Climate Regulation, Firm Emissions, and Green Takeovers *

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Abstract

We exploit an unexpected tightening in EU climate regulation, leading to a strong increase in the price of CO2 emission allowances, to investigate how polluting firms react to carbon pricing. We find that, after the price increase, highly polluting firms significantly improve their emission efficiency, i.e. the amount of output they generate from emiting one tonne of CO2. The efficiency gain comes from a relative decrease in emissions rather than a relative increase in output. Highly polluting firms also change their behavior on the M&A market. After the price increase, they become relatively more likely to take over green firms. Moreover, their targets have become more likely to be located inside (and hence not outside) the EU ETS area. We thus do not find evidence that highly polluting firms seek to relocate pollution outside of the regulatory area in reaction to the price increase, at least not via cross-border M&As.

Keywords: climate regulation, emission trading, firm behaviour, M&A
JEL classification codes: D22, G34, G38, Q53, Q54

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1 Introduction

During the twentieth century, the average temperature on earth has increased with 1°C relative to pre-industrial temperatures, and, scientists predict an increase of 4°C by the end of the twenty-first century (IPCC, 2013). This global warming is caused by the anthropogenic emission of greenhouse gases (IPCC, 2013) and significantly affects the environment (Thomas et al., 2004), our economies (Stern, 2006; Nordhaus, 2019), and firms (Addoum et al., 2020). Policy makers around the world have not remained deaf to this growing evidence and acknowledge the need to transform our economies into low-carbon economies. Typically, climate regulation is seen as a necessary tool to get there.

In 2005, the European Union (EU) introduced the EU Emissions Trading Scheme (ETS), a large-scale 'cap and trade' system aimed at reducing greenhouse gas emissions. Notwithstanding the theoretical attractiveness of emissions trading schemes, it was the first-ever large-scale ETS being implemented. Since then, carbon emissions trading schemes have been on the rise worldwide. The number of ETS evolved from just 1 in 2005 (the EU ETS) to 29 in 2021 (Figure 1), increasing the share of worldwide greenhouse gas emissions covered from around 4.5% to more than 17% (Figure 2).

Figures 1 and 2 HERE

The rationale for introducing carbon emissions trading schemes goes back to the 1960s, with Coase's analysis of the problem of social costs (Coase (1960)), and was specifically applied to environmental problems in later work by e.g. Crocker (1966), Dale (1968), and Montgomery (1972). The basic idea is fairly simple: the total amount of emissions can be controlled by putting a cap on the number of emissions, distributing emission allowances among polluting firms (either for free or through auctions) and creating a market where firms can trade these allowances. The system thereby effectively puts a price on carbon emissions. Under certain market conditions, the market equilibrium in such a cap and trade system should be cost-effective, independent of the initial allocation of the emission allowances.

Notwithstanding the theoretical attractiveness of emissions trading schemes and the strong increase in the number of such schemes active over the past years, we know relatively little about whether and how firms reduce emissions in the presence of such a scheme. Putting a price on emissions essentially implies an increase in input costs for firms, to which they can react in different ways: they can decide to produce less, invest in more efficient ('green') production technologies, or even move production to facilities outside of the ETS area.

This paper shows that emission trading schemes improve the emission efficiency of polluting firms, if the price of emission allowances is sufficiently high. The size of the improvement depends on the initial allocation of free emission allowances: polluting firms receiving fewer emission allowances for free have a stronger incentive to become more efficient. Looking into the mechanisms driving these efficiency gains shows that at least part of the improvement is realized via the acquisition of green firms.

For identification we exploit the tightening in EU ETS regulation in 2017, which made the ETS regulation more binding for polluting firms and led to a steep price increase of emission allowances. During the years before this regulatory tightening, carbon prices in the EU ETS market (EUA) were seen as being too low to push firms to significantly reduce emissions.[1] Prices were low due to a structural oversupply of emission allowances, which was a consequence of a depressed demand in the aftermath of the global financial crisis in combination with an inflexible supply of allowances. Indeed, as can be seen in Figure 3, the price of an EUA fluctuated around 5 to 6 euro for several years between 2013 and 2016.

Figure 3 HERE

In February 2017, the EU ETS reforms gained momentum when both the EU Parliament and the EU Council made their position on how to reform the EU ETS public.

[1] The carbon price in the EU ETS is the price of an EU emission allowance (EUA), which allows the holder to emit 1 tonne of carbon dioxide equivalent.

A key part of their proposals focused on how to absorb the structural oversupply and make the total supply of emission allowances more flexible, and hence intended to make carbon emissions more expensive for firms. To this end, a "Market Stability Reserve" (MSR) would be established in 2019 to remove the excess supply of emission allowances from the market and store it in a reserve. While the establishment of the MSR was already agreed by EU lawmakers in 2015, the published positions of the EU Parliament and Council in February 2017 significantly strengthened the initial agreement. For instance, several parameters were tightened such that twice as many emission allowances will be added to the MSR each year in case of an excess, and a Cancellation Mechanism allowing the MSR to permanently delete emission allowances from the reserve under certain conditions was announced. These proposals were put into legislation in November 2017. As part of the MSR, the EU communicates each year in May about the total supply and demand for emission allowances in the EU ETS, and hence also about the excess supply of emission allowances, allowing market participants to form expectations about the amount of allowances that will be added to the MSR, and potentially deleted later on.[2]

The first ever communication in this context was on May 12, 2017. As can be seen in Figure 3, that day marks the start of a very long price rally in the market for EU emission allowances. By year end, EUA prices had increased up to 8 euro (a 50% increase), and increased further up to around 30 euro by mid 2019 (a remarkable 500% increase).

To investigate the impact of these regulatory changes on firm behaviour, we employ a difference-in-differences identification strategy that consists of two key pillars. First, the strength of the regulatory tightening agreed in 2017 was largely unexpected and 'bites', meaning that the regulatory change was sufficiently important to shift the marginal emission cost curve for polluting firms upward, triggering a reaction in firm behaviour (Reuters, 2017). Evidence of this can be seen in the many lobbying attempts by different sectors to get exceptions to the new regulation, as well as the call for mea-

[2]See section 3 for a detailed overview of the regulatory change.

sures to protect sectors from foreign competition as a compensation for the upcoming regulatory tightening (see, e.g., Times (2017) or Alliance for a fair ETS (2017)). Second, not all firms are equally exposed to the regulatory tightening, because some firms receive more emission allowances for free than others. During the regulatory cycle we study, around 43% of total emission allowances in the EU ETS are allocated for free among firms, the rest needs to be purchased through auctions. The yearly number of emission allowances that a firm exactly gets for free is defined by the EU before the start of a regulatory cycle and depends largely on the sector the firm operates in (see Section 3 below). Firms whose total verified emissions are much higher than the amount of emission allowances they get for free, have a high shortage of free emission allowances. As the rest needs to be purchased through auctions or trades, high allowance shortage firms should be more exposed to the regulatory tightening than firms with a lower allowance shortage.

Our difference-in-differences setup compares firms that ex-ante have a high allowance shortage to firms that ex-ante have a low or no allowance shortage in the same nace 2-digit sector, in the three years before (2014-2016) and after (2017-2019) the regulatory tightening. This way, we are comparing firms producing the same product facing the same product demand, but which mainly differ in the cleanliness of their production technology. Our firm-year level data on the amount of verified emissions and free emission allowances comes from the EU Transactions Log (EUTL). Our final sample consists of 20,095 observations from 3,952 firms, which own a total of 8,820 polluting installations, and cover around 70% of the total greenhouse gas emissions in the EU ETS. We match this data with firm-year level balance sheet and profit & loss account information using Bureau van Dijk's ORBIS database. Information on firms' activities on the market for corporate control, in particular global M&A deal information, comes from Bureau van Dijk's ZEPHYR database.

We show that, once the EU ETS regulation becomes more binding and carbon prices are rising, polluting firms actively reduce emissions and become more carbon efficient, without reducing their overall output. Importantly, this efficiency gain is stronger in sectors that get a relatively lower amount of emission allowances allocated for free, indicating that the initial distribution of allowances seems to matter for firm reactions. Furthermore, we show that the market for corporate control is an important channel to achieve (at least part of) this efficiency gain. Our results indicate that heavily polluting firms are more likely to acquire green firms after 2017. Additionally, the targets of heavily polluting firms are more likely to be located inside the regulated area (i.e. a country participating in the EU ETS) after 2017.

Our paper relates and contributes to three strands of literature, which are (i) the design and effectiveness of climate policies in reducing emissions (ii) the impact of climate policy on firm investment and the market for corporate control and, (iii) the impact of free allowances and carbon leakage on policy effectiveness and firm behavior. A detailed literature review is postponed to the next section, but we already highlight here a few papers that are closest to ours, i.e. studies on the impact of the EU ETS on firm behaviour. Firms' responses to emission trading schemes are multi-faceted and in the context of the EU ETS have been summarized in Martin et al. (2016) and Cludius et al. (2020). Other recent studies have looked at the impact of the EU ETS on technological change, patenting and innovation (Calel and Dechezleprêtre (2016)) or firms' outward Foreign Direct Investment (Borghesi et al. (2020)).

An important concern with any policy or regulation is regulatory arbitrage. Dechezleprêtre et al. (2019) find no such evidence within the EU ETS. In particular, they find no evidence that the EU ETS has led to a displacement of carbon emissions from Europe towards the rest of the world, including in countries with no climate policy in place and within energy-intensive companies. The latter could be due to generous compensations offered by regulators to firms most at risk of such carbon leakage behavior. Martin et al. (2014b) document that such compensation rules proposed under the EU ETS result in substantial overcompensation for given carbon leakage risk. We document sizeable heterogeneity in firms' responses to the EU ETS price run-up depending on whether they are on the carbon leakage list or not.

2 Related literature

In designing policies to reduce GHG emissions, a regulator can resort to a price or quantity mechanism. A large literature researches optimal climate policy under different conditions, and use Weitzman (1974) as the starting point. Stavins (2019) provides an interesting overview of the trade-offs between several carbon-pricing policy instruments, in particular carbon taxes versus cap-and-trade mechanisms. Within the EU, an ETS is in place and the ambition is thus to reduce emissions by limiting quantities. Nevertheless, the price of an emission right acts as an important signal (Hintermann et al. (2016)). While not explicitly stated as such, the introduction of the market stability reserve aspired to increase prices to a meaningful level (Pahle and Quemin (2020)). In this paper, we study a quantity-based mechanism, but use the resulting price evolution as a source of quasi-exogenous variation that enables us to identify causal responses by firms.

Firms' responses to emission trading schemes are multi-faceted and have been studied extensively. For a structured review of the literature (until 2015) of the impact of the EU ETS on regulated firms, we refer the reader to Martin et al. (2016) and the EC's 2015 report on the cost pass-through in the EU ETS (later published as Cludius et al. (2020)) as well as the references cited in both studies. Dechezleprêtre et al. (2018) show that installations falling under the ETS regulation in France, Netherlands, Norway and the United Kingdom reduced their emissions by around 10% between 2005 and 2012, compared to installations not falling under the ETS. Importantly, they don't find any impact of the ETS on firm performance. Other recent studies have looked at the impact of the EU ETS on technological change, patenting and innovation (Calel and Dechezleprêtre (2016)) or firms' outward Foreign Direct Investment (Borghesi et al. (2020)).

Evidence from emission trading schemes or carbon prices is also abundant. Hanna (2010) studies multinationals' location and production decisions in response to strengthened environmental regulation in the United States (the Clean Air Amendment Acts).

Martin et al. (2014a) study the impact of a carbon tax in the UK on manufacturing firms their energy intensity as well as economic performance. **?** study the California cap-and-trade program and document that financial constraints are an important source of heterogeneity in firms' responses to climate policy as well as climate policy effectiveness.

An important concern with any policy or regulation is regulatory arbitrage. Ben-David et al. (2018) document that multinational firms respond to tighter environmental policies at home with performing their polluting activities in countries with relatively weaker policies. Dechezleprêtre et al. (2019), on the other hand, find no such evidence within the EU ETS. In particular, they find no evidence that the EU ETS has led to a displacement of carbon emissions from Europe towards the rest of the world, including in countries with no climate policy in place and within energy-intensive companies. The latter could be due to generous compensations offered by regulators to firms most at risk of such carbon leakage behavior. Martin et al. (2014b) document that such compensation rules proposed under the EU ETS result in substantial overcompensation for given carbon leakage risk. We document sizeable heterogeneity in firms' responses to the EU ETS price run-up depending on whether they are on the carbon leakage list or not.

Finally, our paper is also related to studies on the market for corporate control and corporate valuation. Mitchell and Mulherin (1996) show that corporate takeovers are often the least-cost means for industry structure to respond to the changes brought about by economic shocks. Industries experiencing the greatest amount of takeover activity are those exposed to the greatest fundamental shocks. Relatedly, Harford (2005) also shows that regulatory and technological shocks can drive merger waves. We show that firms that are most affected by the policy shock are more likely to acquire other firms. Firms' market valuation is affected by the (first) publication of compliance data (Jong et al. (2014)) as well as the publication of verified emissions and the stance of the carbon price (Brouwers et al. (2016)).

3 The EU ETS framework: Institutional background

3.1 General

The European Union launched the EU Emissions Trading System (EU ETS) in 2005 as the cornerstone of its strategy for reducing emissions of carbon dioxide (CO_2) as well as the equivalent amount of two other powerful greenhouse gases, nitrous oxide (N_2O) and perfluorocarbons (PFC). After phase I (2005-2017) and phase II (2008-2012), the EU ETS is currently reaching the end of phase III (2013-2020). As of 2019, the EU ETS covers approximately 14,000 power stations and manufacturing plants in the 28 EU Member States plus Iceland, Liechtenstein and Norway.[3] In total, around half of the EU greenhouse gas emissions are regulated by the EU ETS. The system works by putting a limit on overall emissions from regulated installations and reduces the limit each year. The percentage amount with which the total limit is being reduced is known as the Linear Reduction Factor and equals 1.74% during phase III. Each year, the EU supplies an amount of emission allowances equal to the limit to the market. Within this market, firms are free to buy and sell emission allowances. However, once per year, external auditors verify the total amount of emissions of the regulated installations, and firms need to surrender as many allowances as their installations have emitted.

The emission allowances are provided to firms either through auctions or for free. How many emission allowances an installation gets for free each year is determined before the start of a regulatory cycle using information from a reference period (see, for instance, Martin et al. (2014b) p. 2486 and following). The exact amount is calculated based on a formula where its production quantity during the reference period (in tonnes of product) is multiplied with the efficiency benchmark value for that particular product (measured in emissions per tonne of product). For the firms in our analysis the relevant cycle is EU ETS Phase 3 (2013-2020) and the reference period refers to 2007-2008. If an installation produces multiple products, the formula is separately applied for each product and the numbers are then added. Next to the elements in this formula,

[3]The EU ETS also covers aviation activities in these countries, but that is not included in our sample.

the allocation of free emission allowances also depends on the sector.

The total amount of free allowances thus depends on three items. First, the activity level/size of the installation. Logically, it wouldn't make sense if small installations receive the same amount of free allowances as large installations, and, therefore, the amount is proportional to how much output the installation produces. The output is defined before the phase as it is measured during the reference period, but there is an exception possible. If an installation has significantly increased its production capacity after the reference period, or vice versa, then the amount of free allowances will be adjusted proportionally.[4]

Second, the emission efficiency benchmark of the sector. This is set by the most efficient installations in the sector during the reference period. The benchmark shows with how few emissions it is possible to produce the product. By applying a benchmark, the amount of free allowances an installation can receive is limited to the amount of emissions the installation would emit if it would be using the most efficient technology in the sector.

Third, the sector the firm operates in. To safeguard the competitiveness of sectors covered by the EU ETS, sectors deemed to be exposed to the risk of carbon leakage receive a higher share of free allowances. The EU Commission refers to carbon leakage as the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. Roughly speaking, a sector is at risk of carbon leakage if the sector faces either a high exposure to non-EU trade (import+export), a high cost impact of the EU ETS relative to the added value of the sector, or a combination of moderate trade exposure and moderate cost impact.[5]

It is estimated that in phase III, on average, around 43% of the emission allowances will have been provided for free. The amount of emission allowances that is provided for free is thus quite significant. However, there is a large heterogeneity across sectors.

[4]This also holds for new installations in sectors entitled to free allowances, which can apply for free emission allowances from the NER300 programme.

[5]For an exact definition, see https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

For instance, firms in the electricity sector (power generators) get zero[6] emission allowances for free throughout the entire phase, while firms in sectors that are at risk of so-called carbon leakage get a maximum of allowances for free throughout the entire period (i.e. 100% of the formula). Firms in the remaining sectors are in between those extremes: they get some allowances for free but this amount declines over time (from 80% of the formula in 2013 to 30% in 2020).

3.2 The Reforms for trading phase IV (2021-2030)

In February 2017, EU ETS reforms gained momentum, as both the EU Parliament and the Council made their position on how to reform the EU ETS regulation public. A key part of these proposals focussed on how to (further) reduce the total supply of available emission allowances, and hence make emissions more expensive for firms.

Already in July 2015, EU lawmakers agreed on the establishment of the "Market Stability Reserve" (MSR), which would be active from 2019 onwards. The MSR was envisioned to address the structural oversupply of allowances by removing (part of) the excess supply of emission allowances and store it in a reserve. The published positions of the EU Parliament and of the Council in February 2017 strengthened the initial 2015 agreement by tightening its parameters, so that it takes more allowances out of circulation each year, and by allowing the MSR to permanently remove emission allowances from the reserve under certain conditions, known as the Cancellation Mechanism.

More precisely, it was proposed to put 24% instead of 12% of the oversupply of emission allowances into the MSR if the oversupply exceeds 833 million emission allowances in a given year. Furthermore, it was proposed to do this for each year between 2019 and 2023, one year longer than the initial proposal. Additionally, it was proposed that, as of 2023, if the number of allowances in the MSR exceeds the volume

[6]Power generators in Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland and Romania can still get limited allowances for free from their government to allow their economies to catch up with the rest of Europe, but, if so, there are some conditions attached.

auctioned in the previous year, then the excess will be automatically and permanently removed from the market (i.e. MSR). Finally, two tightening measures from the 2015 proposal were confirmed by the Parliament and Council in 2017. This concerned the increase of the annual Linear Reduction Factor from 1.74% to 2.2% as of 2021. And the 900 million allowances that were back-loaded in 2014-2016 will be transferred to the MSR rather than auctioned in 2019-2020. Inter-institutional negotiations between the Parliament, the Council and the Commission were eventually concluded on 9 November 2017, and the final legislation indeed foresaw this significant tightening of the existing regulation.

As part of the MSR, the EU communicates each year in May about the total supply and demand for emission allowances in the EU ETS, and hence also about the excess supply of emission allowances, allowing market participants to form expectations about the amount of allowances that will be added to the MSR, and potentially deleted later on. The first ever communication in this context was on May 12, 2017. The details about the Market Stability Reserve that were then released, confirmed that the 833 million EUR threshold would likely be exceeded during the 2019-2023 period, and that a significant amount of emission allowances would likely be deleted.[7]

4 Empirical setup and identification strategy

4.1 Difference-in-differences setup

In order to identify the impact of emissions trading schemes on firm behaviour, we focus on the regulatory tightening in the EU ETS that was agreed upon in the course of 2017 (see Section 3). We employ a difference-in-differences setup that allows us to

[7] This is clear because the MSR starts with 900 million allowances from the back-loading stored in it and additionally 24% of the structural oversupply will be added to the MSR each year over the period 2019-2023. The reported oversupply in May 2017 equals 1.7 billion, implying that around 870 million allowances (above the threshold of 833 million) can be expected to be added gradually to the MSR over the period 2019-2023. Knowing that the amount of allowances auctioned in 2017 was 950 million and knowing that this amount will decline significantly over the years to come (because of the still ongoing switch from free allowances to auctioning in non-carbon leakage sectors (up to 2020) and because of the linear reduction factor), it can be expected that the amount of emission allowances being cancelled in 2023 will be very large.

compare firms that are immediately exposed to an increase in their input costs as a consequence of this regulatory tightening, with a control group of similar firms that are not, or significantly less exposed to this.

Whether the tightening in regulation and the subsequent jump in the price for emission allowances actually leads to an increase in input costs, depends on a firm's total emissions and the number of emission allowances it receives for free. Before the start of each regulatory cycle, the EU determines for each regulated firm and for each year of the cycle how much emission allowances a firm will receive for free (See section 3 above). As such, firms with higher levels of emissions than free allowances should be more exposed than firms with a smaller shortage.

Therefore, we differentiate between firms' exposure to the tightening in EU ETS regulation by calculating each firm's *Allowance Shortage* over the pre-regulatory tightening period (2013-2016). We define this as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. For a firm i, the *Allowance Shortage* is measured as follows:

$$Allowance\ Shortage_i = \frac{1}{4}\sum_{y=2013}^{2016} \frac{emissions_{i,y} - free\ emission\ allowances_{i,y}}{total\ assets_{i,y}} \tag{1}$$

The numerator captures the number of allowances which will need to be purchased through auctions or trading, and hence proxies for the exposure to the regulatory change and subsequent price increase. The denominator corrects for the fact that a shortage of 1 million emission allowances is very different for firms with 1 billion EUR of assets than for firms with 10 million EUR of assets. The larger the *Allowance Shortage*, the more expensive it will become to keep emitting greenhouse gases once EUA prices start rising after the regulatory tightening.

We use $Allowance\ Shortage_i$ to construct a $High\ Exposure_i$ dummy. This dummy takes the value 1 if a firm has an $Allowance\ Shortage_i$ that is above the median in its NACE 2-

digit sector, and zero otherwise. This way, we are comparing firms that produce similar products, thus facing similar product demand and proportionally receiving similar free allowances, but that differ in the cleanliness of their production technology.

Our main difference-in-differences specification then looks as follows:

$$Y_{i,t} = \beta_1 Post_t + \beta_2 High\ Exposure_i + \beta_3 High\ Exposure_i \times Post_t + \beta_4 X_{i,t} + \epsilon_{i,t} \quad (2)$$

Where, in our main specifications, $Y_{i,t}$ will be either a firm's emission efficiency, proxied by the log of operating revenue over emissions, or the log of total emissions, or the log of operating revenue. $Post_t$ is a dummy equal to one from 2017 onwards, and zero otherwise. Our main coefficient of interest is β_3, which should capture the impact of the regulatory tightening on the exposed firms, relative to the non-exposed firms. $X_{i,t}$ represents a potential set of control variables and/or fixed effects. In most specifications, we will add firm fixed effects and year fixed effects, which implies that respectively β_2 and β_1 will be subsumed. In additional specifications, we saturate this model with country-sector-year fixed effects instead of year fixed effects, in order to control for country-sector level shocks that could bias our estimates (such as, for instance, country level changes in VAT on electricity consumption).

4.2 Underlying assumptions

Our identification strategy relies on two assumptions. First, over the period 2013-2016, the EU ETS regulation had a very limited, or even no impact on firms because the EUA price did not 'bite'. Since the EU ETS did not impact firms during that period, it also did not differentially affect firms with *Low* and *High Exposure*. Second, the tightening of the regulation in 2017 came earlier and stronger than expected, and hence was unanticipated by firms with both *Low* and *High Exposure*. Below, we provide a detailed underpinning of these assumptions. Later, a parallel trend analysis during the pre-regulatory tightening period will provide some empirical underpinning.

In 2008, the European Commission modeled a cost-efficient scenario to assess the economic, social, and environmental impact of climate policies using a carbon price of 39 EUR per ton CO2 (Delbeke et al. (2010)). Most theoretical studies confirm that in order to achieve climate ambitions, carbon prices need to be in that order of magnitude. Knopf et al. (2013), for instance, compare a number of existing economy-energy models, and show that optimal prices range from 20 to 70 EUR per ton CO2 (for 2020). Empirical studies focusing on the causal impact of the EU ETS during phase I (2005-2007) and II (2008-2012) provide evidence in line with this. Petrick and Wagner (2014), Wagner et al. (2014) and Klemetsen et al. (2016) show that regulated firms reduced emissions, while Calel and Dechezleprêtre (2016) show that regulated firms were incentivized to invest in low-carbon technologies. During phase I and II, however, emission prices initially fluctuated around 20 EUR per ton CO2, reached a high of 30 EUR in early 2008, but plummeted to 7 EUR by 2012.

By the time phase III of the EU ETS started in 2013, emission prices had reached an all-time low of around 3 EUR per ton CO2, and remained at very low levels for the years after (see Figure 3). These price levels are widely seen as too low to have a real impact and push firms to abate emissions since buying emission allowances is simply cheaper (see, e.g., Edenhofer et al. (2014), Edenhofer et al. (2017) and Pahle et al. (2018)).

In 2015, the European Commission submitted a legislative proposal to reform the EU ETS for 2021-2030 (COM(2015)0337). The views of the European Council and the European Parliament on the Commission's proposal, however, only became clear on February 28 of 2017.[8] Not only did these views signal that all parties involved very much wanted to push through ETS reforms, the views also came earlier than expected, and their content was stronger than expected.

Ian Duncan, MEP and the European Parliament's rapporteur on ETS reforms at that time, mentioned during the morning of February 28, 2017 at the Argus Emissions Con-

[8]The legislative process in the EU implies that both the EU Parliament and the EU Council adopt a position on the proposal and can amend the proposal. The Commission can then come with an updated proposal. In the end, all parties have to agree on the text, which happened in November 2017.

ference that *"A Council agreement was unlikely before summer at the earliest."*, yet the EU Council made its position public later that day. Two days later, Duncan emphasized in a column[9] that *"The substance of the Council's position is as surprising as its arrival was epiphanic."* and that *"Somewhat unexpectedly, many of their proposals mirror the elements of the agreement that emerged from the parliamentary bunfight: cancellation of a significant number of allowances and increasing the withdrawal rate of the Market Stability Reserve (MSR) being the two main elements."*

5 Data

We combine data from multiple sources. First, we assemble all available information on the yearly amount of free emission allowances and total verified emissions at the installation-level from the European Union Transaction Log (EUTL) during phase III of the EU ETS (2013-2020). This gives us information about 14,268 installations.

The EUTL also contains identifying information (name, address, a national ID number) on the firm that owns the installation. We use this firm information to match the EUTL data with firm balance sheet and P&L data from Bureau van Dijk's ORBIS dataset. For our analysis, we aggregate the installation-year level emissions at the firm-year level, in order to be able to construct emission efficiency measures that include both emissions and firm balance sheet data. Finally, again using this identifying information, we match our data with information on all M&A deals during the sample period from Bureau van Dijk's ZEPHYR dataset.

Our final sample consists of 20,095 observations from 3,952 firms in 27 European countries, which own a total of 8,820 installations. These installations cover around 70% of the yearly total emissions registered in the EUTL (see Figure 4).[10] During the sample period, 1,132 acquisitions have been officially announced by 481 firms from the sample, representing 806 unique firm-year observations given that some firms had

[9] https://www.euractiv.com/section/emissions-trading-scheme/opinion/ets-reform-agreement-catches-its-architect-by-surprise/.

[10] With the notable exception of 2019, where we only cover around 20% of the total emissions. This is due to the fact that firm-level balance sheet data for 2019 is not yet registered in ORBIS for a large part of the firms in our sample. We plan to update the sample as soon as 2019 data is available for these firms.

years where they announced multiple acquisitions.

Figures 4 and 5 HERE

Figure 5 shows the total amount of 2016 emissions (in kiloton CO2 equivalents) for the 5 largest emitting sectors (NACE 2 level) in our sample. The electricity and gas sector (NACE 2 code 35) is the largest emitter, emitting more than 600,000 kiloton in 2016. This corresponds with 49% of total 2016 emissions in our sample (1,227,503 kiloton). Other large emitting sectors are all manufacturing sectors: the manufacturers of non-metallic minerals (10%), basic metals (9%), refined petroleum products (9%), and chemicals (8%). All other sectors together emit less than 15%, and none of these individually emits more than 3.5% of total emissions.

Summary statistics on all variables used throughout the paper can be found in Table 1. Our main variable of interest throughout the paper is a firm's emission efficiency. We proxy for emission efficiency by a firm's operating revenue (in thousand EUR) scaled by total emissions (in ton CO2-equivalent). The higher this value, the more energy-efficient a firm is producing. The evolution of the aggregate emission efficiency in our sample is depicted in Figure 6, The proxy is fairly constant between 2014 and 2016, and then steadily increases from 2017 onwards.

Table 1 and Figure 6 HERE

For all M&A deals, we gather information on the country where the target is located, as well as information on whether the acquisition concerns a new target (i.e. where the firm had no prior (minority) stake). *M&A within the EU* $ETS_{i,j,t}$ is a dummy that takes the value of 1 for firm *i* in year *t* if target *j* is located in one of the 31 countries that participate in the EU ETS, and 0 otherwise. *M&A new* $target_{i,j,t}$ is a dummy that takes the value of 1 if firm *i*'s stake in target *j* prior to the acquisition in year *t* was equal to 0% and, 0 otherwise.

We also gather information on the *greenness* of the deal. We get this information from three variables in ZEPHYR that contain textual information about the deal: namely the deal editorial, deal rationale, and deal comments. We then develop a 'green' dictionary[11] in Wordstat for STATA and analyse how green each deal is. Using this tool to textually analyze the information embedded in these three variables, we obtain a variable $M\&A\ greenness_{i,j,t}$ which measures the % of words in the text that is part of the 'green' dictionary for firm i's acquisition of target j in year t.

As can be seen in Panel B of Table 1, the average deal in the sample scores low on greenness and contains less than one 'green' word per 100 words of text (namely 0.67 per 100 words).[12] However, there is significant heterogeneity in the greenness of acquisitions. On the one hand, around 65% of the deals have an $M\&A\ greenness_{i,j,t}$ equal to 0. On the other hand, around 10% of the deals have an $M\&A\ greenness_{i,j,t}$ larger than 2.5 words per 100 words, and thus explicitly mention green factors motivating the deal. In Appendix A, we give a couple of examples of text from M&A deals in the sample, in particular from some acquisitions that score low and some that score high on $M\&A\ greenness_{i,j,t}$. Because some firms do multiple acquisitions in a given year, we take the average of $M\&A\ greenness_{i,j,t}$ at firm-year level and obtain $M\&A\ greenness_{i,t}$. $M\&A\ within\ the\ EU\ ETS_{i,t}$ is a dummy that takes the value of 1 if at least one the targets j of firm i in year t is located in one of the 31 countries that participate in the EU ETS, and 0 otherwise. $M\&A\ new\ target_{i,t}$ is a dummy that takes the value of 1 if the firm i's stake in at least one of the targets j prior to the acquisition in year t was equal to 0% and, 0 otherwise.

[11]For our green dictionary, we start from the CSR dictionary developed by Pencle and Malaescu (2016), which consists of four dimensions: employees, human rights, social and community, and environment. The environment dictionary contains 451 words like, e.g., green engineering, renewable energy, solar panel, conservation. We started from this dictionary but deleted words that we found less appropriate for green concerns (although they might be considered as environmental concerns) like, e.g., caged animals, bribe, genetically modified.

[12]Note that the analysis leaves out common, meaningless words such as 'the' or 'and' from the word-count.

6 Empirical analysis

We present four sets of results. First, we document that the tightening in ETS regulation increased the emission efficiency of polluting firms. Second, we focus on the role of the initial endowments of ETS rights. Our results suggest that a high amount of initial endowments leads to lower efficiency gains. Third, we investigate the role of M&A activity in the greening process. Our results show that heavily polluting firms are more likely to acquire green firms after the regulatory tightening. Finally, we present a number of test that ensure the robustness of our main findings.

6.1 ETS regulation and firms' emission efficiency

In this section, we document the impact of the tightening in ETS regulation on firms' emission efficiency. Throughout the analysis, a firm's emission efficiency is proxied by the ratio of its operating revenue (in thousand euro) over its total emissions (in tonne CO_2 equivalent).

Table 2 presents the results of four regressions that have the natural logarithm of the emission efficiency measure as dependent variable. In column 1, the regression only includes the $Post_t$ dummy as independent variable, together with a set of firm fixed effects. The $Post_t$ dummy is equal to one for the years 2017, 2018 and 2019. The positive and significant coefficient on this dummy of 0.082 indicates that the emission efficiency of the average firm in our sample increased with around 8% when comparing the 2017-2019 period with 2014-2016.

The specification in column 2 only includes the $High\ exposure_i$ dummy on the right-hand side, together with year fixed effects. As explained in section 4, this dummy is equal to one for the firms that have an allowance shortage that is above the median in its (NACE 2-digit) sector between 2013 and 2016, and are thus most exposed to the regulatory tightening and the subsequent emission price increase. The negative and significant coefficient indicates that, on average, these firms are substantially less emission efficient than the low-exposed firms.

Columns 3 and 4 of Table 2 illustrate our first main finding. These columns report the results from estimating Equation 2. In column 3 we include firm and year fixed effects, while column 4 includes firm and country-sector-year fixed effects. The positive and significant coefficient in both columns indicates that the tightening of the ETS regulation significantly increased the emission efficiency of the high-exposed firms. Depending on the exact specification, we get an estimated improvement of either 4.9% (column 3) or 8.7% (column 4).

Table 2 HERE

Next, we estimate a specification where we replace the *High exposure*$_i$ *x Post*$_t$ interaction with a set of *High exposure*$_i$ *x Year* interaction terms. In this way, we can analyse the yearly difference in emission efficiency between high- and low-exposed firms. In order to avoid a dummy variable trap, this comparison has to be made relative to a benchmark year, which is 2016 in our case (i.e. the last year before the regulatory change takes place).

Figure 8 shows the coefficients on the interaction terms in this specification. The fact that the coefficients in 2014 and 2015 are non-significant indicates that both high- and low-exposed firms where evolving in a very similar way in terms of emission efficiency during the years before the regulatory tightening. This implies that the parallel trends assumption for our setup is unlikely to be violated.

The coefficients for 2017 and 2018 are positive and significant. The relative improvement in emission efficiency for the high-exposure group increases from around 7% in 2017 to above 10% in 2018. For 2019, we still find a positive impact, albeit lower than in 2018 and insignificant. Note, however, that our sample for 2019 is very much incomplete for now, due to balance sheet data not yet being available for more than 80% of the firms in our sample. It is thus difficult to draw strong conclusions for 2019 given this limited sample.

Figure 8 HERE

In Table 3 we show that this improvement in emission efficiency is mainly driven by a reduction in emissions, while operating revenue remained stable. Columns 1 and 2 of Table 3 focus on firm emissions. The dependent variable in both columns is the natural logarithm of total verified firm emissions. Column 1 indicates that over the period 2017-2019, the average reduction of emissions of high exposed firms (relative to low-exposed firms) was 7.2%. Column 2 breaks this average down year-by-year. The results in this column show that by the end of 2019, and relative to low-exposed firms, high-exposed firms reduced their emissions by 11.3%, compared to their average emissions over the period 2014-2016. Columns 3 and 4 of Table 3 show that there is no significant difference in the evolution of operating revenue for the high- and the low-exposed group. The increase in emission efficiency is thus driven by a reduction in emissions, and not by a reduction in firm activity.

Table 3 HERE

6.2 Free allowance allocation and emission efficiency

This section illustrates that the initial allocation of free allowances matters for firms' reaction to regulatory tightening. Firms with a high amount of initial allowances have a lower incentive to scale back emissions.

The first column of Table 4 documents the effect of the regulatory change for the sub-sample of firms that are on the carbon leakage list. Firms on this list get a maximum of allowances for free throughout the entire period. The high-exposed firms in this group do not significantly improve their emission efficiency after the tightening of the regulation. In contrast, Column 2 documents that our main result is driven by firms not on the carbon leakage list. For this group of firms, we do find a significant improvement of the emission efficiency by the high exposed firms. They increase their efficiency by 10.7% once the regulation is tightened.

In column 3 of Table 4 we focus on a group of firms that get zero emission allowances for free: the electricity producers. The reaction of the high-exposed firms in this group is even stronger: relative to the low-exposed firms, they improve their emission efficiency by 15.7%. This further confirms that initial allocation of free emissions matter for a firm's reaction to the regulatory tightening. Column 4 shows that high-exposed, non-electricity producers that are not on the leakage list also improve their emission efficiency, but to a somewhat lesser extent than the electricity producers (with 9.8%). The reason for this is that these firms still get some allowances for free, while the electricity producers receive zero free allowances.

Table 4 HERE

6.3 The market for corporate control

In this section, we shed light on the economic channel through which these high-exposed firms have become more efficient. More specifically, we analyse whether firms that are more exposed to the effects of the regulatory tightening have changed their behaviour in the market for corporate control relative to firms that are less exposed. We look at the market for corporate control as M&As are often seen as the least-cost option when firms face large economic shocks (Mitchell and Mulherin, 1996; Harford, 2005). As mentioned, firms can react to an increase in production costs due to an increase in carbon prices in several ways. Firms can try to acquire targets that would allow them to produce in a more efficient/cleaner way, and hence reduce their exposure to the policy tightening. However, firms can also try to acquire targets outside the regulated area that would allow them to shift the polluting production to non-regulated countries, and hence also reduce their exposure to the policy tightening.

To this end, we first analyse the greenness of the acquisitions that have been announced by the firms in our sample using the same diff-in-diff setting as before.[13] We

[13]We add two firm-year level control variables in the regressions, namely, lagged firm size and lagged firm profitability.

proxy for the greenness of an acquisition by using a textual analysis based variable $M\&A$ $greenness_{i,t}$, which captures the percent of words included in three textual deal variables, that are being identified as 'green' in our dictionary (see Section 5 above for a detailed overview of its construction). As can be seen in column 1 of Table 5, the average acquisition of low exposed firms is slightly less green in the post-regulatory tightening period, relative to before (i.e., -0.126 but insignificantly). Further, the acquisitions of high exposed firms appear to have been less green in the pre-regulatory tightening period than those of low exposed firms (-0.230**). Interestingly, high exposed firms have on average become significantly more focussed on green targets since the regulatory tightening (relative to low exposed firms, 0.350**).

Table 5 HERE

As of column 2 in Table 5 we significantly strengthen the identification and add firm and year fixed effects to the regression. This results in a drop in the number of observations from 806 to 500, as this analysis requires firms to have acquisitions in both the pre- and post-regulatory tightening period. But, this allows us to rule out that the results would be driven by other unobserved heterogeneity in time-invariant characteristics between high and low exposed firms. Indeed, column 2 shows us that the same high exposed firms have adjusted their takeover policy more towards greener targets after the regulatory tightening, in comparison to low exposed firms (0.480**). The results are also economically meaningful as the increase in greenness of high exposed firms of 0.480 equals an increase of 71 percent relative to unconditional average or an increase of 0.43 standard deviation. In columns 3 and 4, we split the sample into firms that operate in sectors that are on the carbon leakage list and in sectors that are not on this list, respectively. As firms that are on the carbon leakage list receive more allowances for free than firms that are not on the list, we expect that the change in takeover policy observed in columns 1 and 2 is predominantly driven by firms that are on not on the carbon leakage list. Indeed, this exactly what we observe. The coefficient for firms that are not on the carbon leakage list (in column 4) is statistically significant and is two and a half times larger than the coefficient for firms on the carbon leakage list (in column 3), which appears to be not significantly different from zero. In Table 6, we further split the sample of firms that are not on the carbon leakage list into electricity producers, which get zero allowances for free, and the rest. In line with previous results and hypotheses, the focus on green takeovers is largest for high exposed electricity producers.

Table 6 HERE

Next, we analyse whether the EU ETS reforms pushed firms to relocate production outside the EU ETS via M&As. We again rely on our diff-in-diff setting but use $M\&A\ within\ the\ EU\ ETS_{i,t}$ as dependent variable. This variable takes the value of 1 if at least one the targets of firm i in year t is located in one of the 31 countries that participate in the EU ETS, and 0 otherwise. The results of this analysis are shown in panel A of Table 7. As can be seen in column 1, low exposed firms have become slightly less likely to acquire targets in the regulated area in the post-regulatory tightening period relative to before (i.e., -0.028 but not significantly different from zero). Further, the targets of high exposed firms were less likely to be located in the EU ETS in the pre-regulatory tightening period relative to the targets of low exposed firms (-0.040 but not significantly different from zero). Interestingly, in comparison with low exposed firms, high exposed firms have become significantly more focussed on taking over firms located inside the EU ETS since the regulatory tightening (0.078*). Column 2 shows again the within-firm effect and controls for year-specific effects in takeover policies. The estimate confirms the finding that high-exposed firms have become more likely to acquire targets inside the EU ETS since 2017 relative to low exposed firms (0.123**). Hence, our results seem not in line with the hypothesis that firms that are more exposed to the regulatory tightening would seek opportunities to relocate production outside the regulated area. This effect is also economically relevant. Since the regulatory tightening, the likelihood that a target is located inside the EU ETS became between 8 and 12 percent higher for high-exposed firms than for low-exposed firms.

Table 7 HERE

We then look whether this effect differs for firms that receive a lot of emission allowances for free (in casu those on the carbon leakage list) versus firms that do not (i.e. those not on the carbon leakage list) in columns 3 and 4. While the coefficient lies around 12 percent for both groups, it is significantly different from zero for firms that only get few free allowances but not significantly different from zero for firms that do get a lot of free allowances.

Finally, we investigate whether the observed effects are indeed coming from an active change in takeover policy. To do so, we test whether exposed firms have become more likely to look for new targets as opposed to increasing their shares in firms where they had prior stakes. For this, we change the dependent variable in our diff-in-diff to *M&A new target*$_{i,t}$, which takes the value of 1 if firm i's stake prior to the acquisition was equal to 0% in at least one of the targets in year t and, 0 otherwise. The results are shown in panel B of Table 7. The diff-in-diff estimates in columns 1 and 2 show that,since the tightening, high- exposed firms have become more likely to invest in new targets than low-exposed firms (0.049 and 0.138). However, the effect is not significantly different from zero, although the t-stat in column 2 gets close (1.44). If we look whether the effect differs for firms on the carbon leakage list versus firms that are not on the carbon leakage list in columns 3 and 4, we see that the effect is zero for firms on the carbon leakage list but high and significant for firms not on the carbon leakage list. This shows that high exposed firms that do not get much emission allowances for free have become more likely to acquire new targets since the regulatory tightening than low exposed firms.

All-in-all, these results indicate that the regulatory tightening of the EU ETS impacted firms that are most exposed to its consequences, to the extent that these firms changed their takeover policy. We find no evidence that highly exposed firms searched for opportunities to relocate production outside the regulated area in reaction to the policy tightening, but rather tried to minimize their exposure by looking for new, greener targets inside the regulated area.

6.4 Robustness

Tables 8 and 9 include a number of robustness checks for the results documented in table 2. First, we focus on alternative proxies for a firm's emission efficiency. Instead of using operating revenue over emissions, we use either sales over total emissions, fixed assets over total emissions or total assets over total emissions as a proxy for emission efficiency. In columns 1 to 3 of table 8 we use these proxies as dependent variable in a specification similar to column 4 in table 2. For all these proxies we find a significant increase in emission efficiency at high-exposed firms, with point estimates ranging between 7.8 and 12.4%.

Column 4 of table 8 re-estimates the specification from column 4 in table 2, but now with additional firm-level control variables included (log of total assets and the firm's profit margin). The result remains qualitatively unchanged. In column 5 we replace the high-exposure dummy with its continuous counterpart, i.e. our *Allowance Shortage* measure. Using this variable also indicates that firms with a higher shortage are increasing their emission efficiency after the regulation is tightened.

Table 8 HERE

Finally, table 9 shows that our main results are not purely driven by the largest sectors in terms of emissions, but that the reaction to the regulatory tightening is a widespread phenomenon. In columns 1-3, we drop the largest emitting sector (NACE code 35: Electricity, gas, steam and airconditioning supply), while in columns 4-6 we additionally drop the next two largest sectors (NACE 23: Manufacture of other non-metallic mineral products; NACE 24 Manufacture of basic metals). Dropping these sectors, we still find a significant improvement of emission efficiency for the high-exposure group, ranging between 6.1 (column 1) and 7.9% (column 4). Additionally, it still holds that this improvement is driven by a reduction in emissions, while there was no significant difference in the change in operating revenue.

Table 9 HERE

7 Conclusion

In designing policies to reduce greenhouse gas emissions, a regulator can resort to a price or a quantity mechanism. In this paper, we study a quantity-based mechanism, but use the price evolution caused by an unexpected quantity tightening as a source of quasi-exogenous variation that enables us to identify causal responses by firms. More specifically, we study how firms respond to the unanticipated price rally in the EU emission allowance market, that took off in 2017, caused by a major tightening in EU ETS regulation.

In a difference-in-differences setup, we study the differential behaviour of firms that are highly exposed to an increase in their input costs as a consequence of this regulatory tightening, with a control group of similar firms that are not, or significantly less exposed to this.

We have three main findings. First, we document that the tightening in EU ETS regulation increased the emission efficiency of polluting firms. The efficiency gain comes from a relative decrease in emissions rather than a relative increase in operating revenue. Second, we focus on the role of the initial endowments of free emission allowances. Our results suggest that a high amount of initial endowments, such as for instance for firms on the carbon leakage list, leads to lower efficiency gains. Third, we investigate the role of M&A activity in the greening process. Our results show that heavily polluting firms are more likely to acquire green targets after the regulatory tightening.

Our paper has a number of important policy implications. First of all, a quantity-based mechanism aimed at reducing greenhouse gas emissions works better when the price of an emission allowance is an informative signal and sufficiently high. Second, the design of the auction mechanism and free allocation of emission allowances matters for the effectiveness of the policy. Third, in an attempt to become more energy-efficient, firms bid for and acquire greener targets. The market for corporate control could thus be an important mechanism for a green transition as it stifles competition among innovative energy-efficient firms to become the next target. Fourth, carbon leakage through FDIs may be limited, as we find that highly exposed firms did not look for opportunities to relocate production outside the regulated area. Whether carbon leakage takes place via extra-EU trade is an unresolved issue and would require international trade data for the firms in the ETS.

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Figures and Tables

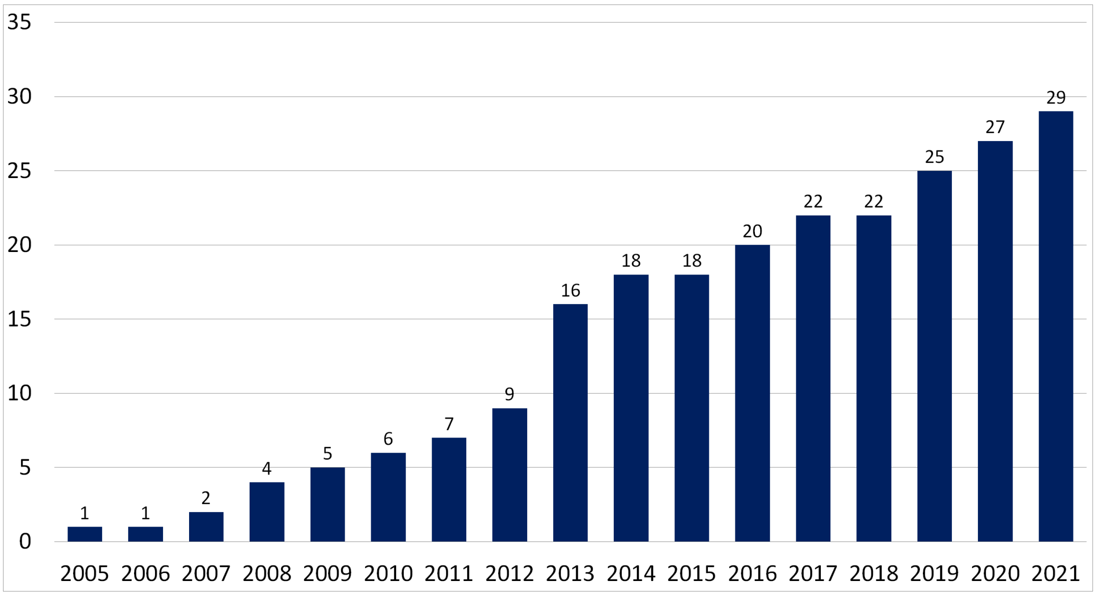

Figure 1: **Number of Emission Trading Schemes worldwide.** This figure show the evolution of the number of the active ETS programmes worldwide. Source: Worldbank Carbon Pricing Dashboard.

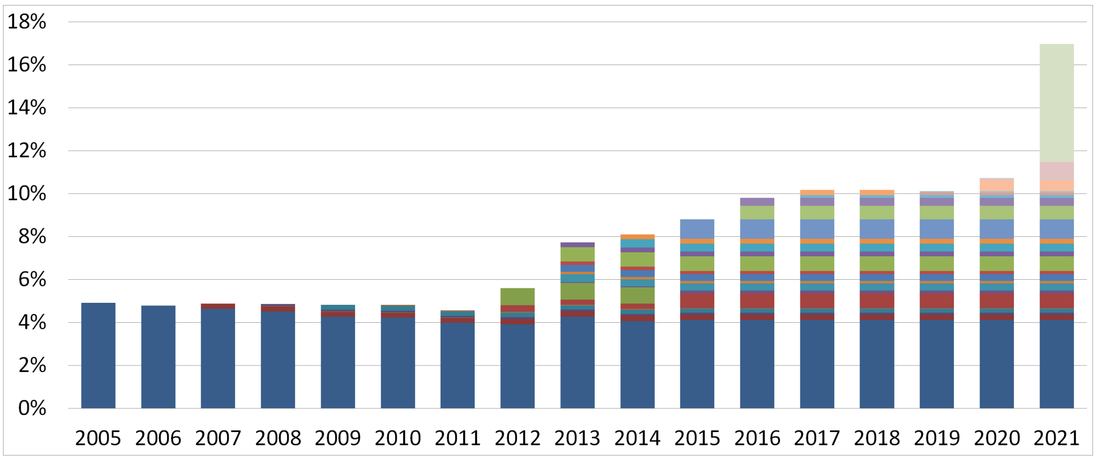

Figure 2: **Emissions covered by Emission Trading Schemes.** This figure show the evolution of the share of worldwide greenhouse gas emissions covered by emissions trading schemes. Source: Worldbank Carbon Pricing Dashboard.

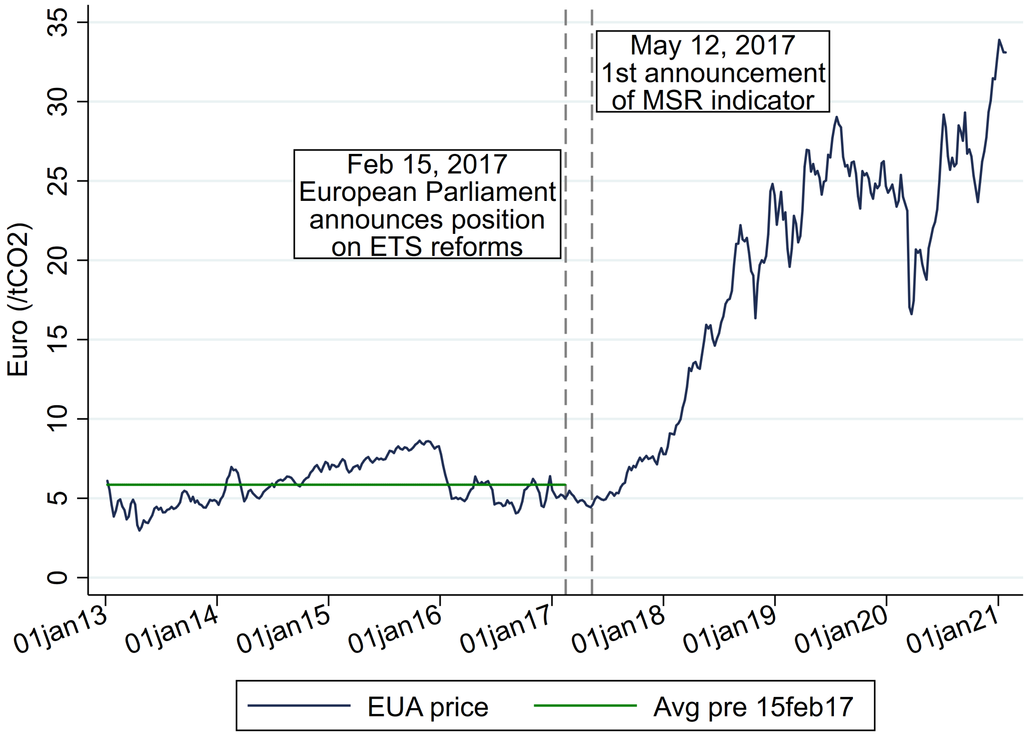

Figure 3: **ETS Carbon Market Prices.** This figure show the evolution of the price of an EUA. One EUA gives the holder the right to emit one tonne of carbon dioxide, or the equivalent amount of two more powerful greenhouse gases, nitrous oxide (N2O) and perfluorocarbons (PFCs). Data is taken from Sandbag.be.

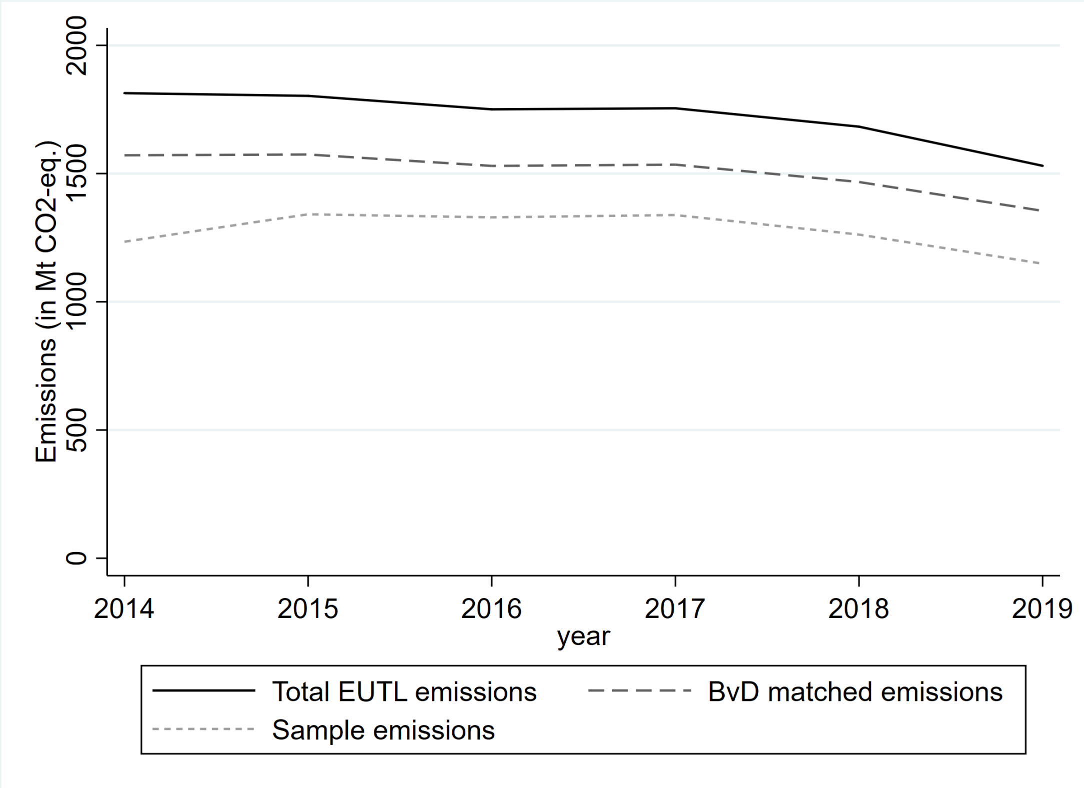

Figure 4: **Emissions over time - sample coverage.** This figure show the evolution of the yearly aggregated verified emissions registered in the EU Transaction Log (solid line), the yearly aggregated verified emissions of the installations for which we find a matching firm in the Bureau Van Dijk Orbis (dashed line), and the yearly aggregated verified emissions in our final regression sample. The difference between the last two series is due to missing balance sheet information for some of the matched firms. Source: EU Transaction Log, BvD Orbis and own calculations.

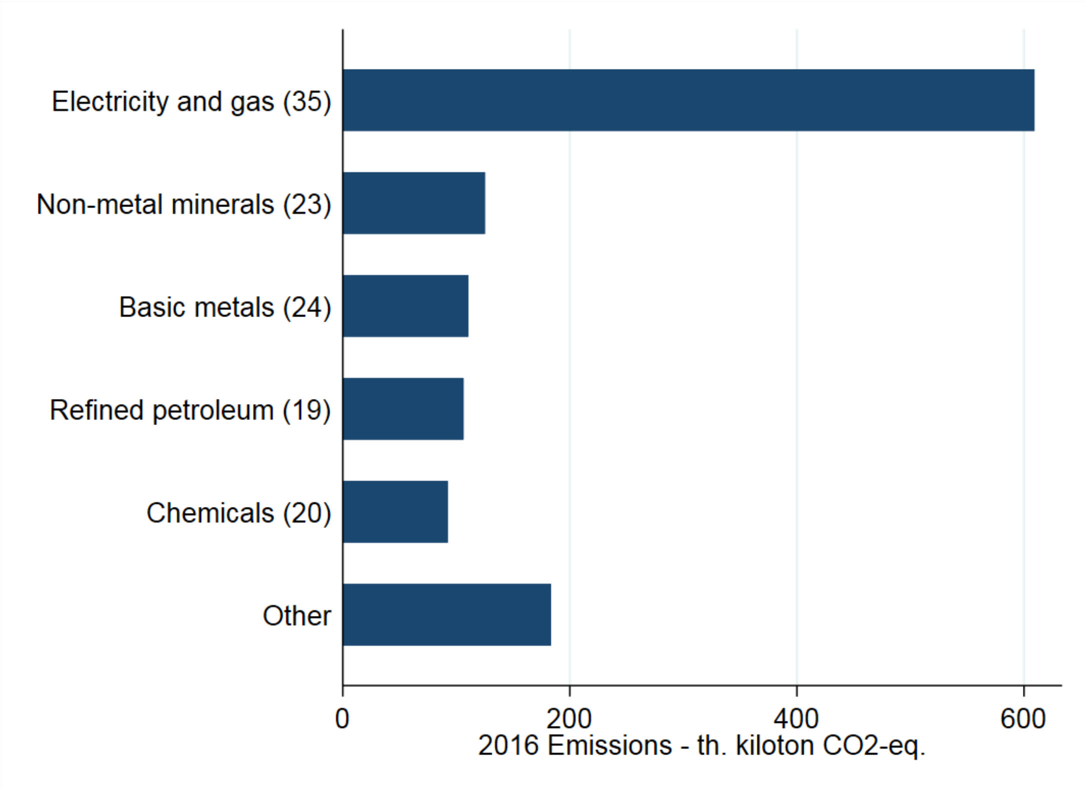

Figure 5: **Emissions by sector in 2016.** This figure show the sector-level greenhouse gas emissions (in kiloton CO2-equivalents) in 2016 for the firms in our sample. The NACE 2 sector code is mentioned between brackets. The official full sector names are *Electricity, gas, steam and air conditioning supply* (35), *Manufacture of other non-metallic mineral products* (23), *Manufacture of basic metals* (24), *Manufacture of coke and refined petroleum products* (19), and *Manufacture of chemicals and chemical products* (20). *Other* contains the emissions of all other sectors, none of which individually emit more than 3.5 % of total 2016 emissions.
Source: EU Transaction Log, BvD Orbis and own calculations.

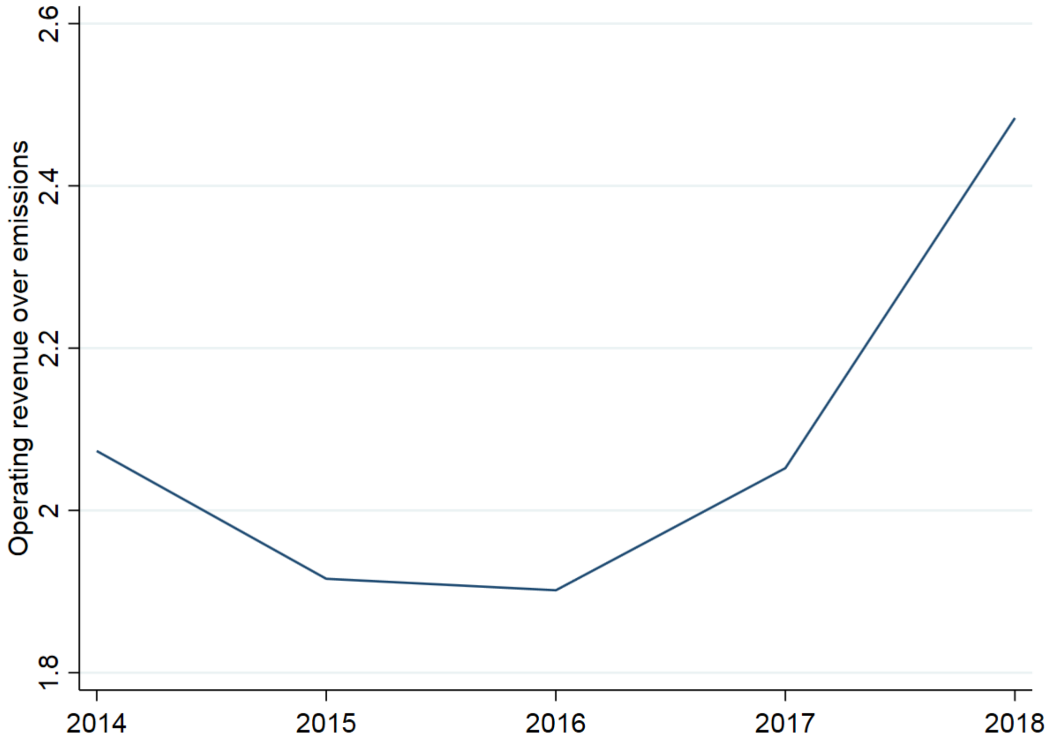

Figure 6: **Aggregate Emission Efficiency.** This figure show the evolution of emission efficiency over time. Aggregate emission efficiency is proxied by operating revenue (in thousand EUR), scaled by aggregate verified emissions (in tons of CO2 equivalents). The sample consists of all firms that have installations falling under ETS regulation for which we have firm-level data.
Source: EU Transaction Log, BvD Orbis and own calculations.

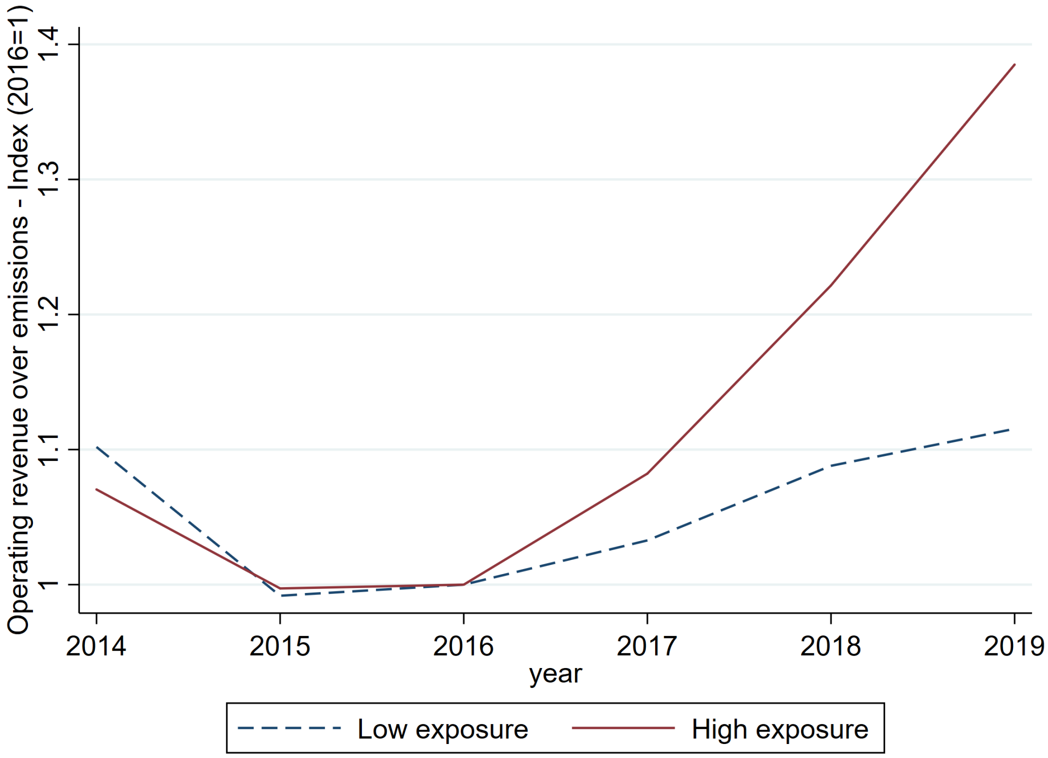

Figure 7: **Aggregate Emission Efficiency - High vs. Low Exposed Firms.** This figure show the evolution of aggregate emission efficiency over time for high -and low-exposed firms in our sample. Aggregate emission efficiency is proxied by operating revenue (in thousand EUR), scaled by aggregate verified emissions (in tons of CO2 equivalents). A high-exposed (low-exposed) firm is defined as a firm with an allowance shortage above (below) the median allowance shortage in their NACE 4-digit sector. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. The sample consists of all firms that have installations falling under ETS regulation for which we have firm-level data.

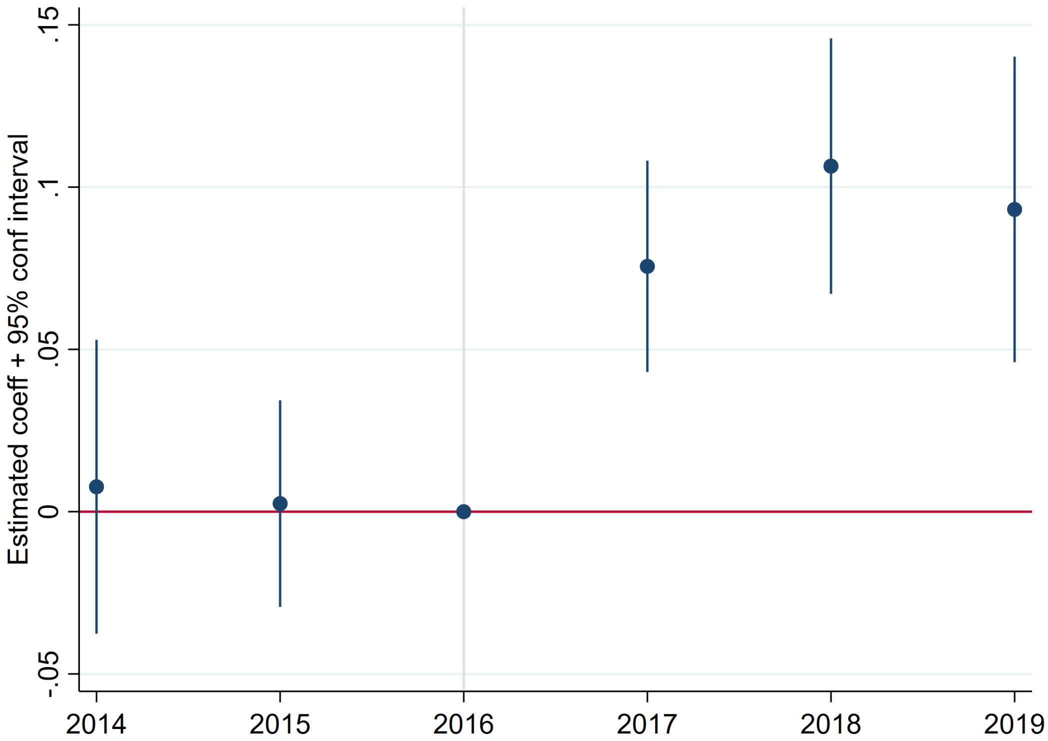

Figure 8: **Parallel trends - yearly coefficients main specification** Note: This figure shows we the β coefficients from estimating the following specification:

$$Y_{i,t} = \sum_{t=2014}^{t=2019} \beta_t High\ Exposure_i \times D_{year=t} + \delta_i + \gamma_{i,c,t} + \epsilon_{i,t} \tag{3}$$

High exposure$_i$ is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 4-digit sector. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets.$D_{year=t}$ is a dummy equal to one for the year t. In order to avoid the dummy variable trap, we leave out the 2016 dummy (i.e. the last year before the regulatory change takes place). δ_i is a firm fixed effect and $\gamma_{i,c,t}$ is an industry-country-year fixed effect.

Table 1: **Summary Statistics**

	All firms				
	Mean	SD	P1	P99	N
Panel A					
Operating revenue (in EUR th.) over emissions (ton CO2 equivalent)	50.45	235.85	0.05	1949.78	20,095
Operating revenue (EUR th.)	689,111	4,103,388	962	12,230,222	20,095
Ln(turnover))	18.15	1.94	13.78	23.01	20,095
Emissions (ton CO2 equivalent)	314,398	1,571,594	41	6,481,606	20,095
Ln(Emissions)	10.19	2.25	3.74	15.51	20,095
Shock exposure	-0.01	0.04	-0.21	0.07	20,095
Ln(Total assets)	18.43	1.93	14.32	23.67	20,087
P/L before tax over sales	-0.03	7.20	-0.65	0.59	18,233
Return on assets (%)	4.58	10.03	-33.57	38.81	19,996
Fixed assets over total assets (%)	56.67	23.35	0.31	95.86	20,077
Leverage	0.54	0.23	0.07	0.99	19231
Cash holdings over total assets (%)	5.77	8.88	0.00	46.45	18,470
Panel B					
M&A greenness$_{i,j,t}$	0.67	1.21	0.00	4.76	1,132
M&A within the EU ETS$_{i,j,t}$	0.81	0.39	0.00	1.00	1,107
M&A new target$_{i,j,t}$	0.61	0.49	0.00	1.00	1,132
Panel C					
M&A greenness$_{i,t}$	0.67	1.12	0.00	4.64	500
M&A within the EU ETS$_{i,t}$	0.86	0.35	0.00	1.00	492
M&A new target$_{i,t}$	0.70	0.46	0.00	1.00	500

This table documents the summary statistics for the variables used throughout the paper. Panel A provides information on the firm-level variables, Panel B includes deal-level summary statistics for the M&A variables, and panel C reports firm-level summary statistics for the M&A variables.

Table 2: **Emission efficiency and ETS regulatory tightening**

	Dependent variable = ln(operating revenue / emissions)$_{i,t}$			
	(1)	(2)	(3)	(4)
Post_t	0.082***			
	(0.009)			
High exposure_i		-1.359***		
		(0.065)		
High $\text{exposure}_i \times \text{Post}_t$			0.049***	0.087***
			(0.017)	(0.019)
Observations	20,095	20,095	20,095	18,778
R-squared	0.954	0.078	0.963	0.968
Firm FE	Y	N	Y	Y
Year FE	N	Y	Y	N
Ind-country-year FE	N	N	N	Y
N. of firms	3,952	3,952	3,952	3,706

The sample consists of firm-year level observations for the period 2014-2019. The dependent variable in each column is the natural logarithm of a firm's emission efficiency, proxied by its operating revenue (in thousand EUR) over emissions (in ton CO2 equivalents). $Post_t$ is a dummy equal to one from 2017 onwards. *High* $exposure_i$ is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 2-digit sector. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. Robust standard errors (clustered at the firm level) are in parentheses.

Table 3: **Emissions, operating revenue and ETS regulatory tightening**

	Ln(emissions)$_{i,t}$		Ln(operating revenue)$_{i,t}$	
	(1)	(2)	(3)	(4)
High exposure$_i$ × Post$_t$	-0.072***		0.012	
	(0.039)		(0.014)	
High exposure$_i$ × D$_{Year=2017}$		-0.045***		0.021
		(0.017)		(0.013)
High exposure$_i$ × D$_{Year=2018}$		-0.094***		0.010
		(0.020)		(0.016)
High exposure$_i$ × D$_{Year=2019}$		-0.113**		-0.060
		(0.049)		(0.054)
Observations	18,778	18,778	18,778	18,778
R-squared	0.975	0.975	0.983	0.983
Firm FE	Y	Y	Y	Y
Ind-country-year FE	Y	Y	Y	Y
N. of firms	3,706	3,706	3,706	3,706

The sample consists of firm-year level observations for the period 2014-2019. The dependent variable in columns 1 and 2 is the natural logarithm of a firm's emissions (in ton CO2 equivalents). In columns 3 and 4, the dependent variable is the natural logarithm of a firm's operating revenue (in thousand EUR). $Post_t$ is a dummy equal to one from 2017 onwards. $High\ exposure_i$ is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 2-digit sector. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. $D_{Year=X}$ is a dummy equal to one for the year X. All specifications include firm fixed effects and industry-country-year fixed effects. Robust standard errors (clustered at the firm level) are in parentheses.

Table 4: **Initial endowments of ETS rights**

	On carbon leakage list	Not on carbon leakage list		
		all	electricity producers	all, except electricity producers
	(1)	(2)	(3)	(4)
	Dep var = **ln(operating revenue / emissions)**$_{i,t}$			
High exposure$_i$ × Post$_t$	0.048	0.107***	0.157**	0.098***
	(0.033)	(0.024)	(0.072)	(0.024)
Observations	5,727	12,672	2,091	10,546
R-squared	0.965	0.969	0.940	0.977
Firm FE	Y	Y	Y	Y
Ind-country-year FE	Y	Y	Y	Y
N. of firms	1,136	2,503	407	2,091

The sample in column 1 consists of firm-year level observations for the period 2014-2019 for all firms that are on the carbon leakage list. The sample in column 2 consists of all firms that are not on the carbon leakage list. In columns 3 and 4, we look at a sub-sample of firms from column 2: column 3 includes all electricity producers, while column 4 includes all non-electricity producers. The dependent variable in each column is the natural logarithm of a firm's emission efficiency, proxied by its operating income (in thousand EUR) over emissions (in ton CO2 equivalents). *Post$_t$* is a dummy equal to one from 2017 onwards. *High exposure$_i$* is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 2-digit sector. For each column, it's calculated based on the sample in that column. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. All columns include firm fixed effects and industry-sector-year fixed effects. Robust standard errors (clustered at the firm level) are in parentheses.

Table 5: **ETS price increases and M&A activity: M&A greenness**

	Dep var = **M&A greenness**$_{i,t}$			
	Full sample		On carbon leakage list	Not on carbon leakage list
	(1)	(2)	(3)	(4)
Post$_t$	-0.126			
	(0.111)			
High exposure$_i$	-0.230**			
	(0.116)			
High exposure$_i$ $\times$ Post$_t$	0.350**	0.480**	0.273	0.644**
	(0.150)	(0.200)	(0.261)	(0.294)
Observations	806	500	242	258
R-squared	0.017	0.536	0.631	0.487
Firm Controls	Y	Y	Y	Y
Firm FE	N	Y	Y	Y
Year FE	N	Y	Y	Y
N. of firms	481	175	82	93

Sample: firm level data of all M&A's of ETS firms with financials between 2014 and 2019, matched with their financials. M&A greenness$_{i,t}$ is based on textual analysis of three variables included in the Zephyr database containing text about the M&A's, namely: dealeditorial, dealrationale, and dealcomments. More specific, M&A greenness$_{i,t}$ captures the percent of words in these textual variables that relate to greenness, averaged over all acquisitions done by firm i in year t. The textual analysis employed an environmental dictionary looking for words like "green", "climate", "emission", etc. Firm controls included in the regressions are Ln(Total assets)$_{i,t}$ and Profit margin$_{i,t}$.

Table 6: **ETS price increases, M&A activity, and M&A greenness: firm level evidence**

	Dep var = **M&A greenness**$_{i,t}$		
	Not on carbon leakage list		
	all	electricity producers	all, except electricity producers
	(1)	(2)	(3)
High exposure$_i$ × Post$_t$	0.644**	1.165*	0.573*
	(0.294)	(0.577)	(0.337)
Observations	258	42	215
R-squared	0.487	0.661	0.449
Firm Controls	Y	Y	Y
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N. of firms	93	14	79

Sample: firm level data of all M&A's of ETS firms with financials between 2014 and 2019, matched with their financials. M&A greenness$_{i,t}$ is based on textual analysis of three variables included in the Zephyr database containing text about the M&A's, namely: dealeditorial, dealrationale, and dealcomments. More specific, M&A greenness$_{i,t}$ captures the percent of words in these textual variables that relate to greenness, averaged over all acquisitions done by firm i in year t. The textual analysis employed an environmental dictionary looking for words like "green", "climate", "emission", etc. Firm controls included in the regressions are Ln(Total assets)$_{i,t}$ and Profit margin$_{i,t}$.

Table 7: **ETS price increases and M&A activity: firm policy reactions**

Panel A	Dep var = **M&A within the EU ETS**$_{i,t}$			
	Full sample		On carbon leakage list	Not on carbon leakage list
	(1)	(2)	(3)	(4)
Post_t	-0.028			
	(0.026)			
High exposure_i	-0.040			
	(0.033)			
High $\text{exposure}_i \times \text{Post}_t$	0.078*	0.123**	0.118	0.137*
	(0.041)	(0.061)	(0.106)	(0.070)
Observations	795	486	232	254
R-squared	0.032	0.521	0.524	0.505
Firm Controls	Y	Y	Y	Y
Firm FE	N	Y	Y	Y
Year FE	N	Y	Y	Y
N. of firms	478	169	77	92

Panel B	Dep var = **M&A new target**$_{i,t}$			
	Full sample		On carbon leakage list	Not on carbon leakage list
	(1)	(2)	(3)	(4)
Post_t	-0.024			
	(0.050)			
High exposure_i	0.074			
	(0.049)			
High $\text{exposure}_i \times \text{Post}_t$	0.049	0.138	-0.028	0.263*
	(0.068)	(0.096)	(0.131)	(0.134)
Observations	806	500	242	258
R-squared	0.023	0.471	0.466	0.508
Firm Controls	Y	Y	Y	Y
Firm FE	N	Y	Y	Y
Year FE	N	Y	Y	Y
N. of firms	481	175	82	93

Sample: firm level data of all M&A's of ETS firms with financials between 2014 and 2019, matched with their financials. M&A within the $\text{ETS31}_{i,t}$ equals one if firm i acquired at least 1 target in year t that is located in one of the 31 countries of the regulated ETS area, and zero if none of the targets was located inside this area. M&A new $\text{target}_{i,t}$ equals 1 if firm i acquired at least 1 target where the firm had no prior stake in before this deal in year t, and zero otherwise. Firm controls included in the regressions are Ln(Total $\text{assets})_{i,t}$ and Profit $\text{margin}_{i,t}$.

Table 8: **Emission Efficiency and ETS regulatory tightening: Robustness**

	(1)	(2)	(3)	(4)	(5)
	ln(sales/emissions)	ln(FA/emissions)	ln(TAs/emissions)	ln(operating revenue/emissions)	
High exposure$_i$ × Post$_t$	0.078***	0.124***	0.116***	0.093***	
	(0.019)	(0.024)	(0.019)	(0.018)	
Ln(Total assets)$_{i,t-1}$				0.398***	
				(0.038)	
Profit margin$_{i,t-1}$				0.024	
				(0.038)	
Allowance shortage$_i$ × Post$_t$					1.227***
					(0.427)
Observations	17,115	18,661	18,769	16,876	18,778
R-squared	0.970	0.963	0.969	0.970	0.970
Firm FE	Y	Y	Y	Y	Y
Ind-country-year FE	Y	Y	Y	Y	Y
N. of firms	3,376	3,689	3,706	3,355	3,706

The sample consists of firm-year level observations for the period 2014-2019. The dependent variables in columns 1 to 3 are alternative proxies for emission efficiency, respectively sales over emissions (column 1), fixed assets over emissions (column 2) and total assets over emissions (column 3). For all these variables, we use their natural logarithm as dependent variable. The dependent variable in column 4 and 5 is the natural logarithm of a firm's emission efficiency, proxied by its operating income (in thousand EUR) over emissions (in ton CO2 equivalents). *Post*$_t$ is a dummy equal to one from 2017 onwards. *High exposure*$_i$ is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 2-digit sector. A firm's *Allowance shortage*$_i$ is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. *Ln(Total assets)*$_{i,t-1}$ is the one-year lagged natural logarithm of a firm's total assets. *Profit margin*$_{i,t-1}$ is the one-year lagged profit margin of a firm. All columns include firm fixed effects and industry-sector-year fixed effects. Robust standard errors (clustered at the firm level) are in parentheses.

Table 9: **Main results robust to dropping largest emitting sectors**

	Dropping largest sector (NACE 35)			Dropping 3 largest sectors (NACE 35, 23, 24)		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(operating rev./ emissions)	ln(emissions)	ln(operating rev.)	ln(operating rev./ emissions)	ln(emissions)	ln(operating rev.)
High exposure$_i$ × Post$_t$	0.061***	-0.048***	0.009	0.079***	-0.051**	0.022
	(0.020)	(0.016)	(0.016)	(0.030)	(0.023)	(0.022)
Observations	13,340	13,340	13,340	8,864	8,864	8,864
R-squared	0.972	0.978	0.983	0.965	0.974	0.978
Firm FE	Y	Y	Y	Y	Y	Y
Ind-country-year FE	Y	Y	Y	Y	Y	Y
N. of firms	2,644	2,644	2,644	1,759	1,759	1,759

The sample in columns 1 to 3 consists of firm-year level observations for the period 2014-2019 for firms that are not part of NACE sector 35 (*Electricity, gas, steam and air conditioning supply*). The sample in columns 4 to 6 consists of firm-year level observations for the period 2014-2019 for firms that are not part of NACE sector 35 (*Electricity, gas, steam and air conditioning supply*), NACE sector 23 (*Manufacture of basic metals*) or NACE sector 24 (*Manufacture of coke and refined petroleum products*). The dependent variable in columns 1 and 4 is the natural logarithm of a firm's emission efficiency, proxied by its operating income (in thousand EUR) over emissions (in ton CO2 equivalents). The dependent variable in columns 2 and 5 is the natural logarithm of a firm's emissions (in ton CO2 equivalents). In columns 3 and 6, the dependent variable is the natural logarithm of a firm's operating income (in thousand EUR). *Post$_t$* is a dummy equal to one from 2017 onwards. *High exposure$_i$* is a dummy equal to one for all firms with an allowance shortage above the median in their NACE 2-digit sector. A firm's allowance shortage is defined as the firm-level 2013-2016 average of the difference between the total verified emissions and the number of free allowances, scaled by total assets. All specifications include firm fixed effects and industry-country-year fixed effects. Robust standard errors (clustered at the firm level) are in parentheses.

Appendix A: textual analysis and the M&A Greenness indicator

We construct an $M\&A\ Greenness_{i,j,t}$ variable based on textual information about merger and acquisition deals. The text is taken from three variables in the Zephyr database: deal editorial, deal rationale, and deal comments, which are available for each M&A deal. Using text analytical tools, we obtain a variable $M\&A\ greenness_{i,j,t}$ which measures the % of words in the text that is part of the 'green' dictionary for firm i's acquisition of target j in year t.

The fragments of text below come from examples of two acquisitions that can be considered as green (i.e. that have a high $M\&A\ Greenness_{i,j,t}$ score), namely examples 1 and 2; and two acquisitions that cannot be considered green (i.e., that have an $M\&A\ Greenness_{i,j,t}$ score that is equal to 0), namely examples 3 and 4.

Example 1 (green)

"...On 04/06/19 Mr Frank Mastiaux, EnBW CEO, said: The acquisition of VALECO marks a significant step forward in the rigorous expansion of EnBW in ***renewable energy*** *to make them one of the main pillars of the company. In addition, the target of reaching 1,000 MW of installed capacity in the* ***onshore wind*** *sector by 2020 has now nearly been achieved. With VALECO, we now have one of the most experienced players on the French* ***renewable energy*** *market at our side. We will exploit the growth opportunities together and become one of the Top 5 players on the French* ***wind*** *and* ***solar*** *market in the medium term as strong partners..."*

Example 2 (green)

"...On 07/06/17 Mr Tomas Pleskac, CEZ Group chief ***renewable energy*** *and distribution officer, stated: This is our first project in the French* ***renewable energy*** *market, and we believe that more will follow. With similar acquisitions in countries with stable regulatory environments, we continue to fulfil our strategy aimed at increasing our operating profit before depreciation from* ***renewable sources*** *by CZK 3 bn (EUR 114 mil) by 2020..."*

Example 3 (not green)

"...On 11/01/17 Mr Finn Klostermann, CEO of Danish Crown Beef, said: We are convinced that we can generate further growth by integrating the German business. We will have access

to larger supplies of German raw materials, and the German company will be able to access Danish Crown Beef's markets worldwide..."

Example 4 (not green)

"...On 28/07/15 the CEO of Daigeo, Mr Ivan Menezes, said: We have worked very successfully with Heineken and NBL throughout our partnership, growing the beer business and establishing market leadership in spirits. From this leadership position we now believe that Diageo has the necessary scale to move to the next stage of growth for spirits, RTDs and our beer and cider portfolio in a focused, simplified ownership structure..."