few extreme observations. Note that the median value of *ASSET GROWTH* is 2.8 percent which is a more reasonable rate of growth.

legal system (i.e., it takes the value 1 for common law legal systems, and 0 otherwise), and ε_{it}, is a stochastic error term. Further, the vector *X* contains additional control variables (i.e., *EU28*, *INSTALLATIONS*) and fixed effects (i.e., PHASE II & III dummies, industry dummies). For H1, H2 and H3 to hold, we primarily anticipate $\gamma_1 > 0$, $\gamma_2 > 0$ and $\gamma_3 > 0$, respectively.

Additionally, $PROx_{it}$ in *Eq.* (3) characterizes one of two types of specific environmental proactivity: $PRO20_{it}$ is a dummy variable that takes the value 1 when $EEP_{it} \leq -20$ percent, and 0 otherwise; $PR20\_IA_{it}$ represents a dummy variable that is 1 when the per-year and per-industry mean adjusted value of $EEP_{it} \leq -20$ percent, and 0 otherwise. To investigate the behaviour of publicly-listed firms, state-owned firms and firms headquartered in common law legal systems within the proactive range, we interact the proactive variables with *PUBLIC*, *STATE* and *COMMON*, respectively. All regression models (as well as all subsequent ones) are estimated using robust standard errors corrected for autocorrelation and heteroscedasticity and clustered across firms and years.

Hypotheses H4 and H5 examine the effect of the firms' EU ETS proactive behaviour on two key areas – emissions reduction and firm performance. As discussed earlier, the fourth hypothesis (H4) examines the extent to which GGE will be reduced by firms that are environmentally proactive, where being environmentally proactive is proxied by either *PRO20* or *PRO20_IA*. As such, we estimate variants of the following regression:

$$GOE_{it+1:t+j} = \theta_0 + \theta_1 PRx_{it} + \theta_2 y_{it} + \sum_{i=1}^{n} \beta_i X_{it} + u_{it+1:t+j}, \tag{4}$$

where $GOE_{it+1:t+j}$ is the future growth rate in a firm's verified emissions between year *t*+1 and *t*+*j*, the vector *X* includes all controls analogously to *Eq.* (3) and $u_{it+1:t+j}$ is a stochastic error term. For H4 to hold, we primarily expect $\theta_1 < 0$.

Our final hypothesis H5 suggests a negative relationship between a firm's environmentally proactive behaviour and firm performance in the short-term, thus, we correspondingly estimate variants of the following regression specification:

$$R_{it+1} = \delta_0 + \delta_1 PROx_{it} + \delta_2 y_{it} + \sum_{i=1}^{n} \beta_i F_{it} + v_{it+1} \qquad (5)$$

where R_{it+1} represents firm performance in year t+1 as captured by either a firm's return on equity (*ROE*) or annual cumulative market return (*RET*) and v_{it+1} is a stochastic error term. The vector *F* includes controls as featured in Table 2 and fixed effects (i.e., phase II and III dummies, industry dummies). *Eq*. (5) is estimated particularly on publicly listed companies where information regarding firm characteristics and performance are available. For H5 to hold, we primarily anticipate $\delta_1 < 0$.

In regression equations (4) and (5) we are attempting to identify causal relationships between a firm's proactive behaviour and future reductions in emissions or firm performance. In this context, endogeneity issues can occur via omitted variable bias or reverse causality. For example, we acknowledge that these relationships may be affected by several factors, such as investment in plant and machinery that is unrelated to the EU ETS, the closure of some plants due to production inefficiencies or poor demand, tax changes, transfer pricing, *et cetera*. Hence, to deal with endogeneity stemming from omitted variable bias we include several control variables which are readily available to us, whilst to mitigate concerns related to reverse causality, we lag the right-hand side variables.

Empirical results

We estimate variants of regression *Eq*. (3) to test the first three hypotheses, namely H1, H2 and H3. Table 3 presents the results when excess emissions measured in percentage terms

(*EEP*) is used as the dependent variable, whereas Table 4 presents similar regression models using the z-score standardized excess emissions in euro terms (zEEE).[16]

[Insert Tables 3 and 4 around here]

Specifically, the first three hypotheses posit that publicly-listed firms (H1), state-owned firms (H2) and firms headquartered in common law legal systems (H3) are less environmentally proactive on average than their peers. In this respect and following the specification of regression *Eq*. (3), we would expect $\gamma_1 > 0$, $\gamma_2 > 0$ and $\gamma_3 > 0$, respectively. Based on the collective evidence reported in columns [1] to [4] of Tables 3 and 4, there is strong statistical evidence (p-values < 0.05) in support of these hypotheses (with a minor exception for *PUBLIC*, which turns not statistically significant when *EEP* is used as the dependent variable in Table 3).

Aside from our ex-ante hypotheses, the interaction terms of the main variables (*PUBLIC*, *STATE*, *COMMON*) with the proactive dummies (*PRO20* and *PRO20_IA*) from estimating *Eq*. (3) provide some interesting results. As shown in columns [5] and [6] these interaction coefficients are negative and, in general, they are at statistically significant levels. This evidence suggests that at least within the specifically proactive range, publicly-listed firms, state-owned firms and firms that operate in common law legal systems tend to be more proactive compared to their peers.[17]

Next, to examine H4, we estimate variants of regression *Eq*. (4) and the results are shown in Table 5. The dependent variable is the future growth rate in verified emissions and takes the two following cases: (i) in columns [1]-[3] we use $GOE_{it+1:t+2}$ measured as the

[16] The standardized variable, *zEEE*, is used hereinafter in the regression analysis.

[17] Regarding the robustness of the results note that they remain robust when we keep in our analysis the industries with less than 1% representations (which we had dropped from the sample as part of the filtering procedure). Also, they remain robust when we trim the sample at the values of *EEP* greater than 500% instead 300%. More importantly, they remain robust for different thresholds of proactiveness (i.e., <=-15% or <=-25%) and results are available on request from the authors. Also note that the exclusion of industry fixed effects does not alter the results. Lastly, they remain robust if we replace the yearly average futures prices with the December's futures (end of year prices).

natural logarithm of the verified emission in year t+2 divided by the verified emission in year t+1; and, (ii) in columns [4]-[6] we use $GOE_{it+1:t+3}$ measured as the natural logarithm of the verified emission in year t+3 divided by the verified emission in year t+1. All independent variables are measured in year *t*. The variables related to testing H4, namely *PRO20* and *PRO20_IA*, are expected to turn negative, However, in Table 5, we also explicitly show the regression coefficients for *EEP* and *zEEE* to investigate whether a firm's excess emissions behaviour is informative regarding the future growth rate of verified emissions.[18]

[Insert Table 5]

Two main results emerge from these tables. First, across the different specifications, *EEP* and *EEE* do not appear to influence the future growth of verified emissions in a statistically significant fashion. Hence, neither the economic cost/benefits of polluting above or below a firm's allocation as captured by *zEEE*, nor the pure excess pollution measure as captured by *EEP*, appear to matter. Second, assessing the results in columns [2] and [5] for *PRO20* and columns [3] and [6] for *PR20_IA*, there is statistical evidence supporting a strong negative relationship between a firm's proactive behaviour and future growth in its verified emissions. This evidence lends credence to the notion that firms that are characterized as having an environmentally proactive behaviour are committed to reducing future GGE. Taken together, this evidence lends strong support to H4.

Finally, to examine H5, we estimate *Eq*. (5) and the results are shown in Table 6. Regarding the dependent variables used, in columns [1]-[3] we present model specifications wherein the dependent variable is the one-year-ahead return on equity (*ROE*), whilst in columns [4]-[7] we present model specifications wherein the dependent variable is the one-year-ahead market return performance (*RET*). In all model specifications, the variables related to testing H5, namely *PRO20* and *PRO20_IA*, are measured in year *t*. Regarding the

[18] There correlation between *EEP* and *zEEE* is 0.173, hence including both of them in the same specification does not create any multicollinearity issues.

control variables, we use the return on assets (*ROA*) in year *t* when the dependent variable is the one-year-ahead *ROE* as per columns [1]-[3], while *ROE* in year *t* is used as a control variable when the dependent variable is the one-year-ahead *RET* as per columns [4]-[6]. As an acid test of H5, column [7] employs a specification wherein we use the one-year-ahead *ROE* as a control variable; this treatment precludes the possibility that a firm's proactive behaviour proxy for firm performance. The regression models shown in these tables include all variables as per Table 2 as additional controls, namely size, operating profitability and cash flow, asset growth, capital expenditures, book leverage, R&D expense, industry competition, country GDP growth and short-term interest rates.

[Insert Table 6 around here]

H5 posits that firms adopting an environmentally proactive stance damage their financial performance in the short-term. In this respect, Table 6 provides ample empirical evidence to support this proposition. Focusing on the main proactive variable, the results in column [2] show a strong negative relationship between *PRO20* and one-year-ahead *ROE* (p-values <0 .01), whilst the results in column [5] also show a strong negative relationship between *PRO20* and one-year-ahead *RET* (p-values < 0.01). This latter negative relationship persists even, as in column [7], we use the one-year-ahead *ROE* as a control variable. The use of *PRO20_IA* as an alternative proactive behaviour variable in general[19] supports the previous inferences suggesting that environmentally proactive firms have lower firm performance.

Discussion and conclusions

Environmental policy and the associated regulation are often designed with both an expected level of compliance and a normative encouragement to further reduce production-related pollution. But how do firms respond to such regulation and how does this affect their

[19] Although in column [6] of Table 6, the coefficient on *PRO20_IA*, whilst negative, is not significant.

performance? In the Business and Management literature, the environmental behaviour of firms is typically measured by KLD ratings, however the EU Emissions Trading System (EU ETS) provides a more natural experiment to observe behaviour. Specifically, firm-level data on verified and allocated emissions allowances from the trading scheme captures actual firm behaviour rather than imputed behaviour derived from survey measures.

In the extant literature, proactive firms are generally characterised as providing a response to policy which is more positive than mere compliance; for example, cutting emissions more than required. We suggest that distance between verified and allocated emissions provides a potential measure for the proactivity of firms. In particular, if verified emissions are substantially less than those allocated, this could be categorised as an environmentally proactive firm. Moreover, given allowances can be bought or sold within the EU ETS, an economic version of this measure can be calculated.

Drawing on literature from the economic, finance, stakeholder and comparative capitalism arenas, we posit five hypotheses related to corporate environmental proactivity, GGE and firm performance, testing these using a panel approach with data covering the EU ETS firms from 2005 to 2016. In sum, we typically find evidence in favour of the hypotheses and therefore that: publicly-listed firms (H1), state-owned firms (H2) and firms headquartered in common law legal systems (H3) are less environmentally proactive than their peers; additionally, firms which have environmentally proactive behaviour are found to reduce future GGE by more than other firms (H4) and diminish their future financial performance (H5).

Reflecting on the effectiveness of EU ETS, and given that whilst environmental proactiveness is associated with greater reductions in GGE it is also linked with poorer firm performance, our results suggest there is an economic cost to good environmental behaviour. In other words, whilst the EU ETS is reducing emissions for participating installations, it is not yet adequately compensating proactive firms or penalising those who pollute. Why might this be?

As shown in Figure 2 and discussed earlier, GGE futures prices are relatively volatile, moving relatively quickly from around €20 in 2005 to their all-time high in mid-2008, dropping quickly below €15 in early 2009, and then plunging even further to lower values as we move forward to more recent periods. One might assume that the typical firm would consider the overall economic cost/benefit; indeed, this is the premise behind cap-and-trade schemes such as the EU ETS. For example, given fluctuating GGE futures prices, the economic cost for a firm that overshoots by 5% in 2008 is many times higher compared to the same firm when it overshoots by 5% in 2016. In fact, the relatively high emission prices in Phase II would have created many incentives for firms to become *temporally proactive*, restricting their production process and selling their allocated emissions in the open market. On the contrary, the cost of buying carbon emissions from the open market in recent years has been relatively low, hence the cost of polluting more has also been commensurately low. If such reasoning is correct, then firms would have been more proactive in Phase II rather than Phase III. In fact, this is supported by the data. To show this Table 7 presents the coefficients from estimating a logit regression where the dependent variable is *PRO20* in columns [3] and [4]. Moreover, to get a sense of what happens in the neighbourhood of *PRO20*, we also estimate the logit model for *PRO15* in columns [1]-[2] and *PRO25* in columns [5]-[6]; these variables are defined analogously to *PRO20* but for thresholds of -15 and -25 percent.

[Insert Table 7 around here]

Considering the phase dummies estimated in Table 7 for *PRO20* shows clearly that phase II is more likely to observe firms behaving proactively (in column [4] the odds ratio suggests that it’s 71 percent more likely), whereas in phase III, a firm being environmentally proactive becomes much less likely (in column [4] the odds ratio suggests that it's 55 percent less likely). Similar results are inferred when considering *PRO15* and *PRO25*. This provides an important policy implication as it appears that firms will switch from being proactive when GGE market prices are relatively high to becoming non-proactive when prices are relatively low. Such a finding correlates with evidence in Oestreich and Tsiakas (2015) who show there is a large and statistically significant carbon premium in stock returns at the beginning of Phase II.

To return to the earlier question, the EU ETS is not yet adequately compensating proactive firms or penalising polluters because GGE market prices have often been too low, particularly during Phase III. This provides further evidence that policymakers need to be mindful of any large oversupply of allowances and suggests that the twin policies of 'back-loading' in phase III (i.e., the postponement of allowance auctions) and the market stability reserve (i.e., a permanent operational function to oversee the supply and demand of emissions) due to start in January 2019 are necessary to ensure the EU ETS encourages corporate environmental proactivity and therefore the reduction of GGE. The work in this study indicates the market stability reserve should be operated to ensure GGE market prices are at a high enough level to significantly increase the compensation for proactive firms and in doing so will increase the number of such firms.

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Appendix

Variable definitions

		European Union's Emissions Trading System (EU ETS) Related Variables
AE	=	Allocated emissions in metric tonnes CO2 equivalent (aggregated across all firm installations).
VE	=	Verified emissions measured in metric tonnes CO2 equivalent (aggregated across all firm installations).
EE	=	The per-firm excess emissions calculated as: VE - AE.
EEP	=	The per-firm excess emissions in percentage terms, calculated as: (VE – AE) / AE.
EEE	=	An economic measure of excess emissions in Euro term, calculated as: EE * *f*, whereby *f* represents the relevant futures price for CO2 EU allowances.
zEEE		A *z*-score standardized version of EEE.
Phase I		Phase I of the EU ETS and, accordingly, it takes the value 1 for years from 2005 to 2007, and 0 otherwise.
Phase II		Phase II of the EU ETS and, accordingly, it takes the value 1 for years from 2008 to 2012, and 0 otherwise.
Phase III		Phase III of the EU ETS and, accordingly, in our sample it takes the value 1 for years from 2013 to 2016, and 0 otherwise.
		Main Variables Used in Hypotheses Testing
PUBLIC	=	A dummy variable indicating publicly-listed firms and, accordingly, it takes the value 1 for a publicly-listed firm, and 0 otherwise.
STATE	=	A dummy variable indicating stated-owned firms and, accordingly, it takes the value 1 when the government has a stake of 5 percent or more, and 0 otherwise.
COMMON	=	A dummy variable indicating that a firm operates in a common law legal system and, accordingly, it takes the value 1 when the firm's headquarters are in a common law legal system, and 0 otherwise.
PRO20	=	A dummy variable to capture the environmentally proactive firms, which takes the value 1 for firm-year observations whereby *EEP* ≤ -20 percent, and 0 otherwise.
PRO20_IA	=	A year-industry adjusted dummy variable to capture the environmentally proactive firms, which takes the value 1 for firm-year observations whereby the per year and per-industry adjusted *EEP* ≤ -20 percent, and 0 otherwise.
		Other Variables
EU28	=	Takes the value 1 for firms headquartered with the EU-28 zone, and 0 otherwise.
INSTALATIONS	=	The number of GGE emitting installations.
RET	=	Annual cumulative market returns computed from monthly compounded returns during the fiscal year.
ROE	=	The ratio of income before interests and taxes to book value of equity.
ROA	=	The ratio of income before extraordinary items to assets.
SIZE	=	The natural logarithm of total assets.
CASH FLOW	=	Operating income before depreciation divided by beginning of the year net assets.
ASSET GROWTH	=	The difference between year *t* and *t*-1 in total assets divided by beginning of the year total assets.
CAPEX	=	Capital expenditures divided by beginning of the year total assets.
LEV	=	The ratio of total loans to book value of equity.
R&D	=	The ratio of research and development expenses to total assets (missing values of research and development expenses are replaced with zero).
HERFINDAHL	=	The sum for each year of the squared ratio of segment sales at the 4-digit SIC code level to firm sales divided by the squared sum for each year of the ratio of segment sales at the 4-digit SIC code level to firm sales.
GDP GROWTH	=	The country growth in GDP between years *t* and *t*-1.
RATE	=	Country short term interest rates (average of commercial banks).

Tables and Figures

Table 1: Summary statistics for firm emissions and related variables

Variable	N	Mean	Std. Dev.	Q1	Median	Q3
AE	8,942	2,339,412	7,890,990	70,153	336,205	1,400,000
VE	8,942	2,427,191	8,702,215	54,829	307,740	1,400,000
EE	8,942	87,779	2,225,890	-100,000	-9,804	13,151
EEP	8,942	-0.020	0.496	-0.266	-0.091	0.110
EEE	8,942	994,319	33,827,256	-1,442,667	-114,477	121,940
PRO20	8,942	0.335	0.472	0	0	1
PRO20_IA	8,942	0.209	0.407	0	0	0
INSTALLATIONS	8,942	9.707	23.613	1	3	8
PUBLIC	8,942	0.306	0.461	0	0	1
STATE	8,942	0.057	0.233	0	0	0
COMMON	8,942	0.145	0.352	0	0	0
EU28	8,942	0.892	0.311	1	1	1
Phase I	8,942	0.261	0.439	0	0	1
Phase II	8,942	0.443	0.497	0	0	1
Phase III	8,942	0.296	0.457	0	0	1

Notes. This table reports the summary statistics for firm emissions and related variables. The sample covers the period 2005-2016. The definitions of all variables are provided in the Appendix.

Table 2: Summary statistics for firm performance and related variables

Variable	N	Mean	Std Dev	Q1	Median	Q3
ROE (*t+1*)	1605	0.206	0.206	0.083	0.177	0.302
RET (*t+1*)	1150	0.034	0.375	-0.182	0.027	0.234
ROA	1605	0.061	0.181	0.005	0.033	0.066
SIZE	1605	9.054	1.906	7.840	9.004	10.341
EARN	1605	0.294	0.880	0.083	0.148	0.228
CASH FLOW	1605	0.533	1.353	0.165	0.298	0.462
ASSET GROWTH	1605	0.505	3.100	-0.040	0.028	0.111
CAPEX	1605	0.094	0.231	0.032	0.052	0.080
LEV	1605	0.960	0.833	0.461	0.742	1.222
R&D	1605	0.009	0.015	0.000	0.001	0.009
HERFINDAHL	1605	0.133	0.272	0.000	0.003	0.087
GDP GROWTH	1605	0.012	0.027	0.002	0.016	0.030
RATE	1605	0.021	0.017	0.006	0.014	0.039

Notes. This table reports the summary statistics for firm financial performance and related variables. The sample covers the period 2005-2016. The definitions of all variables are provided in the Appendix.

Table 3: Firm-level ownership structure, legal system and excess emissions measured in percentage terms

	Excess emissions measured in percentage terms (EEP)					
	[1]	[2]	[3]	[4]	[5]	[6]
PUBLIC	0.017			0.011	-0.016	-0.010
	(1.47)			(0.95)	(-1.27)	(-0.93)
STATE			0.064***	0.0689***	0.088***	0.0888***
			(2.65)	(2.79)	(3.33)	(3.70)
COMMON		0.067***		0.071***	0.059***	0.047***
		(4.44)		(4.68)	(3.57)	(3.36)
PRO20					-0.560***	
					(-60.63)	
PRO20 x PUBLIC					0.111***	
					(7.01)	
PRO20 x STATE					-0.195***	
					(-5.52)	
PRO20 x COMMON					-0.018	
					(-0.91)	
PRO20_IA						-0.659***
						(-59.44)
PRO20_IA x PUBLIC						0.0888***
						(4.75)
PRO20_IA x STATE						-0.107***
						(-2.86)
PRO20_IA x COMMON						-0.004
						(-0.17)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Phase II & III dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sq	0.195	0.197	0.196	0.198	0.440	0.463
Obs.	8,942	8,942	8,942	8,942	8,942	8,942

Notes. This table reports the regression results of *Eq*. (3) for testing H1, H2 and H3 using data covering the years 2005-2016. In all specifications, the dependent variable is the excess emissions measured in percentage terms (*EEP*). Regression models are estimated with control variables (*EU28*, *INSTALLATIONS*) and fixed effects (Phase II & III dummies, industry dummies). Regression coefficients' *t*-statistics (reported in parentheses) are estimated using robust standard errors corrected for autocorrelation and heteroscedasticity and clustered across firms and years. All variable definitions are provided in the Appendix. *, ** and *** indicate 10%, 5%, and 1% levels of significance, respectively.

Table 4: Firm-level ownership structure, legal system and excess emissions measured in euro terms

	Excess emissions measured in euro terms (zEEE)					
	[1]	[2]	[3]	[4]	[5]	[6]
PUBLIC	0.080***			0.069***	0.199***	0.075***
	(4.07)			(3.29)	(6.25)	(3.01)
STATE			0.153**	0.140**	0.189**	0.210***
			(2.53)	(2.25)	(2.54)	(2.88)
COMMON		0.051**		0.058***	0.082***	0.068**
		(2.32)		(2.58)	(2.72)	(2.54)
PRO20					-0.106***	
					(-12.14)	
PRO20 x PUBLIC					-0.362***	
					(-6.69)	
PRO20 x STATE					-0.280***	
					(3.02)	
PRO20 x COMMON					-0.068*	
					(-1.63)	
PRO20_IA						-0.100***
						(-11.27)
PRO20_IA x PUBLIC						-0.025
						(-0.84)
PRO20_IA x STATE						-0.355***
						(-4.46)
PRO20_IA x COMMON						-0.071**
						(-1.97)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
PHASE II & III dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sq	0.036	0.035	0.036	0.038	0.065	0.043
Obs.	8,942	8,942	8,942	8,942	8,942	8,942

Notes. This table reports the regression results of *Eq*. (3) for testing H1, H2 and H3 using data covering the years 2005-2016. In all specifications, the dependent variable is the z-score standardized excess emissions measured in euro terms (z*EEE*). Regression models are estimated with control variables (*EU28*, *INSTALLATIONS*) and fixed effects (Phase II & III dummies, industry dummies). Regression coefficients' *t*-statistics (reported in parentheses) are estimated using robust standard errors corrected for autocorrelation and heteroscedasticity and clustered across firms and years. All variable definitions are provided in the Appendix. *, ** and *** indicate 10%, 5%, and 1% levels of significance, respectively.

Table 5: Environmentally proactive behaviour and future growth in verified emissions

	$GOE_{it+1:t+2}$			$GOE_{it+1:t+3}$		
	[1]	[2]	[3]	[4]	[5]	[6]
PRO20		-0.027**			-0.048***	
		(-2.23)			(-2.55)	
PRO20_IA			-0.036**			-0.081***
			(-1.98)			(-2.98)
EEP	0.005	-0.015	-0.017	0.015	-0.026	-0.039
	(0.26)	(-0.81)	(-1.01)	(0.45)	(-0.68)	(-1.10)
zEEE	0.001	0.001	0.002	0.002	0.001	0.004
	(0.49)	(0.27)	(0.76)	(0.56)	(0.43)	(1.04)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes
PHASE II & III dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sq	0.018	0.018	0.018	0.043	0.044	0.045
Obs.	7,192	7,192	7,192	6,354	6,354	6,354

Notes. This table reports the regression results of *Eq*. (4) for testing H4 using data covering the years 2005-2016. The dependent variable is the future growth rate in verified emissions; particularly, in columns [1]-[3] it is measured as the natural logarithm of the verified emission in year t+2 divided by the verified emission in year t+1, whilst in columns [4]-[6] it is measured as the natural logarithm of the verified emission in year t+3 divided by the verified emission in year t+1. *EEP* is excess emissions measured in percentage terms and *zEEE* is the z-score standardized version of *EEE* that measures excess emissions in Euro terms. Regression models are estimated with control variables (*PUBLIC, STATE, COMMON*, *EU28*, *INSTALLATIONS*) and fixed effects (Phase II & III dummies, industry dummies). Regression coefficients' *t*-statistics (reported in parentheses) are estimated using robust standard errors corrected for autocorrelation and heteroscedasticity and clustered across firms and years. All variable definitions are provided in the Appendix. *, ** and *** indicate 10%, 5%, and 1% levels of significance, respectively.

Table 6: Environmentally proactive behaviour and future financial performance

	ROE	ROE	ROE	RET	RET	RET	RET
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
PRO20		-0.036***			-0.036***		-0.072**
		(-3.18)			(-3.28)		(-2.54)
PRO20_IA			-0.044***			-0.032	
			(-2.93)			(-0.80)	
EEP	0.017	-0.001	-0.002	0.013	-0.033	0.001	-0.025
	(1.40)	(-0.01)	(-0.13)	(0.47)	(-1.23)	(0.01)	(-0.96)
zEEE	0.009***	0.009***	0.010***	-0.006	-0.007	-0.006	-0.011**
	(4.01)	(3.77)	(4.15)	(-1.24)	(-1.31)	(-1.20)	(-2.43)
ROA	0.262***	0.265***	0.263***				
	(2.57)	(2.62)	(2.60)				
ROE				0.029	0.024	0.031	
				(0.34)	(0.28)	(0.36)	
ROE ($t + 1$)							0.529***
							(6.33)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PHASE II & III dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sq	0.635	0.635	0.635	0.037	0.045	0.037	0.092
Obs.	1,605	1,605	1,605	1,150	1,150	1,150	1,150

Notes. This table reports the regression results of *Eq*. (5) for testing H5 using data covering the years 2005-2016. The dependent variable is a firm's future one-year-ahead financial performance, particularly, in columns [1]-[3] it is measured as return on equity (*ROE*) in year *t+1*, whilst in columns [4]-[7] it is measured as the annual cumulative market return (*RET*) in year *t+1*. *EEP* is excess emissions measured in percentage terms, *zEEE* is the z-score standardized version of *EEE* that measures excess emissions in Euro terms and *ROA* is returns on assets. Regression models are estimated with control variables (*SIZE, EARN, CASH FLOW, ASSET GROWTH, CAPEX, LEV, R&D, HERFINDAHL, GDP GROWTH, RATE*) and fixed effects (Phase II & III dummies, industry dummies). Regression coefficients' *t*-statistics (reported in parentheses) are estimated using robust standard errors corrected for autocorrelation and heteroscedasticity and clustered across firms and years. All variable definitions are provided in the Appendix. *, ** and *** indicate 10%, 5%, and 1% levels of significance, respectively.

Table 7: EU ETS phase II & III and environmentally proactive behaviour

	PRO15		PRO20		PRO25	
	[1]	[2]	[3]	[4]	[5]	[6]
PHASE II	0.460***	0.462***	0.534***	0.537***	0.498***	0.502***
	(6.14)	(6.15)	(7.02)	(7.03)	(6.53)	(6.54)
PHASE III	-0.993***	-0.994***	-0.793***	-0.793***	-0.676***	-0.679***
	(-9.76)	(-9.76)	(-7.60)	(-7.59)	(-6.42)	(-6.37)
Control variables	No	Yes	No	Yes	No	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
QICu	11,220.64	11,186.12	10,702.42	10,660.54	9,896.19	9,822.18
Obs.	8,942	8,942	8,942	8,942	8,942	8,942

Notes. This table reports logistic regression results using data covering the years 2005-2016 for testing a firm's environmentally proactive behaviour across the EU ETS phases. The dependent variable is a firm's environmentally proactive behaviour, particularly, in columns [1]-[2] it is measured with a dummy that takes the value 1 when *EEP*≤-15 percent and 0 otherwise (*PRO15*), in columns [3]-[4] it is measured with a dummy that takes the value 1 when *EEP*≤-20 percent and 0 otherwise (*PRO20*) and in columns [5]-[6] it is measured with a dummy that takes the value 1 when *EEP*≤-25 percent and 0 otherwise (*PRO25*). Regression models in columns [1], [3] and [5] do not include any control variables, whereas those in columns [2], [4] and [6] include control variables (i.e., *PUBLIC, STATE, COMMON, EU28, INSTALLATIONS*). All models include fixed effects (Phase II & III dummies, industry dummies). Regression coefficients' *z*-statistics (reported in parentheses) are estimated using robust standard errors corrected for autocorrelation and clustered across firms. All variable definitions are provided in the Appendix. *, ** and *** indicate 10%, 5%, and 1% levels of significance, respectively.

Figure 1: Historical emissions of GGE

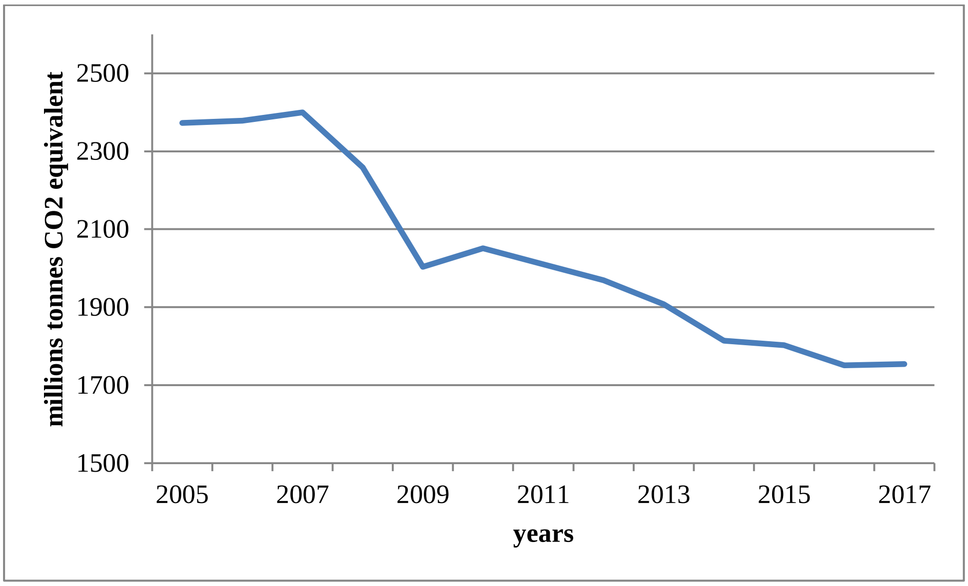

Figure 2: Futures price of GGE