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# Firms' Response to Climate Regulations

## Empirical Investigations Based on the European Emissions Trading System

Fotios Kalantzis, Salma Khalid, Alexandra Solovyeva, and Marcin Wolski

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# Firms' Response to Climate Regulations: Empirical Investigations Based on the European Emissions Trading System

Prepared by **Fotios Kalantzis, Salma Khalid, Alexandra Solovyeva, and Marcin Wolski***

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**ABSTRACT:** Using a novel cross-country dataset, which merges firm-level financials with information on firms' participation in the European Unions' Emissions Trading System (ETS), we investigate how firm performance is affected by tightening of environmental policies that put a price on pollution. We find that more stringent policies do not have a strong negative impact on the profitability of ETS-regulated or non-ETS firms. While firms report an increase in their input costs during periods of high carbon prices, their reported turnover is also higher. Among ETS-regulated firms which must purchase emission certificates under the EU ETS, tightening of climate policies in periods of high carbon prices results in increased investment, particularly in intangible assets. We establish robustness of our results using a quantile regression analysis, ensuring our key findings are not driven by distributional irregularities. Our findings provide support for the benefits of EU ETS on accelerating firms' climate transition, while keeping firm-level financial costs at bay.

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# Contents

# 1. Introduction

Carbon pricing is a key policy instrument for reducing Greenhouse Gas (GHG) emissions and mitigating climate risks. It works by increasing the cost of carbon-based fuels relative to less carbon-intensive and/or energy efficient alternatives, thus creating incentives for firms and consumers to switch to less carbon-intensive technologies and behaviors. However, carbon pricing may also have implications for the economic performance of firms, especially those directly regulated under a carbon pricing scheme. The impact of carbon pricing on firms may depend on several factors, such as the stringency of regulation, the level of the carbon price, the availability of low-carbon alternatives, the degree of competition, and the ability to pass on the costs to consumers, among others (Dechezlepretre et al., 2023).

The European Union's Emissions Trading System (ETS) is the largest and longest running carbon market in the world, launched in 2005 and covering nearly 40 percent of the EU's total GHG emissions. The ETS operates by setting a cap on the total amount of emissions that can be emitted by regulated installations and allowing their owners to trade emission allowances in the secondary market, with the EU-wide emission cap decreasing every year. At the end of each year, owners of the installations need to give back the number of allowances matching the actual emissions. The price of emission allowances reflects the scarcity of the permits and the marginal cost of abatement. Studies that explore the impact of the EU ETS on firm performance show mixed results, partly due to the use of different samples, timeframes, and variations in methodology (Martin et al., 2016; Calel and Dechezlepretre, 2016; Abrell et al., 2019).

Our work extends this literature by examining how firms' financial performance responds to changes in the stringency of market-based climate policies, using the EU ETS as a natural experiment. We construct a novel dataset using a sample of roughly 1 million firms from 12 European countries over 1995-2020, within which we can identify a subset of 1,870 firms that own at least one installation in the ETS between 2008 and 2020. We combine firm-level financial accounts across EU economies from the Bureau van Dijk's Orbis database with measures of country-level price-based regulatory intensity from the OECD's Environmental Policy Stringency (EPS) Index, information on the price of emissions allowances traded on the EU ETS market, and information on whether the ETS-regulated firms have to pay for their emissions (hereafter payable emissions) in a given year. We use a panel regression specification to examine the impact of tightening price-based regulations using the market-based component of the OECD EPS index, allowing for heterogeneity in firm type – regulated or not

regulated the ETS – and heterogeneity in the carbon price faced by firms, directly or indirectly via input costs, as measured by the trading price of emissions permits in the EU ETS market.

We find that more stringent market-based climate policies have no sizable impact on the economic performance of an average firm during periods of low carbon prices. During periods of high carbon prices, non-ETS firms face higher input costs, but also earn more revenues, allowing their profitability to remain stable. This implies that they change their output composition or transfer the increasing costs to their customers.

Stricter climate rules have varying effects on ETS firms, depending on how increased emission costs influence their profit function. Our findings reveal that firms with no payable emissions[1] experience windfall profits during the period of high carbon prices when climate policies become more stringent. This is likely attributed to their ability to sell unused emissions allowances in the secondary markets at higher prices. Conversely, firms with positive payable emissions face heightened input costs amid tighter regulations, but they also witness increased turnover. Despite these shifts, there is no statistically significant impact on their overall profitability. Such regulated firms are thus demonstrating resilience by adjusting their production mix or passing on costs to consumers, thereby safeguarding their profitability despite being subject to high carbon prices and having to pay for their emissions. Moreover, we find that an increase in the market-based EPS index by one unit is associated with an increase in fixed assets by about 4.5 percentage points among these firms.[2] Given that we find no investment effect from high carbon prices among firms with no payable emissions, nor investment increases during periods of low carbon prices, our results suggest that the combination of high carbon prices and binding regulations incentivizes firms to invest in mitigating the impact of higher carbon costs. We also find that relative to firms without payable emissions, firms with payable emissions redirect their investment focus towards greater investment in intangible capital. Previous literature supports the assertion that investments in production efficiency and energy efficiency are reflected in changes in intangible capital (Wu and Wang, 2022; Yang and Shi, 2018), further supporting the case that change in investment behavior among regulated firms during period of high carbon prices is in lowering their emissions footprint.

Our findings remain robust across various tests designed to ensure the validity of our model specifications. To confirm that the estimated effects of the ETS firms are not influenced by the outliers or distributional irregularities,

[1] These firms have allocation of free emission certificates which exceeds their actual emissions, such that they do not have to pay for their emissions.

[2] Total effect is calculated as a linear combination of the marginal effects for stricter climate regulations, high carbon price periods and ETS firms with payable emissions.

we estimate a quantile panel model for the median of the distribution of the outcome variables. Remarkably, we find that the main effects persist, reinforcing the reliability of our conclusions. Furthermore, our results withstand additional scrutiny when we introduce additional firm-level control variables and utilize an alternative measure of tangible fixed assets. This indicates that the patterns we observe are consistent and not contingent on specific variables or measurement methods. Finally, our investigation into the behavior of firms with payable emissions reveals that they respond differently in periods of high ETS price levels and not necessarily high price volatility. This suggests that the impact of stricter climate regulations is driven more by binding budget constraints than by fluctuations in carbon prices.

Our findings are consistent with previous studies that find no evidence that more stringent climate policies harmed firms' economic performance (Dechezleprêtre et al. 2023; Dechezleprêtre and Krause 2022). We also contribute to the studies that found that the EU ETS led to an increase in investment in fixed capital assets of regulated firms (Marin et al. 2018; Dechezleprêtre et al. 2023) by providing further evidence that tighter climate policies are associated with an increase in fixed assets of ETS-regulated firms during the periods of elevated carbon prices over the years 2012-2020, which are characterized by substantially more binding environmental policies. Overall, our results indicate that during periods of more stringent market-based climate regulations and elevated carbon prices, ETS-regulated firms have room for adjustment which allow them to protect their profitability while enhancing their overall level of investment.

This paper is organized as follows. Section 2 provides background information on the structure of the ETS and examines the existing literature on the impacts of the ETS on firms. Section 3 outlines the data sources and empirical strategy. Section 4 discusses the results and Section 5 concludes.

# 2. The EU Emissions Trading System

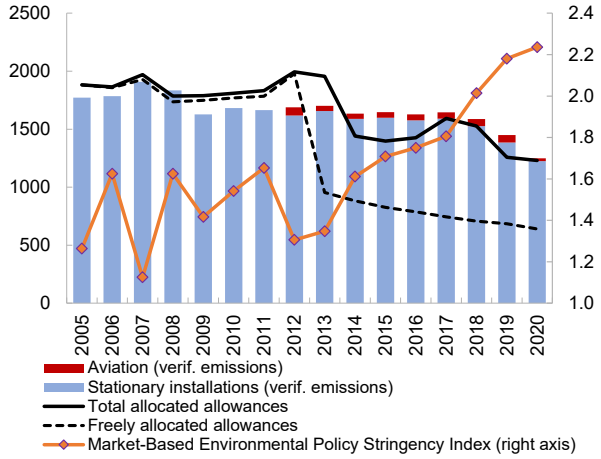
The European Union (EU) is leading the global battle to fight the climate change by pledging to become the first block to become climate-neutral by 2050. This pledge has been further supported by a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels.[3] While these policies will undeniably affect the functioning of the EU's business model, its impact is ex-ante ambiguous. On the one hand a stricter regulatory landscape may result in higher costs and therefore weigh on competitiveness. On the other hand, the Porter hypothesis claims that stricter

[3] These proposals are often referred to as the European Green Deal.

environmental policies can spur innovation and technological progress, with net positive effects on firms' performance (Porter and van der Linde, 1995).

**Figure 1. European carbon market.**

(a) ETS and Environmental Policy Stringency Index (Metric tons of carbon dioxide equivalent, left scale; EPS index, right scale)




Sources: Authors' calculations based on EU Emissions Trading System, and OECD. Note: The figure shows a simple average of market-based Environmental Policy Stringency indices of 12 European countries.

(b) ETS emission price (Euro)


Source: EU Emissions Trading System.

To comprehensively assess the impact of a wider array of climate policy instruments on firms' dynamics, we closely examine the OECD's index of market-based Environmental Policy Stringency (EPS). The EPS index is a cross-country measure of stringency of environmental policy. The market-based sub-component of the EPS index groups regulatory policies that put a price on pollution, including CO2 trading schemes (permit price), CO2 taxes, fuel taxes, NOx and SOx tax rates, among others.[4] On average, stringency of market-based policies remained low until 2012, with large year-to-year variation (Figure 1a). Starting from 2012, countries have been steadily tightening their market-based environmental policies, and the average stringency has almost doubled by 2020.

Dechezlepretre and Sato (2018) found that ambitious environmental policies, as exemplified by the EPS, can have small but statistically significant negative effects on trade, employment, plant location and productivity in the short run, especially for carbon- and energy-intensive sectors. We study to what extent stricter climate-related

[4] Some of the components of market-based EPS index do not relate to emissions regulated under the EU ETS.

policies are transmitted among the group of firms particularly exposed to tighter carbon markets, namely the ones regulated under the EU ETS.

The EU ETS is a cap-and-trade system that regulates carbon emissions from various sectors (energy and industry[5]) by setting a cap on the total amount of allowances and letting the market determine the price that will lead to emissions reduction in a cost-effective manner. It went over four phases, each with different features and goals (Figure 1a). The first phase (2005-2007) was a trial period with free allowances for power and industry sectors. The second phase (2008-2012) reduced the cap by 6.5% and added three more countries (Iceland, Liechtenstein and Norway). The third phase (2013-2020) and fourth phase (2021-2030) further tightened the cap (by 1.74% and 2.2% annually, respectively) and expanded the scope to include aviation.

The free allocation was also gradually phased out, except for some exceptions to support decarbonization or prevent carbon leakage. As a result, the payable emissions increased over time. The EU ETS has achieved significant emissions reductions, surpassing the 2020 target of 21% below 2005 levels. The carbon prices have also fluctuated according to the market conditions and policy changes (Figure 1b). The ETS prices varied widely across the four phases of the EU ETS: they began at around €8 in 2005, reached around €30 in 2006, fell to almost zero in 2007 amid the global financial crisis, stayed at around €14 in Phase 2 and €11 in Phase 3, and surged to above €70 in the first 2.5 years of Phase 4, influenced by the EU's bold climate targets and the energy crisis.

Existing literature is mixed on the impact of the EU ETS on firms, but studies vary widely in their geographical scope or the phases of the ETS that are examined, capturing large periods of excess allocations of permits and therefore low permit prices in the permit trading market. In addition, most studies examine the impacts of the EU ETS on firms' productivity or employment, with fewer studies examining turnover, investment, and profitability[6]. For example, Marine et al. (2018) assessed the impact of the EU ETS between 2006 and 2014 (first two phases of the EU ETS) for manufacturing firms only and found no negative effect on firm performance, with turnover, markups, investment intensity and labour productivity showing increases following the implementation of the EU ETS. Petrick and Wagner (2014) also supported that the EU ETS did not harm German manufacturing firms'

[5] Scope of regulated activities includes electricity and heat generation and energy-intensive industry sectors, including oil refineries, steel works, and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals.

[6] A comprehensive review of studies on the EU ETS, including studies on early phases and national samples, can be found in Venmans, et al. (2020).

turnover, employment or exports, over 2007 to 2010. Jaraite and Di Maria (2016) found evidence for small increases in investments in the second phase of the EU ETS among Lithuanian firms, over 2003 to 2010. Klemetsen et al. (2020) found positive effects of the second phase of the EU ETS on firm value added in Norway. Deschezlepretre et al. (2023) used data on the first two phases of the EU ETS for four covered countries and found significant increases in revenue and fixed assets among regulated firms relative to a matched sample of unregulated firms. However, other studies have found mixed or negative effects of the EU ETS on firms. For instance, Chan, Li and Zhang (2013) found that the EU ETS increased costs and revenues in the power sector, but had no impact on employment, in 10 EU countries between 2001 and 2009.

More recent literature shows that firms react differently to climate-related policies, depending on their speed and degree of adaptation. Bijnens and Swartenbroekx (2022) argued that moving production within sectors to less carbon-intensive firms could cut emissions with little output loss. Looking beyond the scope of the ETS, Berthold et al. (2023) exploited granular firm-level data and documented that high-emissions firms are more responsive to ETS price change.

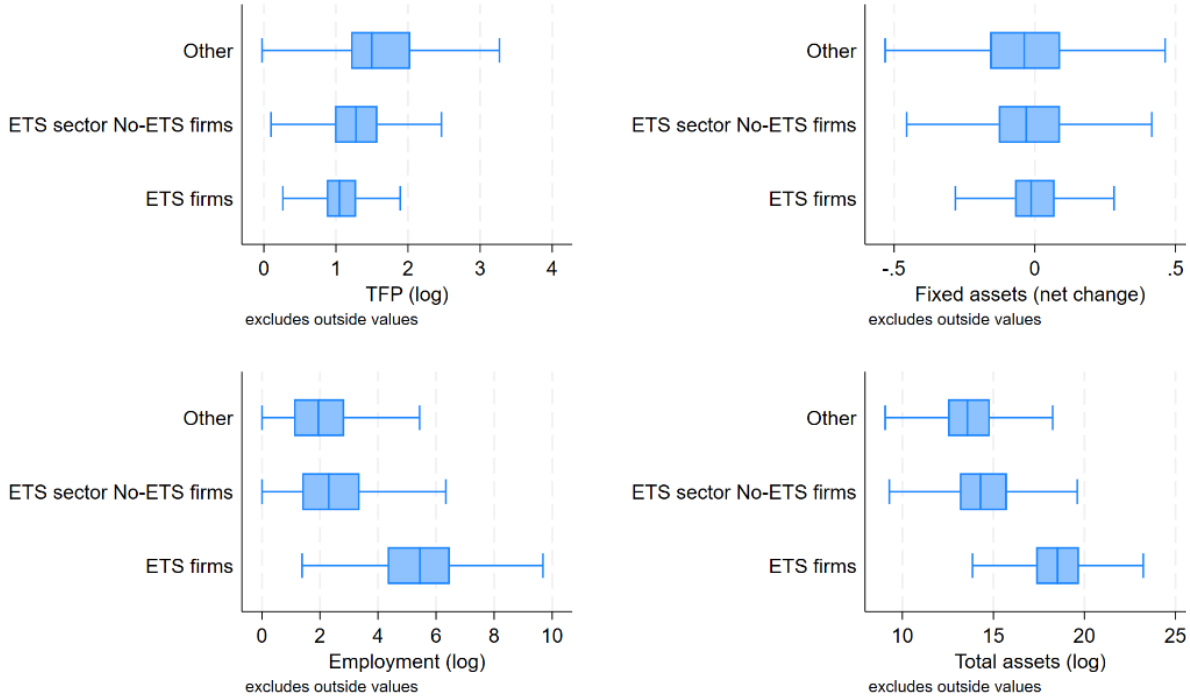
Our contribution to this literature capitalizes on a vast cross-country database of firm financials, enabling us to assess not only the direct impact of the EU ETS on regulated firms but also the spillover effects on other firms in the same country and sector. By considering the differences in emissions or energy intensities at the sectoral level, we explore the heterogeneity of these indirect effects. Additionally, we exploit variations in the price of emissions permits to assess differential impacts during periods of high and low prices, leveraging the longer time dimension of our panel database. Lastly, our study ensures the robustness of the results across the distribution of the ETS firms and various outcome variables, essential for empirical studies covering the EU ETS, given the non-homogeneous distribution of firms within the ETS system (Bijnens and Swartenbroekx, 2022).

Specifically, by looking at the level of Total Factor Productivity (TFP), investment, employment and total assets of ETS-reporting firms and firms located in the same sectors (at Nace Rev. 2, 4-digit classification) but not under the ETS-reporting requirement, we see differences in distribution moments (see Figure 2).[7] Typically, despite higher median investment levels ETS-sectors are less productive, and within the ETS sectors the ETS-reporting firms are even less productive despite even higher investment levels. ETS sectors are also bigger in terms of

[7] We use here the simplified box plots to introduce the argument, and detailed summary statistics are presented in the next section.

median employment and asset size, with ETS-reporting firms being even bigger. The size variables, in particular employment, seem to have a wider range of the distribution among the ETS firms.

**Figure 2. Distribution of outcome variables by country and ETS status.**




Sources: EU Emissions Trading System, and Orbis.
Note: Distribution charts of firms present the minimum, first quartile, median, third quartile and maximum parts of the distribution. Outside values are skipped.

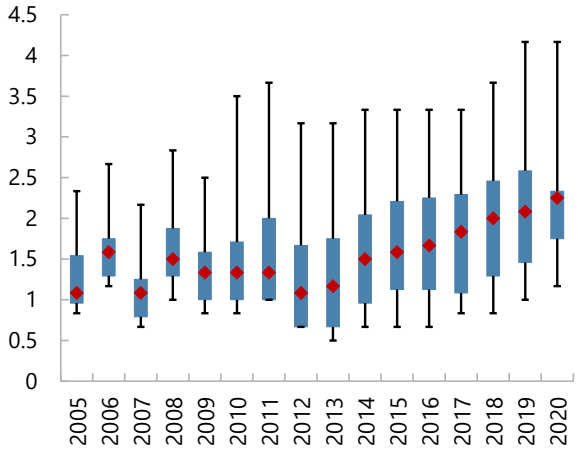
The irregularity of the ETS firms' distribution is also visible in the shape of the tails. For instance, the coefficient of variation of firms above the 3rd quartile of TFP distribution is nearly two times higher among the ETS firms than among firms in non-ETS sectors. For the fixed investment, this metric is 15% higher for the ETS firms. Overall, since the mean estimates are known to be susceptible to data outliers, we confirm the main results by estimating the equivalent median regressions as a robustness check.

# 3. Data and Empirical Specification

For our analysis, we create a novel dataset that matches firm-level financial accounts across EU economies, with country- and sector-wide regulatory and energy variables. We use the OECD's Environmental Policy Stringency (EPS) index to identify firm exposure to the impacts of climate policy at the country-year level. The EPS allows

for measurement and comparison of climate policies across time and countries. The index is composed of sub-indices that capture market-based (MB) as well as non-market-based (NMB) policies and regulations. Market-based policies include all policies that place price on pollution, including emissions trading schemes, CO2 taxes, taxes on NOx, SOx and fuel taxes. Non-market-based policies include emission limits, and content limits.

**Figure 3. Market-Based Environmental Policy Stringency Index, Variation across Countries**
(Index)




Source: Organisation for Economic Co-operation and Development.
Note: Figure shows variation in OECD market-based Environmental Policy Stringency Index across 12 European countries, with the interquartile range (box), the median level (marker), and minimum and maximum levels (whiskers).

Stringency of market-based policies increased significantly between 2005 and 2020, with a twofold increase in the market-based EPS index for a median country in the sample (Figure 3). Starting from 2012, market-based EPS indices have been rising in all countries, by 0.9 points on average. Stringency tightened the most in France (by 3.2 points since 2012), followed by Belgium and Portugal with 1.2 points increases in both countries over the same period. Over time, the distribution of policy stringency across countries became more negatively skewed, with more countries moving to the upper tail of the distribution by 2020. As for the countries with the least stringent market-based policies, Greece and Germany remained at the bottom of the distribution despite some tightening of market-based policies, by 0.5 points since 2012.

We use comprehensive annual information on firms' financials from the Bureau van Dijk's Orbis database, including information on turnover, cost of goods sold, stock of fixed assets and EBITDA. We follow cleaning steps for the Orbis data as outlined in Diez et al. (2021), including converting all flow variables into real variables using the 2-digit NACE level deflators and the World Bank WDI investment deflators at the country level (for fixed assets), and keep only non-financial firms with at least 10 consecutive years of sales data. We are also able to identify a subset of firms which own at least one installation in the EU Emission Trading System between 2008 and 2020, and therefore are subject to closer carbon reporting as carbon costs directly affect their production

decisions. We match EU ETS data on verified emissions and free allocated emission allowances of firms with ETS-regulated installations with the firms' financials in the Orbis database[8]. Our baseline panel includes 980

**Table 1. Summary statistics of different all firms and the ones subject to ETS regulation.**

| **Full sample** | | | | | |
|---|---|---|---|---|---|
| | Obs | Mean | Std. dev. | Min | Max |
| Turnover (net change) | 8,815,354 | 0.020 | 0.280 | -11.956 | 13.816 |
| Material costs (net change) | 7,387,437 | 0.008 | 0.562 | -14.411 | 15.126 |
| EBITDA (net change) | 8,815,354 | 0.005 | 0.825 | -13.448 | 11.365 |
| Fixed assets (net change) | 8,815,354 | 0.028 | 0.544 | -15.585 | 13.455 |
| N. of employees (log) | 8,815,354 | 2.21 | 1.44 | 0.00 | 13.42 |
| Total assets (log) | 8,815,354 | 13.88 | 1.83 | 2.75 | 27.08 |
| **EU ETS** | | | | | |
| | Obs | Mean | Std. dev. | Min | Max |
| Turnover (net change) | 6,356 | 0.012 | 0.209 | -6.817 | 4.034 |
| Material costs (net change) | 5,540 | 0.005 | 0.373 | -6.925 | 7.008 |
| EBITDA (net change) | 6,356 | 0.026 | 0.576 | -6.743 | 6.927 |
| Fixed assets (net change) | 6,356 | 0.020 | 0.291 | -9.694 | 9.729 |
| N. of employees (log) | 6,356 | 5.65 | 1.76 | 0.00 | 13.42 |
| Total assets (log) | 6,356 | 18.89 | 1.82 | 13.73 | 26.98 |

Sources: EU Emissions Trading System, and Orbis.

thousand firms (including 1,870 ETS-regulated firms) from 12 European countries over 1995-2020[9].

The empirical analysis exploits several sources of variation. We start by distinguishing between firms which have installations regulated by the ETS and average firms (non-ETS). In particular, we look into the subset of ETS firms for which higher carbon emission costs cannot be offset by free emission allowances and therefore affect directly the firms' profit function (ETS firms with payable emissions). In addition, we evaluate heterogeneity in the response of firms when the carbon price faced by firms is high, as measured by the trading price of emissions permits in the EU ETS market. We anticipate that tightening of regulations amidst high prices of emissions permits would reflect more binding constraints on firm budgets relative to time periods where the cost of emissions is low, particularly among firms with payable emissions that are emitting beyond their ETS allocation limit. Given the distributional differences between firms, as depicted in Figure 2, as a robustness check we estimate the effects for the median as an outlier-robust metric of the outcome variable.

[8] Orbis identifiers are available for about 7,200 ETS-regulated firms, which covers 66 percent of all installations.

[9] The sample includes Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Portugal, Spain, United Kingdom. The sample period coverage varies by country.

### i. Model specification

The general form of the baseline panel regression specification is as follows:

$$\Delta y_{ict} = \Theta^{MB}\, \Delta EPS^{MB}_{ct-1} \times X_{ict-1} + \Omega W_{ict-1} + \Upsilon\, Z_{ct-1} + D_{cs} + D_{st} + D_i + \varepsilon_{ict}, \quad (1)$$

where $\Delta y_{ict} = y_{ict} - y_{ict-1}$, and $y_{ict}$ is log of turnover, input costs (material costs), profits (EBITDA), fixed assets (total non-current assets after depreciation) of firm *i* from country *c* in year *t*. $\Delta EPS^{MB}_{ct}$ denote changes in the market-based (non-market based) Environmental Policy Stringency in country *c* between years *t-1* and *t*. $X_{ict} = [1, D^{CO2}_t, ETS^0_{ic}, ETS^0_{ic} \times D^{CO2}_t, ETS^P_{ict}, ETS^P_{ict} \times D^{CO2}_t]$ is a vector of variables, where the dummy variable $ETS^0_{ic}$ indicates if a firm has at least one installation subject to the ETS; $ETS^P_{ict}$ indicates whether the ETS-regulated firm had positive payable emissions in year t (emissions exceeding the free allowance level); and $D^{CO2}_t$ is a binary variable that indicates if carbon prices are above the 75th percentile calculated over 2008-2020 (excluding the first phase of ETS during 2005-2007 because at that time allowances were largely free at national level). $\Theta^{MB}$ is a vector of corresponding regression coefficients. $W_{ict}$ and $Z_{ct}$ are vectors of firm-level and country-level control variables (including changes in the non-market-based EPS index, $\Delta EPS^{NMB}_{ct}$), respectively. The regression also includes country-sector and sector-year fixed effects, $D_{cs}$ and $D_{st}$. Firm-level fixed effects are absorbed by $D_i$.

### ii. Robustness of the baseline model to distributional effects

To provide a distribution-robust metric of firm-level reaction to climate-related policies, we estimate the baseline model at the median of outcomes' distribution using a quantile regression. After Imbens and Wooldridge (2014), we control for unobserved firm-level heterogeneity using the Mundlak (1978) device, whereby the within-firm variation is absorbed by a vector of firm-level means of relevant variables in a pooled regression specification. As a result, we estimate the following model:

$$\mathrm{Q_q}(\Delta y_{\mathrm{icst}} | \mathrm{V_{icst-1}}) = \beta V_{icst-1} + \bar{\beta}\bar{V}_{icst-1} + \varepsilon_{icst}, \quad (2)$$

where *q* is the quantile of interest (in our case q=0.5 which is the median), $X_{i,t}$ is the vector of RHS variables from the baseline model, $V_{icst} = [\Delta EPS^{MB}_{ct} \times X_{\mathrm{icst}},\ W_{\mathrm{isct}},\ Z_{ct}]$, $\bar{V}_{icst}$ is the vector of firm-specific means calculated over the time dimension. In the empirical application, we skip firm-level and country-level control variables $W_{icst}$ and $Z_{ct}$, due to convergence difficulties, such that $\bar{V}_{icst}$ includes the means of the vector of $\Delta EPS^{MB}_{ct} \times X_{\mathrm{icst}}$ variables. Mundlak (1978) notes that the least-squares estimators of fixed effects models and when controlling for group differences by including group averages of the covariates are identical. In the context of a pooled quantile

regression in an unbalanced panel, $\beta$ estimates from the Mundlak device offer an approximation of the effect at a given quantile $q$ when unobserved firm-level heterogeneity is absorbed by group means (Imbens and Wooldridge (2014)). We use firm-clustered standard errors.

# 4. Results

Results suggest that more stringent market-based climate policies have had no significant impact on performance of an average non-ETS firm (Table 2), consistent with the findings of limited aggregate impact on output from higher carbon prices (Colmer et al., 2022). An increase in the market-based EPS index by one unit is associated with marginal declines in input costs and turnover (around 1 percentage point) and a small increase in profits, with no significant change in fixed assets.[10]

**Table 2. Estimates of Tightening of Market-Based Policy Stringency**

| | Δ Log Input Costs | Δ Log Turnover | Δ Log Profits | Δ Log Fixed Assets |
|---|---|---|---|---|
| Lag ΔEPS Market | -0.00989*** | -0.0131*** | 0.0104*** | 0.00296** |
| Lag ΔEPS Non-Market | 0.0109*** | 0.00168*** | -0.00412*** | -0.00493*** |
| Lag ΔEPS Market × High carbon price | 0.0503*** | 0.0537*** | 0.0159*** | -0.000477 |
| Lag ΔEPS Market × ETS firm | -0.0346*** | -0.0114* | -0.0448** | -0.0113 |
| Lag ΔEPS Non-Market × ETS firm | 0.00210 | 0.00109 | 0.00542 | 0.00562 |
| Lag ΔEPS Market × ETS firm × High carbon price | -0.0474* | -0.0292** | 0.150*** | -0.0176 |
| Lag ΔEPS Market × ETS firm with payable emissions | 0.0121 | -0.0115 | 0.0477 | 0.0139 |
| Lag ΔEPS Non-Market × ETS firm with payable emissions | -0.0419 | -0.00496 | 0.0756 | 0.0116 |
| Lag ΔEPS Market × ETS firm with payable emissions × High carbon price | 0.0973** | 0.0435* | -0.217*** | 0.0598* |
| Lag Log Employment | -0.0538*** | -0.0523*** | 0.000801 | 0.0184*** |
| Lag Log Total Assets | -0.130*** | -0.112*** | -0.245*** | -0.187*** |
| Lag Real GDP growth | 0.0148*** | 0.0131*** | 0.0179*** | 0.00691*** |
| Lag Output gap | -0.00905*** | -0.00592*** | -0.0120*** | -0.000906*** |
| Constant | 1.890*** | 1.651*** | 3.354*** | 2.569*** |
| Observations | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 |
| R-squared | 0.126 | 0.201 | 0.091 | 0.135 |
| Firm Fixed Effect | Yes | Yes | Yes | Yes |
| Sector | Non-Fin | Non-Fin | Non-Fin | Non-Fin |
| Country-Sector Fixed Effect | Yes | Yes | Yes | Yes |
| Year-Sector Fixed Effect | Yes | Yes | Yes | Yes |

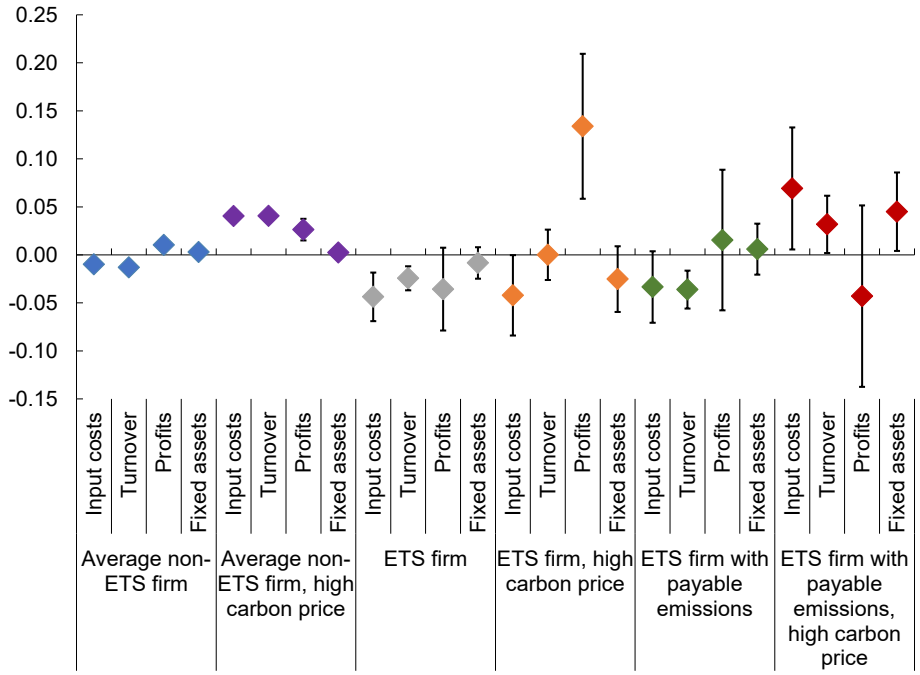
Sources: EU Emissions Trading System; European Investment Bank; IMF, World Economic Outlook database, ORBIS; and Organisation for Economic Co-operation and Development.
Note: The table presents the estimated coefficients from a panel regression model based on EU ETS and Bureau van Dijk ORBIS database. The sample consists of 12 European countries covering 1995–2020 and data cleaning follows Diez, Fan, and Villegas-Sánchez (2021). The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, tax, depreciation, and amortization), and fixed assets (in logarithms). ΔEPS Market and ΔEPS Non-Market correspond to changes in Organisation for Economic Co-operation and Development market-based and non-market-based Environmental Policy Stringency indices, respectively. ETS firms correspond to firms with ETS-registered installations. Payable emissions are calculated as a difference between verified emissions and free allowances. "High carbon price" takes on a value of 1 in years with the EU carbon price above the 75th percentile. Standard errors are not reported here but are available from authors. ***, **, and * denote statistical significance at 1 percent, 5 percent, and 10 percent levels, respectively. ETS = Emission Trading System.

ETS-regulated firms have not been adversely affected (Figure 4). Despite a decrease in turnover (2.4 percentage points), profits remain unchanged on average (though there are large differences across firms which may be

[10] An average increase in the market-based EPS index for 12 countries in our sample over the 2012–20 period is about 0.9. Hence, a unit increase in the index can be interpreted as tightening of climate policies over the medium term.

partially driven by differences in freely allocated emission allowances). There is also no significant change in fixed assets for an average ETS firm.

**Figure 4. Estimated Impact of Environmental Policy Stringency on Firms' Performance**
(Coefficient estimates)

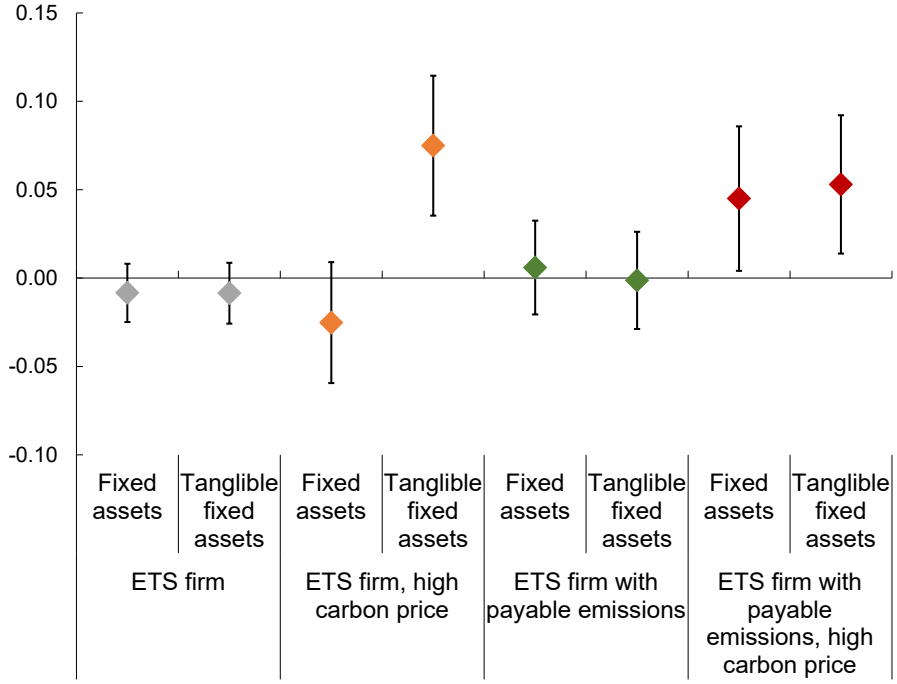



Sources: EU Emissions Trading System; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.
Note: Figure shows estimated coefficients from a panel regression of 12 European countries over 1995–2020 based on EU ETS and Bureau van Dijk ORBIS data. The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, taxes, depreciation and amortization), and fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable by firm group. ETS-regulated firms are those with ETS-registered installations. Payable carbon emissions are calculated as the difference between verified emissions and free allowances. "High carbon price" is a dummy variable that takes on a value of 1 in years with the carbon prices exceeding the 75th percentile. The whiskers indicate the 95 percent confidence interval of the estimated coefficients. The regression includes firm, country-sector, and year-sector fixed effects and robust standard errors clustered at the firm level. ETS = Emissions Trading System.

If we distinguish between periods of high and low carbon prices, we find that ETS firms report declines in input costs and large increases in profitability if the EPS tightens during period of high carbon prices and they have no payable emissions. This is likely driven by the ability of these firms to trade their emission permits since their emissions are lower than their allowances. However, among ETS firms with payable emissions, tightening of the EPS when carbon prices are high results in increases in input costs of over 6 percent. Turnover increases for these firms by 3 percent, indicating some degree of pass-through of higher carbon prices, while profitability impacts are negative but not statistically significant. Given evidence of pass-through from directly regulated firms during periods of high carbon prices, it should perhaps be unsurprising that unregulated firms also report small increases in input costs when carbon prices are high. However, unregulated firms show even stronger evidence

of pass-through as turnover rises in lockstep with input costs, resulting in no profitability impacts on these firms, even in periods of high carbon price. While the impact of tighter policies on investment—proxied by changes in fixed assets—of an average ETS-regulated firm that emits more than free allowance levels is not statistically different from zero, it turns positive and significant when carbon prices are high (Figure 4). Specifically, a tightening of market-based regulations by one unit is associated with a rise in fixed assets by about 4.5 percentage points.

**Figure 5. Estimated Impact of Environmental Policy Stringency: Total Fixed and Tangible Fixed Assets**
(Coefficient estimates)




Sources: EU Emissions Trading System; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.
Note: Figure shows estimated coefficients from two panel regressions of 12 European countries over 1995–2020 based on EU ETS and Bureau van Dijk ORBIS data. The dependent variables are changes in total fixed assets and tangible fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable by firm group. ETS-regulated firms are those with ETS-registered installations. Payable carbon emissions are calculated as the difference between verified emissions and free allowances. "High carbon price" is a dummy variable that takes on a value of 1 in years with the carbon prices exceeding the 75th percentile. The whiskers indicate the 95 percent confidence interval of the estimated coefficients. Both regressions include firm, country-sector, and year-sector fixed effects and robust standard errors clustered at the firm level. ETS = Emissions Trading System.

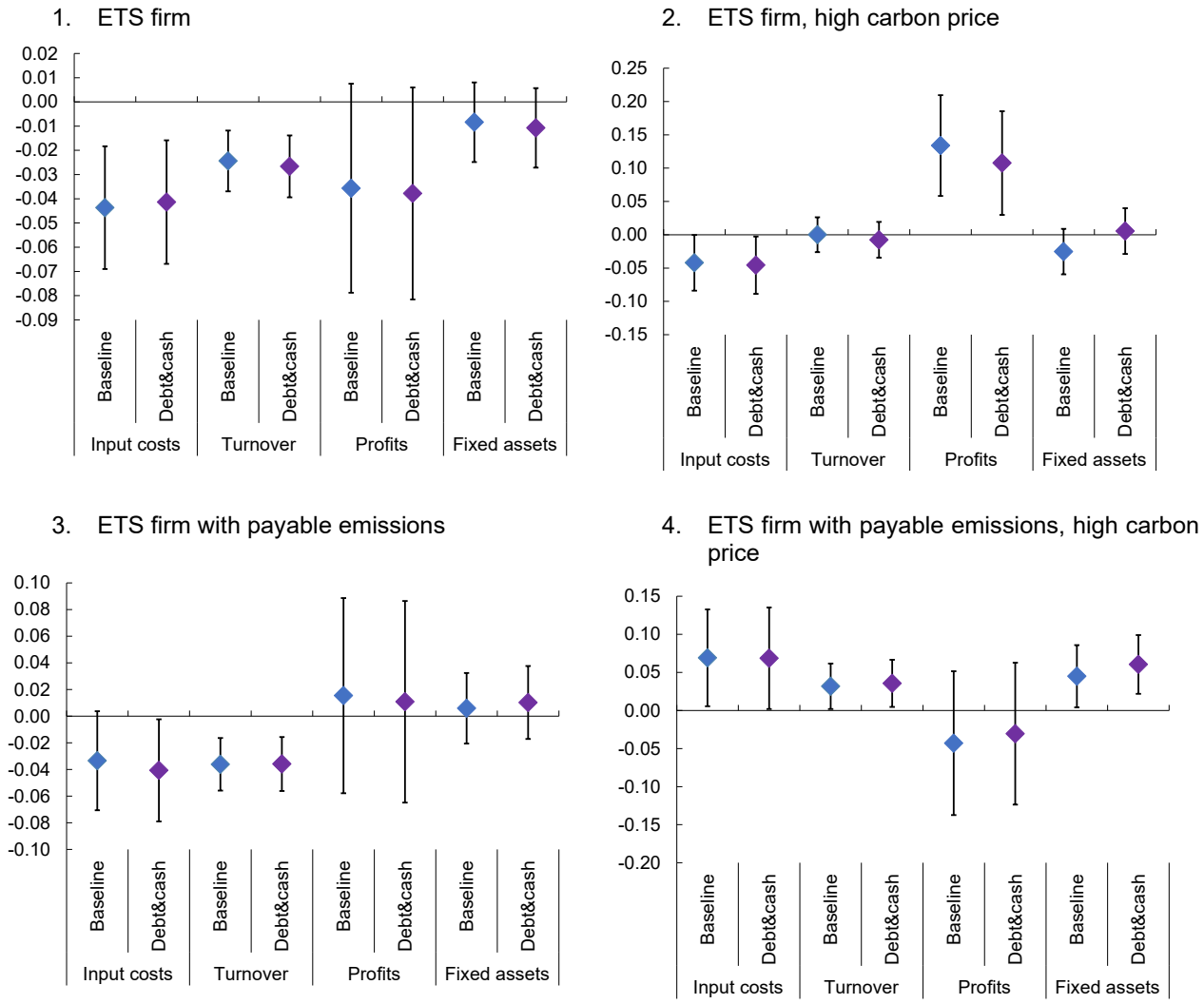
We further explore the investment effect by distinguishing between investments in tangible fixed assets and intangible fixed assets[11]. Figure 5 shows the estimated changes in tangible fixed assets for the subsample of ETS firms compared to those in total fixed assets. In periods of high carbon prices, ETS firms with payable emissions report commensurate increases in total fixed assets and tangible fixed assets, implying that intangible fixed asset investments are also increasing. In contrast, only tangible fixed assets increase among firms who do not have payable emissions (7 percentage points), and total fixed assets remain unchanged, implying a decline in investment in intangibles. This signals that when firms have to pay for their emissions, they switch their investment portfolio in favour of greater investment in intangible capital, in line with the assertion in the literature that the use of greater intangible capital relative to tangible capital reduces energy intensity of production (Yang and Shi, 2018). Novel surveys conducted for representative firms in Germany during the 2023 energy crisis also show that firms increase their investment in energy efficiency to cope with higher energy costs (IMF, 2023). This result also aligns with literature on China's ETS which also indicates that regulations bias firms towards greater intangible capital investments, given that tangible investments in regulated industries are expensive and difficult to relocate while intangible investments reflect innovations and improvements in production efficiency (Wu and Wang, 2022). The finding is also consistent with the results of De Jonghe, Mulier and Schepens (2020), whereby ETS firms exposed to higher costs of carbon are more likely to acquire green targets after the regulatory tightening. In cases where the acquisition price exceeds the net fair value of the purchased assets, it would be reflected as an increase of intangible capital.

# 5. Robustness

To verify if the main results are susceptible to changes in model variables or assumptions, we carry out a batter of robustness checks. Firstly, we control for additional firm-level characteristics to address concerns over potential omitted variable bias. In particular, we include cash-to-asset ratio and leverage (debt-to-asset ratio), as proxies for firm's resilience or amplification variables to external shocks, respectively. Secondly, we verify whether estimation results are sensitive to the alternative measure of investment, namely tangible investment proxied by changes in tangible fixed assets. Third, we also explore to what extent more stringent climate policies affect firms during periods of low carbon prices, as well as during periods of high carbon price volatility. Last but

[11] Given that a large number of firms in the sample report intangible fixed assets as zero, we do not examine this variable directly but indirectly through changes in tangible fixed assets relative to changes in total fixed assets, where total fixed assets are the sum of tangible fixed assets and intangible fixed assets.

**Figure 6. Estimated Impact of Environmental Policy Stringency on Firms' Performance**
(Coefficient estimates)



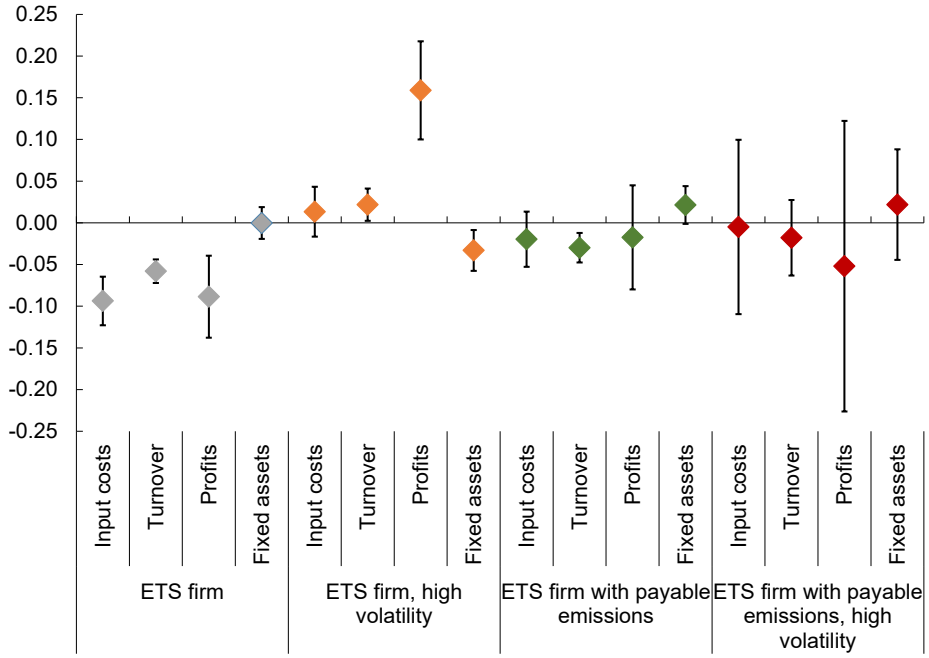

Sources: EU Emissions Trading System; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.
Note: Figure shows estimated coefficients from two panel regressions of 12 European countries over 1995–2020 based on EU ETS and Bureau van Dijk ORBIS data. "Debt&cash" is the baseline regression with two additional firm-level control variables (cash-to asset and debt-to-asset ratios). The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, taxes, depreciation and amortization), and fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable. ETS-regulated firms are those with ETS-registered installations. Payable carbon emissions are calculated as the difference between verified emissions and free allowances. "High carbon price" is a dummy variable that takes on a value of 1 in years with the carbon prices exceeding the 75th percentile. Both regressions include firm, country-sector, and year-sector fixed effects and robust standard errors clustered at the firm level. The whiskers indicate the 95 percent confidence interval of the estimated coefficients. ETS = Emissions Trading System.

not least, given that the ETS-dependent firms differ from an average firm (see Figure 2 in Section 2), we estimate the model for different quantiles of distribution to make sure that the main effects are not only a result of

distributional irregularities. We find that our main results are robust to the inclusion of (lagged) cash-to-asset and debt-to-asset ratios in the baseline regression (Annex Table 1).

The estimated impacts of more stringent market-based climate policies on changes in input costs, turnover, profits, and fixed assets remain broadly the same as in the baseline across all subgroups of ETS-regulated firms, including during periods of high carbon prices (see Figure 6). Precision of some parameter estimates somewhat improves. The main difference with the baseline estimation is that more stringent climate policies are associated with slightly larger increase in fixed assets (by 6 percentage points compared to 4.5 in the baseline).

**Figure 7. Estimated Impact of Environmental Policy Stringency on Firms' Performance: High Carbon Price Volatility**
(Coefficient estimates)




Sources: EU Emissions Trading System; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.
Note: Figure shows estimated coefficients from a panel regression of 12 European countries over 1995–2020 based on EU ETS and Bureau van Dijk ORBIS data. The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, taxes, depreciation and amortization), and fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable by firm group. ETS-regulated firms are those with ETS-registered installations. Payable carbon emissions are calculated as the difference between verified emissions and free allowances. "High volatility" is a dummy variable that takes on a value of 1 in years with the standard deviation of carbon prices above the 75th percentile, respectively. The whiskers indicate the 95 percent confidence interval of the estimated coefficients. The regression includes firm, country-sector, and year-sector fixed effects and robust standard errors clustered at the firm level. ETS = Emissions Trading System.

To explore whether the impact of tighter market-based climate policies varies depending on high versus low carbon price environment, we include a dummy variable corresponding to low carbon price periods into the baseline regression (see Annex Figure 1). In contrast to periods of high carbon prices, there is no change in input

costs or profits of ETS firms when carbon prices are low, with the latter is likely due to lack of excess profits from trading emission permits. Responses of input costs and turnover of ETS firms with payable emissions look more symmetric: tightening of EPS when carbon prices are low is associated with almost 9 percent decline in input costs, part of which is passed-through resulting in 7 percent decline in turnover. During periods of both low and high carbon prices, the impact on profits of ETS firms with payable emissions is negative but not statistically significant. As for investment in fixed assets, more stringent climate policies do not seem to enhance investment by ETS firms with payable emissions in a low carbon price environment.

In contrast to periods of high carbon prices, we do not observe any significant response of ETS firms with payable emissions to tightening of climate policies during periods of volatile carbon prices (Figure 7). Higher volatility of carbon prices, which could partly reflect higher degree of carbon market uncertainty, does not induce ETS firms to accumulate fixes assets. ETS firms with no payable emissions even reduce their fixed assets on average despite benefiting from volatile carbon prices. This suggests that regulated firms are more likely to respond to stricter climate policies when they face tighter budget constraints rather than carbon price uncertainty.

Quantile regression results for the medians of the outcome variables are reported in Figure 8. Our main focus is on the ETS subsample, which we present in a graphical format for better readability, but the results for other specifications are available upon request. Firstly, nearly all of the median effects are not statistically different from the baseline results at 5% significance level.[12] This suggests that the majority of the reported results are representative of at least 50% of ETS firms, and therefore not necessarily driven data irregularities.

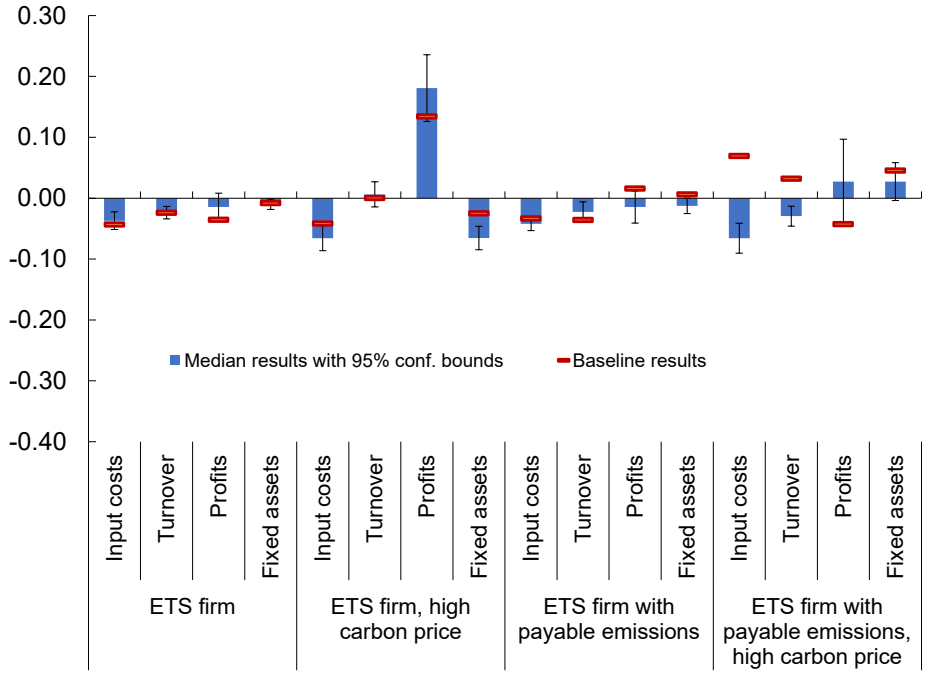
Secondly, the median effects for the input costs and turnover become modestly negative among ETS firms with payable emissions in the periods of high carbon prices. These are in fact the only statistically distinct results from the baseline specification. It suggests that the pass-through of higher ETS prices to the production costs is observed among rather few ETS companies with payable emissions. Overall, however, a median ETS firm observes modest slowdown in economic activity, as exemplified by lower input costs and/or turnover, irrespective of the carbon price level or the exposure to payable emissions. Importantly, the median profits of ETS firms remain protected or even increase in the periods of high carbon prices. This supports the previous conclusion that the financial impact of stricter climate rules on ETS firms is rather limited, not only on average but also when considering at least 50% of ETS firms.

[12] The statistical testing procedure includes the estimation errors for both the mean and the median coefficients.

The investment impact among ETS firms with payable emissions remains positive. The median effects are estimated at roughly 3%, being modestly weaker than the average results but still statistically significant and economically meaningful. It highlights that carbon price investment incentives are well reflected in the broader ETS market, with a few firms rolling out more ambitious investment plans. Overall, we view the results from the quantile panel regression as a confirmation of robustness of the main results with respect to possible distributional irregularities of the ETS firms.

**Figure 8. Quantile Impact of Environmental Policy Stringency on Firms' Performance**

(Coefficient estimates)




Sources: EU Emissions Trading System; European Investment Bank; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.
Note: The table presents the estimated coefficients from a quantile panel regression model based on EU ETS and Bureau van Dijk ORBIS database, estimated at quantile q=0.5 (median). The sample consists of 12 European countries covering 1995–2020 and data cleaning follows Diez, Fan, and Villegas-Sánchez (2021). The model absorbs firm-level unobserved heterogeneity using the Mundlak device. The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, tax, depreciation, and amortization), and fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable by firm group. ETS firms correspond to firms with ETS-registered installations. Payable emissions are calculated as a difference between verified emissions and free allowances. "High carbon price" takes on a value of 1 in years with the EU carbon price above the 75th percentile. For comparison, we plot the results from the baseline regression with corresponding 95% confidence bounds. ETS = Emissions Trading System.

# 6. Conclusion

We examine how changes in the stringency of market-based climate policies impact firm performance. Our novel database allows us to examine a large cross-country sample over 15 years, capturing several phases of the EU ETS, characterized by varying levels of emissions constraints in the form of allocation of emissions allowances and a range of carbon prices in the ETS. Leveraging firm-level data, we explore the effect of market-based policy changes on key indicators of firm performance, including fixed assets, input costs, turnover and profits. Our analysis also delves into the heterogeneous impact of policy shocks on different types of firms, such as those with and without payable emissions, and firms operating during periods of high and low carbon prices.

Our findings indicate that more stringent market-based climate policies do not negatively impact the average firm or ETS firms. Instead, they incentivize these firms to invest in low-carbon technologies and reduce their emissions. Notably, ETS-firms with payable emissions increase their investment levels during periods of high carbon prices.

These findings suggest that market-based mechanisms, such as the ETS, can help firms to achieve emission reduction goals and mitigate climate risks, without imposing significant economic burdens on them. They create a price signal for carbon that reflects the social cost of emissions and encourage the adoption of cleaner technologies and practices. However, it is important to consider the design and coordination of market-based policies, as well as the distributional effects across different types of firms within the regulated sectors.

One important aspect of this debate is the degree of a pass-through. For instance, Cludius et al. (2020) found that some sectors in the EU ETS market have earned additional profits through mechanisms such as overallocation of free emission allowances and the use of international offsets. While these results seem to vary across sectors and countries, they put in question the fairness of the scheme. Our results show that the cost pass-through effects can be in fact smaller when taking into account the distribution of firms and controlling for firm- and country-specific factors. In particular, our quantile panel regression results suggest while most firms manage to protect their profitability from the impact of stricter climate policies, only a few firms choose to pass on increased input costs downstream.

Striking a balance that incentivizes all firms to invest in low-carbon technologies is crucial. This necessitates coordinated policies across different sectors, regions and countries to avoid policy fragmentation, duplications, or inconsistency. In parallel, it is crucial to monitor and address any distributional effects across different types of firms within the regulated sectors, by providing support to those that are more vulnerable to emissions costs

or are less able to adapt to changing market conditions (i.e., hard to abate sectors). Only by doing so, it can be ensured that market-based mechanisms are fair, effective, and efficient in achieving emission reduction goals and mitigating climate change risks.

Looking ahead, we view the findings of this study as a prelude to a structural analysis on the transmission of regulatory shocks to firms' performance. One of the key factors determining corporate strategy to internalize higher carbon costs is technological availability. Extending our work, a natural direction is to explore whether the innovation capacity and distance to technological frontier of firms regulated under the ETS interact with their investment response to stricter climate rules. Another important avenue of research is exploring the quantile regression results beyond the median, to shed great light on risks to tail-end firms.

# Annex I.

**Annex Table 1. Estimates of Tightening of Market-Based Policy Stringency**

| | Δ Log Input Costs | | Δ Log Turnover | | Δ Log Profits | | Δ Log Fixed Assets | | Δ Log Tangible Fixed Assets | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lag ΔEPS Market | -0.00989*** | -0.0106*** | -0.0131*** | -0.0145*** | 0.0104*** | 0.0108*** | 0.00296** | -0.000390 | 0.00713*** | 0.00525*** |
| Lag ΔEPS Market × High carbon price | 0.0503*** | 0.0530*** | 0.0537*** | 0.0576*** | 0.0160*** | 0.0126** | -0.000476 | 0.0180*** | 0.00867** | 0.0221*** |
| Lag ΔEPS Market × ETS firm | -0.0338*** | -0.0308** | -0.0113* | -0.0121* | -0.0461** | -0.0486** | -0.0113 | -0.0103 | -0.0157* | -0.0143 |
| Lag ΔEPS Market × ETS firm × High carbon price | -0.0487** | -0.0573** | -0.0293** | -0.0385*** | 0.154*** | 0.133*** | -0.0163 | -0.00183 | 0.0748*** | 0.0976*** |
| Lag ΔEPS Market × ETS firm with payable emissions | 0.0102 | 0.000672 | -0.0118 | -0.00922 | 0.0511 | 0.0486 | 0.0143 | 0.0210 | 0.00728 | 0.00884 |
| Lag ΔEPS Market × ETS firm with payable emissions × High carbon price | 0.101** | 0.114*** | 0.0435* | 0.0524** | -0.228*** | -0.187** | 0.0559* | 0.0340 | -0.0292 | -0.0485 |
| Lag ΔEPS Non-Market | 0.0109*** | 0.0100*** | 0.00169*** | 0.00169*** | -0.00408*** | -0.00701*** | -0.00490*** | -0.00242*** | -0.00587*** | -0.00293*** |
| Lag Log Employment | -0.0538*** | -0.0480*** | -0.0523*** | -0.0468*** | 0.000802 | 0.00384*** | 0.0184*** | 0.0191*** | 0.00825*** | 0.00816*** |
| Lag Log Total Assets | -0.130*** | -0.137*** | -0.112*** | -0.116*** | -0.245*** | -0.260*** | -0.187*** | -0.169*** | -0.171*** | -0.155*** |
| Lag Cash to Total Assets Ratio | | -0.110*** | | -0.0940*** | | -0.555*** | | 0.550*** | | 0.468*** |
| Lag Debt to Total Assets Ratio | | 0.0798*** | | 0.0696*** | | 0.334*** | | -0.160*** | | -0.178*** |
| Lag Real GDP growth | 0.0148*** | 0.0154*** | 0.0131*** | 0.0137*** | 0.0179*** | 0.0187*** | 0.00691*** | 0.00575*** | 0.00694*** | 0.00586*** |
| Lag Output gap | -0.00905*** | -0.00873*** | -0.00592*** | -0.00551*** | -0.0120*** | -0.00921*** | -0.000905*** | -0.00330*** | 0.00128*** | 0.000277 |
| Constant | 1.890*** | 2.005*** | 1.651*** | 1.727*** | 3.354*** | 3.612*** | 2.569*** | 2.292*** | 2.362*** | 2.134*** |
| Observations | 7,326,460 | 6,223,366 | 7,326,460 | 6,223,366 | 7,326,460 | 6,223,366 | 7,326,460 | 6,223,366 | 7,236,517 | 6,165,198 |
| R-squared | 0.126 | 0.138 | 0.201 | 0.214 | 0.091 | 0.109 | 0.135 | 0.165 | 0.134 | 0.157 |
| Firm Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-Sector Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Sector Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Sources: EU Emissions Trading System; European Investment Bank; IMF, World Economic Outlook database, ORBIS; and Organisation for Economic Co-operation and Development.
Note: The table presents the estimated coefficients from a panel regression model based on EU ETS and Bureau van Dijk ORBIS database. The sample consists of 12 European countries covering 1995–2020 and data cleaning follows Diez, Fan, and Villegas-Sánchez (2021). The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, tax, depreciation, and amortization), fixed assets, and tangible fixed assets (in logarithms). ΔEPS Market and ΔEPS Non-Market correspond to changes in Organisation for Economic Co-operation and Development market-based and non-market-based Environmental Policy Stringency indices, respectively. ETS firms correspond to firms with ETS-registered installations. Payable emissions are calculated as a difference between verified emissions and free allowances. "High carbon price" takes on a value of 1 in years with the EU carbon price above the 75th percentile. Standard errors are not reported here but are available from authors. ***, **, and * denote statistical significance at 1 percent, 5 percent, and 10 percent levels, respectively. ETS = Emissions Trading System.

**Annex Table 2. Estimates of Tightening of Market-Based Policy Stringency: High vs Low Carbon Prices**

| | Δ Log Input Costs | | Δ Log Turnover | | Δ Log Profits | | Δ Log Fixed Assets | |
|---|---|---|---|---|---|---|---|---|
| Lag ΔEPS Market | -0.00989*** | -0.00587*** | -0.0131*** | -0.0101*** | 0.0104*** | 0.0214*** | 0.00296** | -0.00541*** |
| Lag ΔEPS Market × High carbon price | 0.0503*** | 0.0465*** | 0.0537*** | 0.0509*** | 0.0160*** | 0.00551 | -0.000476 | 0.00746** |
| Lag ΔEPS Market × Low carbon price | | -0.0322*** | | -0.0240*** | | -0.0880*** | | 0.0670*** |
| Lag ΔEPS Market × ETS firm | -0.0338*** | -0.0435*** | -0.0113* | -0.0149** | -0.0461** | -0.0648*** | -0.0113 | -0.00798 |
| Lag ΔEPS Market × ETS firm × High carbon price | -0.0487** | -0.0382 | -0.0293** | -0.0254* | 0.154*** | 0.175*** | -0.0163 | -0.0208 |
| Lag ΔEPS Market × ETS firm × Low carbon price | | 0.0837** | | 0.0267 | | 0.140* | | -0.00146 |
| Lag ΔEPS Market × ETS firm with payable emissions | 0.0102 | 0.0503* | -0.0118 | 0.00622 | 0.0511 | 0.0447 | 0.0143 | 0.0458** |
| Lag ΔEPS Market × ETS firm with payable emissions × High carbon price | 0.101** | 0.0602 | 0.0435* | 0.0253 | -0.228*** | -0.232*** | 0.0559* | 0.0305 |
| Lag ΔEPS Market × ETS firm with payable emissions × Low carbon price | | -0.140*** | | -0.0530** | | -0.0826 | | -0.0725** |
| Lag Log Employment | -0.0538*** | -0.0537*** | -0.0523*** | -0.0523*** | 0.000802 | 0.00105 | 0.0184*** | 0.0182*** |
| Lag Log Total Assets | -0.130*** | -0.130*** | -0.112*** | -0.112*** | -0.245*** | -0.245*** | -0.187*** | -0.187*** |
| Lag ΔEPS Non-Market | 0.0109*** | 0.0114*** | 0.00169*** | 0.00204*** | -0.00408*** | -0.00278*** | -0.00490*** | -0.00589*** |
| Lag Real GDP growth | 0.0148*** | 0.0145*** | 0.0131*** | 0.0129*** | 0.0179*** | 0.0170*** | 0.00691*** | 0.00765*** |
| Lag Output gap | -0.00905*** | -0.00901*** | -0.00592*** | -0.00590*** | -0.0120*** | -0.0119*** | -0.000905*** | -0.000983*** |
| Constant | 1.890*** | 1.889*** | 1.651*** | 1.650*** | 3.354*** | 3.353*** | 2.569*** | 2.570*** |
| Observations | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 |
| R-squared | 0.126 | 0.126 | 0.201 | 0.201 | 0.091 | 0.091 | 0.135 | 0.135 |
| Firm Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country-Sector Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Sector Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Sources: EU Emissions Trading System; European Investment Bank; IMF, World Economic Outlook database, ORBIS; and Organisation for Economic Co-operation and Development.

Note: The table presents the estimated coefficients from a panel regression model based on EU ETS and Bureau van Dijk ORBIS database. The sample consists of 12 European countries covering 1995–2020 and data cleaning follows Diez, Fan, and Villegas-Sánchez (2021). The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, tax, depreciation, and amortization), and fixed assets (in logarithms). ΔEPS Market and ΔEPS Non-Market correspond to changes in Organisation for Economic Co-operation and Development market-based and non-market-based Environmental Policy Stringency indices, respectively. ETS firms correspond to firms with ETS-registered installations. Payable emissions are calculated as a difference between verified emissions and free allowances. "Low carbon price" and "High carbon price" are dummy variables that take on a value of 1 in years with the carbon prices below the 25$^{th}$ and above the 75th percentile, respectively Standard errors are not reported here but are available from authors. ***, **, and * denote statistical significance at 1 percent, 5 percent, and 10 percent levels, respectively. ETS = Emissions Trading System.

**Annex Table 3. Estimates of Tightening of Market-Based Policy Stringency: High Carbon Price Volatility**

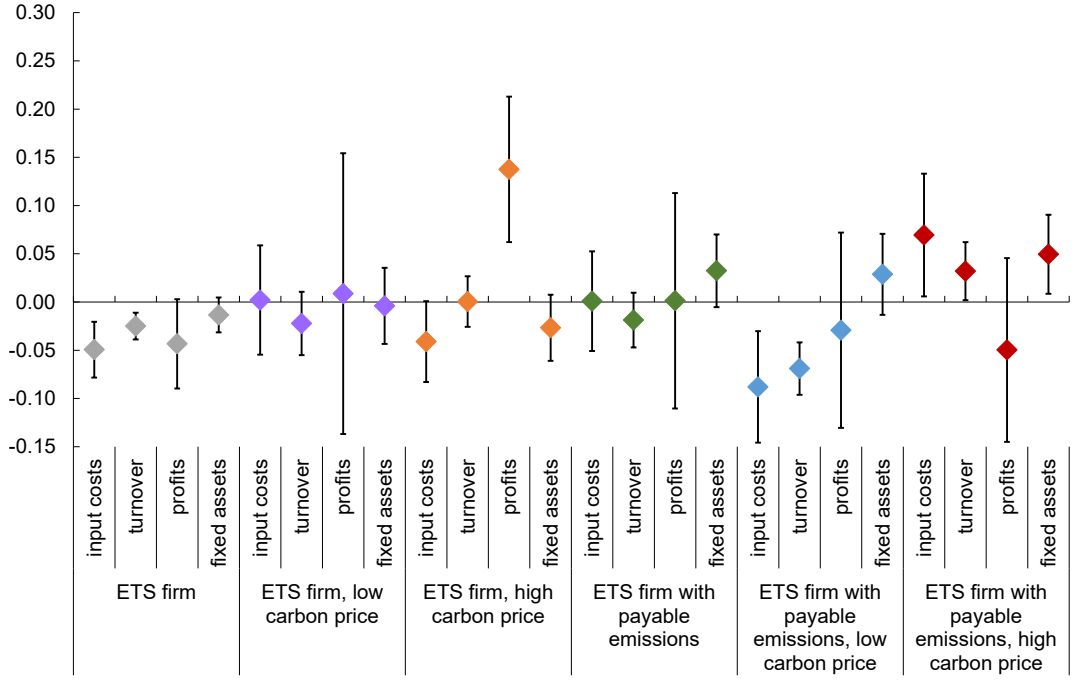
| | Δ Log Input Costs | Δ Log Turnover | Δ Log Profits | Δ Log Fixed Assets |
|---|---|---|---|---|
| Lag ΔEPS Market | -0.0237*** | -0.0201*** | -0.0123*** | 0.00640*** |
| Lag ΔEPS Market × High volatility | 0.0560*** | 0.0374*** | 0.0697*** | -0.00993*** |
| Lag ΔEPS Market × ETS firm | -0.0700*** | -0.0380*** | -0.0764*** | -0.00666 |
| Lag ΔEPS Market × ETS firm × High volatility | 0.0510** | 0.0424*** | 0.178*** | -0.0229 |
| Lag ΔEPS Market × ETS firm with payable emissions | 0.0741*** | 0.0282** | 0.0712* | 0.0217 |
| Lag ΔEPS Market × ETS firm with payable emissions × High volatility | -0.0923* | -0.0679** | -0.282*** | 0.0332 |
| Lag ΔEPS Non-Market | 0.0113*** | 0.00206*** | -0.00387*** | -0.00492*** |
| Lag Log Employment | -0.0539*** | -0.0524*** | 0.000760 | 0.0184*** |
| Lag Log Total Assets | -0.130*** | -0.112*** | -0.245*** | -0.187*** |
| Lag Real GDP growth | 0.0134*** | 0.0121*** | 0.0163*** | 0.00715*** |
| Lag Output gap | -0.00871*** | -0.00565*** | -0.0117*** | -0.000947*** |
| Constant | 1.894*** | 1.653*** | 3.359*** | 2.568*** |
| | | | | |
| Observations | 7,326,460 | 7,326,460 | 7,326,460 | 7,326,460 |
| R-squared | 0.126 | 0.201 | 0.091 | 0.135 |
| Firm Fixed Effect | Yes | Yes | Yes | Yes |
| Country-Sector Fixed Effect | Yes | Yes | Yes | Yes |
| Year-Sector Fixed Effect | Yes | Yes | Yes | Yes |

Sources: EU Emissions Trading System; European Investment Bank; IMF, World Economic Outlook database, ORBIS; and Organisation for Economic Co-operation and Development.

Note: The table presents the estimated coefficients from a panel regression model based on EU ETS and Bureau van Dijk ORBIS database. The sample consists of 12 European countries covering 1995–2020 and data cleaning follows Diez, Fan, and Villegas-Sánchez (2021). The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, tax, depreciation, and amortization), and fixed assets (in logarithms). ΔEPS Market and ΔEPS Non-Market correspond to changes in Organisation for Economic Co-operation and Development market-based and non-market-based Environmental Policy Stringency indices, respectively. ETS firms correspond to firms with ETS-registered installations. Payable emissions are calculated as a difference between verified emissions and free allowances. "High volatility" is a dummy variable that takes on a value of 1 in years with the standard deviation of carbon prices above the 75th percentile, respectively. Standard errors are not reported here but are available from authors. ***, **, and * denote statistical significance at 1 percent, 5 percent, and 10 percent levels, respectively. ETS = Emissions Trading System.

**Annex Figure 1. Estimated Impact of Environmental Policy Stringency on Firms' Performance: Low vs High Carbon Prices**

(Coefficient estimates)




Sources: EU Emissions Trading System; IMF, World Economic Outlook database; ORBIS; and Organisation for Economic Co-operation and Development.

Note: Figure shows estimated coefficients from a panel regression of 12 European countries over 1995–2020 based on EU ETS and Bureau van Dijk ORBIS data. The dependent variables are changes in input costs (material costs), turnover, profits (earnings before interest, taxes, depreciation and amortization), and fixed assets (in logarithms). Each coefficient estimate represents the impact from a change in Organisation for Economic Co-operation and Development market-based Environmental Policy Stringency index on the corresponding dependent variable by firm group. ETS-regulated firms are those with ETS-registered installations. Payable carbon emissions are calculated as the difference between verified emissions and free allowances. "Low carbon price" and "High carbon price" are dummy variables that take on a value of 1 in years with the carbon prices below the 25$^{th}$ and above the 75th percentile, respectively. The whiskers indicate the 95 percent confidence interval of the estimated coefficients. The regression includes firm, country-sector, and year-sector fixed effects and robust standard errors clustered at the firm level. ETS = Emissions Trading System.

# References

Bijnens, G., and Swartenbroekx, C. (2022). "Carbon emissions and the untapped potential of activity reallocation. Lessons from the EU ETS," National Bank of Belgium Economic Review, 1-29.

Brendan B., Cesa-Bianchi A., Di Pace, F., and Haberis, A. (2023). "The heterogeneous effects of carbon pricing: macro and micro evidence," Discussion Papers 2319, Centre for Macroeconomics (CFM).

Chan, H. S. R., Li, S., and Zhang, F. (2013). "Firm competitiveness and the European Union emissions trading scheme." *Energy Policy*, 63, 1056-1064.

Colmer, J., Martin, R., Muûls, M., and Wagner, U.J. (2022). "Does pricing carbon mitigate climate change? Firm-level evidence from the European Union Emissions Trading Scheme." CEPR Discussion Paper DP16982, Centre for Economic Performance, London.

Cludius, J., de Bruyn, S., Schumacher, K., & Vergeer, R. (2020). "Ex-post investigation of cost pass-through in the EU ETS - an analysis for six industry sectors." Energy Economics, 91, 104883.

Dechezleprêtre, A., and Sato, M. (2018). "Green policies and firms' competitiveness." OECD Green Growth and Sustainable Development Forum Issue Paper, Organisation for Economic Co-operation and Development, Paris.

Dechezleprêtre, A., and Kruse, T. (2022). "The effect of climate policy on innovation and economic performance along the supply chain: A firm- and sector-level analysis." OECD Environment Working Paper 189, Organisation for Economic Co-operation and Development, Paris.

Dechezleprêtre, A., Nachtigall, D., and Venmans, F. (2023). The joint impact of the European Union emissions trading system on carbon emissions and economic performance. *Journal of Environmental Economics and Management*, *118*, 102758.

De Jonghe, O., Mulier, K., and Schepens, G. (2020). Going green by putting a price on pollution: Firm level evidence from the EU. *NBB Working Paper No. 390*.

Diez, F., Fan, J., and Villegas-Sanchez, C. (2021). "Global declining competition?" *Journal of International Economics*, 132.

European Investment Bank (2023). "EIB Investment Survey 2022: European Union Overview." Luxembourg.

Imbens, G., and Wooldridge, J. (2014). "Quantile regression." In Econometrics of Cross Section and Panel Data. cemmap/PEPA.

International Monetary Fund (2023). "Climate crossroads: fiscal policies in a warming world," Fiscal Monitor, October.

Jaraitė, J., and Di Maria, C. (2016). "Did the EU ETS make a difference? An empirical assessment using Lithuanian firm-level data," *The Energy Journal*, 37 (1): 1–23.

Klemetsen, M., Rosendahl, K. E., and Jakobsen, A. L. (2020). "The impacts of the EU ETS om Norwegian plants' environmental and economic performance," *Climate Change Economics*, 11(01), 2050006.

Marin, G., Marino, M., and Pellegrin, C. (2018). "The impact of the European Emission Trading Scheme on multiple measures of economic performance." *Environmental and Resource Economics*, 71, 551-582.

Mundlak, Y. (1978). "On the pooling of time series and cross section data." *Econometrica*, 46(1), 69-85.

Porter, M., E., and van der Linde, C. (1995). "Toward a new conception of the environment-competitiveness relationship." *The Journal of Economic Perspectives*, 9(4): 97–118.

Venmans, F., Ellis, J., and Nachtigall, D. (2020). "Carbon pricing and competitiveness: are they at odds?" *Climate Policy*, 20(9), 1070-1091.

Wagner, U., and Petrick, S. (2014). "The impact of carbon trading on industry: Evidence from German manufacturing firms."

Wu, Q., & Wang, Y. (2022). How does carbon emission price stimulate enterprises' total factor productivity? Insights from China's emission trading scheme pilots. *Energy Economics*, *109*, 105990.

Yang, S., & Shi, X. (2018). Intangible capital and sectoral energy intensity: Evidence from 40 economies between 1995 and 2007. Energy Policy, 122, 118-128.

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