Do Carbon Prices Affect Stock Prices?*

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Abstract

We explore how carbon pricing affects corporate financial performance. Our setting exploits time series changes in European carbon allowance prices and cross-sectional heterogeneity in carbon emissions during Phase 3 of the European Union Emissions Trading Scheme (EU ETS). We find that the relationship between carbon prices and stock prices depends critically on the proportion of verified emissions covered by emission permits: For firms with a significant shortfall in emissions allowances, an increase in daily carbon prices is associated with a decrease in contemporaneous stock prices. For firms with a greater permit coverage, an increase in daily carbon prices is associated with higher contemporaneous stock prices. We provide additional evidence that firms with a significant permit shortfall reduce regulated but not global emissions.

JEL Classification: G12, G30, Q54, Q58

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1 Introduction

The European Union launched the EU Emissions Trading Scheme (EU ETS) in 2005 as its flagship policy to drive reductions in greenhouse gas (GHG) emissions and the transition to a net-zero carbon economy. The EU ETS is currently in Phase 4 (2021-2030). Phases 1 (2005-2007) and 2 (2008-2012) were largely institutional experimentation phases with respect to the allocation, trading, and banking of carbon emission allowances. During Phase 3 (2013-2020), the focus of our study, the EU ETS underwent significant changes and attained maturity. First, an EU-wide cap on verified emissions was introduced, which decreased annually by a linear reduction factor of 1.74%. Second, the proportion of emissions allowances that were allocated for free decreased significantly. For example, free allocations to manufacturing firms decreased from 80% in 2013 to 30% in 2020. Third, the expansion of sectors included in the ETS increased, with more firms subject to carbon pricing. Most importantly, the cost of emission allowances increased sixfold over Phase 3, rising from €5 for a ton of CO_2 in 2013 to €30 in 2020.

In this paper, we examine whether the EU cap-and-trade system during Phase 3 has had an effect on the corporate financial performance for the companies included in the EU ETS. We link installations in the EU ETS Union Registry and obtain the total amount of allowances allocated for free (hereafter referred to as "free permits") and verified emissions (hereafter referred to as "regulated emissions") for firms that are listed in stock exchanges in Europe. We use free permits and regulated emissions to capture the *firm-specific* exposure to EU carbon prices. We obtain daily stock returns data from Datastream, daily carbon prices data from the European Energy Exchange, annual corporate financial data from Orbis and annual global carbon emissions data from Trucost. For these companies we can establish a direct link between carbon prices and their stock returns, operating performance, and emissions activities in the EU and globally. We do this by estimating several specifications of a regression model that associates daily company stock returns (or yearly ROA and emissions) with daily changes in carbon prices (or the log of the year-end carbon price), and the shortfall in individual company carbon emission allowances relative to their regulated emissions, controlling for other company characteristics and for exposure to Fama-French market risk factors.

Our study makes two novel contributions to a growing literature examining the relationship between carbon prices and stock prices. First, we determine the total exposure to EU carbon prices of listed companies by identifying which installations are subject to the EU

ETS, measuring the regulated emissions of each installation, and aggregating over all installations owned by each listed company. This is a major challenge, as it requires identifying which of the over 14,000 ETS installations in the EU ETS Registry are owned by listed companies, for which we have stock price and financial data. We are able to identify around 3,000 installations that are owned by 284 listed companies in Europe and thereby to determine both the total amount of free permits and regulated emissions of these listed companies.

We do this for the entire period covered by Phase 3, in particular for the later years of Phase 3 when carbon prices surged significantly. Such precise measures of firm-specific carbon price exposure have been lacking in prior studies. By measuring the regulated emissions of the installations owned by each listed company we are able to determine how much a company is affected by changes in the EU carbon price. The key finding of our study is that the impact of EU carbon prices on stock prices critically depends on how much a company's regulated emissions are covered by emission permits. If the company has a shortfall in emission permits then an increase in the EU carbon price is associated with a decline in the stock price, but if the company has a surplus in emission permits then the increase in the EU carbon price is associated with an increase in stock price. This relation between carbon price and stock price is especially significant in the later years of Phase 3 when the carbon price approached €30 for a ton of CO_2.

The second contribution of our study relates to the company's total carbon emissions, whether they are regulated under the EU ETS or not. By keeping track of total carbon emissions we can explore how changes in the EU carbon price affect not only the company's regulated emissions but also its total emissions. Our main finding here is that while firms with a significant shortfall in emission permits do lower their regulated emissions in the EU, they do not lower their emissions globally. Together, these findings suggest that while the EU carbon price has reached levels in the later years of Phase 3 that materially penalize firms with a shortfall in free permits, it is likely that the EU carbon price only exerts a regional effect on corporate carbon emissions.

Determining the effects of carbon pricing on corporate profitability is important to inform policymakers and to assess whether the EU ETS has the desired effects of creating incentives to limit carbon emissions. Earlier studies have focused on Phase 1 (2005-2007), when an excess of emission allowances led to the eventual collapse of the carbon price, and on Phase 2 (2008-2012), when the great recession and the resulting decrease in demand for allowances depressed the carbon price. Given these circumstances, it is not surprising that the studies covering these phases have not found conclusive evidence of an effect of carbon pricing on profitability or stock returns. Another reason why the findings of these studies are inconclusive is that the empirical methodologies they use do not keep track of firm-level regulated or unregulated carbon emissions.[1] Oberndorfer (2009), Veith et al. (2009), and Scholtens and van der Goot (2014) find a positive correlation between changes in the EU carbon price and stock returns in Phase 1. In contrast, Mo et al. (2012), and Zhu et al. (2018) found a negative correlation between carbon prices and stock returns in Phase 2.

In independent work Millischer et al. (2023) (MEF) have undertaken a closely related study. They address the same basic question, cover much of the same data, but consider somewhat different empirical specifications. Their results are consistent with and highly complementary to ours. Given the closeness of their study we provide greater detail on the commonalities and key differences in approaches. The two studies cover the same sample period (MEF also include the first year of Phase 4) and a similar sample of companies. They take similar approaches to matching installations under the EU ETS with their listed parent companies. Our matching procedure builds on Martin et al. (2014) whereas MEF rely on a procedure developed by Jaraitė et al. (2014).[2] The two studies, however, consider somewhat different specifications. MEF estimate the direct effect of carbon prices on stock prices, whereas we compare the differential effects of carbon pricing on stock prices conditional on permit shortfall/permit coverage.[3] That is, we highlight the critical importance of a company's positive or negative net exposure to carbon prices (whether it has a shortfall or excess of allowances), whereas the specifications in MEF only capture gross exposures. These different specifications produce somewhat different findings. Some of the key findings in MEF are: i) a positive association between carbon prices and stock prices; ii) however, MEF also find that carbon prices are negatively associated with stock prices for firms with high carbon intensity; iii) carbon prices are not related to stock prices for firms with emissions that are covered by freely allocated allowances; iv) these findings hold for electricity companies, but

[1] The empirical methodologies fall into two large categories. First, Oberndorfer (2009), Veith et al. (2009) and Mo et al. (2012) perform security level analyses using multifactor models. Second, Oberndorfer (2009), Scholtens and van der Goot (2014) and Zhu et al. (2018) perform industry or sector level analyses using portfolios. Additionally, Zhu et al. (2018) use a quantile regression methodology to study whether carbon prices affect markets with higher and lower returns differently. Bushnell et al. (2013) use an event study methodology to study how stock prices respond to large swings in carbon prices.

[2] MEF match 5800 account holders in the EU ETS with companies in Orbis and identify 2112 account holders that are controlled by 338 listed companies. We identify 13,143 installations (nearly the entire universe of the EU ETS in Phase 3). Of these, we identify 3,221 installations that are owned by 366 listed companies.

[3] MEF consider changes on a weekly frequency, whereas we look at daily changes. They include industry-month fixed effects, whereas we include day (and industry) fixed effects, which absorb the direct effect of carbon prices on stock prices. MEF cluster standard errors by firms, whereas we cluster by firm and date.

not in other sectors. Our study also goes beyond MEF in several respects. We show that the EUA market is informationally efficient by establishing the unit root process for EUA prices. Second, we show how EUA prices are linked to stock prices through a profitability channel. Third, we estimate the real effects of EUA prices on verified and non-verified emissions.

Another earlier related study by Bushnell et al. (2013) finds that firms with higher carbon intensity (emissions per MWh or market cap) obtained higher abnormal stock returns following the unexpected collapse of EU carbon prices in April 2006. Bushnell et al. (2013) also look at the permit coverage of regulated emissions of electricity companies and find an insignificant negative effect on stock returns of companies with an excess coverage following the collapse of the EU carbon price.

Carbon prices rose sharply over the period covered by Phase 3. After remaining below €10 per tonne of CO_2 in the early years of Phase 3, carbon prices increased from 2018 on, reaching a high of €33.28 on 28^{th} December 2020. In addition the allocation of free permits was substantially reduced. It is therefore to be expected that the effect of carbon prices on stock valuations is likely to be less pronounced in the early years of Phase 3, when carbon prices were low and a larger proportion of permits was freely allocated. This is indeed what we find: Carbon prices only had a significant negative effect on the stock price of firms with a permit shortfall in the 2018-2020 sub-period. We also find that the carbon price only had a significant positive effect on the stock price of firms with the largest permit coverage in the 2018-2020 sub-period.

We further explore the channels through with the carbon price affects financial performance. Our second main finding is that the direct economic channel through which carbon pricing affects corporations is through the impact on profitability. Firms with a significant permit shortfall see their profitability impaired following a rise in carbon prices, while firms with a positive permit coverage see an increase in their profitability. In a nutshell, when carbon prices rise firms with a surplus of allowances realize higher profits and firms with a deficit in allowances realize lower profits.

In addition, we explore how carbon pricing affects corporate behavior. We explore whether increases in carbon prices induced firms to cut their emissions. Our third main finding is that companies with a significant allowance shortfall have reduced their regulated emissions in response to a rise in carbon prices. However, in contrast with Colmer et al. (2020), we do not find any evidence that firms that have a significant permit shortfall have increased their capital expenditures in an effort to reduce their emissions.

The majority of empirical studies on how carbon pricing affects financial performance find that stock returns are significantly positively associated with carbon prices in Phase 1, but the relationship becomes significantly negative in Phase 2. Oberndorfer (2009), Veith et al. (2009), Bushnell et al. (2013), and Zhu et al. (2018) interpret this finding through a cost pass-through channel, with firms being able to pass on the increases in carbon prices to consumers. Oberndorfer (2009), Mo et al. (2012), Oestreich and Tsiakas (2015) and Zhu et al. (2018) also highlight the role of windfall gains from free allocations and the change in permit allocations between Phase 1 and Phase 2. Finally, Zhu et al. (2018) also find that carbon price changes are positively associated with stock returns during Phase 1, and negatively associated with stock returns in Phase 2. They suggest that this reversal may have been due to the global financial crisis and the European sovereign debt crisis. By constructing firm-specific exposures to carbon prices using ETS emissions data, we contribute to this literature by showing that the relationship between carbon prices and stock returns depends critically on permit coverage. We also provide evidence that this is driven by a profitability channel, which is partially consistent with the windfall hypothesis but not the cost pass-through hypothesis.[4]

Our paper is also related to a strand of literature that uses firm-level global carbon emissions to study the relationship between carbon emissions and stock returns. Bolton and Kacperczyk (2021) provide evidence that investors demand compensation for exposure to carbon emissions risk in the US, and Bolton and Kacperczyk (Forthcoming) provide evidence that carbon transition risk is priced globally in stocks and varies with investor awareness, the size of the renewable energy sector, and carbon emissions regulatory risk. Our study uses firm-level carbon emissions under the EU ETS to capture a firm's exposure to carbon pricing, and shows that carbon prices affect stock prices via a profitability channel.

Finally, our paper is related to the literature on the effectiveness of climate policies. An important question is whether emissions reductions achieved through carbon pricing are undone by firms switching activities to jurisdictions where they can escape carbon pricing. We find that there is no carbon leakage in Phase 3 for the regulated firms in our sample. Yet, EU carbon prices have had no significant effect on firm-level non-EU scope 1 emissions. Most closely

[4] If the cost pass-through hypothesis holds, we should find revenue to be positively associated with carbon prices. However, in un-tabulated results, we find that the log of sales is not significantly related to the log of carbon prices.

related to this paper is Dechezleprêtre et al. (2022), who show that in between 2007 and 2014, modest carbon prices did not induce multinational companies to displace their carbon emissions from Europe to non-EU subsidiaries. The wider literature is surveyed in Martin et al. (2016). Also, using administrative data on French manufacturing firms, Colmer et al. (2020) find that regulated firms reduce carbon emissions by 8%-12% without an increase in imports in Phase 2. Focusing on foreign direct investment, Borghesi et al. (2020) provide some evidence of the establishment of foreign subsidiaries and a larger effect on production in existing foreign subsidiaries among Italian firms, and Koch and Basse Mama (2019) find a small effect in German multinational firms that are less capital intensive. Using the Californian cap-and-trade program, Bartram et al. (2022) show that financially constrained firms shift production and emissions out of California. Focusing on the syndicated loan market, Benincasa et al. (2022) find that increases in domestic climate policy stringency leads to an increase in cross-border lending, which suggests possible carbon leakage via debt markets. Our paper shows that while higher carbon prices in the EU ETS lowers emissions within the EU for firms with a significant permit shortfall, global emissions for these firms remain unaffected. This suggests that a regional cap-and-trade system only has regional effects.

The remainder of the paper is organized as follows. Section 2 describes the institutional background. Section 3 develops predictions from a simple model with financial constraints. Section 4 describes the empirical setting. Section 5 discusses the results. Section 6 presents our robustness checks. Section 7 concludes.

2 Institutional Background

The EU ETS, set up in 2005, is the first international cap-and-trade scheme on greenhouse gas emissions.[5] Under the system, emissions from operating installations must be covered by tradeable emissions allowances. Each allowance gives the holder the right to emit one ton of carbon dioxide (CO_2), or the equivalent amount of other powerful greenhouse gases (European Commission (2022d)). The purpose of trading of allowances is so that "emissions are cut where it costs least to do so", and to promote investment and innovation in low-carbon technologies (European Commission (2022c)).

There have been several phases in the development of the EU ETS. Phase 1 (2005-2007)

[5] The EU ETS covers (1) carbon dioxide (CO_2) from electricity & heat generation, and production activities in energy-intensive industry sectors, (2) nitrous oxide (N_2O) from production of nitric, adipic, and glyoxylic acids, and glyoxal, and (3) perfluorocarbons (PFCs) from the production of aluminium (European Commission (2022c)).

and Phase 2 (2008-2012) were largely institutional experimentation phases, which involved setting up the infrastructure and coverage of the trading scheme. Significant changes have been made during Phase 3 (2013-2020), the sample period of this study. First, an overall EU cap in allowable emissions was introduced, which decreases by a linear reduction factor of 1.74% annually (European Commission (2022d)). Second, main method for the distribution of allowances was via auction rather than free allowance grants: 57% of allowances were auctioned off (European Commission (2022e)) and free allocations for manufacturing firms decreased from 80% in 2013 to 30 % in 2020 (European Commission (2022a)). Electricity producers were required to purchase all their allowances, although some free allocations were permitted in EU member states that were modernizing their energy sectors (European Commission (2022f)).

During Phases 1 and 2 too many allowances had been granted, so that the carbon price plunged to €0.10 in Phase 1, and €2.81 in Phase 2. It was only late in Phase 3 that the allowance price reached levels that analysts deemed material. Carbon prices have languished substantially below €10 per ton of CO_2 from 2013 — the beginning of Phase 3 — to 2018. However, carbon prices have risen significantly since 2018, from a low of €7.62 on January 8, 2018 to a high of €33.28 on December 28, 2020. In the spring of 2022 the carbon price has briefly exceeded €90 per ton of CO_2.[6] Given that emissions allowance prices have been so low for so long it is reasonable to expect that the impact of carbon pricing on financial performance and stock valuations only manifests itself in recent years, when the carbon price began to rise above €20.

3 Predictions from a Simple Model with Financial Constraints

We consider a single firm in a simple static setting where the firm can invest in carbon emission abatement and/or asset maintenance at the end of a first production and sales cycle. These investments, in turn, generate a continuation value V. The firm has an operating asset K. The operating asset generates cash-flow $Y = AK$ and carbon emissions $C = \lambda K$. The firm has a carbon emission allowance E. If $E < \lambda K$ the firm must purchase additional allowances at price p, and if $E > \lambda K$ the firm can generate additional cash-flow $p(E - \lambda K)$.

[6] Reuters (2022) reported that analysts on average expected carbon prices to be €84.14 in 2022, €91.71 in 2023 and €94.11 in 2024.

End of period cash-flows are therefore equal to

$$Y + p(E - \lambda K), \tag{1}$$

and the firm's accumulated internal funds at the end of the period are

$$w = Y + p(E - \lambda K). \tag{2}$$

At the end of the period the firm can make capital expenditures I to either reduce its emissions from operations going forward or maintain its operating asset. The investment has decreasing returns: By investing I the firm generates an incremental cash flow $f(I) > 0$ going forward which is increasing and concave in I: $f'(I) > 0$ and $f''(I) < 0$.

The firm's internal funds w may not be sufficient to fund its desired capital expenditures. The firm can raise additional external funds, but these are more costly (that is a simple way of modelling financial constraints). If the firm raises outside funds o it incurs a cost $\psi(o)$. We assume that $\psi(o)$ is increasing and convex: $\psi_o > 0$ and $\psi_{oo} \geq 0$. The firm chooses its investment level I and outside financing o to maximize its payoff:

$$\max_{I,o} \quad f(I) + w - [I + \psi(o)], \tag{3}$$

where $o = \max\{I - w, 0\}$. We denote by $V(w)$ the firm's continuation value as a function of its internally accumulated funds w.

When the firm has sufficient internal funds, or when there are no additional costs from outside funds the first-best optimal investment level is given by the first-order condition:

$$f'\left(I^{FB}\right) = 1. \tag{4}$$

The firm is financially constrained if $w < I^{FB}$ and if $\psi(o) > 0$ for any strictly positive amount of outside funds o. In that case the firm uses up its internal funds w first and raises the additional amount of funds $o = \max\{I - w, 0\}$ from outside capital markets. The firm's optimal investment level I^* is then given by the following first-order condition:

$$f'(I^*) = 1 + \psi_o (I^*(w) - w). \tag{5}$$

The value of the firm after substituting for $I^*(w)$ (given by (5)) into its payoff function (3) is then given by:

$$V^*(w) = f\left(I^*(w)\right) + w - \left[I^*(w) + \psi\left(o^*(w)\right)\right], \tag{6}$$

where $o^*(w)$ is the outside financing amount

$$o^*(w) = I^*(w) - w\,. \tag{7}$$

From the envelope theorem, we then obtain the following key prediction:

$$V_w^*(w) = f'\left(I^*(w)\right) = 1 + \psi_o\left(e^*(w)\right) > 1. \tag{8}$$

In other words an additional dollar in internal funds is worth more than a dollar. This is a robust prediction that continues to hold in dynamic settings as shown in Bolton et al. (2011). Consider finally the effects of a change in EUA price p on firm value. We have

$$\frac{dw}{dp} = (E - \lambda K).$$

Therefore,

$$\frac{\partial V^*(w)}{\partial p} = f'\left(I^*(w)\right)(E - \lambda K),$$

so that firm value (or the stock price) increases with the EUA price p when the firm has an allowance surplus $E > \lambda K$, and decreases with the EUA price p when it has an allowance shortfall $E > \lambda K$. Moreover, the size of the effect of a change in EUA price is bigger the larger the allowance surplus or shortfall.

For simplicity we have illustrated the main relevant prediction for our analysis — that firm value increases with the EUA price p when the firm has an allowance surplus — in a static setting. The model can be extended to a dynamic setup as in Bolton et al. (2011), and it can be shown that the key prediction extends to such a dynamic setting. The additional consideration that can be introduced in the dynamic model is the choice for the firm to sell or bank any surplus in allowances at any moment in time. The firm will then prefer to sell rather than hoard its surplus allowances if the EUA price p exceeds the shadow value of its allowances. Either way, simple revealed preference logic implies that a firm with a surplus of allowances will always benefit from an increase in the EUA price p (and a firm with a shortfall will always be made worse off).

4 Empirical Setting

4.1 Data

4.1.1 ETS Carbon Emissions Data

We have obtained EU ETS emissions trading data from the European Union Transaction Log (EUTL). The EUTL is a registry run by the European Commission, which records and verifies all transactions in the trading system. It provides verified carbon emission levels for each regulated installation on an annual basis. We refer to these emissions as "regulated emissions". The EUTL also reports the number of allowances that are allocated for free to each installation each year. Specifically, the EUTL provides a breakdown of: (1) allowances allocated free of charge to existing installations; (2) allowances allocated free of charge for the modernization of electricity generation; and (3) allowances allocated free of charge from the new entrant reserve.[7]

We match the EUTL data for ETS installations to the Orbis data from Bureau van Dijk that provides financial data on corporations. Our matching procedure involves two steps. In the first step, we match ETS installations to firms in Orbis by national identifiers. In the second step, we match the installations with no national identifiers to firms via a name-matching algorithm and verify the matches based on country and sector information. The match between the installation in the EUTL and the firm in Orbis allows us to identify the listed parent companies using Orbis's ownership information on immediate shareholders, domestic ultimate owners, and global ultimate owners.[8] We then construct firm level ETS emissions and free allocations by aggregating across installations owned by the same publicly listed corporation each year.

In Phase 3 of the EU ETS (2013-2020), there were 13,914 stationary ETS installations in the EUTL. For 13,143 of these, corresponding to 97% of ETS emissions, we established a match to an Orbis firm. Given that many firms run more than one ETS installation, our final list comprises 7,985 Orbis firms. Using ownership information from Orbis, we determined that close to 10,000 installations are part of (ultimately) privately owned companies, whereas 3,221 installations were identified as being owned by 366 publicly traded companies. We further require firms to be listed in a country covered by the EU ETS and to have non-

[7] The New Entrants Reserve (NER) is a reserve of emission allowances for new installations (and existing installations that increase capacity and are eligible for additional free allocations).

[8] Ownership linkages in Orbis Europe are "current" and do not keep track of past changes in ownership. We use ownership linkages as of December 2020.

missing values for firm-level control variables. The final sample consists of 284 unique firms. Table B1 tabulates the filtering process. These represent close to 50% of EU ETS emissions, as reported in Table B2. There was a slight increase in the number of firms over Phase 3. These firms are primarily manufacturing firms from the United Kingdom, Germany and France. Table 1 provides descriptive statistics of the sample.

[Insert Table 1 Here]

4.1.2 Trucost Global Emissions Data

We also match the Trucost data on firm-level carbon emissions to our sample of 284 firms. The Trucost EDX dataset reports carbon emissions resulting from firms' economic activity as described in detail in Bolton and Kacperczyk (2021). These are divided into three categories: (1) Scope 1 emissions that result directly from production; (2) Scope 2 indirect emissions that arise from the production of the electricity (or heat or steam) the firm has bought and consumed; and (3) Scope 3 upstream indirect emissions that occur through the supply chain, waste disposal, or outsourced activities. Our primary focus is on Scope 1 emissions.

4.1.3 EU Allowance Price Data

We obtain daily spot prices for emissions allowances from the European Energy Exchange (EEX). EEX offers spot and derivative products on EU allowances and has been an auction platform for the EUAs during Phase 3.

[Insert Figure 1 Here]

Figure 1 plots the daily spot settlement price for EU allowances. Between 2013 and 2018, the daily spot price fluctuated between €5 and €10. The strong upward trend from 2018 onward is, according to experts due to a combination of three factors (European Central Bank, 2021). First, the aggregate emission allowances (the EU-wide cap in emissions) have been gradually reduced by 1.74% every year. Second, reforms in the allocation of allowances have been introduced, which further affected the carbon price. Mainly, the share of auctioned allowances has increased, and a market price stabilization mechanism, the Market Stability Reserve (MSR), has been introduced, which can hold an inventory of allowances so as to smooth year-by-year variations in the supply of excess allowances. Third, expectations of tighter future climate policies have shifted, with investors expecting a more rapid phase-out of free allowance allocations. Indeed, the EU Commission published the revised EU ETS Directive for Phase 4 in April 2018, and announced the European Green Deal at the end of 2019. Both of these announcements increased the credibility of the EU ETS scheme and hence carbon prices. (European Central Bank (2021)).

4.1.4 Stock Prices, Financial, and Global Emissions Data

We obtain daily stock prices in Euros from Datastream. As highlighted above, firm financial data is obtained from Orbis.

4.2 Variable Construction

This section defines and describes our main variables. Summary statistics are reported in Table 2.

Emissions Variables. Regulated emissions (i.e., the verified emissions from EUTL) are designated as $REGEM$. We construct an emissions allowances shortfall indicator, $SHORTFALL_{it-1}^{COVERAGE<50\%}$, which takes the value one if firm i's free permits are less than 50% of its regulated emissions in year $t-1$. The $SHORTFALL_{it-1}^{COVERAGE<50\%}$ indicator variable thus identifies the firms with a significant shortfall in emissions allowances in the previous year. Firms for which $SHORTFALL_{it-1}^{COVERAGE<50\%}$ takes the value one are exposed to an increase in the carbon price; these firms are required to purchase emissions allowances either in the auction or on secondary markets to cover the shortfall. In our sample there are 28% of firm-year observations with a significant shortfall in emissions allowances. As shown in Figure 2, the proportion of these firms has increased over time.

[Insert Figure 2 Here]

The complement to $SHORTFALL_{it-1}^{COVERAGE<50\%}$ is the variable $PERMIT\ COVERAGE_{it-1}$, which is given by the fraction of regulated emissions of firm i in year $t-1$ that are covered by free permits. The variable $PERMIT\ COVERAGE_{it-1}$ takes the value one if the total amount of free permits exceeds regulated emissions. This variable is a measure of how tight a constraint the firm faces with respect to its ETS regulated emissions. When this variable takes the value one the firm essentially faces no constraint; it has sufficient allowances to cover its regulated emissions. When the variable takes the value zero the firm needs to purchase allowances to cover some of its regulated emissions.

Free permits have been included in the design of the ETS to forestall carbon leakage (European Commission (2022b)). At the beginning of Phase 3, manufacturing firms on average received 80% of their emission allowances for free. This fraction gradually decreased to 30% by 2020 (European Commission (2022e)).

We keep track of the total size of free permits allocated to a firm through the measure $LOG(FREE\ EM_{it-1})$, which is the log of free permits allocated to firm i in year $t-1$. The logarithm implies that only firms with a positive amount of $FREE\ EM$ in year $t-1$ are included.

To aid interpretation, we standardize $PERMIT\ COVERAGE_{it-1}$ and $LOG(FREE\ EM_{it-1})$, by subtracting the sample mean and dividing by the sample standard deviation.

Financial Characteristics. We include a number of firm-level financial control variables that are likely to influence stock valuations. These comprise $LOG(TOTAL\ ASSETS)$, $NET\ INCOME/ASSETS$, $LOG(MV)$, where MV is given by the market capitalization of the company, $LOG(MARKET\ TO\ BOOK)$, $LEVERAGE$, and $ASSET\ TANGIBILITY$.

Security Characteristics. We also compute factor loadings on the Fama-French 5-factor model (market risk, size, value, investment and profitability) and momentum using a 252-day rolling window, to control for stock price changes that may be driven by these factors. Finally, we compute stock price volatility using a 252-day rolling window.

4.3 Hypothesis: Linking Carbon Prices to Stock Prices

Given that participants in the emissions allowance market can exploit any arbitrage gains from changes in carbon prices over time, we should expect that the equilibrium price of emission allowances be arbitrage-free. If that is the case, then any change in the equilibrium carbon price should be a permanent shock. We begin our analysis by testing this hypothesis and verify whether daily carbon prices follow a unit root process.

Firms emit carbon through their operations. This is in effect a form of joint production, with one vector of outputs being the products sold in the market and the other vector of outputs being GHG emissions. With the introduction of the emissions allowance market, a fraction of emissions is priced, so that the vector of emission outputs generates a loss for firms.All else equal, regulated firms without sufficient emissions permits are required to purchase emissions allowances, which will decrease earnings. If the carbon price change is a permanent shock, then the company's present discounted value and therefore its stock price should decrease in response to a carbon price increase. Moreover, this effect should be larger the bigger the gap between the firm's verified emissions and its freely allocated permits. Our leading hypothesis therefore is that there is a negative relation between contemporaneous stock prices and increases in the carbon price for the firms with verified emissions that exceed their allowances. Indeed, these firms will need to purchase more allowances and the compliance cost for these firms will be higher the higher is the carbon price. Vice versa, the firms that have a surplus in carbon emission allowances are potential sellers of allowances in the ETS. As sellers of allowances, these firms benefit from a price increase in the carbon market so that their stock price should be positively related to the carbon price.

4.4 Empirical Specification

4.4.1 Firm-Day Level Analyses

Our main empirical specification associates daily stock price changes with daily changes in carbon prices, taking into account company emissions-allowances shortfalls. We interact the allowance shortfall indicator with carbon prices, whilst controlling for company characteristics and other market risk factors that may affect the company's stock price:

$$\begin{aligned}\Delta P\%_{i\tau} = {}& \beta_1 SHORTFALL_{it-1}^{COVERAGE<50\%} \times \Delta EUA\%_\tau + \beta_2 \Delta EUA\%_\tau \\ & + \beta_3 SHORTFALL_{it-1}^{COVERAGE<50\%} + \gamma^T x_{it-1} + \alpha_\tau + \varepsilon_{it}\end{aligned} \tag{9}$$

where: $\Delta P\%_{i\tau}$ is the percentage change of firm i's stock price on day τ, $\Delta EUA\%_\tau$ is the daily percentage change in carbon prices from day $\tau-1$ to day τ, and $SHORTFALL_{it-1}^{COVERAGE<50\%}$ is the emissions allowances shortfall indicator, which takes the value one if firm i's free permits are less than 50% of its regulated emissions in year $t-1$. In other words, $SHORTFALL_{it-1}^{COVERAGE<50\%}$ identifies firms with a significant shortfall in emissions allowances in the previous year.

The first set of control variables includes the following lagged annual firm-specific variables: $LOG(ASSETS)$ in year $t-1$, $LEVERAGE$ the ratio of total debt to assets in year $t-1$, $TANGIBILITY$ the ratio of PPE to total assets in year $t-1$, $NET\ INCOME/ASSETS$ in year $t-1$. The second set of control variables include the following lagged daily firm-specific variables: $LOG(M/B)$ the market-to-book ratio on day $\tau-1$, $LOG(MV)$ on day $\tau-1$, $VOLATILITY$ the daily stock price volatility estimated using a 252-day rolling window, loadings on risk factors, market MKT, size SMB, value HML, operating profitability RMW, investment CMA, and momentum WML, calculated using a 252-day rolling window. We also include country, industry and date fixed effects. These control variables and fixed effects pick up other common sources of risk (than the risk with respect to changes in carbon allowance prices) that are tied to the company's operations and exposures to common aggregate risk factors.

We center our analysis around this main specification. To the extent that carbon prices have become a material cost during Phase 3, we expect to find a negative significant coefficient for β_1. When carbon prices increase, this hurts the bottom line of firms with the highest shortfall emission allowances the most, so that investors should be expected to lower the stock price of firms with the highest shortfall the most given that these firms will face the steepest cost increase as a result of higher carbon prices.

4.4.2 Firm-Year Level Analyses

As data on emissions and operations are only available at an annual frequency, we use the following empirical model at the firm-year level:

$$y_{it} = \beta_1 E_{it-1} \times LOG(EUA_{it}) + \beta_2 E_{it-1} + \beta_3 LOG(EUA_{it}) + \gamma^T x_{it-1} + \alpha_i + \alpha_t + \varepsilon_{it} \quad (10)$$

where: y_{it} is an outcome variable for firm i in year t. E_{it-1} is one of the emissions variables for firm i in year $t-1$. $LOG(EUA_{it})$ is the log of carbon prices at fiscal closing date for firm i and year t. Since firms have different fiscal year enddates, $LOG(EUA_{it})$ is firm-year specific. For the firm-year level analyses, we use the level of carbon prices rather than percentage changes, given that annualized changes are less easy to interpret. Since we are regressing levels on levels, we include firm fixed effects (α_i) to absorb time-invariant unobserved heterogeneity.

5 Results

We begin by reporting our findings on the dynamic process of carbon prices. We then proceed to the analysis of the effect of changes in carbon prices on stock prices. We further explore the effects of changes in carbon prices on operating performance.

5.1 Do Carbon Prices Follow a Random Walk?

Are changes in carbon prices transitory or permanent shocks? This is a fundamental first question for our analysis, since transitory shocks are less likely to have an impact on stock prices. We perform augmented Dickey-Fuller tests to examine whether the daily carbon price follows a random walk; that is, whether the change in carbon prices is a permanent shock. Since it is unclear a priori whether there is a time trend or a drift term in the evolution of carbon prices, we perform three versions of the test: (1) without an intercept, (2) with a linear time trend, and (3) with a drift term. We present our results (with the inclusion of one lagged difference and 30 lagged differences) in Table 3.

[Insert Table 3 Here]

Under all these specifications, we fail to reject the hypothesis that daily carbon prices follow a random walk. This means that the carbon price today is the best predictor of the carbon price tomorrow. Hence, the daily percentage changes in carbon price, $\Delta EUA\%_{\tau}$, can be interpreted as an unexpected permanent change in the cost of carbon allowances.

5.2 Do Carbon Prices Affect Stock Prices?

A company that has free permits that exactly cover its regulated emissions is not affected by changes in the carbon price since it does not need to purchase any additional allowances. This simple observation, however, ignores the effect of the carbon price on a company's incentives to reduce its emissions. Companies would in theory equate their marginal cost of reducing their emissions to the carbon price on the market. If the price increases, a company would reduce its emissions more, for example to sell free permits it would not need. The size of the carbon emission reduction would depend on the shape of its abatement cost curve. Also, there is likely to be an investment timing decision, given that emissions abatements are lumpy and irreversible investments, so that carbon emission reductions will not continuously react to daily changes in carbon price. A company with verified emissions that exceed its current allowances is negatively affected by an increase in the carbon price, since it must purchase more allowances to comply with emissions regulations in a timescale that does not allow for emission reducing investments to be implemented. The bigger the shortfall in allowances the higher is the cost impact of an increase in the carbon price for the company.

Given that the information on free allocations was publicly available at the installation level, it is reasonable to expect that investors were pricing in these effects. Accordingly, we expect a negative impact on the stock price following an increase in the carbon price for the companies that have a shortfall in allowances, and that this impact to be larger for a larger shortfall.

5.2.1 Permit Shortfall

To be sure, our key finding is that carbon price increases are negatively related with the stock price of firms with a significant allowance shortfall. Table 4 reports the results from estimating Equation 9.

[Insert Table 4 Here]

In Column (1) we regress daily stock price changes against the interaction of a shortfall indicator variable and daily percentage changes in carbon prices, without controlling for firm characteristics, nor market risk factors. In Column (2), we add company characteristics as controls, and in Column (3) we also include loadings on standard risk factors and stock volatility. Interestingly, the coefficient of the interaction term $SHORTFALL_{it-1}^{COVERAGE<50\%} \times \Delta EUA_{\tau}\%$ is highly significant and negative, and remains essentially unchanged under all three specifications. These results suggest that there is a contemporaneous negative association between stock prices and carbon prices for companies with an allowance shortfall. Investors perceive higher carbon prices to negatively impact the future profitability of companies with a shortfall in allowances. Based on the estimate in Column (3), for firms with a significant shortfall in emissions allowances, a one standard deviation change in $\Delta EUA\%_{\tau}$ (3.00%) translates into a -0.0372% lower stock price.

5.2.2 Permit Coverage

As a mirror image of our main finding above, we hypothesize that stock prices and carbon prices have a positive correlation for firms with a larger fraction of free emissions allowances. To test this hypothesis, we link stock price changes with the variable $PERMIT\ COVERAGE_{it-1}$ described above, which is the proportion of regulated emissions covered by free permits for firm i in year $t-1$. For firms with a full permit coverage (for which regulated emissions are lower than the free allocations of allowances) this variable $PERMIT\ COVERAGE_{it-1}$ takes the value 1. Table 5 reports the results.

[Insert Table 5 Here]

The coefficient of $PERMIT\ COVERAGE_{it-1} \times \Delta EUA\%_{\tau}$ is significantly positive at the 10% level across all specifications, and its size remains stable after the inclusion of company characteristics and risk factors as control variables. In other words, when carbon prices increase, the stock price of firms with a higher proportion of free permits relative to regulated emissions also increases. Thus, the following consistent picture emerges from our analysis: While firms with a permit shortfall are negatively affected by an increase in carbon prices, firms with a positive permit coverage benefit.

Note also that in Column (3), where company characteristics and loadings on risk factors are included, two other variables are significant: $LOG(M/B)$ which has a highly significant negative coefficient, and $\beta_{i\tau}^{RMW}$, which has a positive coefficient. The negative coefficient of

$LOG(M/B)$ indicates that a higher market-to-book ratio in day $\tau - 1$ predicts a lower stock price in day τ, which could be interpreted as some form of mean reversion of stock prices. The positive coefficient of $\beta_{i\tau}^{RMW}$ indicates that the firms with a higher loading on RMW are more profitable firms with higher associated returns.

5.2.3 Free Allocations

Our analysis above establishes an effect of carbon prices on stock prices of emitting firms, which depends critically on the difference between the emission allowances that have been freely allocated to a company and its verified emissions. To the extent that a large fraction of emission allowances have been allocated for free, we further expect that it is not only the proportion but also the absolute size of freely obtained carbon allowances that matters for how stock prices are associated with carbon prices. Our explanatory variable $PERMIT\ COVERAGE_{it-1}$ is bounded above by 1. It therefore does not entirely capture the effects on stock prices of free allowance allocations that are strictly greater than regulated emissions. We further examine the importance of free allocations in excess of regulated emissions by replacing this explanatory variable with $LOG(FREE\ EM_{it-1})$, which is the log of free permits. Note that the log operator restricts the sample to firms with a positive amount of free allocations in year $t-1$. The results of this regression are reported in 6.

[Insert Table 6 Here]

We find that across all specifications the coefficient of $LOG(FREE\ EM_{it-1}) \times \Delta EUA\%_\tau$ is positive and statistically significant at the 1% level. Again, the size of the coefficient is essentially unchanged after the inclusion of control variables. This finding underscores the importance of free carbon allowances. Companies receiving a larger number of free carbon emission allowances saw their financial performance as reflected in their stock price less affected by carbon prices. This is to be expected based on simple economics: the value of the EUAs they received for free and hold in their books increases when the carbon price increases. For the companies that received free allocations of carbon emission allowances that are one standard deviation above the mean, a 1% increase in carbon prices is associated with 0.0033% higher stock prices.

This magnitude, however, likely masks the heterogeneity in free allocations, which is highly skewed. Accordingly, to better explore how the cross-sectional heterogeneity in the allocation of free carbon emission allowances affects the results presented in Table 6, we decompose $LOG(FREE\ EM_{it-1})$ into two variables: $FREE\ EM_{it-1}^{QUARTILE\ 1}$, which takes on a value of one if $FREE\ EM_{it-1}$ is in the lowest quartile in the sample, and $FREE\ EM_{it-1}^{QUARTILE\ 4}$, which takes on a value of one if $FREE\ EM_{it-1}$ is in the highest quartile. We report the results of this regression in 7.

[Insert Table 7 Here]

We find that the coefficient of $FREE\ EM_{it-1}^{QUARTILE\ 1} \times \Delta EUA\%_{\tau}$ is negative but not statistically significant, whereas that of $FREE\ EM_{it-1}^{QUARTILE\ 1} \times \Delta EUA\%_{\tau}$ is positive and statistically significant at the 1% level. This suggests that relative to the middle quartiles, a 1% increase in the carbon price is associated with a 0.0193% higher stock price. The positive effect of carbon pricing on contemporaneous stock prices is therefore primarily driven by emitters with the highest amount of free carbon emission allowance allocations.

5.2.4 Effect of the Recent Surge in Carbon Prices

The progressive reduction in freely allocated carbon emission allowances from 80% in 2013 to 30% in 2020, and the uninterrupted rise in carbon prices over the duration of Phase 3 suggest that the impact of carbon prices on company valuations materialized primarily in the later years of Phase 3. To be sure, carbon prices languished substantially below €10 per tonne of CO_2 for several years. The carbon price has risen significantly since 2018, however, climbing from a low of €7.62 on 8^{th} January, 2018, to a high of €33.28 on 28^{th} December, 2020. Given that carbon prices have been very low until 2018, it is reasonable to expect that the effect of carbon pricing on company valuations only manifests itself in the last three years of Phase 3. We test this hypothesis by interacting our previous emissions variables with the sub-period indicators $YEAR_{2013-2017}$ and $YEAR_{2018-2020}$. The results are reported in Table 8.

[Insert Table 8 Here]

As shown in Column (1), we find that carbon prices only had a significant negative effect on stock prices for firms with an important permit shortfall in the 2018-2020 sub-period. Consistent with this finding we also find in Column (2) that the carbon price only had a significant positive effect on the stock prices of firms with a greater permit coverage in the 2018-2020 sub-period. All in all, in the earlier sub-period the carbon price had no significant effect on company valuations. The carbon price was too low to have a material impact. However, when the carbon price increased four folds between 2018 and 2020, the effects became significant and were amplified by the difference between free emissions allowances and regulated emissions. Interestingly, in Column (3), where we use $LOG(FREE\ EM_{it-1})$ as our emissions variable, we find that the effect of carbon prices on stock prices was significant in both sub-periods. However, in terms of magnitude, the coefficient of $LOG(FREE\ EM_{it-1}) \times \Delta EUA_{\tau}\% \times YEAR_{2018-2020}$ is nearly four times that of $LOG(FREE\ EM_{it-1}) \times \Delta EUA_{\tau}\% \times YEAR_{2013-2017}$, suggesting a stronger effect in the later period. Together, these findings indicate that carbon prices affected stock prices in an economically and statistically significant way only when the level of carbon prices increased substantially.

5.3 Do Carbon Prices Affect Operations?

In this section we explore the channels through which carbon prices have affected operations. Carbon prices matter in several ways. First, companies decisions on how much to invest in emissions reductions could be affected. Second, the extent to which free permits cover the firms' regulated emissions will affect both the availability of cash and the salience of carbon emissions in operations and decision making. To explore these potential effects, we investigate whether carbon prices have had a material effect on companies' operating performance, carbon emissions, investment, and R&D.

5.3.1 Operating Performance

The most direct economic channel through which carbon pricing can be expected to affect corporate valuations is through the impact of carbon pricing on profitability. If the cost of goods sold increases because of an increase in carbon prices and/or an increase in the fraction of emissions that are subject to carbon pricing, then it is to be expected that profit margins could be affected. We explore the extent to which increases in the carbon price have affected the bottom line of companies under the EU allowance scheme. We hypothesize that firms with a significant permit shortfall have suffered financially from higher carbon prices, whereas firms with a greater permit coverage have benefited. The results are reported in Table 9.

[Insert Table 9 Here]

We find in Column (1) that the coefficient of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$ is negative and statistically significant at the 1% level. This means that the higher cost of carbon emission allowances has hurt the profitability of the firms with the greatest shortfall in allowances. For the firms with a significant permit shortfall, a one standard deviation increase in $LOG(EUA_{it})$ is associated with a 0.0066 lower return on assets. Given that the mean return on assets in the sample is 0.036, this translates into an 18.3% lower net profitability, which is substantial.

We also find in Column (2) that the coefficient of $PERMIT\ COVERAGE_{it-1} \times LOG(EUA_{it})$ is positive and statistically significant at the 1% level, meaning that profitability has increased for firms with a greater permit coverage. The firms for which the $PERMIT\ COVERAGE_{it-1}$ is one standard deviation above the mean, a one standard deviation increase in $LOG(EUA_{it})$ is associated with a 0.00924 higher return on assets. This translates into a 25.67% higher net profitability, which is again substantial.

In sum, when carbon prices rise, firms with a surplus of allowances realize higher profits and firms with a deficit in allowances realize lower profits.

5.3.2 Carbon Emissions

The goal of carbon pricing is to curb carbon emissions that cause global overheating. It is therefore natural to ask what the effect of carbon prices has been on corporate carbon emissions. We have established that carbon price rises have had a negative impact on stock valuations of companies with a shortfall in allowances, and that carbon price increases have substantially affected the operating performance of these companies. This suggests that carbon pricing should have provided a strong incentive for these companies to reduce their emissions. To test whether carbon prices have affected emissions, we estimate Equation 10, with EU and global emission levels as dependent variables. Table 10 reports the results.

[Insert Table 10 Here]

In Column (1) the dependent variable is $LOG(REG\ EM_{it})$, the log of regulated emissions. We find that the coefficient of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$ is negative and significant at the 1% level. This means that firms with a significant allowance shortfall have reduced their regulated emissions in response to a rise in carbon prices. For the firms with a significant allowance shortfall, a one standard deviation higher $LOG(EUA_{it})$ is associated with a 0.04092 lower $LOG(REG\ EM_{it})$. This is an encouraging finding for the EU ETS. It suggests that carbon pricing is having the desired effect, at least qualitatively. But this result begs the question of the effect on overall corporate carbon emissions, those that fall under the EU ETS and those that do not. The listed companies that are subject to the EU ETS are likely to have other operations that do not fall under the jurisdiction of the EU ETS. Presumably, these companies can therefore substitute their activities towards subsidiaries or regions outside of the EU ETS system, whose carbon emissions are not priced.

We explore this question in Columns (2) and (3). In Column (2), the dependent variable is $LOG(NET\ SCOPE\ 1_{it})$, the log of a corporation's total scope 1 emissions (its *direct* emissions) less its regulated emissions under the EU ETS. These "net" Scope 1 emissions represent global non-regulated emissions by the EU. We find that the coefficient of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$, although positive, is statistically insignificant, suggesting that non-EU corporate emissions have not been affected by changes in the EUA price. In Column (3), the dependent variable is $LOG(SCOPE\ 2_{it})$, the company's total scope 2 emissions defined as indirect emissions from business operations, mostly from the purchase of non-renewable electricity. We find that the coefficient of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$ is positive but statistically insignificant. In Table C7 of our robustness tests, we however find that the coefficient is occasionally positive and statistically significant (depending on the threshold for emissions), suggesting that some regulated firms might have replaced their self-generation of fossil-fuel based electricity to the purchase of electricity from the grid.

Given the lack of exogenous variation in both the emissions variables and the carbon price variable, this set of results does not lend itself to a causal interpretation. However, these results reveal that the effect of EU carbon pricing is restricted to regulated emissions in the European Union. Prior literature has shown that there is limited evidence of carbon leakage in Phases 1 and 2 of the ETS. In Phase 3, we find that the same holds by comparing emissions of listed firms: the EU carbon price is negatively associated with regulated emissions by the EU ETS for firms with a significant permit shortfall, but there is no effect on non-EU scope 1 emissions. We find some weak evidence of an increase in global scope 2 emissions, highlighting the potential for regulatory arbitrage in a regional cap-and-trade system.

5.3.3 Investment and Innovation

How did carbon prices affect incentives for firms to transition to less polluting technologies? To examine this question, we look at capital expenditures and research and development expenses. If increases in the carbon price induce firms do invest in less polluting technologies, then we expect the coefficient of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$ to be positive and significant. Small changes in price, however, are unlikely to sway investment decisions if investment in green technologies is lumpy and irreversible. There is a real option embedded in the investment decision in this case and small changes in carbon price will not induce the firm to act unless the carbon price is near the strike price that triggers investment. The effect of changes in carbon price on investment is therefore likely to depend on the level of the carbon price. Table 11 reports the results of the regression linking capital expenditures to carbon prices.

[Insert Table 11 Here]

We find that the coefficients of $SHORTFALL_{it-1}^{COVERAGE<50\%} \times LOG(EUA_{it})$ is statistically insignificant in each columns. We therefore do not find any evidence that firms that have a significant permit shortfall have increased their capital expenditures in an effort to reduce their emissions. Colmer et al. (2020) found that regulated firms in France increased their capital in Phase 2. The lack of an effect of carbon prices on investment during Phase 3 could possibly be due to the fact that regulated firms have already made investments before 2013 in anticipation of carbon price increases during Phase 3.

All in all, our results on the direct effects of carbon pricing are that higher carbon prices have lowered operating performance for firms with a permit shortfall, which suggests that carbon prices do provide incentives for firms to lower emission levels in the EU. This is true when the price is sufficiently high and when firms do not receive allowances for free.

6 Robustness

We perform several robustness checks. First, we explore whether our baseline results are driven only by the electricity and airline sectors, which are most exposed to carbon pricing. Table C1 replicates Table 4 but excludes firms in the electricity and transportation industries.

Second, we vary the threshold that identifies firms with a significant permit shortfall. Our main shortfall variable, $SHORTFALL_{it-1}^{COVERAGE<50\%}$, identifies firms with permit coverage below 50% as having a significant permit shortfall. In the Internet Appendix, we report results for 10% threshold increments. Table C2 replicates Table 4. The coefficient of the shortfall indicator becomes negative and statistically significant when the threshold is lower than 60%, except for the 10% threshold. This is likely due to (1) lower statistical power and (2) firms with a $20\% - 60\%$ permit coverage are significantly more exposed to carbon pricing. Table C2 confirms that higher carbon prices are associated with lower stock prices mainly for firms with a significant permit shortfall.

Table C3 and Table C4 replicate Table 9. The main difference in Table C3 is that the dependent variable is return on equity. We lose statistical power given that this sample is at the firm-year level, but the interaction terms remain significant for several thresholds.

These findings corroborate the finding that higher carbon prices are associated with lower operational performance mainly for firms with a significant permit shortfall.

Table C5 replicates Column (1) of Table 10. While the interaction term is positive and marginally significant for $SHORTFALL_{it-1}^{COVERAGE<90\%} \times LOG(EUA_{it})$, it turns significant for lower thresholds. These results confirm our findings that higher carbon prices are associated with lower verified emissions primarily for firms with a significant permit shortfall.

Table C6 replicates Column (2) of Table 10. None of the interaction terms is statistically significant. This suggests that the reduction in global Scope 1 emissions, net of EU regulated emissions, is not statistically different from zero. Table C7 replicates Column (3) of Table 10. The interaction terms are positive, several of which are statistically significant. This suggests that firms with a permit shortfall, at a minimum, do not reduce global Scope 2 emissions and might increase them when the level of carbon prices is high.

Table C8 replicates Column (1) of Table 11, and Table C9 replicates Column (2) of Table 11. Across all specifications, we do not find a significantly positive coefficient of the interaction terms, which confirms our finding that higher carbon prices do not seem to affect investment or R&D for firms with a significant permit shortfall.

In the third set of robustness checks, we replace $LOG(FREE\ EM_{it-1})$ with $LOG(REG\ EM_{it-1})$ as the emissions variable. Given that in Phase 3, 57% of emission allowances were allocated for free, verified emissions and free allocations are highly correlated. Table C10 replicates Table 6, and Table C11 replicates Table 7. The magnitudes are slightly smaller, but the statistical significance remains.

In the final set of robustness checks, we examine whether the returns of a portfolio consisting of stocks of companies that have some operations that are subject to the EU ETS loads on changes in carbon prices. Given that a significant portion of emissions allowances were allocated for free, we hypothesize that these portfolios will load positively on carbon prices, in line with the cross-sectional results in Table 6 and Table C10. Table C12 reports the results. In Panel A, we construct value-weighted portfolios. In Panel B, we construct free allocations-weighted portfolios. In Panel B, we construct free allocations-weighted portfolios. In both cases, the returns of these portfolios load positively on changes in carbon prices.

7 Conclusion

This paper studies how carbon pricing affects corporate financial performance during Phase 3 of the EU ETS, when carbon prices increased sufficiently to become material. Our empirical setting exploits differences in regulated emission levels and free emission allowance allocations across emitting firms. A first major contribution of our study is to precisely determine the net exposure to EU carbon prices of listed companies by identifying which installations are subject to the EU ETS and computing the emission allowance shortfall or surplus of each company. Precise measures of firm-specific carbon price exposures have been lacking in prior studies but our findings reveal that the relation between carbon prices and stock prices is crucially dependent on these exposures. Indeed, our key finding is that if a company has a shortfall in emission permits then an increase in the EU carbon price is associated with a decline in its stock price, but if the company has a surplus in emission permits then the increase in the EU carbon price is associated with an increase in its stock price. These relationships between carbon price and stock price are significant during the years when the carbon price approached €30 for a ton of CO_2. Our second main finding is that while firms with a significant shortfall in emission permits do lower their regulated emissions in the EU, they do not lower their emissions globally.

Overall our findings are that the EU ETS has achieved the qualitatively desired effects during Phase 3 of creating incentives to limit carbon emissions. Earlier studies for Phases 1 (2005-2007) and 2 (2008-2012) have found largely inconclusive evidence on the effects of carbon pricing, but these were largely experimentation phases with in retrospect overly generous allocations of free carbon emission allowances in the context of a global financial crisis. Carbon prices have risen sharply in the later years of Phase 3. They have become material. So much so that carbon prices had a significant negative effect on the stock price of firms with permit shortfalls in the 2018-2020 period of Phase 3. We also find that the firms with a significant permit shortfall have seen their profitability eroded following carbon price rises, while firms with a positive permit coverage have seen an increase in their profitability. Finally, we found evidence that companies with a significant allowance shortfall have reduced their regulated emissions in response to a rise in carbon prices.

Although our findings are qualitatively consistent with basic economic predictions, the quantitative effects of carbon pricing are somewhat small. The effects on company valuations have been small and the effects on carbon emission reductions have also been small. The conclusions emerging from these findings are thus that: 1) firms do appear to have the financial capacity to absorb even higher carbon prices, and 2) higher carbon prices may be required to bring about the much larger carbon emission reductions needed to achieve the 2050 net zero targets of the European Union.

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Tables and Figures

Table 1: Sample Description

Panel A: Year	
Year	ETS Firms
2013	175
2014	196
2015	202
2016	211
2017	242
2018	236
2019	243
2020	227
Panel B: Country	
Country	ETS Firms
Austria	10
Belgium	11
Croatia	1
Czech Republic	1
Denmark	4
Finland	13
France	36
Germany	41
Greece	4
Hungary	2
Ireland	8
Italy	17
Luxembourg	4
Netherlands	14
Norway	9
Poland	13
Portugal	6
Romania	1
Slovenia	1
Spain	24
Sweden	15
United Kingdom	49
Total Unique Observations	284

NOTES: This table tabulates descriptive statistics of the sample. Panel A tabulates the number of unique firms by year. Panel B tabulates the number of unique firms by headquarters country. Panel C tabulates the number of unique firms by industry.

Sample Description (Continued)

Panel C: Industry	
NACE Main Section	ETS Firms
Administrative And Support Service Activities	4
Construction	15
Electricity, Gas, Steam And Air Conditioning Supply	35
Financial And Insurance Activities	4
Information And Communication	9
Manufacturing	163
Mining And Quarrying	22
Professional, Scientific And Technical Activities	6
Public Administration And Defence; Compulsory Social Security	1
Real Estate Activities	1
Transportation And Storage	14
Water Supply; Sewerage, Waste Management And Remediation Activities	4
Wholesale And Retail Trade; Repair Of Motor Vehicles And Motorcycles	6
Total Unique Observations	284

NOTES: This table tabulates descriptive statistics of the sample. Panel A tabulates the number of unique firms by year. Panel B tabulates the number of unique firms by headquarters country. Panel C tabulates the number of unique firms by industry.

Table 2: Summary Statistics

Variable	Mean	SD	25$^{\text{th}}$ Pct	50$^{\text{th}}$ Pct	75$^{\text{th}}$ Pct	Obs
Panel A: Firm-Day Level Variables						
$\text{RET}_{i\tau}$	0.029	1.800	-0.920	0.000	0.970	427701
$\text{LOG}(\text{M/B}_{i\tau-1})$	-6.500	0.720	-6.900	-6.500	-6.000	427701
$\text{LOG}(\text{MV}_{i\tau-1})$	8.600	1.600	7.400	8.700	9.800	427701
$\beta_{i\tau}^{SMB}$	-0.290	0.680	-0.760	-0.310	0.140	427701
$\beta_{i\tau}^{HML}$	0.064	0.920	-0.510	0.036	0.610	427701
$\beta_{i\tau}^{RMW}$	0.160	0.970	-0.460	0.140	0.750	427701
$\beta_{i\tau}^{CMA}$	-0.021	0.960	-0.600	-0.018	0.520	427701
$\beta_{i\tau}^{MKT}$	0.690	0.330	0.460	0.660	0.890	427701
$\beta_{i\tau}^{WML}$	0.005	0.590	-0.320	0.029	0.360	427701
$\text{VOLATILITY}_{i\tau}$	0.019	0.007	0.014	0.017	0.022	427701
Panel B: Firm-Year Level Variables						
$\text{CASH}_{it-1}/\text{ASSETS}_{it-1}$	0.088	0.066	0.041	0.074	0.120	1732
LEVERAGE_{it-1}	0.044	0.045	0.012	0.032	0.058	1732
$\text{LOG}(\text{ASSETS}_{it-1})$	9.200	1.500	8.100	9.100	10.000	1732
$\text{LOG}(\text{EMPLOYEES}_{it-1})$	9.700	1.500	8.800	9.800	11.000	1687
$\text{LOG}(\text{TURNOVER}_{it-1})$	8.800	1.500	7.700	8.800	9.900	1732
$\text{LOG}(\text{FREE EM}_{it-1})$	0.016	0.940	-0.640	-0.017	0.700	1635
$\text{LOG}(\text{REG EM}_{it-1})$	0.048	0.980	-0.680	0.058	0.790	1732
$\text{NET INCOME}_{it-1}/\text{EQUITY}_{it-2}$	0.100	0.160	0.047	0.100	0.160	1732
$\text{PERMIT COVERAGE}_{it-1}$	-0.120	1.000	-0.810	0.180	0.850	1732
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$	0.280	0.450	0.000	0.000	1.000	1732
$\text{TANGIBILITY}_{it-1}$	0.360	0.200	0.190	0.350	0.500	1732
Panel C: Time Series Variables						
$\Delta\text{EUA}\%_{\tau}$	0.140	3.000	-1.500	0.000	1.800	2029

NOTES: This table tabulates summary statistics for the security-day sample. The sample period is 2013 to 2020. Variables are winsorized at the 1$^{\text{st}}$ and 99$^{\text{th}}$ percentiles. Data sources and variable definitions are in Table A1.

Table 3: EUA Prices: Augmented Dickey-Fuller Tests

Model	Lag	Test Statistic	10% Critical Value	Obs
Without Intercept	1	1.183	-1.620	2027
With Trend	1	-2.003	-3.120	2027
With Drift	1	-0.098	-1.282	2027
Without Intercept	30	1.613	-1.620	1998
With Trend	30	-1.553	-3.120	1998
With Drift	30	0.416	-1.282	1998

NOTES: This table reports the augmented Dickey-Fuller test statistics that test whether daily EU allowance prices follow unit root processes. The null hypothesis is that daily EU allowance prices follow a unit root process. The sample period begins in 2013 and ends in 2020.

Table 4: Carbon Prices, Permit Shortfall and Stock Returns

	(1) $\text{RET}_{i\tau}$	(2) $\text{RET}_{i\tau}$	(3) $\text{RET}_{i\tau}$
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \Delta\text{EUA\%}_{\tau}$	-0.0123**	-0.0123**	-0.0124**
	(0.0061)	(0.0061)	(0.0061)
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$	0.0006	0.0006	0.0030
	(0.0083)	(0.0083)	(0.0081)
$\text{LOG}(\text{ASSETS}_{it-1})$		-0.0235*	-0.0279**
		(0.0134)	(0.0134)
$\text{TANGIBILITY}_{it-1}$		0.0132	0.0119
		(0.0254)	(0.0233)
LEVERAGE_{it-1}		0.0190	0.0278
		(0.0897)	(0.0848)
$\text{LOG}(\text{MV}_{i\tau-1})$		0.0183	0.0196*
		(0.0118)	(0.0117)
$\text{LOG}(\text{M/B}_{i\tau-1})$		-0.0466***	-0.0495***
		(0.0094)	(0.0096)
$\text{NET INCOME}_{it-1}/\text{EQUITY}_{it-2}$		0.0145	0.0142
		(0.0294)	(0.0280)
$\text{CASH}_{it-1}/\text{ASSETS}_{it-1}$		0.0125	0.0021
		(0.0508)	(0.0511)
$\text{LOG}(\text{TURNOVER}_{it-1})$		0.0085	0.0088
		(0.0082)	(0.0080)
$\beta_{i\tau}^{SMB}$			-0.0119
			(0.0144)
$\beta_{i\tau}^{HML}$			-0.0079
			(0.0113)
$\beta_{i\tau}^{RMW}$			0.0168*
			(0.0091)
$\beta_{i\tau}^{CMA}$			0.0023
			(0.0081)
$\beta_{i\tau}^{MKT}$			-0.0154
			(0.0259)
$\beta_{i\tau}^{WML}$			0.0013
			(0.0135)
$\text{VOLATILITY}_{i\tau}$			1.0461
			(1.2613)
Constant	0.0296***	-0.2952***	-0.3015***
	(0.0020)	(0.0682)	(0.0844)
Observations	427,701	427,701	427,701
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	284
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5: Carbon Prices, Permit Coverage and Stock Returns

	(1) $\text{RET}_{i\tau}$	(2) $\text{RET}_{i\tau}$	(3) $\text{RET}_{i\tau}$
$\text{PERMIT COVERAGE}_{it-1} \times \Delta\text{EUA\%}_{\tau}$	0.0147*	0.0147*	0.0148*
	(0.0078)	(0.0078)	(0.0078)
$\text{PERMIT COVERAGE}_{it-1}$	-0.0029	-0.0029	-0.0037
	(0.0042)	(0.0043)	(0.0042)
$\text{LOG(ASSETS}_{it-1})$		-0.0237*	-0.0282**
		(0.0134)	(0.0133)
$\text{TANGIBILITY}_{it-1}$		0.0138	0.0124
		(0.0252)	(0.0232)
LEVERAGE_{it-1}		0.0217	0.0299
		(0.0892)	(0.0842)
$\text{LOG(MV}_{i\tau-1})$		0.0183	0.0197*
		(0.0118)	(0.0117)
$\text{LOG(M/B}_{i\tau-1})$		-0.0465***	-0.0496***
		(0.0094)	(0.0096)
$\text{NET INCOME}_{it-1}/\text{EQUITY}_{it-2}$		0.0142	0.0139
		(0.0295)	(0.0281)
$\text{CASH}_{it-1}/\text{ASSETS}_{it-1}$		0.0144	0.0033
		(0.0510)	(0.0513)
$\text{LOG(TURNOVER}_{it-1})$		0.0087	0.0089
		(0.0081)	(0.0079)
$\beta_{i\tau}^{SMB}$			-0.0119
			(0.0144)
$\beta_{i\tau}^{HML}$			-0.0078
			(0.0113)
$\beta_{i\tau}^{RMW}$			0.0167*
			(0.0091)
$\beta_{i\tau}^{CMA}$			0.0023
			(0.0081)
$\beta_{i\tau}^{MKT}$			-0.0154
			(0.0259)
$\beta_{i\tau}^{WML}$			0.0013
			(0.0135)
$\text{VOLATILITY}_{i\tau}$			1.0716
			(1.2626)
Constant	0.0275***	-0.2975***	-0.3036***
	(0.0009)	(0.0683)	(0.0842)
Observations	427,701	427,701	427,701
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	284
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 6: Carbon Prices, Free Allocations and Stock Returns

	(1) $RET_{i\tau}$	(2) $RET_{i\tau}$	(3) $RET_{i\tau}$
LOG(FREE EM_{it-1})×ΔEUA$\%_\tau$	0.0033***	0.0033***	0.0033***
	(0.0009)	(0.0009)	(0.0009)
LOG(FREE EM_{it-1})	-0.0064	-0.0117*	-0.0122*
	(0.0058)	(0.0067)	(0.0069)
LOG($ASSETS_{it-1}$)		-0.0254*	-0.0315**
		(0.0146)	(0.0146)
$TANGIBILITY_{it-1}$		0.0180	0.0155
		(0.0260)	(0.0239)
$LEVERAGE_{it-1}$		0.0238	0.0268
		(0.0918)	(0.0858)
LOG($MV_{i\tau-1}$)		0.0192	0.0230*
		(0.0124)	(0.0122)
LOG(M/$B_{i\tau-1}$)		-0.0487***	-0.0517***
		(0.0100)	(0.0104)
NET $INCOME_{it-1}$/$EQUITY_{it-2}$		0.0183	0.0212
		(0.0305)	(0.0287)
$CASH_{it-1}$/$ASSETS_{it-1}$		0.0125	0.0014
		(0.0517)	(0.0519)
LOG($TURNOVER_{it-1}$)		0.0114	0.0114
		(0.0086)	(0.0084)
$\beta^{SMB}_{i\tau}$			-0.0103
			(0.0142)
$\beta^{HML}_{i\tau}$			-0.0043
			(0.0115)
$\beta^{RMW}_{i\tau}$			0.0141
			(0.0092)
$\beta^{CMA}_{i\tau}$			0.0057
			(0.0082)
$\beta^{MKT}_{i\tau}$			-0.0139
			(0.0259)
$\beta^{WML}_{i\tau}$			-0.0012
			(0.0136)
$VOLATILITY_{i\tau}$			1.1442
			(1.2944)
Constant	0.0233***	-0.3331***	-0.3439***
	(0.0017)	(0.0710)	(0.0888)
Observations	404,259	404,259	404,259
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	269	269	269
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 7: Carbon Prices, Free Allocations and Stock Returns: Heterogeneity

	(1) $RET_{i\tau}$	(2) $RET_{i\tau}$	(3) $RET_{i\tau}$
LOG(FREE EM_{it-1})QUARTILE 1×ΔEUA%$_\tau$	-0.0060	-0.0061	-0.0061
	(0.0051)	(0.0051)	(0.0051)
LOG(FREE EM_{it-1})QUARTILE 4×ΔEUA%$_\tau$	0.0194***	0.0193***	0.0193***
	(0.0051)	(0.0051)	(0.0051)
LOG(FREE EM_{it-1})	-0.0062	-0.0114*	-0.0118*
	(0.0058)	(0.0067)	(0.0069)
LOG($ASSETS_{it-1}$)		-0.0253*	-0.0314**
		(0.0146)	(0.0146)
$TANGIBILITY_{it-1}$		0.0180	0.0154
		(0.0260)	(0.0239)
$LEVERAGE_{it-1}$		0.0238	0.0269
		(0.0916)	(0.0857)
LOG($MV_{i\tau-1}$)		0.0190	0.0228*
		(0.0124)	(0.0122)
LOG($M/B_{i\tau-1}$)		-0.0485***	-0.0515***
		(0.0100)	(0.0104)
NET $INCOME_{it-1}$/$EQUITY_{it-2}$		0.0187	0.0216
		(0.0305)	(0.0286)
$CASH_{it-1}$/$ASSETS_{it-1}$		0.0126	0.0015
		(0.0516)	(0.0519)
LOG($TURNOVER_{it-1}$)		0.0112	0.0112
		(0.0085)	(0.0084)
$\beta_{i\tau}^{SMB}$			-0.0102
			(0.0142)
$\beta_{i\tau}^{HML}$			-0.0043
			(0.0115)
$\beta_{i\tau}^{RMW}$			0.0141
			(0.0092)
$\beta_{i\tau}^{CMA}$			0.0057
			(0.0082)
$\beta_{i\tau}^{MKT}$			-0.0139
			(0.0259)
$\beta_{i\tau}^{WML}$			-0.0011
			(0.0136)
$VOLATILITY_{i\tau}$			1.1463
			(1.2948)
Constant	0.0286***	-0.3250***	-0.3358***
	(0.0005)	(0.0706)	(0.0883)
Observations	404,259	404,259	404,259
R-squared	0.2552	0.2553	0.2553
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Firm FE	No	No	No
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	269	269	269
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 8: Carbon Prices and Stock Returns: Effects by Sub-Periods

	(1) $\text{RET}_{i\tau}$	(2) $\text{RET}_{i\tau}$	(3) $\text{RET}_{i\tau}$
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2013-2017}$	-0.0036		
	(0.0069)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2018-2020}$	-0.0215**		
	(0.0094)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$	0.0041		
	(0.0081)		
$\text{PERMIT COVERAGE}_{it-1} \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2013-2017}$		0.0018	
		(0.0028)	
$\text{PERMIT COVERAGE}_{it-1} \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2018-2020}$		0.0088*	
		(0.0045)	
$\text{PERMIT COVERAGE}_{it-1}$		-0.0039	
		(0.0042)	
$\text{LOG(FREE EM}_{it-1}) \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2013-2017}$			0.0056**
			(0.0025)
$\text{LOG(FREE EM}_{it-1}) \times \Delta\text{EUA}\%_{it} \times \text{YEAR}_{2018-2020}$			0.0198***
			(0.0050)
$\text{LOG(FREE EM}_{it-1})$			-0.0128*
			(0.0069)
$\text{LOG(ASSETS}_{it-1})$	-0.0279**	-0.0281**	-0.0315**
	(0.0134)	(0.0134)	(0.0146)
$\text{TANGIBILITY}_{it-1}$	0.0118	0.0122	0.0148
	(0.0234)	(0.0232)	(0.0240)
LEVERAGE_{it-1}	0.0268	0.0292	0.0263
	(0.0849)	(0.0843)	(0.0858)
$\text{LOG(MV}_{i\tau-1})$	0.0196*	0.0197*	0.0229*
	(0.0117)	(0.0117)	(0.0122)
$\text{LOG(M/B}_{i\tau-1})$	-0.0495***	-0.0495***	-0.0517***
	(0.0096)	(0.0097)	(0.0104)
$\text{NET INCOME}_{it-1}/\text{EQUITY}_{it-2}$	0.0139	0.0136	0.0211
	(0.0280)	(0.0280)	(0.0287)
$\text{CASH}_{it-1}/\text{ASSETS}_{it-1}$	0.0021	0.0033	0.0014
	(0.0510)	(0.0513)	(0.0519)
$\text{LOG(TURNOVER}_{it-1})$	0.0087	0.0088	0.0114
	(0.0080)	(0.0079)	(0.0084)
$\beta_{i\tau}^{SMB}$	-0.0118	-0.0118	-0.0103
	(0.0144)	(0.0144)	(0.0142)
$\beta_{i\tau}^{HML}$	-0.0080	-0.0079	-0.0043
	(0.0113)	(0.0113)	(0.0115)
$\beta_{i\tau}^{RMW}$	0.0168*	0.0167*	0.0141
	(0.0091)	(0.0091)	(0.0092)
$\beta_{i\tau}^{CMA}$	0.0023	0.0023	0.0058
	(0.0081)	(0.0081)	(0.0081)
$\beta_{i\tau}^{MKT}$	-0.0155	-0.0155	-0.0137
	(0.0259)	(0.0259)	(0.0259)
$\beta_{i\tau}^{WML}$	0.0013	0.0012	-0.0014
	(0.0135)	(0.0135)	(0.0136)
$\text{VOLATILITY}_{i\tau}$	1.0506	1.0707	1.1351
	(1.2614)	(1.2629)	(1.2936)
Constant	-0.3015***	-0.3020***	-0.3370***
	(0.0844)	(0.0842)	(0.0886)
Observations	427,701	427,701	404,259
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	269
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 9: Carbon Prices and Profitability

	(1) $\frac{NET\ INCOME_{it}}{ASSETS_{it-1}}$	(2) $\frac{NET\ INCOME_{it}}{ASSETS_{it-1}}$
SHORTFALL$_{it-1}^{COVERAGE<50\%}$×LOG(EUA$_{it}$)	-0.010***	
	(0.004)	
SHORTFALL$_{it-1}^{COVERAGE<50\%}$	0.014	
	(0.009)	
PERMIT COVERAGE$_{it-1}$×LOG(EUA$_{it}$)		0.014***
		(0.005)
PERMIT COVERAGE$_{it-1}$		-0.006
		(0.004)
LOG(EUA$_{it}$)	0.019**	0.006
	(0.009)	(0.009)
LOG(ASSETS$_{it-1}$)	-0.083***	-0.082***
	(0.015)	(0.016)
LOG(M/B$_{it-1}$)	0.015*	0.016**
	(0.008)	(0.008)
LOG(MV$_{it-1}$)	0.018**	0.018**
	(0.007)	(0.007)
TANGIBILITY$_{it-1}$	-0.078	-0.077
	(0.052)	(0.052)
LEVERAGE$_{it-1}$	-0.054	-0.051
	(0.034)	(0.034)
LOG(TURNOVER$_{it-1}$)	0.021**	0.021**
	(0.010)	(0.010)
CASH$_{it-1}$/ASSETS$_{it-1}$	-0.018	-0.017
	(0.038)	(0.037)
Constant	0.541***	0.550***
	(0.140)	(0.141)
Observations	1,527	1,527
Firm FE	Yes	Yes
Year FE	Yes	Yes
Cluster	Firm	Firm
Firms	241	241
Adj. R-Sq.	0.566	0.566

NOTES: This table reports results from OLS panel regressions. The dependent variable is $\frac{NET\ INCOME_{it}}{ASSETS_{it-1}}$, net income for firm i in year t, divided by book value of assets in year $t-1$. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 10: Carbon Prices and Emissions

	(1) LOG(REG EM$_{it}$)	(2) LOG(NET SCOPE 1$_{it}$)	(3) LOG(SCOPE 2$_{it}$)
SHORTFALL$_{it-1}^{COVERAGE<50\%}$×LOG(EUA$_{it}$)	-0.062***	0.055	0.036
	(0.021)	(0.074)	(0.027)
SHORTFALL$_{it-1}^{COVERAGE<50\%}$	0.188***	-0.132	-0.079
	(0.061)	(0.176)	(0.056)
LOG(EUA$_{it}$)	0.027	0.020	-0.002
	(0.059)	(0.109)	(0.040)
LOG(ASSETS$_{it-1}$)	-0.041	0.268	0.099
	(0.039)	(0.194)	(0.068)
LOG(M/B$_{it-1}$)	-0.011	0.152	-0.032
	(0.024)	(0.114)	(0.041)
LOG(MV$_{it-1}$)	0.011	-0.177	0.060
	(0.033)	(0.126)	(0.042)
TANGIBILITY$_{it-1}$	0.054	1.186**	0.005
	(0.089)	(0.525)	(0.265)
LEVERAGE$_{it-1}$	-0.072	0.020	0.140
	(0.139)	(0.781)	(0.225)
LOG(TURNOVER$_{it-1}$)	-0.017	0.846***	0.085
	(0.032)	(0.201)	(0.052)
CASH$_{it-1}$/ASSETS$_{it-1}$	0.031	0.345	-0.149
	(0.118)	(0.746)	(0.228)
NET INCOME$_{it-1}$/ASSETS$_{it-2}$	0.008	-0.510	-0.172
	(0.097)	(0.628)	(0.184)
Constant	0.383	5.504***	-1.320**
	(0.494)	(1.737)	(0.603)
Observations	1,518	1,416	1,470
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Cluster	Firm	Firm	Firm
Firms	241	230	235
Adj. R-Sq.	0.983	0.939	0.930

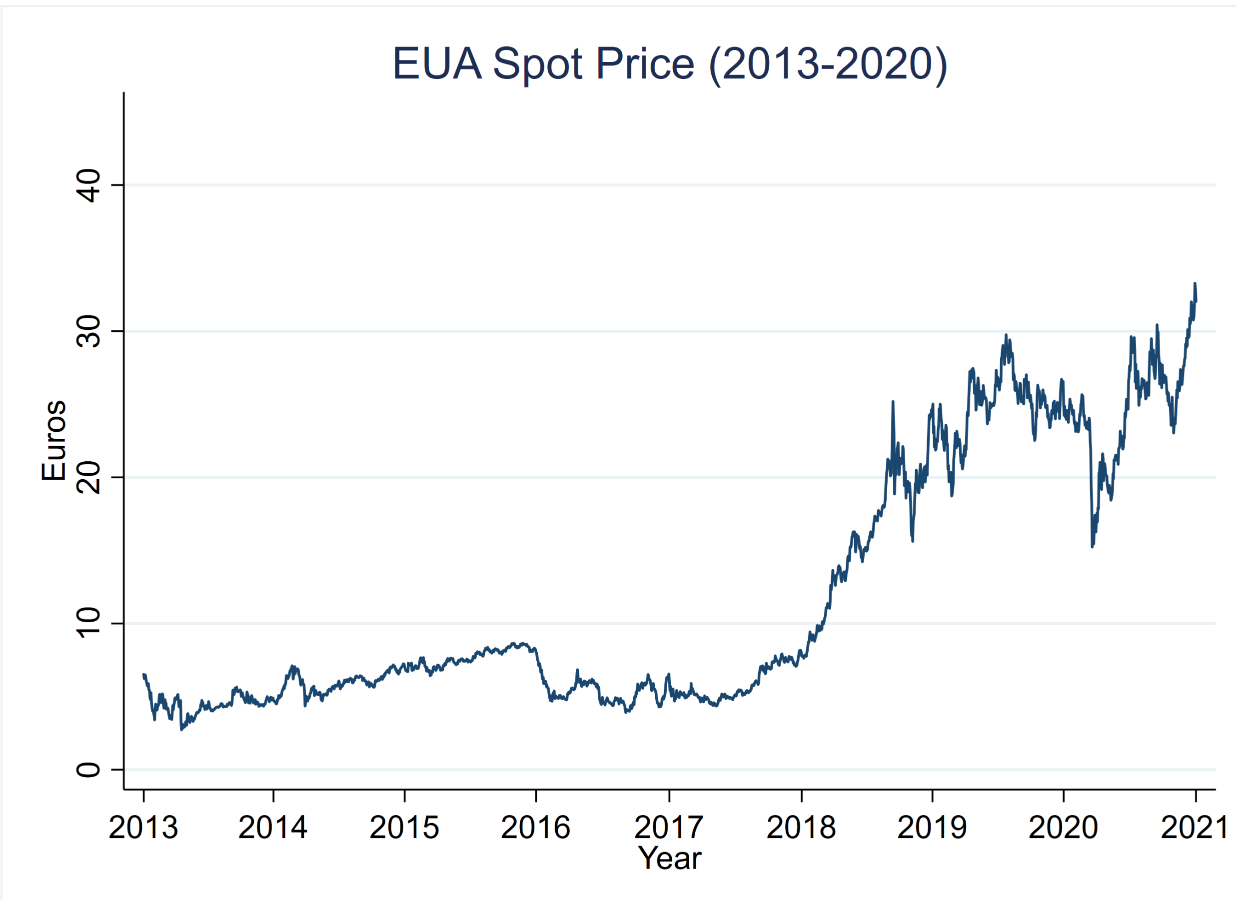
NOTES: This table reports results from OLS panel regressions. In Column (1), the dependent variable is $LOG(REG\ EM_{it})$, the log of ETS regulated emissions for firm i in year t. In Column (2), the dependent variable is $LOG(NET\ SCOPE\ 1_{it})$, the log of Trucost Scope 1 emissions minus ETS regulated emissions for firm i in year t. In Column (3), the dependent variable is $LOG(SCOPE\ 2_{it})$, the log of Trucost Scope 2 emissions for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 11: Carbon Prices and Investment

	(1) $\frac{CAPX_{it}}{ASSETS_{it-1}}$	(2) $\frac{R\&D_{it}}{ASSETS_{it-1}}$
SHORTFALL$_{it-1}^{COVERAGE<50\%}$×LOG(EUA$_{it}$)	-0.004	0.001
	(0.008)	(0.001)
SHORTFALL$_{it-1}^{COVERAGE<50\%}$	-0.006	-0.002
	(0.023)	(0.002)
LOG(EUA$_{it}$)	-0.016	-0.000
	(0.017)	(0.001)
LOG(ASSETS$_{it-1}$)	-0.196***	-0.008***
	(0.032)	(0.003)
LOG(M/B$_{it-1}$)	-0.000	-0.000
	(0.018)	(0.002)
LOG(MV$_{it-1}$)	0.029	0.000
	(0.018)	(0.002)
TANGIBILITY$_{it-1}$	-0.047	0.003
	(0.113)	(0.004)
LEVERAGE$_{it-1}$	0.025	-0.005
	(0.076)	(0.006)
LOG(TURNOVER$_{it-1}$)	0.030	0.002
	(0.022)	(0.002)
CASH$_{it-1}$/ASSETS$_{it-1}$	0.330***	0.005
	(0.080)	(0.004)
NET INCOME$_{it-1}$/ASSETS$_{it-2}$	0.145**	-0.003
	(0.065)	(0.006)
Constant	1.327***	0.065*
	(0.286)	(0.037)
Observations	1,524	1,524
Firm FE	Yes	Yes
Year FE	Yes	Yes
Cluster	Firm	Firm
Firms	241	241
Adj. R-Sq.	0.232	0.923

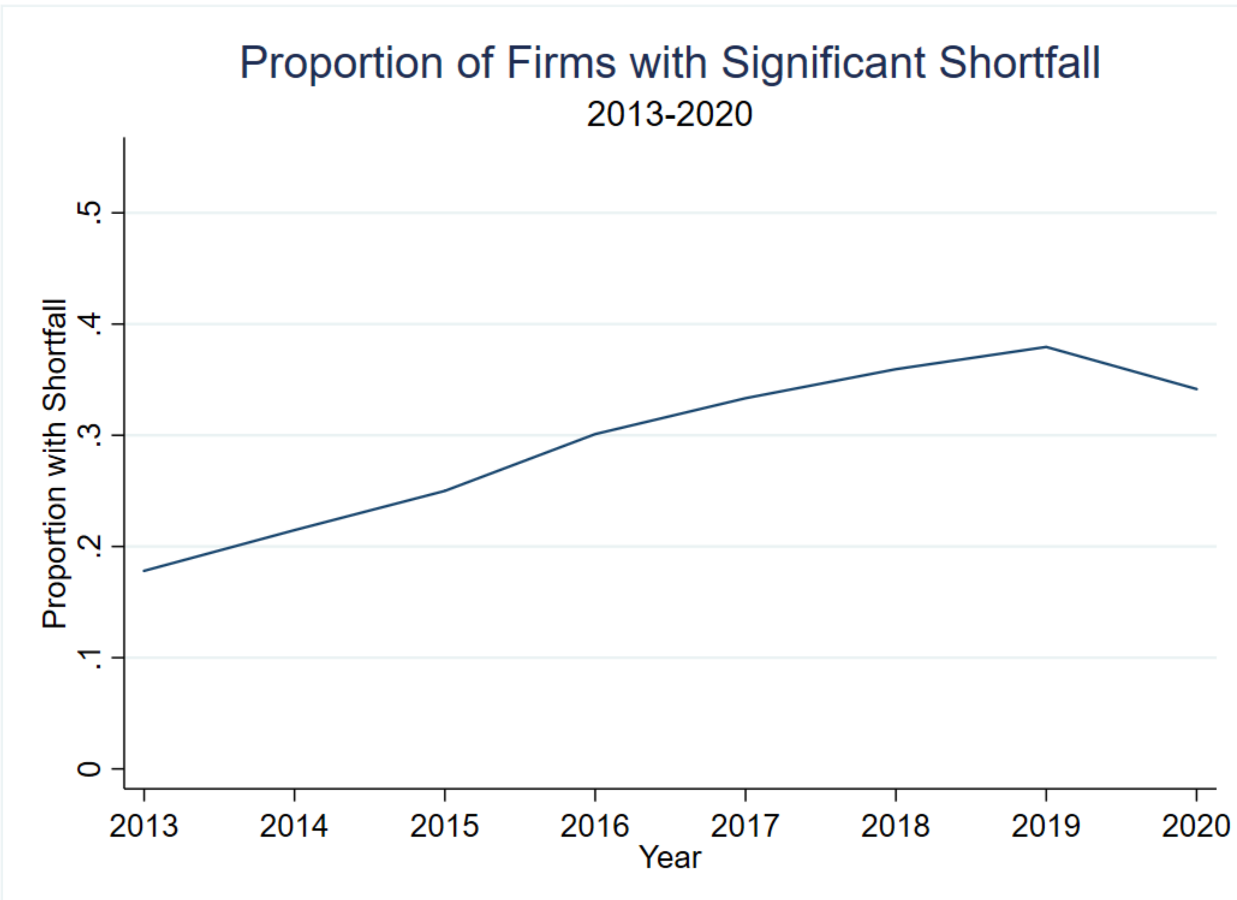
NOTES: This table reports results from OLS panel regressions. In Column (1), the dependent variable is $\frac{CAPX_{it}}{ASSETS_{it-1}}$, capital expenditures scaled by total assets for firm i in year t. In Column (2), the dependent variable is $\frac{R\&D_{it}}{ASSETS_{it-1}}$, R&D expenditures scaled by total assets for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Figure 1: EUA Spot Settlement Prices (2013-2020)



NOTES: This figure plots the time series of daily EUA spot settlement prices in euros during the EU Emissions Trading System Phase 3 (2013-2020).

Figure 2: Proportion of Firms with a Significant Permit Shortfall (2013-2020)



NOTES: This figure plots the proportion of firms with a significant permit shortfall (i.e. proportion of freely allocated permits is less than 50% of verified emissions) in Phase 3 (2013-2020).

Online Appendices – Not for Publication

Contents

A Variable Definition

Table A1: Variable Definition

Panel A: Firm-Year Level Emission Variables		
FREE $EM_{it-1}^{QUARTILE\ 1}$	ETS Union Registry/Orbis	Large free allocations receiver indicator for firm i in year $t-1$, takes on a value of one if LOG(FREE EM_{it-1}) is in the lowest quartile in the sample.
FREE $EM_{it-1}^{QUARTILE\ 4}$	ETS Union Registry/Orbis	Small free allocations receiver indicator for firm i in year $t-1$, takes on a value of one if LOG(FREE EM_{it-1}) is in the highest quartile in the sample.
LOG(FREE EM_{it-1})	ETS Union Registry/Orbis	Log of freely allocated ETS emission allowances by firm $i$in year $t-1$, standardized by subtracting sample mean then divided by standard deviation.
LOG(REG EM_{it})	ETS Union Registry/Orbis	Log of verified ETS emissions for firm i in year t, i.e. LOG(REG EM_{it}).
LOG(REG EM_{it-1})	ETS Union Registry/Orbis	Log of verified ETS emissions by firm i in year $t-1$, standardized by subtracting sample mean then divided by standard deviation.
LOG(SCOPE 1_{it})	Trucost	Log of global scope 1 emissions for firm i in year t, i.e. LOG(SCOPE 1_{it}).
PERMIT $COVERAGE_{it-1}$	ETS Union Registry/Orbis	Permit coverage for firm i in year $t-1$, i.e. total amount of freely allocated emissions divided by total verified emissions.
$SHORTFALL_{it-1}$	ETS Union Registry/Orbis	Shortfall indicator for firm i in year $t-1$, takes on a value of one if the amount of freely allocated ETS emission allowances falls below regulated emissions.
$SHORTFALL_{it-1}^{COVERAGE<X\%}$	ETS Union Registry/Orbis	Coverage/shortfall indicator for firm i in year $t-1$, takes on a value of one if the proportion of freely allocated ETS emission allowances falls below X% of regulated emissions.

NOTES: This table tabulates data sources and variable definitions.

Variable Definition (Continued)

Panel B: Firm-Day Level Financial Variables		
$\beta^{CMA}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European CMA factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
$\beta^{HML}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European HML factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
$\beta^{MKT}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European MKT factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
$\beta^{RMW}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European RMW factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
$\beta^{SMB}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European SMB factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
$\beta^{WML}_{i\tau}$	Datastream/Kenneth French's Website (Daily European 5-factor)	Firm i's loading on the European WML factor in Fama-French 5 factor model on day τ, calculated using daily returns data in a 252-day window.
ΔEUA%$_{\tau}$	EEX	Percentage change in daily EUA closing price from day $\tau - 1$ to day τ
LOG(M/B$_{i\tau-1}$)	Datastream/Orbis	Market-to-Book ratio for firm i in day $\tau - 1$, i.e. market value of equity divided by beginning-of-period book value of equity ($mv_{i\tau-1}/shfd_{it-1}$).
LOG(MV$_{i\tau-1}$)	Datastream	Log of market value on day $\tau - 1$ (log($mv_{i\tau-1}$).
RET$_{i\tau}$ (%)	Datastream	Change in daily Euros-denominated stock price ($P\ E_{i\tau}/P\ E_{i\tau-1}$).
VOLATILITY$_{i\tau}$	Datastream	Daily volatility for firm i on day t, i.e. 252-day moving standard deviation of euro-denominated stock returns.
Panel C: Firm-Year Level Financial Variables		
LEVERAGE$_{it-1}$	Orbis	Leverage for firm i in year $t-1$, i.e. book value of debt divided by book value of assets ($loan_{it-1}/toas_{it-1}$).
LOG(ASSETS$_{it-1}$)	Orbis	Log of total assets for firm i in year $t - 1$, i.e. log($toas$).
LOG(EUA$_{it}$)	EEX/Orbis	Percentage change in fiscal year-end adjusted carbon price for firm i in year t.
LOG(M/B$_{it-1}$)	Datastream/Orbis	Market-to-Book ratio for firm i on day $\tau - 1$, i.e. market value of equity divided by beginning-of-period book value of equity ($mv_{it-1}/shfd_{it-1}$).
LOG(MV$_{it-1}$)	Datastream	Log of market value on fiscal year end date for firm i in year t (log(mv_{it}).
LOG(TURNOVER$_{it-1}$)	Orbis	Log of turnover (sales) for firm i in year $t - 1$, i.e. log($turn$).
NET INCOME$_{it}$/ASSETS$_{it-1}$	Orbis	Net inome scaled by beginning-of-period assets for firm i in year $t - 1$ (($pl_{it}/toas_{it-1}$).
NET INCOME$_{it}$/EQUITY$_{it-1}$	Orbis	Net inome scaled by beginning-of-period book equity for firm i in year $t - 1$ (($pl_{it}/shfd_{it-1}$).
NET INCOME$_{it-1}$/EQUITY$_{it-2}$	Orbis	Return on equity for firm i in year $t-1$, i.e. net income divided by beginning-of-period book value of equity ($pl_{it}/shfd_{it-1}$).
TANGIBILITY$_{it-1}$	Orbis	Asset tangibility for firm i in year $t - 1$, i.e. fixed assets divided by total assets ($fias_{it}/toas_{it}$).

Notes: This table tabulates data sources and variable definitions.

Variable Definition (Continued)

Panel D: Time-Series Variables		
RET_{τ}^{AW} (%)	Datastream/ETS/Orbis	Return on a free ETS allocations-weighted portfolio of ETS-regulated stocks from day $\tau-1$ to day τ.
RET_{τ}^{VW} (%)	Datastream/ETS/Orbis	Return on a value-weighted portfolio of ETS-regulated stocks from day $\tau-1$ to day τ.
SMB_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European SMB factor in Fama-French 5 factor model on day τ.
HML_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European HML factor in Fama-French 5 factor model on day τ.
MKT-RF_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European MKT-RF factor in Fama-French 5 factor model on day τ.
WML_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European WML factor on day τ.
CMA_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European CMA factor in Fama-French 5 factor model on day τ.
RMW_{τ}	Datastream/Kenneth French's Website (Daily European 5-factor)	European RMW factor in Fama-French 5 factor model on day τ.

NOTES: This table tabulates data sources and variable definitions.

B Descriptive Statistics

Table B1: Sample Construction

Step	Number of Firms	Number of Firms Dropped
Listed Orbis Europe ETS Firms	366	
Filter [1]: European Union		14
Filter [2]: Datastream returns data		9
Filter [3]: Phase 3 (2013-2020)		22
Filter [4]: Non-missing financial control variables		13
Filter [5]: Non-missing Trucost emissions		24
Final Sample	284	

NOTES: This table tabulates the number of filters added to the sample for the security-day level analyses. We first identified 366 publicly listed firms in the Orbis Europe that have owned at least one EU ETS installation in between 2005 and 2020. Filter [1] requires these firms to be within the European Union, i.e. we have dropped firms from Switzerland, Turkey and Russia. Filter [2] requires these firms to have non-missing stock returns data from Datastream in Phase 3. Filter [3] requires these firms are active in Phase 3 (2013-2020). Filter [4] requires these firms to have non-missing financial control variables, as outlined in Section 4.2. Filter [5] requires these firms to have global emissions data from Trucost. The resulting sample consists of 284 firms.

Table B2: ETS Emissions and Coverage

(1) Year	(2) Emissions by All Installations (tons)	(3) Emissions by Orbis-Linked Installations (tons)	(4) Emissions Coverage by Orbis-Linked Installations	(5) Emissions by Installations in Sample	(6) Emissions Coverage in Sample
2013	1930000000	1861000000	0.96	949700000	0.49
2014	1840000000	1772000000	0.96	909700000	0.49
2015	1838000000	1776000000	0.97	934700000	0.51
2016	1800000000	1742000000	0.97	906100000	0.50
2017	1807000000	1747000000	0.97	907500000	0.50
2018	1740000000	1683000000	0.97	871000000	0.50
2019	1595000000	1544000000	0.97	783400000	0.49
2020	1325000000	1285000000	0.97	647600000	0.49

NOTES: This table tabulates ETS emissions levels and the percentage of emissions by Orbis and listed firms.

Table B3: Summary Statistics

Panel A: Firm-Day Level Analyses						
Firm-Day Level Variables						
Variable	Mean	SD	25^{th} Pct	50^{th} Pct	75^{th} Pct	Obs
$\text{RET}_{i\tau}$	0.029	1.800	-0.920	0.000	0.970	427701
$\text{LOG(FREE EM}_{it-1})\times\Delta\text{EUA\%}_\tau$	1.700	36.000	-17.000	0.000	20.000	404259
$\text{LOG(REG EM}_{it-1})\times\Delta\text{EUA\%}_\tau$	1.800	37.000	-17.000	0.280	21.000	427701
$\text{PERMIT COVERAGE}_{it-1}\times\Delta\text{EUA\%}_\tau$	0.096	2.200	-0.820	0.000	1.000	427701
$\text{SHORTFALL}_{it-1}\times\Delta\text{EUA\%}_\tau$	0.110	2.300	-0.660	0.000	0.860	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}\times\Delta\text{EUA\%}_\tau$	0.099	2.100	-0.410	0.000	0.580	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}\times\Delta\text{EUA\%}_\tau$	0.082	1.900	0.000	0.000	0.180	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}\times\Delta\text{EUA\%}_\tau$	0.070	1.700	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}\times\Delta\text{EUA\%}_\tau$	0.057	1.500	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}\times\Delta\text{EUA\%}_\tau$	0.047	1.400	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}\times\Delta\text{EUA\%}_\tau$	0.036	1.200	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}\times\Delta\text{EUA\%}_\tau$	0.029	0.970	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}\times\Delta\text{EUA\%}_\tau$	0.026	0.840	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}\times\Delta\text{EUA\%}_\tau$	0.022	0.760	0.000	0.000	0.000	427701
$\text{FREE EM}_{it-1}^{QUARTILE\ 1}\times\Delta\text{EUA\%}_\tau$	0.035	1.300	0.000	0.000	0.000	404259
$\text{FREE EM}_{it-1}^{QUARTILE\ 4}\times\Delta\text{EUA\%}_\tau$	0.031	1.300	0.000	0.000	0.000	404259
$\text{REG EM}_{it-1}^{QUARTILE\ 1}\times\Delta\text{EUA\%}_\tau$	0.033	1.300	0.000	0.000	0.000	427701
$\text{REG EM}_{it-1}^{QUARTILE\ 4}\times\Delta\text{EUA\%}_\tau$	0.034	1.300	0.000	0.000	0.000	427701
$\text{LOG(FREE EM}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2013-2017}$	0.002	1.900	-0.100	0.000	0.100	416942
$\text{LOG(FREE EM}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2018-2020}$	-0.007	1.400	0.000	0.000	0.000	415018
$\text{LOG(REG EM}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2013-2017}$	0.004	2.000	-0.120	0.000	0.130	427701
$\text{LOG(REG EM}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2018-2020}$	0.000	1.500	0.000	0.000	0.000	427701
$\text{LOG(PERMIT COVERAGE}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2013-2017}$	0.005	2.000	-0.140	0.000	0.140	427701
$\text{LOG(PERMIT COVERAGE}_{it-1})\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2018-2020}$	-0.032	1.700	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2013-2017}$	0.009	0.780	0.000	0.000	0.000	427701
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}\times\Delta\text{EUA\%}_\tau\times\text{YEAR}_{2018-2020}$	0.040	0.940	0.000	0.000	0.000	427701
$\text{LOG(M/B}_{i\tau-1}$	-6.500	0.720	-6.900	-6.500	-6.000	427701
$\text{LOG(MV}_{i\tau-1}$	8.600	1.600	7.400	8.700	9.800	427701
$\beta_{i\tau}^{SMB}$	-0.290	0.680	-0.760	-0.310	0.140	427701
$\beta_{i\tau}^{HML}$	0.064	0.920	-0.510	0.036	0.610	427701
$\beta_{i\tau}^{RMW}$	0.160	0.970	-0.460	0.140	0.750	427701
$\beta_{i\tau}^{CMA}$	-0.021	0.960	-0.600	-0.018	0.520	427701
$\beta_{i\tau}^{MKT}$	0.690	0.330	0.460	0.660	0.890	427701
$\beta_{i\tau}^{WML}$	0.005	0.590	-0.320	0.029	0.360	427701
$\text{VOLATILITY}_{i\tau}$	0.019	0.007	0.014	0.017	0.022	427701

NOTES: This table tabulates summary statistics for the security-day sample. The sample period is 2013 to 2020. Variables are winsorized at the 1st and 99th percentiles. Data sources and variable definitions are in Table A1.

Summary Statistics (Continued)

Firm-Year Level Variables						
LOG(FREE EM_{it-1})	0.016	0.940	-0.640	-0.017	0.700	1635
LOG(REG EM_{it-1})	0.048	0.980	-0.680	0.058	0.790	1732
PERMIT $COVERAGE_{it-1}$	-0.120	1.000	-0.810	0.180	0.850	1732
$SHORTFALL_{it-1}$	0.690	0.460	0.000	1.000	1.000	1732
REG EM_{it-1}/SCOPE $1\&2_{it-1}$	1.300	1.500	0.057	0.880	2.300	1732
$SHORTFALL_{it-1}^{COVERAGE<90\%}$	0.520	0.500	0.000	1.000	1.000	1732
$SHORTFALL_{it-1}^{COVERAGE<80\%}$	0.220	1.000	-0.840	1.200	1.200	1732
$SHORTFALL_{it-1}^{COVERAGE<70\%}$	0.430	0.500	0.000	0.000	1.000	1732
$SHORTFALL_{it-1}^{COVERAGE<60\%}$	0.350	0.480	0.000	0.000	1.000	1732
$SHORTFALL_{it-1}^{COVERAGE<50\%}$	0.280	0.450	0.000	0.000	1.000	1732
$SHORTFALL_{it-1}^{COVERAGE<40\%}$	0.220	0.410	0.000	0.000	0.000	1732
$SHORTFALL_{it-1}^{COVERAGE<30\%}$	0.170	0.380	0.000	0.000	0.000	1732
$SHORTFALL_{it-1}^{COVERAGE<20\%}$	0.140	0.340	0.000	0.000	0.000	1732
$SHORTFALL_{it-1}^{COVERAGE<10\%}$	0.120	0.330	0.000	0.000	0.000	1732
LOG($ASSETS_{it-1}$)	9.200	1.500	8.100	9.100	10.000	1732
$TANGIBILITY_{it-1}$	0.360	0.200	0.190	0.350	0.500	1732
$LEVERAGE_{it-1}$	0.044	0.045	0.012	0.032	0.058	1732
NET $INCOME_{it-1}$/$EQUITY_{it-2}$	0.100	0.160	0.047	0.100	0.160	1732
LOG($TURNOVER_{it-1}$)	8.800	1.500	7.700	8.800	9.900	1732
LOG($EMPLOYEES_{it-1}$)	9.700	1.500	8.800	9.800	11.000	1687
$CASH_{it-1}$/$ASSETS_{it-1}$	0.088	0.066	0.041	0.074	0.120	1732
Time Series Variables						
$\Delta EUA\%_{\tau}$	0.140	3.000	-1.500	0.000	1.800	2029
RET_{τ}^{EM}	0.016	1.100	-0.500	0.047	0.600	2029
WML_{τ}	0.038	0.710	-0.260	0.080	0.380	2029
$MKT\text{-}RF_{\tau}$	0.032	1.000	-0.440	0.060	0.540	2029
SMB_{τ}	0.011	0.430	-0.220	0.010	0.250	2029
HML_{τ}	-0.018	0.500	-0.280	-0.030	0.250	2029
RMW_{τ}	0.015	0.290	-0.160	0.030	0.180	2029
CMA_{τ}	-0.011	0.270	-0.170	-0.010	0.150	2029

NOTES: This table tabulates summary statistics for the security-day sample. The sample period is 2013 to 2020. Variables are winsorized at the 1^{st} and 99^{th} percentiles. Data sources and variable definitions are in Table A1.

Summary Statistics (Continued)

Panel B: Firm-Year Level Analyses						
Firm-Year Level Variables						
LOG(EUA$_{it}$)	2.300	0.660	1.800	2.000	3.200	1527
LOG(REG EM$_{it}$)	0.110	0.950	-0.580	0.100	0.820	1521
LOG(NET SCOPE 1$_{it}$)	13.000	2.100	12.000	13.000	15.000	1426
LOG(SCOPE 2$_{it}$)	13.000	1.800	11.000	13.000	14.000	1479
LOG(FREE EM$_{it-1}$)	0.056	0.910	-0.560	0.001	0.740	1444
LOG(REG EM$_{it-1}$)	0.110	0.950	-0.590	0.087	0.820	1527
PERMIT COVERAGE$_{it-1}$	-0.140	1.000	-0.840	0.160	0.820	1527
SHORTFALL$_{it-1}$	0.680	0.460	0.000	1.000	1.000	1527
SHORTFALL$_{it-1}^{COVERAGE<90\%}$	0.520	0.500	0.000	1.000	1.000	1527
SHORTFALL$_{it-1}^{COVERAGE<80\%}$	0.260	1.000	-0.800	1.200	1.200	1527
SHORTFALL$_{it-1}^{COVERAGE<70\%}$	0.420	0.490	0.000	0.000	1.000	1527
SHORTFALL$_{it-1}^{COVERAGE<60\%}$	0.340	0.480	0.000	0.000	1.000	1527
SHORTFALL$_{it-1}^{COVERAGE<50\%}$	0.280	0.450	0.000	0.000	1.000	1527
SHORTFALL$_{it-1}^{COVERAGE<40\%}$	0.210	0.410	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<30\%}$	0.170	0.370	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<20\%}$	0.130	0.340	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<10\%}$	0.120	0.320	0.000	0.000	0.000	1527
PERMIT COVERAGE$_{it-1}\times$LOG(EUA$_{it}$)	1.500	0.860	1.000	1.500	2.000	1527
SHORTFALL$_{it-1}\times$LOG(EUA$_{it}$)	1.600	1.200	0.000	1.800	2.800	1527
SHORTFALL$_{it-1}^{COVERAGE<90\%}\times$LOG(EUA$_{it}$)	1.500	1.300	0.000	1.800	2.800	1527
SHORTFALL$_{it-1}^{COVERAGE<80\%}\times$LOG(EUA$_{it}$)	1.200	1.300	0.000	1.700	2.000	1527
SHORTFALL$_{it-1}^{COVERAGE<70\%}\times$LOG(EUA$_{it}$)	1.000	1.300	0.000	0.000	2.000	1527
SHORTFALL$_{it-1}^{COVERAGE<60\%}\times$LOG(EUA$_{it}$)	0.840	1.200	0.000	0.000	1.800	1527
SHORTFALL$_{it-1}^{COVERAGE<50\%}\times$LOG(EUA$_{it}$)	0.680	1.200	0.000	0.000	1.700	1527
SHORTFALL$_{it-1}^{COVERAGE<40\%}\times$LOG(EUA$_{it}$)	0.520	1.100	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<30\%}\times$LOG(EUA$_{it}$)	0.410	0.960	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<20\%}\times$LOG(EUA$_{it}$)	0.330	0.860	0.000	0.000	0.000	1527
SHORTFALL$_{it-1}^{COVERAGE<10\%}\times$LOG(EUA$_{it}$)	0.290	0.810	0.000	0.000	0.000	1527
NET INCOME$_{it}$/ASSETS$_{it-1}$	0.036	0.053	0.012	0.035	0.061	1527
NET INCOME$_{it}$/EQUITY$_{it-1}$	0.092	0.180	0.040	0.097	0.160	1527
CAPX$_{it}$/ASSETS$_{it-1}$	0.023	0.090	-0.022	0.012	0.050	1527
R&D$_{it}$/ASSETS$_{it-1}$	0.012	0.022	0.000	0.002	0.015	1527
CASH$_{it-1}$/ASSETS$_{it-1}$	0.089	0.064	0.044	0.075	0.120	1527
LOG(ASSETS$_{it-1}$)	9.200	1.500	8.200	9.100	10.000	1527
LOG(M/B$_{it-1}$)	-6.500	0.710	-6.900	-6.500	-6.000	1527
LOG(MV$_{it-1}$)	8.600	1.600	7.400	8.700	9.800	1526
TANGIBILITY$_{it-1}$	0.360	0.190	0.200	0.350	0.500	1527
LEVERAGE$_{it-1}$	0.044	0.044	0.013	0.032	0.059	1527
LOG(TURNOVER$_{it-1}$)	8.800	1.500	7.800	8.800	9.900	1527
LOG(EMPLOYEES$_{it-1}$)	9.700	1.500	8.800	9.800	11.000	1497
PERMIT COVERAGE$_{it-1}$ (NON-STANDARDIZED)	0.680	0.340	0.450	0.780	1.000	1527
REG EM$_{it-1}$/SCOPE 1$_{it-1}$ (NON-STANDARDIZED)	0.360	0.300	0.100	0.270	0.550	1527
REG EM$_{it-1}$/SCOPE 1&2$_{it-1}$ (NON-STANDARDIZED)	0.270	0.260	0.054	0.180	0.410	1527

NOTES: This table tabulates summary statistics for the security-day sample. The sample period is 2013 to 2020. Variables are winsorized at the 1st and 99th percentiles. Data sources and variable definitions are in Table A1.

C Additional Tables

Table C1: Carbon Prices, Permit Shortfall and Stock Returns (Excl. Elec/Tran Industries)

	(1) $\text{RET}_{i\tau}$	(2) $\text{RET}_{i\tau}$	(3) $\text{RET}_{i\tau}$
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \Delta\text{EUA\%}_{\tau}$	-0.0127*	-0.0127*	-0.0128**
	(0.0065)	(0.0065)	(0.0065)
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$	-0.0016	-0.0008	0.0012
	(0.0086)	(0.0091)	(0.0089)
$\text{LOG(ASSETS}_{it-1})$		-0.0300**	-0.0403***
		(0.0146)	(0.0147)
$\text{TANGIBILITY}_{it-1}$		-0.0113	-0.0197
		(0.0274)	(0.0265)
LEVERAGE_{it-1}		0.0550	0.0524
		(0.0923)	(0.0844)
$\text{LOG(MV}_{i\tau-1})$		0.0175	0.0256**
		(0.0125)	(0.0125)
$\text{LOG(M/B}_{i\tau-1})$		-0.0449***	-0.0497***
		(0.0107)	(0.0112)
$\text{NET INCOME}_{it-1}/\text{EQUITY}_{it-2}$		0.0036	0.0079
		(0.0281)	(0.0266)
$\text{CASH}_{it-1}/\text{ASSETS}_{it-1}$		-0.0033	-0.0119
		(0.0532)	(0.0542)
$\text{LOG(TURNOVER}_{it-1})$		0.0133	0.0155
		(0.0095)	(0.0095)
$\beta_{i\tau}^{SMB}$			-0.0058
			(0.0145)
$\beta_{i\tau}^{HML}$			-0.0003
			(0.0121)
$\beta_{i\tau}^{RMW}$			0.0139
			(0.0095)
$\beta_{i\tau}^{CMA}$			0.0081
			(0.0084)
$\beta_{i\tau}^{MKT}$			-0.0244
			(0.0270)
$\beta_{i\tau}^{WML}$			-0.0021
			(0.0137)
$\text{VOLATILITY}_{i\tau}$			1.7464
			(1.3296)
Constant	0.0300***	-0.2504***	-0.2931***
	(0.0011)	(0.0775)	(0.0964)
Observations	345,502	345,502	345,502
Sample	Excl. Elec & Tran	Excl. Elec & Tran	Excl. Elec & Tran
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	235	235	235
Adj. R-Sq.	0.270	0.270	0.270

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$, excluding firms in the electricity or transportation industries. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C2: Carbon Prices, Permit Shortfall and Stock Returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					$\text{RET}_{i\tau}$					
$\text{SHORTFALL}_{it-1} \times \Delta\text{EUA\%}_\tau$	-0.0030									
	(0.0044)									
SHORTFALL_{it-1}	0.0100									
	(0.0073)									
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%} \times \Delta\text{EUA\%}_\tau$		-0.0040								
		(0.0045)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}$		-0.0017								
		(0.0063)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%} \times \Delta\text{EUA\%}_\tau$			-0.0053							
			(0.0047)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}$			-0.0006							
			(0.0031)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%} \times \Delta\text{EUA\%}_\tau$				-0.0081						
				(0.0050)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}$				-0.0023						
				(0.0074)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%} \times \Delta\text{EUA\%}_\tau$					-0.0107*					
					(0.0056)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}$					0.0038					
					(0.0075)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \Delta\text{EUA\%}_\tau$						-0.0124**				
						(0.0061)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$						0.0030				
						(0.0081)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%} \times \Delta\text{EUA\%}_\tau$							-0.0139**			
							(0.0069)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}$							0.0037			
							(0.0096)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%} \times \Delta\text{EUA\%}_\tau$								-0.0173**		
								(0.0081)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}$								0.0055		
								(0.0119)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%} \times \Delta\text{EUA\%}_\tau$									-0.0146*	
									(0.0084)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}$									0.0185*	
									(0.0105)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%} \times \Delta\text{EUA\%}_\tau$										-0.0118
										(0.0087)
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}$										0.0229*
										(0.0119)
Observations	427,701	427,701	427,701	427,701	427,701	427,701	427,701	427,701	427,701	427,701
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	284	284	284	284	284	284	284	284
Adj. R-Sq.	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C3: Carbon Prices and Profitability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	10
					$\frac{NET\ INCOME_{it}}{ASSETS_{it-1}}$					
$\text{SHORTFALL}_{it-1} \times \text{LOG}(\text{EUA}_{it})$	-0.013***									
	(0.004)									
SHORTFALL_{it-1}	0.023**									
	(0.009)									
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%} \times \text{LOG}(\text{EUA}_{it})$		-0.003								
		(0.002)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}$		-0.001								
		(0.005)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%} \times \text{LOG}(\text{EUA}_{it})$			-0.010***							
			(0.004)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}$			0.008**							
			(0.004)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%} \times \text{LOG}(\text{EUA}_{it})$				-0.012***						
				(0.003)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}$				0.019**						
				(0.008)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%} \times \text{LOG}(\text{EUA}_{it})$					-0.012***					
					(0.004)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}$					0.023***					
					(0.008)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \text{LOG}(\text{EUA}_{it})$						-0.010***				
						(0.004)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$						0.014				
						(0.009)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%} \times \text{LOG}(\text{EUA}_{it})$							-0.005			
							(0.004)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}$							0.006			
							(0.010)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%} \times \text{LOG}(\text{EUA}_{it})$								-0.004		
								(0.005)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}$								0.005		
								(0.013)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%} \times \text{LOG}(\text{EUA}_{it})$									-0.003	
									(0.005)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}$									-0.005	
									(0.012)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%} \times \text{LOG}(\text{EUA}_{it})$										-0.005
										(0.005)
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}$										0.001
										(0.014)
Constant	0.508***	0.511***	0.528***	0.531***	0.533***	0.541***	0.536***	0.531***	0.533***	0.537***
	(0.140)	(0.141)	(0.142)	(0.141)	(0.142)	(0.140)	(0.142)	(0.142)	(0.144)	(0.143)
Observations	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	241	241	241	241	241	241	241	241	241	241
Adj. R-Sq.	0.566	0.562	0.565	0.567	0.566	0.566	0.563	0.562	0.562	0.562

NOTES: This table reports results from OLS panel regressions. The dependent variable is $\frac{NET\ INCOME_{it}}{ASSETS_{it-1}}$, net income for firm i in year t, divided by book value of assets in year $t-1$. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and year level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C4: Carbon Prices and Profitability (ROE)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					$\frac{NET\ INCOME_{it}}{EQUITY_{it-1}}$					
SHORTFALL$_{it-1}$×LOG(EUA$_{it}$)	-0.058***									
	(0.017)									
SHORTFALL$_{it-1}$	0.109***									
	(0.035)									
SHORTFALL$_{it-1}^{COVERAGE<90\%}$×LOG(EUA$_{it}$)		-0.014**								
		(0.007)								
SHORTFALL$_{it-1}^{COVERAGE<90\%}$		0.007								
		(0.019)								
SHORTFALL$_{it-1}^{COVERAGE<80\%}$×LOG(EUA$_{it}$)			-0.042***							
			(0.014)							
SHORTFALL$_{it-1}^{COVERAGE<80\%}$			0.041**							
			(0.017)							
SHORTFALL$_{it-1}^{COVERAGE<70\%}$×LOG(EUA$_{it}$)				-0.050***						
				(0.014)						
SHORTFALL$_{it-1}^{COVERAGE<70\%}$				0.100***						
				(0.038)						
SHORTFALL$_{it-1}^{COVERAGE<60\%}$×LOG(EUA$_{it}$)					-0.054***					
					(0.016)					
SHORTFALL$_{it-1}^{COVERAGE<60\%}$					0.118***					
					(0.039)					
SHORTFALL$_{it-1}^{COVERAGE<50\%}$×LOG(EUA$_{it}$)						-0.041**				
						(0.016)				
SHORTFALL$_{it-1}^{COVERAGE<50\%}$						0.065				
						(0.039)				
SHORTFALL$_{it-1}^{COVERAGE<40\%}$×LOG(EUA$_{it}$)							-0.011			
							(0.016)			
SHORTFALL$_{it-1}^{COVERAGE<40\%}$							0.009			
							(0.039)			
SHORTFALL$_{it-1}^{COVERAGE<30\%}$×LOG(EUA$_{it}$)								0.002		
								(0.016)		
SHORTFALL$_{it-1}^{COVERAGE<30\%}$								-0.019		
								(0.041)		
SHORTFALL$_{it-1}^{COVERAGE<20\%}$×LOG(EUA$_{it}$)									0.004	
									(0.017)	
SHORTFALL$_{it-1}^{COVERAGE<20\%}$									-0.043	
									(0.041)	
SHORTFALL$_{it-1}^{COVERAGE<10\%}$×LOG(EUA$_{it}$)										0.003
										(0.019)
SHORTFALL$_{it-1}^{COVERAGE<10\%}$										-0.037
										(0.048)
Observations	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	241	241	241	241	241	241	241	241	241	241
Adj. R-Sq.	0.448	0.442	0.445	0.448	0.448	0.446	0.441	0.440	0.440	0.440

Notes: This table reports results from OLS panel regressions. The dependent variable is $\frac{NET\ INCOME_{it}}{EQUITY_{it-1}}$, net income for firm i in year t, divided by book value of equity in year $t-1$. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and year level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C5: Carbon Prices and ETS Emissions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	LOG(REG EM_{it})									
$\text{SHORTFALL}_{it-1}\times\text{LOG}(\text{EUA}_{it})$	-0.021									
	(0.016)									
SHORTFALL_{it-1}	0.145***									
	(0.049)									
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}\times\text{LOG}(\text{EUA}_{it})$		0.018*								
		(0.010)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}$		0.041**								
		(0.020)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}\times\text{LOG}(\text{EUA}_{it})$			-0.031**							
			(0.014)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}$			0.065***							
			(0.022)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}\times\text{LOG}(\text{EUA}_{it})$				-0.036**						
				(0.016)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}$				0.134***						
				(0.044)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}\times\text{LOG}(\text{EUA}_{it})$					-0.050***					
					(0.018)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}$					0.162***					
					(0.051)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}\times\text{LOG}(\text{EUA}_{it})$						-0.062***				
						(0.021)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$						0.188***				
						(0.061)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}\times\text{LOG}(\text{EUA}_{it})$							-0.053**			
							(0.023)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}$							0.133**			
							(0.065)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}\times\text{LOG}(\text{EUA}_{it})$								-0.051*		
								(0.029)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}$								0.152*		
								(0.088)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}\times\text{LOG}(\text{EUA}_{it})$									-0.072**	
									(0.036)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}$									0.179*	
									(0.101)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}\times\text{LOG}(\text{EUA}_{it})$										-0.073*
										(0.041)
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}$										0.206*
										(0.123)
Observations	1,518	1,518	1,518	1,518	1,518	1,518	1,518	1,518	1,518	1,518
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	241	241	241	241	241	241	241	241	241	241
Adj. R-Sq.	0.984	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983

NOTES: This table reports results from OLS panel regressions. The dependent variable is $LOG(REG\ EM_{it})$, the log of ETS regulated emissions for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and year level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C6: Carbon Prices and Global Emissions (Net Scope 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	LOG(NET SCOPE 1_{it})									
$\text{SHORTFALL}_{it-1} \times \text{LOG}(\text{EUA}_{it})$	0.026									
	(0.057)									
SHORTFALL_{it-1}	-0.131									
	(0.148)									
$\text{SHORTFALL}_{it-1}^{COVERAGE<<90\%} \times \text{LOG}(\text{EUA}_{it})$		-0.041								
		(0.029)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<<90\%}$		0.070								
		(0.103)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<<80\%} \times \text{LOG}(\text{EUA}_{it})$			-0.044							
			(0.064)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<<80\%}$			0.058							
			(0.084)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<<70\%} \times \text{LOG}(\text{EUA}_{it})$				-0.051						
				(0.070)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<<70\%}$				-0.001						
				(0.180)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<<60\%} \times \text{LOG}(\text{EUA}_{it})$					-0.058					
					(0.071)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<<60\%}$					0.020					
					(0.171)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<<50\%} \times \text{LOG}(\text{EUA}_{it})$						0.055				
						(0.074)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<<50\%}$						-0.132				
						(0.176)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<<40\%} \times \text{LOG}(\text{EUA}_{it})$							0.035			
							(0.082)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<<40\%}$							-0.031			
							(0.206)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<<30\%} \times \text{LOG}(\text{EUA}_{it})$								0.024		
								(0.096)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<<30\%}$								0.019		
								(0.256)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<<20\%} \times \text{LOG}(\text{EUA}_{it})$									-0.025	
									(0.108)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<<20\%}$									-0.017	
									(0.273)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<<10\%} \times \text{LOG}(\text{EUA}_{it})$										-0.031
										(0.125)
$\text{SHORTFALL}_{it-1}^{COVERAGE<<10\%}$										0.063
										(0.316)
Constant	5.587***	5.579***	5.676***	5.680***	5.722***	5.504***	5.460***	5.442***	5.703***	5.669***
	(1.715)	(1.718)	(1.731)	(1.691)	(1.706)	(1.737)	(1.747)	(1.760)	(1.757)	(1.785)
Observations	1,416	1,416	1,416	1,416	1,416	1,416	1,416	1,416	1,416	1,416
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	230	230	230	230	230	230	230	230	230	230
Adj. R-Sq.	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939

NOTES: This table reports results from OLS panel regressions. The dependent variable is $LOG(SCOPE\ 1\_it)$, the log of Trucost Scope 1 emissions (net of ETS regulated emissions) for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C7: Carbon Prices and Global Emissions (Scope 2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					LOG(SCOPE 2_{it})					
SHORTFALL$_{it-1}$ ×LOG(EUA$_{it}$)	0.034									
	(0.021)									
SHORTFALL$_{it-1}$	-0.084*									
	(0.051)									
SHORTFALL$_{it-1}^{COVERAGE<90\%}$ ×LOG(EUA$_{it}$)		0.002								
		(0.009)								
SHORTFALL$_{it-1}^{COVERAGE<90\%}$		-0.013								
		(0.026)								
SHORTFALL$_{it-1}^{COVERAGE<80\%}$ ×LOG(EUA$_{it}$)			0.052**							
			(0.024)							
SHORTFALL$_{it-1}^{COVERAGE<80\%}$			-0.062**							
			(0.027)							
SHORTFALL$_{it-1}^{COVERAGE<70\%}$ ×LOG(EUA$_{it}$)				0.039						
				(0.027)						
SHORTFALL$_{it-1}^{COVERAGE<70\%}$				-0.104						
				(0.068)						
SHORTFALL$_{it-1}^{COVERAGE<60\%}$ ×LOG(EUA$_{it}$)					0.041					
					(0.025)					
SHORTFALL$_{it-1}^{COVERAGE<60\%}$					-0.083					
					(0.053)					
SHORTFALL$_{it-1}^{COVERAGE<50\%}$ ×LOG(EUA$_{it}$)						0.036				
						(0.027)				
SHORTFALL$_{it-1}^{COVERAGE<50\%}$						-0.079				
						(0.056)				
SHORTFALL$_{it-1}^{COVERAGE<40\%}$ ×LOG(EUA$_{it}$)							0.056*			
							(0.028)			
SHORTFALL$_{it-1}^{COVERAGE<40\%}$							-0.068			
							(0.079)			
SHORTFALL$_{it-1}^{COVERAGE<30\%}$ ×LOG(EUA$_{it}$)								0.061*		
								(0.032)		
SHORTFALL$_{it-1}^{COVERAGE<30\%}$								-0.060		
								(0.097)		
SHORTFALL$_{it-1}^{COVERAGE<20\%}$ ×LOG(EUA$_{it}$)									0.044	
									(0.037)	
SHORTFALL$_{it-1}^{COVERAGE<20\%}$									-0.055	
									(0.109)	
SHORTFALL$_{it-1}^{COVERAGE<10\%}$ ×LOG(EUA$_{it}$)										0.041
										(0.040)
SHORTFALL$_{it-1}^{COVERAGE<10\%}$										-0.041
										(0.114)
Constant	-1.240**	-1.263**	-1.350**	-1.307**	-1.316**	-1.320**	-1.443**	-1.497**	-1.385**	-1.400**
	(0.597)	(0.601)	(0.594)	(0.595)	(0.597)	(0.603)	(0.599)	(0.594)	(0.584)	(0.587)
Observations	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	235	235	235	235	235	235	235	235	235	235
Adj. R-Sq.	0.930	0.930	0.931	0.931	0.931	0.930	0.931	0.931	0.931	0.930

NOTES: This table reports results from OLS panel regressions. The dependent variable is $LOG(SCOPE\ 2\_it)$, the log of Trucost Scope 2 emissions for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C8: Carbon Prices and Capital Expenditures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					$\text{CAPX}_{it}/\text{ASSETS}_{it-1}$					
$\text{SHORTFALL}_{it-1} \times \text{LOG}(\text{EUA}_{it})$	-0.003									
	(0.008)									
SHORTFALL_{it-1}	0.016									
	(0.018)									
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%} \times \text{LOG}(\text{EUA}_{it})$		-0.004								
		(0.004)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<90\%}$		0.012								
		(0.010)								
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%} \times \text{LOG}(\text{EUA}_{it})$			-0.006							
			(0.008)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<80\%}$			0.010							
			(0.010)							
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%} \times \text{LOG}(\text{EUA}_{it})$				-0.008						
				(0.008)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<70\%}$				0.005						
				(0.021)						
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%} \times \text{LOG}(\text{EUA}_{it})$					-0.004					
					(0.008)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<60\%}$					-0.002					
					(0.021)					
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%} \times \text{LOG}(\text{EUA}_{it})$						-0.004				
						(0.008)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<50\%}$						-0.006				
						(0.023)				
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%} \times \text{LOG}(\text{EUA}_{it})$							-0.004			
							(0.009)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<40\%}$							-0.001			
							(0.026)			
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%} \times \text{LOG}(\text{EUA}_{it})$								-0.002		
								(0.010)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<30\%}$								0.003		
								(0.029)		
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%} \times \text{LOG}(\text{EUA}_{it})$									-0.012	
									(0.010)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<20\%}$									0.021	
									(0.027)	
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%} \times \text{LOG}(\text{EUA}_{it})$										-0.018*
										(0.010)
$\text{SHORTFALL}_{it-1}^{COVERAGE<10\%}$										0.040
										(0.031)
Observations	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	241	241	241	241	241	241	241	241	241	241
Adj. R-Sq.	0.231	0.232	0.232	0.233	0.232	0.232	0.232	0.231	0.232	0.232

NOTES: This table reports results from OLS panel regressions. The dependent variable is $CAPX\_it/ASSETS_{it-1}$, capital expenditures scaled by total assets for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are clustered at the firm level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C9: Carbon Prices and R&D Expenditures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					R&D$_{it}$/ASSETS$_{it-1}$					
SHORTFALL$_{it-1}$ ×LOG(EUA$_{it}$)	0.001									
	(0.001)									
SHORTFALL$_{it-1}$	-0.002									
	(0.001)									
SHORTFALL$_{it-1}^{COVERAGE<90\%}$ ×LOG(EUA$_{it}$)		-0.000								
		(0.000)								
SHORTFALL$_{it-1}^{COVERAGE<90\%}$		0.000								
		(0.001)								
SHORTFALL$_{it-1}^{COVERAGE<80\%}$ ×LOG(EUA$_{it}$)			0.001							
			(0.001)							
SHORTFALL$_{it-1}^{COVERAGE<80\%}$			-0.001							
			(0.001)							
SHORTFALL$_{it-1}^{COVERAGE<70\%}$ ×LOG(EUA$_{it}$)				0.001						
				(0.001)						
SHORTFALL$_{it-1}^{COVERAGE<70\%}$				-0.004**						
				(0.002)						
SHORTFALL$_{it-1}^{COVERAGE<60\%}$ ×LOG(EUA$_{it}$)					0.001					
					(0.001)					
SHORTFALL$_{it-1}^{COVERAGE<60\%}$					-0.002					
					(0.002)					
SHORTFALL$_{it-1}^{COVERAGE<50\%}$ ×LOG(EUA$_{it}$)						0.001				
						(0.001)				
SHORTFALL$_{it-1}^{COVERAGE<50\%}$						-0.002				
						(0.002)				
SHORTFALL$_{it-1}^{COVERAGE<40\%}$ ×LOG(EUA$_{it}$)							0.000			
							(0.001)			
SHORTFALL$_{it-1}^{COVERAGE<40\%}$							-0.000			
							(0.002)			
SHORTFALL$_{it-1}^{COVERAGE<30\%}$ ×LOG(EUA$_{it}$)								0.000		
								(0.001)		
SHORTFALL$_{it-1}^{COVERAGE<30\%}$								-0.001		
								(0.002)		
SHORTFALL$_{it-1}^{COVERAGE<20\%}$ ×LOG(EUA$_{it}$)									0.001	
									(0.001)	
SHORTFALL$_{it-1}^{COVERAGE<20\%}$									-0.001	
									(0.002)	
SHORTFALL$_{it-1}^{COVERAGE<10\%}$ ×LOG(EUA$_{it}$)										0.001
										(0.001)
SHORTFALL$_{it-1}^{COVERAGE<10\%}$										-0.002
										(0.002)
Observations	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524	1,524
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Firms	241	241	241	241	241	241	241	241	241	241
Adj. R-Sq.	0.922	0.922	0.923	0.923	0.922	0.923	0.922	0.922	0.922	0.922

Notes: This table reports results from OLS panel regressions.The dependent variable is $R\&D\_it/ASSETS_{it-1}$, R&D expenditures scaled by total assets for firm i in year t. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. In Column (1), the sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. In Column (2), the sample consists of listed firms in ETS-participating countries with a positive amount of Trucost global emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and year level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C10: Carbon Prices, Regulated Emissions and Stock Returns

	(1) $RET_{i\tau}$	(2) $RET_{i\tau}$	(3) $RET_{i\tau}$
LOG(REG EM_{it-1})×ΔEUA$\%_{\tau}$	0.0021***	0.0021***	0.0021***
	(0.0008)	(0.0008)	(0.0008)
LOG(REG EM_{it-1})	-0.0037	-0.0098*	-0.0099*
	(0.0054)	(0.0058)	(0.0058)
LOG($ASSETS_{it-1}$)		-0.0233*	-0.0278**
		(0.0135)	(0.0134)
$TANGIBILITY_{it-1}$		0.0207	0.0187
		(0.0250)	(0.0230)
$LEVERAGE_{it-1}$		0.0216	0.0286
		(0.0891)	(0.0846)
LOG($MV_{i\tau-1}$)		0.0179	0.0191
		(0.0118)	(0.0117)
LOG($M/B_{i\tau-1}$)		-0.0468***	-0.0498***
		(0.0096)	(0.0099)
NET $INCOME_{it-1}$/$EQUITY_{it-2}$		0.0126	0.0124
		(0.0296)	(0.0282)
$CASH_{it-1}$/$ASSETS_{it-1}$		0.0120	0.0004
		(0.0512)	(0.0512)
LOG($TURNOVER_{it-1}$)		0.0110	0.0112
		(0.0082)	(0.0080)
$\beta_{i\tau}^{SMB}$			-0.0123
			(0.0144)
$\beta_{i\tau}^{HML}$			-0.0071
			(0.0114)
$\beta_{i\tau}^{RMW}$			0.0164*
			(0.0091)
$\beta_{i\tau}^{CMA}$			0.0027
			(0.0081)
$\beta_{i\tau}^{MKT}$			-0.0139
			(0.0259)
$\beta_{i\tau}^{WML}$			0.0015
			(0.0134)
$VOLATILITY_{i\tau}$			0.9913
			(1.2613)
Constant	0.0256***	-0.3240***	-0.3276***
	(0.0016)	(0.0688)	(0.0855)
Observations	427,701	427,701	427,701
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	284
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau - 1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t - 1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C11: Carbon Prices, Regulated Emissions and Stock Returns: Heterogeneity

	(1) $RET_{i\tau}$	(2) $RET_{i\tau}$	(3) $RET_{i\tau}$
LOG(REG EM_{it-1})QUARTILE 1×ΔEUA$\%_{\tau}$	-0.0029	-0.0030	-0.0030
	(0.0049)	(0.0049)	(0.0049)
LOG(REG EM_{it-1})QUARTILE 4×ΔEUA$\%_{\tau}$	0.0100*	0.0099*	0.0099*
	(0.0055)	(0.0055)	(0.0055)
LOG(REG EM_{it-1})	-0.0034	-0.0094	-0.0095
	(0.0054)	(0.0057)	(0.0058)
LOG($ASSETS_{it-1}$)		-0.0232*	-0.0277**
		(0.0135)	(0.0134)
$TANGIBILITY_{it-1}$		0.0208	0.0188
		(0.0250)	(0.0230)
$LEVERAGE_{it-1}$		0.0220	0.0290
		(0.0891)	(0.0846)
LOG($MV_{i\tau-1}$)		0.0178	0.0190
		(0.0118)	(0.0117)
LOG($M/B_{i\tau-1}$)		-0.0467***	-0.0497***
		(0.0096)	(0.0098)
NET $INCOME_{it-1}$/$EQUITY_{it-2}$		0.0128	0.0127
		(0.0296)	(0.0282)
$CASH_{it-1}$/$ASSETS_{it-1}$		0.0122	0.0006
		(0.0512)	(0.0512)
LOG($TURNOVER_{it-1}$)		0.0109	0.0111
		(0.0082)	(0.0080)
$\beta_{i\tau}^{SMB}$			-0.0123
			(0.0145)
$\beta_{i\tau}^{HML}$			-0.0071
			(0.0114)
$\beta_{i\tau}^{RMW}$			0.0163*
			(0.0091)
$\beta_{i\tau}^{CMA}$			0.0027
			(0.0081)
$\beta_{i\tau}^{MKT}$			-0.0138
			(0.0259)
$\beta_{i\tau}^{WML}$			0.0016
			(0.0134)
$VOLATILITY_{i\tau}$			0.9871
			(1.2612)
Constant	0.0292***	-0.3190***	-0.3225***
	(0.0006)	(0.0688)	(0.0854)
Observations	427,701	427,701	427,701
Industry FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Cluster	Firm & Date	Firm & Date	Firm & Date
Firms	284	284	284
Adj. R-Sq.	0.251	0.251	0.251

NOTES: This table reports results from OLS panel regressions. The dependent variable is $RET_{i\tau}$, the return for firm i from day $\tau-1$ to day τ. Variable definitions are provided in Table A1. Variables are winsorized at the 1% and 99% levels. The sample consists of listed firms in ETS-participating countries with a positive amount of ETS verified emissions in year $t-1$. The sample period begins in 2013 and ends in 2020. Industry is defined by 2-digit NACE codes. Standard errors are two-way clustered at the firm and date level. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table C12: Carbon Prices and Stock Returns: Time Series Evidence

Panel A: Value-Weighted Portfolio Returns						
	(1)	(2)	(3)	(4)	(5)	(6)
	RET_τ^{VW}					
ΔEUA%$_\tau$	0.0628***	0.0076**	0.0106***	0.0100***	0.0106***	0.0102***
	(0.0208)	(0.0038)	(0.0033)	(0.0034)	(0.0032)	(0.0033)
MKT-RF$_\tau$		0.9169***	0.7477***	0.7452***	0.7349***	0.7352***
		(0.0335)	(0.0475)	(0.0517)	(0.0444)	(0.0470)
SMB$_\tau$			-0.6804***	-0.6758***	-0.6884***	-0.6838***
			(0.0690)	(0.0722)	(0.0682)	(0.0701)
HML$_\tau$			0.0808	0.0129	0.2868***	0.2114**
			(0.0518)	(0.0584)	(0.0722)	(0.0869)
RMW$_\tau$					0.4510***	0.4082***
					(0.0822)	(0.0918)
CMA$_\tau$					0.0919	0.1049
					(0.0707)	(0.0668)
WML$_\tau$				-0.0829*		-0.0621
				(0.0468)		(0.0456)
α_τ	0.0316	0.0094	0.0236**	0.0257**	0.0220**	0.0238**
	(0.0243)	(0.0113)	(0.0114)	(0.0120)	(0.0111)	(0.0117)
Observations	2,029	2,029	2,029	2,029	2,029	2,029
Newey-West Lags	30	30	30	30	30	30

Panel B: Free Allocations-Weighted Portfolio Returns						
	(1)	(2)	(3)	(4)	(5)	(6)
	RET_τ^{AW}					
ΔEUA%$_\tau$	0.0742***	0.0160***	0.0141***	0.0129***	0.0140***	0.0132***
	(0.0231)	(0.0052)	(0.0039)	(0.0040)	(0.0037)	(0.0038)
MKT-RF$_\tau$		0.9669***	0.8185***	0.8138***	0.7997***	0.8002***
		(0.0331)	(0.0350)	(0.0401)	(0.0306)	(0.0341)
SMB$_\tau$			-0.2419***	-0.2333***	-0.2578***	-0.2486***
			(0.0531)	(0.0578)	(0.0497)	(0.0528)
HML$_\tau$			0.5939***	0.4652***	0.8415***	0.6923***
			(0.0449)	(0.0506)	(0.0579)	(0.0728)
RMW$_\tau$					0.6021***	0.5175***
					(0.0881)	(0.1031)
CMA$_\tau$					0.0968	0.1227
					(0.0847)	(0.0802)
WML$_\tau$				-0.1572***		-0.1229***
				(0.0386)		(0.0389)
α_τ	0.0038	-0.0197	-0.0013	0.0025	-0.0040	-0.0005
	(0.0290)	(0.0141)	(0.0133)	(0.0131)	(0.0129)	(0.0128)
Observations	2,029	2,029	2,029	2,029	2,029	2,029
Newey-West Lags	30	30	30	30	30	30

NOTES: This table reports results from time series regressions. In Panel A, the dependent variable is RET_τ^{VW}, the daily return of a value-weighted portfolio of firms with a positive amount of ETS emissions. In Panel B, the dependent variable is RET_τ^{AW}, the daily return of an free ETS allocations-weighted portfolio of firms with a positive amount of ETS emissions. The portfolio is rebalanced in May each year. Variable definitions are provided in Table A1. The sample period begins in 2013 and ends in 2020. Standard errors are calculated using the Newey-West estimator with a 30-day lag. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.