Green pressure, lean measures: Unveiling corporate downsizing within the European Union Emissions Trading System

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Forthcoming at Journal of Financial and Quantitative Analysis.

ABSTRACT

In 2017, the European Union Emissions Trading System underwent a policy intervention which resulted in a surge in carbon prices. Using this setting as a quasi-natural experiment, we focus on employment, productivity, and emission outcomes among covered enterprises. Results show that emission-intensive private firms, particularly those with financial constraints, are more likely to downsize by divesting production assets, reducing both workforce and emissions. Smaller, cash-strapped listed firms are also prone to downsize by decreasing their operating leverage while maintaining emission output and asset levels. Positive productivity outcomes indicate that both private and listed firms become leaner post-intervention.

Keywords: downsizing, employment, emissions trading, European Union Emissions Trading System

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I. Introduction

Governments and policymakers worldwide are increasingly incentivizing enterprises to reduce their greenhouse gas emissions and account for their broader societal impact. One globally employed policy instrument to achieve this objective is the so-called "cap-and-trade scheme". Within this system, subjected firms are handed a limited amount of emission allowances each year that gradually decrease over time. Additional emission allowances can be purchased from and sold to other participants (Hitzemann and Uhrig-Homburg, 2018). Such a system imposes limitations on firm-level carbon emissions and assigns a monetary value to carbon pollution through supply-and-demand mechanics. The pioneering and most well-known cap-and-trade scheme is the European Union Emissions Trading System (henceforth EU ETS). Although thoroughly studied for its environmental impact (e.g., Andreou and Kellard (2021), and Bayer and Aklin (2020)), critics call for more evidence of the direct and indirect economic consequences of this environmental policy (OECD, 2022). Our study contributes to this debate by investigating how firms cope with increased carbon costs from an employment perspective. Companies possess a host of strategic employment reduction responses to react to such cost increases, ranging from employment downsizing while maintaining output levels, to simultaneously divesting production assets (i.e., downscaling).[1] Moreover, such employment reduction actions could carry productivity and emission consequences.

Industry interest groups and trade unions often criticize the EU ETS for its potential to impose substantial costs, which, in turn, could distort day-to-day operations and lead to layoffs (i.e. downsizing), accompanying asset divestments (i.e. downscaling) or relocations outside Europe. For instance, a letter signed by the CEOs of 76 steel manufacturers in Europe urged the EU not to burden them with additional carbon costs, citing that these would make them "uncompetitive against foreign rivals and raise the risk of job losses and plant closures" (Lewis,

[1] "Employment downsizing" takes place when a reduction of at least 5% of the workforce takes place relative to the year prior. Throughout this work, we use "downsizing" and "employment downsizing" interchangeably. If both employment downsizing and a reduction in fixed assets takes place, we refer to "downscaling".

2017). Cembureau—the representative of the European cement industry—estimates a loss of 20,500 jobs under a scenario in which the EU aims to achieve a 55% reduction in greenhouse gas emissions (Cembureau, 2021). A spokesperson for FuelsEurope—representing the European fuel industry—argued that "closing refineries and opening new facilities outside Europe, then importing the products could make economic sense" (Euractiv, 2017b).

However, despite the prevalence of such job loss-related concerns, academic research found very little evidence of reductions in workforce size. In an early study to gauge the impact of the EU ETS on employment outcomes, Anger and Oberndorfer (2008) use a sample of 419 German firms covered by the EU ETS and found no statistically significant evidence of layoffs. Commins, Lyons, Schiffbauer, and Tol (2011) use a sample of over 100,000 firms to test the impact of energy taxes and the EU ETS on a variety of corporate outcomes. While they find a significant effect of energy taxes on employment reductions and changes in tangible assets, they do not find any impact of the EU ETS to this end. Chan, Li, and Zhang (2013) leverage a large sample of EU ETS- and non-EU ETS-compliant firms in the cement, iron, and steel sectors and document no significant changes in employment between the two groups. This finding is reinforced by Petrick and Wagner (2014), who find no significant workforce reduction using data on over 1,500 German installations. Finally, Marin, Marino, and Pellegrin (2018) use a large set of European EU ETS-compliant firms and find no employment impact of the emissions trading scheme.[2]

In part, the absence of convincing evidence with regard to workforce size reductions can be attributed to these studies taking place in phases I and II of the EU ETS, which were characterized by an overallocation of free allowances (see Section 2), and thus low incentives to

[2] The only two papers that do find evidence of workforce reductions are Wagner, Muûls, Martin, and Colmer (2014) and Abrell, Ndoye Faye and Zachmann (2011). Using French plant-level data, Wagner et al., (2014) report a 7% decrease in employment in their working paper when comparing EU ETS plants to matched non-EU ETS-compliant plants, but only in the later years of their sample period. Similarly, Abrell et al., (2011) find a small decrease in employment of 0.9%, only for firms in the nonmetallic mineral sector, relative to non-EU ETS-compliant firms.

stimulate changes in corporate behavior (see Ikkatai, Ishikawa, and Sasaki (2008) and Ikkatai, Hori, and Kurita (2011) for interview-based evidence confirming this lack of stimulus). In this study, we shift our focus towards a more recent time period (more specifically phase III of the scheme, which ran from 2013 to 2020) and exploit an important and unexpected intervention by the European Council (EC) that took place on February 28, 2017. On this day, the EC agreed to a series of changes in the current EU ETS system, all of which increased the scarcity of emission allowances, thereby driving up the carbon emission price. This made the carbon costs imposed by the EU ETS more substantial to covered firms for the first time since the initiation of the scheme (De Jonghe, Mulier, and Schepens, 2020).[3] Given this tightening of the regulation from 2017 onwards, and the resulting significant increase in carbon costs for EU ETS-covered enterprises, it is worthwhile to examine whether and which firms started internalizing these costs. In the post-intervention period, firms have already cited the environmental costs brought about by the EU ETS as a motivation for their employment downsizing decisions. For instance, in 2019, Sokolosvka Uhelna (the smallest brown coal mining company in the Czech Republic) announced cutting 2,000 jobs "motivated by the increasing price of emission allowances,"[4] while Hungary's ISD Dunaferr mentioned "burdensome environmental regulation" as a motivation for announcing 350 job losses in their steel manufacturing operations.[5] Dillinger Hüttenwerke announced laying off 1,500 jobs and offshoring another 1,000 positions motivated by "new environmental policies, which require investments of resources in CO_2 allowances and new technologies."[6]

We draw data from the European Union Transaction Log, which we augment with financial data from Orbis Global. Our sample comprises 2,337 firms that are collectively responsible for approximately 35% of all emissions covered by the EU ETS throughout the

[3] The corresponding increase in value of the carbon market for stationary installations resulted in a change in total value from 8.12 billion euros on January 1, 2017 to 39.90 billion euros on December 31, 2020.
[4] See https://apps.eurofound.europa.eu/restructuring-events/detail/99156.
[5] See https://apps.eurofound.europa.eu/restructuring-events/detail/98957.
[6] See https://apps.eurofound.europa.eu/restructuring-events/detail/98759.

sample period. Of these firms, 832 are listed or have a listed owner and 1,505 are private firms. Next, we match all EU ETS-compliant firms to a set of control firms that are not covered by the EU ETS.

Our findings demonstrate a general EU ETS effect, indicating an increase in employment downsizing following the EC's intervention. When decomposing this sample into listed and private firms, we find that this effect can largely be attributed to the private firms in our sample. The probability of EU ETS-covered private firms engaging in employment downsizing during the post-intervention period increases by 5.2% relative to non-EU ETS-covered private firms.

Next, we focus on the cross-sectional variation within our set of EU ETS-subjected firms and test whether emission intensive firms are more prone to engage in workforce reductions following the increase in carbon prices. We operationalize this by linking the firm's industry-corrected emission intensity—measured as the decile rank of the industry-adjusted verified emissions relative to realized sales—to their probability of engaging in employment downsizing. Our baseline findings report a weakly significant effect of the firms' industry-corrected emission intensity on their downsizing decisions for the full sample. However, when we separate our sample into private and listed firms once more, we again find a strong effect only for the subset of private firms. There is a 5.7% increase in the probability of downsizing per decile rank increase in emission intensity.

To gain more insight into our baseline results, we subject our analyses to potential moderating factors such as local employment factors and sectoral protection measures. We find weak evidence that downsizing is more likely to occur in low-employment regions—only for listed firms relative to their matched non-EU ETS counterparts —which we attribute to reducing personnel being less costly when the supply of potential workers is higher. A similar finding is obtained for sectoral protection measures established by the EU in that only private firms downsize as emission intensity increases when they are not included in the carbon leakage list, which are awarded a larger share of free emission allowances by the EU.

Next, we investigate three plausible motivations behind downsizing. More precisely, we question whether downsizing is a response to (i) employment inefficiency, (ii) the inability to pass costs through to customers, and (iii) financial constraints. We test each of these mechanisms and find support that downsizing occurs only in a subset of emission intensive private firms with low cash levels, which is in line with financial constraint motivations.

This raises the question of why these cash constrained firms are engaging in downsizing. In additional analyses testing for the economic channels behind this specific response, we first rule out the alternative explanation that firms' cash levels reflect agency conflicts by testing whether firms' outside ownership explains the downsizing response (Bena and Xu, 2017, Gogineni, Linn, and Yadav, 2022). However, we find that this agency view does not explain our findings. Second, cash constrained firms could be smaller and have less established working capital management and a harder time obtaining financing, making it difficult to smoothen idiosyncratic productivity shocks. Our findings do not suggest that firm size is an important moderator for private cash constrained firms, but we do find evidence of smaller cash constrained listed firms experiencing an increased likelihood in downsizing. Third, we consider that the downsizing response of cash constrained firms may stem from a reduction in production. When studying their fixed asset changes, we find evidence of the downsizing response in cash constrained private firms being driven by downscaling relative to their industry peers. For listed firms, divestments do not explain the downsizing likelihood.

Finally, we investigate downsizing outcomes and particularly whether downsizing firms experience significant changes in their emission levels and productivity. We find evidence that private firms that downsize in the post-intervention period experience a significant decrease in emissions by about 7.8%, while experiencing an increase in productivity levels. The emission levels of listed firms engaging in downsizing do not significantly change, but their productivity does increase. Collectively, our findings are consistent with cash constrained private firms responding to increasing carbon costs by downscaling, arguably resulting in a reduced need for personnel.[7] We find that downsizing listed firms tend to maintain their emission output and production asset levels, suggesting motives of reducing operating leverage. Yet, both private and listed firms achieve positive productivity outcomes. This implies that despite the different employment reduction strategies followed by both types of firms, a similar benefit arises in terms of becoming leaner after the EC's intervention.

This study contributes to the existing literature in several ways. First, we add to the literature on corporate downsizing. Prior research has mainly focused on decreasing firm performance and market value as common antecedents (Dial and Murphy, 1995, Hallock, 1998, Chen, Mehrotra, Sivakumar, and Yu, 2001, Hillier, Marshall, McColgan, and Werema, 2007), while more recent research demonstrated the role of policymakers and law enforcement. Various interventions have been tested such as the impact of stricter employment protection rules (Albanese, Picchio, and Ghirelli, 2020), increases in minimum wages (Bossler and Gerner, 2020), and distinct reforms to increase firms' financial stability (Barrot and Nanda, 2020, Granja, Makridis, Yannelis, and Zwick, 2022), to which we now add climate policy interventions and associated environmental costs.

Second, we contribute to the finance literature investigating the drivers and outcomes of corporate environmental behavior. For instance, Shive and Forster (2020) point out that ownership structure helps explain firm-level pollution outcomes by showing that independent private firms are less likely to pollute and incur environmentally related penalties. Akey and Appel (2021) demonstrate that stronger parent-level liability increases subsidiaries' pollution levels. Related to these papers, Bellon (2020) demonstrates that government incentives help explain how private equity-backed firms alter their pollution levels. Karpoff, Lott, and Wehrly (2005) demonstrate that environmental penalties alter firms' market value in a significant manner, with Chang, Fu, Li, Tam, and Wong (2021) showing their impact on the balance sheet

[7] For listed firms, we provide anecdotal evidence that larger listed firms may have a host of alternative responses at their disposal (e.g., R&D investments, complex management of EU ETS derivatives), which are less likely to be available to smaller cash constrained ones.

structure, as firms correspondingly reduce their debt levels. Our findings further the insights from Xu and Kim (2022) that firms balance environmental abatement costs vis-à-vis the cost of legal penalties, by demonstrating that carbon costs are weighted against employment costs. We document that, in this pursuit, firms realize productivity gains through either downsizing or downscaling, with this latter avenue also being accompanied by emission output reductions.

Our study also contributes to our nascent understanding of firms' responses to the EU ETS. Prior work focusing on large, listed firms finds evidence of diverse coping strategies, such as rendering their business process greener (De Jonghe et al., 2020), shifting operations offshore, or exiting the market altogether (De Beule, Dewaelheyns, Schoubben, Struyfs, and Van Hulle, 2022, De Beule, Schoubben, Struyfs, 2022, Misch and Wingender, 2021), passing through costs to customers through higher prices, or even back to the government through tax avoidance (Alexeeva-Talebi, 2011, Compagnie, Struyfs, and Torsin, 2023). For listed firms, we find some evidence of downsizing also being such a response. We also demonstrate the importance of considering private firms in future research on the EU ETS whose corporate responses may differ. Our finding that downscaling by private firms comes with a lower emission output and productivity gains furthers the insights from Bayer and Aklin (2020) on the behavior-correcting capacity of carbon markets.

Fourth, our study contributes more formally to the ramifications of the EU ETS on labor outcomes. Early work generally found little to no employment impact from being covered by cap-and-trade systems (e.g., Anger and Oberndorfer, 2008, Commins et al., 2011, Chan et al., 2013, Petrick and Wagner, 2014, Wagner et al., 2014, and Marin et al., 2018). We depart from this research by extending our analyses to the third phase of the EU ETS—which was characterized by a notable intervention resulting in a steep increase in carbon prices—as well as by considering the cross-sectional heterogeneity in emission intensity within the set of EU ETS-compliant firms. In addition, while prior work in this domain has mostly considered a single-country setting (e.g., Petrick and Wagner, 2014, and Wagner et al., 2014), we take a more holistic approach and use granular corporate information from firms located across 27 countries. The international nature of our sample allows us to test local working conditions and institutional characteristics as moderating factors. In so doing, this study answers Martin, Muûls, and Wagner's (2016) call for more research on the causal impact of the EU ETS on labor market outcomes by exploiting aggregate shocks and micro-level data. This call is warranted by the status of the EU ETS as a global frontrunner in terms of climate policy, with the scheme being one of the largest active multinational cap-and-trade systems.

As other countries are increasingly introducing and adopting their own cap-and-trade systems and given that existing schemes are often struggling with low carbon prices (Black, Parry, and Zhunussova, 2022), the findings of this study should be of interest to policymakers around the globe aiming to establish or intervene in emissions trading schemes and trying to balance the costs of environmental externalities (i.e., emissions) with socio-economic ones (i.e., employment). That is, policymakers must be aware of the imposed transition costs relative to uncovered firms as rising emission costs make firms more likely to adopt downsizing strategies. Within the EU ETS-covered sample, our findings that cash constrained private firms engage in downsizing as their emission intensity increases and this downsizing response rather stems from a reduced production scale than from myopic agency costs, points towards significant hurdles for such firms to achieve a green transition. Providing green transition financing, loan programs, or even guarantees, may allow governments to effectively sustain their economic production levels, and help dampen broader employment adjustment shocks while allowing firms to transform their business processes to more environmentally accommodating ones.

II. The European Union's Emissions Trading System

The EU ETS is the cornerstone of the European Union's climate policy. As the flagship instrument, it covers over 12,000 highly emitting installations, collectively responsible for approximately half of all industrial gas emissions of EU member states. The scheme works on a “cap-and-trade” basis. This means that a specific pre-defined limit of emissions is allowed in any given year (i.e., “the cap”). At the end of the year, each installation owner needs to hand over certificates equal to the amount of gasses emitted. While a certain number of certificates are given to owners for free at the beginning of the year, based on the efficiency of the installation, additional (excess) certificates can be purchased (sold) by trading with other owners (i.e., “the trade”). The underpinning of the system is that both the cap and the number of freely given certificates decrease over time. Through basic supply-and-demand mechanics, this scarcity should render emission allowances more costly over time, thereby prompting corporate efforts to reduce emissions.

The EU ETS consists of multiple phases that each try to add more stringency to the scheme. Phase I (2005–2007) was characterized by a large overallocation of emission allowances, such that there was very little demand for additional certificates. In phase II (2008–2012) the cap of the system was lowered by about 6.5%, but the economic crisis affected the demand for emission allowances drastically, resulting in underwhelming emission price levels (Grubb, Azar, and Persson, 2005, Joltreau and Sommerfeld, 2019) such that emissions were never truly costly for subjected firms to begin with. Ikkatai et al. (2008) and Ikkatai et al. (2011) corroborate this by interviewing managers of EU ETS-subjected firms in Poland, Belgium, and the Netherlands. They provide anecdotal evidence that—while competitiveness concerns did exist among firm management—there was a redundancy of emission allowances that dampened the incentive to abate emissions. If firms had operated under such a business-as-usual scenario, workforce reductions may not have occurred to begin with.

While phase III (2013–2020) started out with a low carbon price because of the oversupply of allowances that were still floating around in the system after being transferred from phase II, the European Council took drastic measures mid-phase III to incentivize firms more adequately. Specifically, on February 28, 2017, the European Council decided to redirect a larger share of excess emission allowances towards a market stability reserve and further introduced a cancellation mechanism for phase IV, which would eliminate a large fraction of the oversupply of allowances. Even member of the European Parliament and rapporteur on the EU ETS reform, Ian Duncan, was taken by surprise at the agreement by the European Council: "Just that morning I had declared (…) that Council agreement was unlikely before summer at the earliest. By the time I disembarked from my flight, Twitter was ablaze with the news that the Council had done a deal. Hereafter I will retire my crystal ball" (Euractiv, 2017a).

This intervention was met with substantial opposition from firms and interest groups. For instance, FuelsEurope stated that "several market analysts (…) concluded that this will have an early, direct impact on the carbon market and the allowances price" (FuelsEurope, 2017). The emission price indeed rose substantially. The price of one ton of CO_2-equivalent emissions doubled from €5.15 per ton of emissions on January 1, 2017 to €11.06 by January 1, 2018, and again to €22.23 by January 1, 2019, to finish phase III at a level of € 32,57 on the December 31, 2020.[8] As pollution became a costly practice, firms may have become more prone to engage in corporate restructuring and workforce size reduction relative to the first two phases. To test this notion, this study exploits the price increase following the European Council's decision as an exogenous shock to the firm's operating conditions and examine the downsizing, productivity, and emission outcomes.[9]

III. Data and Sample Description

In this section, we detail the data collection procedure and elaborate on the empirical model and summary statistics. Appendix A1. provides detailed variable descriptions.

A. Data Collection

We start our sample construction from the European Union Transaction Log (EUTL). This platform contains yearly emission information about all installations covered by the EU ETS,

[8] We refer the reader to Appendix A2. for a detailed graphic representation.
[9] To further justify that this shock is not spurious, we perform dynamic analyses to ensure the absence of pre-trends.

such as their freely allocated emission allowances as well as the verified emissions, alongside information on the installations' account holders.

To gauge the exposure of our sample firms to the EU ETS, we performed the following procedure. First, we extracted the account holder names for every installation in the EUTL, accessed on December 1, 2022. Second, we can only observe the name of the current account holder as historical information gets overwritten on the platform. Yet, a historical record of former operating holding accounts for the register change 2012/2013 still exists.[10] We compare the name of the current account holder for an installation with the historical one and retain only the installations in which there was no change in ownership. We then aggregate the emission data of all installations belonging to the same account holder to understand the latter's total emission behavior. Third, we manually matched the account holder names to the company names in the Orbis Global universe, from which we also gather our firm-level financial data. When constructing our sample, we consider a firm as being publicly listed when their shares are listed, or if they are controlled by a listed owner who controls at least 50% of the subsidiaries' shares. All other firms are considered privately held.

In sum, we obtain information on 2,337 firms, collectively controlling 3,460 installations that account for approximately 35% of all emissions covered by the EU ETS throughout the sample period. The sample consists of 832 firms that are listed or have a listed owner, controlling 1,414 installations and 1,505 private firms controlling 2,046 installations. Our listed and private firms account for about 20% and 15% of the system's emissions, respectively.

B. Model and Variables

We study the extent to which the EU ETS influences firms' downsizing decisions following the EC's intervention. To this end, we first match our EU ETS-covered sample with firms that are not covered by EU ETS policy through propensity score matching. Specifically, we retrieve data

[10] More precisely, for the register change in 2012/2013, the former operator holding accounts were matched to their respective installations by Dr. Jan Abrell who made the data available on the website https://www.euets.info.

on all firms operating in the EU ETS-covered countries from Orbis Global and match, without replacement, EU ETS-covered with non-EU ETS-covered enterprises based on country, industry, listing status (i.e., a private or public firm indicator), and an estimated propensity score based on growth, ROA, current ratio, long term debt, size, age, cost of employment, and assets per employee (using a caliper of 0.3). Having constructed our dataset, in which non-EU ETS-covered firms are the benchmark, we are able to examine changes in downsizing likelihood linked to EU ETS-coverage using the following difference-in-differences linear probability model[11]:

$$(1)\ DOWNSIZING_{it+1} = \alpha + \beta \times EU\_ETS_i \times POST_t + \delta \times POST_t + \sum Firm_{it} + \gamma_i + \varepsilon_{it},$$

where the binary dependent variable $DOWNSIZING_{it+1}$ indicates whether firm *i* has decreased its total number of employees by 5% in year *t+1* relative to year *t*. Our 5% cutoff is not chosen arbitrarily. We follow the prior literature suggesting that a 5% cutoff is reflective of strategic managerial decision-making (Osterman, 2000, Ahmadjian and Robinson, 2001, Vicente-Lorente and Suárez-González, 2007). *POST* is a dummy variable taking the value of one for the years from 2017 onwards. *EU_ETS* is an indicator variable equal to one for EU ETS-covered enterprises, zero otherwise. Note that, due to the inclusion of firm fixed effects (γ_i) in Equation (1), the variable *EU_ETS* itself drops out. Our variable of interest is the interaction term *EU_ETS* × *POST* in Equation (1), as it captures the relationship differential between EU ETS-coverage and the downsizing decision before and after 2017. A positive coefficient value for β would indicate an increase in the downsizing likelihood for firms after the EC's intervention if they are exposed to the EU ETS.

In Equation (1), *FIRM* captures a relevant set of control variables that could explain the firm's need for employment. First, we control for the firm's performance by including its return

[11] Based on prior literature we estimate Equations (1) to (3) using linear probability models (Bai, Fairhurst, and Serfling, 2019, Beaver, Cascino, and Correia, 2024) as they are better suited to implement more demanding fixed effect structures (Wooldridge, 2010). We do so particularly to avoid an incidental parameter problem, which could bias the coefficient of our variable of interest (Neyman and Scott, 1948, Lancaster, 2000).

on assets (*ROA*), as well as its sales growth (*GROWTH*). We further control for the firm's liquidity position by including its current ratio, measured as the current assets scaled by its current liabilities (*CURRENT_RATIO*). In addition, we add the firm's long-term debt relative to its total assets to proxy for the firm's financing structure (*LTD*), the firm's size measured by the natural logarithm of total assets (*SIZE*), and the firm's age (*AGE*) measured as the number of years since its incorporation. We further include two employment-level measures. First, we incorporate the employment costs scaled by the total revenue of the firm (*COST_OF_EMPLOYMENT*). Second, we account for the employment intensity of the firm by dividing its total assets by the number of employees to gauge the overall importance of employees to the firm's business model (*ASSETS_PER_EMPLOYEE*).

After performing this analysis based on the matched sample, we next assess whether cross-sectional differences within the subset of EU ETS-covered enterprises can explain the downsizing likelihood.[12] The increase in carbon prices following the intervention by the European Council should arguably have a greater impact on firms' downsizing likelihood as their cost exposure is higher (i.e., the more the firm pollutes). To uncover the influence of emission intensity, we modify Equation (1) and replace *EU_ETS* with a measure of emission intensity. This results in the following linear probability model:

$$(2)\ \ DOWNSIZING_{it+1} = \alpha + \beta \times RANK_{it} \times POST_t + \rho \times RANK_{it} + \delta \times POST_t + \sum Firm_{it} + \gamma_i + \varepsilon_{it}.$$

Herein, *RANK* captures the decile-ranked industry-adjusted emission intensity of the firm. The industry-corrected emission intensity is calculated by taking the verified emissions of the firm divided by its sales in any given year, minus the median verified emissions over sales of all

[12] Note that since we are now zooming in on the firms that are exposed to the EU ETS, we abstain from a classic difference-in-difference analysis, because all firms can essentially be considered as treated. The only way to establish a "treatment" and "control" group would be through defining an artificial cut-off in terms of their emission intensity. We, however, opt to use a before-and-after single treatment model, as propagated by Roberts and Whited (2013).

other firms in the same industry—based on four-digit NACE codes—for that year (Compagnie et al., 2023).[13] Since emission intensity (even when industry corrected) can vary significantly in magnitude among firms, we create a decile rank of this measure ranging from "1" (lowest) to "10" (highest). As such, we effectively categorize firms in buckets based on their exposure to rising emission prices.

The interaction term *RANK* × *POST* in Equation (2) should capture the relationship differential between emission intensity and the downsizing decision before and after 2017. A positive coefficient loading would suggest a higher downsizing likelihood as emission intensity increases after the EC's intervention. *FIRM* represents the same firm-level control variables as in Equation (1), with the extension of two variables that capture emission-related confounding factors that could alter the firm's exposure to the emissions trading system. More precisely, we add the difference between the allowances the firm has been granted for free and their actual emissions made, scaled by the actual emissions (*ETC*). Higher values for this variable could be seen as a decreasing overall exposure to the EU ETS. In addition, we include the number of EU ETS-covered installations that the firm owns directly (*INSTALLATIONS*).

Equations (1) and (2) are augmented with firm-level dummies (γ). The inclusion of these firm-fixed effects should capture the unobserved heterogeneity stemming from firm strategies that could explain employment changes. Equations (1) and (2) do not include any year-fixed effects, which would otherwise swallow the *POST* variable.[14]

C. Summary Statistics

We report the summary statistics of our sample in Table 1 and discuss the most salient numbers. In Panel A, we provide the descriptives of the full sample, which comprises all EU ETS-

[13] When calculating this industry-corrected emission intensity, we require availability of at least ten unique observations for each industry-year pair. Firms belonging to industries for which there are fewer than ten unique observations each year are grouped together for that year.

[14] In untabulated tests, we rerun these equations with year-fixed effects. The findings are qualitatively similar and available upon request.

compliant and matched firms. We find that downsizing occurs in approximately 13.6% of the sample observations (*DOWNSIZING*). When looking at EU ETS firms alone (Panel B), downsizing occurred slightly more: approximately in 14.3% of the firm-year observations. The median firm in our sample emits 15% more than allocated (*ETC*). *ETC* has a high standard deviation, suggesting the existence of large heterogeneity across the sample. Looking at the number of installations, we observe that the firms included in our sample have a maximum of eight installations with an average of 1.51 (*INSTALLATIONS*). The mean sample firm has a cost of employment relative to their turnover of 13.96%, with a relatively high standard deviation of 8.60%, showing that employment costs represent a substantial cost. Our sample firms are profitable on average with a mean *ROA* of approximately 5% and an average sales growth of 2.3% (*GROWTH*). They finance about 11.2% of their total assets through long-term debt (*LTD*). In Panels C and D of Table 1, we further decompose our sample in public and private firms, respectively.

< Insert Table 1 about here. >

The correlation matrices of the matched sample and the EU ETS-covered sample are reported in the online appendix, Table OA1. Overall, we find that the correlations between our variables do not raise any concerns about multicollinearity.[15, 16]

[15] The mean VIF value in our main regression equals 1.26, with a maximum value of 1.85. These are well below the traditionally accepted threshold of 5.

[16] For parsimony, we do not report the correlation matrix of the private and public subsections. These, however, also do not indicate any multicollinearity issues and are available upon request.

IV. Empirical Results

A. Employment Downsizing Due to the EU ETS: Matched Sample

First, we present evidence of the effect of operating under the EU ETS on the likelihood of downsizing using our propensity score matched sample. The results are reported in Panel A of Table 2 and Model (1) reports the results of Equation (1). We observe that there is an increased downsizing likelihood for the EU ETS-covered firms in the post-intervention period (*EU_ETS* × *POST*) (p-value < 0.01). However, when decomposing our initial sample into listed and private firms throughout Models (2) to (4), we find that being covered by the EU ETS only increases the likelihood of downsizing in a statistically significant manner after the EC's intervention for this latter group. This effect is economically sizeable. The probability of EU ETS-covered private firms engaging in downsizing during the post-intervention period increases by 5.2% relative to non-EU ETS firms.

To further augment our understanding of this effect, we draw inspiration from Nguyen and Phan (2020) and estimate a dynamic model. This allows us to identify when exactly the EU ETS started exerting an influence on the downsizing likelihood of the covered private firms while simultaneously testing for the presence of potential pre-trends in the data. We do so by interacting our pollution specific variable (*EU_ETS*) with year dummies (EC_t) reflecting three years prior (2014) until two years after the EC's intervention (2019). The observed coefficients loading on these interaction terms capture the change in downsizing likelihood relative to the first year of our sample (i.e., 2013), which acts as a reference point. More precisely, we employ the following model:

$$(3) \quad DOWNSIZING_{it+1} = \alpha + \beta_1 \times EU\_ETS_{i,2014} \times EC_{2014} + \beta_2 \times EU\_ETS_{i,2015} \times EC_{2015} + \beta_3 \times EU\_ETS_{i,2016} \times EC_{2016} + \beta_4 \times EU\_ETS_{i,2017} \times EC_{2017} + \beta_5 \times EU\_ETS_{i,2018} \times EC_{2018} + \beta_6 \times EU\_ETS_{i,2019} \times EC_{2019} + \sum Firm_{it} + \gamma_i + \delta_t + \varepsilon_{i,t}.$$

The results of Equation (3) are reported in Table 2 Model (5). We observe an absence of pre-trends and find that being covered by the EU ETS increased the likelihood of downsizing only in the years after the intervention. This finding highlights that differences in terms of downsizing behavior between EU ETS-covered and non-EU ETS-covered firms did not exist prior to 2017 with the downsizing likelihood of private firms only increasing afterwards. A graphical representation of the dynamic model for the full, listed and private matched sample is provided in Figure 1.

< Insert Table 2 and Figure 1 about here. >

B. Emission Intensity and Employment Downsizing: Intra-EU ETS Sample

As the carbon price surged in the third phase, emission intensive firms should arguably be more affected by this shock. To investigate this notion, we report the results of Equation (2) in Panel B of Table 2. These findings present weak evidence (p-value < 0.1) that firms with a higher emission intensity are more prone to downsize after the surge in carbon prices (*RANK* × *POST*) for the full sample of EU ETS-covered firms. However, again, when we decompose our sample into public (Model 2) and private firms (Models 3 and 4), the downsizing response appears primordially driven by the private ones, with no effect for listed firms. Specifically, the relative probability of downsizing increases with 0.8% per decile increase in emission intensity (*RANK*). Given the average downsizing rate of 14.1% for the subsample of EU ETS-subjected private firms, this constitutes a 5.7% increase in probability per decile. To further provide reassurance that this effect is not driven by a non-random nature of our control variables within the EU ETS sample, we rerun our analysis using a propensity score matched sample of high-*RANK* (>5) and low-*RANK* (≤ 5) firms and reproduce our findings (Model 5). We find that our main conclusions hold.[17] Finally, also when estimating the dynamic model for the private EU ETS-covered enterprises, we again show that differences between more and less polluting firms in terms of

[17] We report the quality of the matching in the Online Appendix, Table OA2. We find that many of the statistically significant differences regarding the control variables between the two samples tend to disappear after matching, but the matching remains imperfect due to the limited default sample size. To that end, we further perform an entropy balancing between the high-*RANK* and low-*RANK* set of firms and our conclusions hold. These results are also available in the Online Appendix.

the downsizing response only exist in the post-intervention period (Model 6). A graphical representation of the dynamic model for the full, listed and private intra-EU ETS sample is provided in Figure 2.

< Insert Figure 2 about here. >

Overall, our findings suggest a positive association between emission intensity and downsizing for privately held firms, but not for their listed counterparts. In the following sections, we investigate several underlying drivers potentially explaining this effect.

C. Additional Analyses

We expect the downsizing response to vary with country-, industry-, and firm characteristics and therefore subject both our matched sample and EU ETS-covered sample to several additional analyses.[18]

1. The Moderating Impact of Employment and Sectoral Conditions

Matched sample

We start our additional analyses by focusing on the moderating role of the employment environment and sectoral protection measures established by the EU. First, we control for the employment environment in three ways: through (i) the local unemployment levels, (ii) the strength of collective bargaining in the country in which the firm is headquartered, and (iii) country-level regulatory strength. Second, we control for sectoral protection measures by testing for the moderating role of carbon leakage sectors—industries identified by the EU as facing strong competition from outside the EU—where firms are significantly less burdened by carbon

[18] For our listed sample, we have also explicitly tested for media scrutiny as this may influence the extent to which they potentially engage in downsizing. When using the both the natural logarithm of number of annual media mentions and the number of analysts covering the firm as proxies for scrutiny, we find no significant downsizing response for either low or highly scrutinized listed firms. Untabulated results are available upon request.

costs (Clò, 2010). That is, since firms in these leakage sectors are more prone to exit the EU, they are given more emission allowances for free to decrease their cost exposure.[19] We report these results for the matched sample in Panel A of Table 3.

We measure the local unemployment at the NUTS2-region in which the firm is headquartered. In higher regional unemployment levels, employees are arguably a less scarce resource, making employee turnover less costly (Vicente-Lorente and Suárez-González, 2007). We interact our variable of interest *EU_ETS* × *POST* with a dummy variable *UNEMPLOYMENT*, which is an indicator taking the value of one if the firm is headquartered in a NUTS2-region with higher than sample median unemployment, zero otherwise. We find no significant coefficient loading on *EU_ETS* × *POST* × *UNEMPLOYMENT* for private enterprises (Model 1), whereas we do observe a weakly significant effect for listed enterprises in Model (5) (p-value < 0.1). This finding is important because it demonstrates that, while listed firms on average do not engage more in downsizing (see Table 2), listed firms do engage more in downsizing when located in regions with higher unemployment levels.

We next interact our variable of interest with an indicator variable (*BARGAINING*), which takes the value of one if the percentage of employees covered by a bargaining agreement in the country in which the firm is headquartered is larger than the sample median, zero otherwise. Greater labor protection could reduce the proneness to resort to downsizing, as bargaining allows for negotiations on wages and other labor conditions (Qiu, 2019). However, we find no statistical significance for either the private or listed firms (Models (2) and (6), respectively).

Third, to proxy for the strength of employment law, we create an indicator variable (*RULE_OF_LAW*), which takes the value of one if the rule of law index of the country in which the firm is headquartered is larger than the sample median, zero otherwise. The rule of law index measures the country-level confidence in the quality of contract enforcement. When interacting

[19] Many of the industries that rely on local extraction (e.g., mining of ores) are considered in this list. The full list of leakage industries is available in Annex C of the Carbon Leakage List. For more information, we refer the reader to https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/1146-Carbon-Leakage-List-2021-2030_en.

this indicator variable with our variables of interest, no effect is found for both private and listed firms (Models (3) and (7), respectively). Based on these three analyses, we cannot classify the labor market environment as an important moderator of the downsizing response in our matched sample. Nonetheless, in the subsample of listed firms there is some evidence of an increased downsizing likelihood in high unemployment regions.

Finally, we investigate whether the downsizing effect is more pronounced in non-leakage sectors. Models (4) and (8) report no significant effect for either the private or the listed subsamples, such that we also refrain from classifying sectoral leakage classification as an important moderator in our matched sample analysis.

< Insert Table 3 about here. >

Intra-EU ETS sample

We repeat the same analyses for our intra-EU ETS sample in Panel B of Table 3. When studying the employment environment (Models (1-3) for private firms and (5-7) for listed firms), we find no significant coefficient loading on any of the triple interaction terms. When studying the leakage industries, we do observe a reduced likelihood in downsizing for private firms, as evidenced by the significant and negative coefficient loading on *RANK* × *POST* × *LEAKAGE* (*p*-value < 0.1). This finding is consistent with leakage firms being less burdened by the EU ETS due to additional protection by the EU, resulting in a reduced likelihood of downsizing.

In summary, employment protection does not carry much explanatory power in explaining differences in the downsizing response of private EU ETS-covered firms as they become more emission intensive. However, some sectoral heterogeneity exists with leakage firms engaging less in downsizing. Employment and sectoral conditions play no role in the downsizing decisions of listed firms intra-EU ETS.

2. Understanding the Drivers of Downsizing

The underlying assumption behind firms' downsizing response to the EC's intervention is to safeguard profit margins. We investigate three strategic settings where we expect this to be particularly pronounced. These are: (i) when faced with financial constraints, (ii) when faced with a competitive market environment, and (iii) when faced with higher marginal efficiency gains. We test each driver for the matched and intra-EU ETS samples.

Matched sample

First, firms with more financial flexibility should be better equipped to overcome temporary (and future) cost increases. While these firms may still reduce employment levels to sustain profit margins, their financial buffer at least allows them a less disruptive transition, such that larger layoffs are less likely to occur. We thus predict that the increase in emission prices is particularly detrimental for enterprises with lower pre-shock precautionary savings, as approximated by their cash position (Beuselinck, Markarian, and Verriest, 2021). We create a dummy variable *CASH* that takes the value of one if their cash ratio (i.e., cash divided by total assets) is larger than the sample median, zero otherwise.[20] Models (1) and (4) in Panel A of Table 4 report no significantly different downsizing response for private and listed firms in the matched sample.

Second, downsizing is arguably less likely to occur when firms can pass on their costs more easily to customers. We approximate this by using an indicator variable taking the value of one if the within-industry Herfindahl-Hirschman Index (*HHI*) is larger than the sample median, zero otherwise (see Beuselinck et al., 2021). We again find no significant effect on the triple interaction terms in both the private (Model 2) and listed (Model 6) subsamples, such that we cannot conclude the pass-through argument to be a driver for the matched sample.

[20] In untabulated tests, we also split our sample based on both leverage and cash, where constrained enterprises have both lower than median levels of cash and higher than median levels of leverage (Arslan-Ayaydin, Florackis, and Ozkan, 2014). These results are qualitatively similar and available upon request.

Third, firms may want to downsize to improve their efficiency (e.g., Ahmadijan and Robinson, 2001, Cascio, Chatrath, and Christie-David, 2021) with marginal efficiency gains arguably being higher for firms with lower levels of ex-ante employment efficiency. We create an indicator variable that takes the value of one if the firm's industry-adjusted natural logarithm of value added per employee is higher than the sample median, zero otherwise (*VALUE_ADDED*). We interact this indicator with our term of interest *EU_ETS* × *POST*. We, however, find no significant coefficient loadings on the triple interaction terms.

In conclusion, for our sample of EU ETS-covered firms relative to uncovered firms, we cannot clearly pinpoint one specific channel explaining the downsizing decision. Rather, the overall fact of being covered by the EU ETS and having to cope with the associated cost increase relative to uncovered firms not having to face these carbon costs appears to be crucial, especially for private enterprises.

< Insert Table 4 about here. >

Intra-EU ETS sample

We test whether the proposed drivers carry explanatory value when considering the cross-sectional variation in emission intensity among the EU ETS-covered firms and repeat our analyses in Panel B of Table 4. First, with regards to financial constraints, we find a strong and statistically significant coefficient loading on *RANK* × *POST* × *CASH* for the private firms in Model (1), but not for the listed firms in Model (4). Financial constraints thus tend to be a crucial moderator for private enterprises within the EU ETS in explaining the downsizing response following the European Council's intervention. To further illustrate this, we display the results of a dynamic analysis for cash constrained and unconstrained private and listed firms in

Figure 3. Figure 3b demonstrates a clear increased likelihood of downsizing in the post-intervention period, without pre-trends being present.[21]

We next define triple interactions based on the proxies for market power (*HHI*) and efficiency (*VALUE_ADDED*) in Models (2) and (3) for the private firms and Models (5) and (6) for the listed firms. Yet, none of these model specifications demonstrate any statistical significance. Therefore, the pass-through and efficiency arguments cannot be supported.

In sum, only financial constraints appear to act as an underlying driver influencing the downsizing response of emission intensive private firms after the intervention of the European Council.

3. The Economic Channels of Financial Constraints

The finding that financial constraints result in downsizing provides us with an interesting vantage point for several deeper analyses. First, the cash position could be determined by the agency costs present in the firm. For instance, a high cash position provides management with more leeway to sustain their polluting activities rather than altering their business model.[22] We therefore want to test whether the cash-related findings can be explained by internal agency conflicts. Second, the extent to which financial constraints hamper firm behavior depends heavily on their size. Larger and more established firms generally have more opportunities to obtain financing, build reserves, and establish sounder working capital management practices than smaller firms. In addition, larger firms generally have more ease in obtaining external financing in the case of cash deficits, such that their low cash position is less problematic and easier to overcome. Third, cash constrained firms' downsizing may be more likely to alter their production scale to entail lower emissions. This reduced production should, in turn, result in a

[21] The untabulated results are available upon request.
[22] We sincerely thank an anonymous reviewer for raising this point.

reduced need for manpower. We test each of these assumptions for both our matched sample and intra-EU ETS sample.

Matched sample

First, to approximate the agency costs within the firm, we follow Bena and Xu (2017) and Gogineni et al., (2022) and consider a firm's ownership structure to approximate for agency conflicts. Specifically, we calculate the ownership concentration as the Herfindahl-Hirschman Index of the percentage ownership of all outside shareholders (i.e., all shares not owned by the enterprise itself), where higher values represent more concentrated ownership (Gogineni et al., 2022). The results are provided in Model (1) of Panel A in Table 5 for private firms and in Model (4) for listed firms. We do not find statistical significance in the subsamples of private and listed firms.

Second, pertaining to firm size, we create an indicator variable that takes the value of one if the firm has lower than median cash levels and has a lower than median firm size (*LOW_CASH_SIZE*) and interact this with *EU_ETS* × *POST*. The results are reported in Models (2) and (5) for private firms and listed firms, respectively. We find no significant coefficient loading on either triple interaction term.

Third, we infer a reduced production scale through changes in fixed assets, which comprise the crucial equipment, machinery, and facilities of the firm. To test whether the observed downsizing response in our paper can be explained by divestments, we create an indicator variable that takes the value of one if the firm has lower than median cash levels and has a lower than median percentage change in industry-adjusted fixed assets in the downsizing period (*CASH_Δ_FIXED_ASSETS*). We report the results of this analysis in Models (3) and (6) but find no statistical significance.

< Insert Table 5 about here. >

Intra-EU ETS sample

We repeat these analyses for the intra-EU ETS sample in Panel B of Table 5. First, we note that agency issues are unable to explain the downsizing response, given the insignificant coefficient loadings on *RANK* × *POST* × *OWNERSHIP_CONCENTRATION* in Models 1 (private firms) and 5 (listed firms), indicating that cash is not a simple corollary of agency costs.

Second, we investigate the influence of size in Models (2) and (6). Interestingly, we find a positive and statistically significant coefficient loading on *RANK* × *POST* × *LOW_CASH_SIZE* within the subset of listed firms (p-value < 0.05). As such, while our results thus far have largely excluded listed firms from engaging in downsizing, we now find strong evidence that within the subset of smaller and cash constrained listed firms, there is a significantly heightened downsizing likelihood in the post-intervention period that increases with the firm's emission intensity. We further find no additional moderating role of size for the private firms.

Third, pertaining to production downscaling, we find strong evidence that downsizing occurs only in the segment of private firms with low-cash and who are divesting their fixed assets relative to their peers (Model 3), with no result for listed firms (Model 7). Thus, the downsizing response in private firms can be explained by changes in production efforts.[23, 24]

Altogether, the analysis of the economic channels demonstrates that cash constrained private firms' downsizing response can be explained by a reduction in production scale. Moreover, smaller cash constrained listed firms engage significantly more in downsizing as their emission intensity increases. Downsizing listed firms, however, do not engage in downscaling.

[23] Results for changes in fixed assets are robust to using a zero cutoff instead of the median values to specifically examine net divestments. We also explicitly test for existence of downscaling in small, cash constrained listed firms, but find no significant evidence of this. These analyses are available upon request.
[24] We thank an anonymous reviewer for this suggestion.

4. *The Consequences of Downsizing*

We next question the impact corporate downsizing has on these firms. In particular, we are interested in understanding whether downsizing resulted in emission reductions and changes in productivity. We test this empirically for the intra-EU ETS sample by employing the following equations:

$$(4)\ \Delta EMISSIONS_{it+1} = \alpha + \beta \times DOWNSIZER_{i,t} \times POST_t + \rho \times DOWNSIZER_{i,t} + \delta \times POST_t + \sum Firm_{it} + \gamma_i + \varepsilon_{it},$$

and

$$(5)\ \Delta TFP_{it+1} = \alpha + \beta \times DOWNSIZER_{i,t} \times POST_t + \rho \times DOWNSIZER_{i,t} + \delta \times POST_t + \sum Firm_{it} + \gamma_i + \varepsilon_{it},$$

in which $\Delta EMISSIONS_{it+1}$ is the logarithmic change in emissions between year *t+1*, relative to year *t*. $DOWNSIZER_{it}$ is a dummy variable taking the value of one if firm *i* downsized in year *t*. The coefficient loading on $DOWNSIZER \times POST$ captures the percentage change in emissions and total factor productivity changes following employee downsizing, respectively. Equations (4) and (5) take the same control variables and fixed effects estimations as per our baseline regression (Equation 2). In Equation (5), ΔTFP_{it+1} represents the change in total factor productivity in year *t+1* relative to year *t*. We follow the procedure by Faleye, Mehrotra, and Morck (2006) to calculate total factor productivity, assuming that sales (*NET_SALES*) are generated by the number of employees (*NUMBER_OF_EMPLOYEES*) and the firm's property, plant, and equipment (*PPE*) through the following Cobb-Douglas function:

$$(6)\ NET\_SALES_{it} = A \times NUMBER\_OF\_EMPLOYEES_{it}^{\beta} \times PPE_{it}^{\gamma}$$

where A, β, and γ are parameters. Equation (6) is estimated at the two-digit SIC industry level for the intra-EU ETS sample and the total factor productivity entails the residuals of the logarithmic transformation of Equation (6) as per Faleye et al., (2006).

We display the results of Equation (4) in Models (1) and (3) of Table 6, where we observe a negative and significant coefficient loading on $DOWNSIZER \times POST$ only in the private subsample. This indicates that downsizing private firms in the post-intervention period (i.e., when prices increased) significantly reduced their emissions, which is in line with the reduced production channel observed in Table 5. This effect is also economically sizeable as it constitutes a 7.8% drop in emissions. Additionally, when estimating Equation (5) to gauge productivity outcomes, we find that both downsizing private firms (Model (2)) and downsizing listed firms (Model (4)) experience an increase in productivity.

Taken together, our findings reveal different downsizing motivations for private and listed firms. Cash constrained private firms primarily downsized by divesting production assets post-intervention reducing both personnel and emissions. In contrast, small, cash-strapped listed firms used downsizing primarily to reduce their operating leverage while maintaining emission output and asset levels. Improved productivity outcomes for both groups indicate that downsizing ultimately helped them to operate in a leaner manner.

< Insert Table 6 here >

D. Robustness Tests

1. Alternative Model Specifications

We conduct various robustness checks to ensure the validity of our main findings. We start by performing two types of placebo tests. First, we draw 5,000 random firm-year observations, assign a random treatment year, and run the baseline regression 2,000 times. We find that the true coefficient loading on $RANK \times POST$ exceeds 99.45% of the estimated distribution. This falls within the 90% confidence interval (e.g., Cousins, Dutordoir, Lawson, and Frota Neto, 2020, and Crane and Koch, 2018) and corroborates the influence of the EC's intervention in driving the downsizing response for pollution-intensive private firms. As a second placebo test, we retained our full sample of 7,773 firm-year observations and assigned a random *RANK* and a random treatment year. We repeated this procedure 2,000 times, with the true coefficient estimate on *RANK* × *POST* now being above 99.85% of the estimated distribution.

We next employ a series of different model specifications for which the results for the matched sample analyses can be found in Panel A of Table 7 and in Panel B for the intra-EU ETS sample. Firstly, the linear probability model used in our main analysis could return biased estimates as it does not take into account the binary distribution of the error term. To mitigate any concerns in this regard, we estimate both random-effects (Models (1) and (2)) and fixed-effects logit models (Models (3) and (4)) for the listed and private matched sample and intra-EU ETS sample. We find that the coefficient loadings on *EU_ETS* × *POST* and *RANK* × *POST* remain robust. We also add other fixed-effects specifications based on country, industry, and year fixed effects. Models (5) and (6) in Panel A and Panel B add these fixed effects separately, while Models (7) and (8) employ country × industry × year fixed effects.[25] The results are again robust for both the matched sample and the intra-EU ETS sample.

Third, as firms can arguably enter and exit the EU ETS in an endogenous way, we repeat our analyses on a balanced panel of firms for which all observations are available (Models (9) and (10) in Panels A and B) and find that the results remain qualitatively similar for both the matched and EU ETS-covered private and listed samples. Finally, rather than measuring emission intensity (*RANK*) on a year-by-year basis, we consider the exposure at the time of the intervention (i.e., in 2017). When we replace our time-variable measure *RANK* with the time-invariant measure *RANK2017*, our results remain robust (Models (11) and (12) in Panel B).

[25] We thank an anonymous reviewer for this suggestion.

We further implement alternative cut-offs and definitions of our dependent variable. We replace the original 5% cut-off with a 10% cut-off in line with Chen and Kao (2022). Interestingly, we find that there are limits to the impact of the EC's intervention on the downsizing decision of pollution-intensive private firms, as the coefficient of *RANK* × *POST* becomes insignificant.[26] This triggered our interest in obtaining a rough estimate of the size of the corresponding workforce reduction. To this end, we construct a model in line with Filatotchev, Buck and Zhukov (2000). Specifically, we take the natural logarithm of the number of employees as the dependent variable and regress it on our original set of controls, alongside the lagged natural logarithm of the number of employees as an additional control variable.[27] The advantage of this model is that its log-linear form allows for an easy interpretation of the magnitude of *EU_ETS* × *POST* and *RANK* × *POST*. Concretely, Panel A of Table 7 reports a coefficient estimate of -0.019 (p-value < 0.01) for the *EU_ETS* × *POST* term in Model (12). As such, being covered by the EU ETS leads to a reduction in the size of the workforce by approximately 1.9% after the intervention of the European Council, compared to non-EU ETS-covered firms. When directing our attention towards the intra-EU ETS sample in Model (14) of Panel B, the coefficient loading of -0.004 (p-value < 0.05) on the *RANK* × *POST* term translates into the most pollution-intensive firms (*RANK*=10), decreasing their workforce size by just over 3.5% relative to the least pollution-intensive firms (*RANK*=1).

< Insert Table 7 about here. >

[26] These results are available upon request.
[27] To avoid any multicollinearity issues, size has been omitted from this model.

2. *Understanding and Contextualizing the Behavior of Listed Firms*

Our results show that only small and cash constrained listed firms engage in corporate downsizing intra-EU ETS. This begs the question of whether larger listed firms are even bothered at all by the cost increase, and if so, what they are doing to cope with these costs.

We have downloaded all available annual reports, press releases, and CSR disclosures of the listed firms in our sample and looked for relevant keywords such as "EU ETS", "emission allowances", and "emission costs" among others. We found various instances in which EU ETS related concerns were explicitly mentioned, with several firms documenting how they responded to the associated costs.

First, firms mention that they invest more in R&D and in transitioning their business model. For instance, ArcelorMittal mentioned in their 2019 annual report that their global R&D division "continues to research processes to support carbon neutrality and energy efficiency." (ArcelorMittal, 2019, p. 56), while Grupa Azoty Puławy mentions in 2017 that "a PLN 293 thousand grant was transferred to the Company for the project to develop a method […] for the support of low-emission agriculture" (Grupa Azoty Puławy, 2017, p.82).

Second, some firms hint that costs are (at least partially) shifted through to customers. For instance, we extract from the 2018 annual report of Grupa Azoty Zaklady Chemiczne that for "CO2 emission allowances (where the price almost tripled)" the firm "was unable to fully pass through these substantial increases in raw material prices to product prices in the reporting period." (Grupa Azoty Zaklady Chemiczne, 2018, p. 33).

Third, firms are using financial instruments to hedge the risk exposure: "the risk of an adverse effect of EUA prices on the EU ETS market is mitigated by averaging the prices of emission units purchased on the spot market and by purchasing CO2 emission allowances in financial derivatives" (Grupa Azoty Puławy, 2018, p. 114).

Fourth, we found hints of firms relocating activities outside the EU region: "Depending on the extent of the difference between the requirements in developed regions (such as Europe) and developing regions (such as China or the CIS), this competitive disadvantage could be severe and render production in the developed region structurally unprofitable. High carbon costs, in combination with weakening demand, rising imports, high energy costs, and high iron ore prices was one of the factors underlying the company's decision to implement production cuts in Europe in 2019" (ArcelorMittal, 2020, p. 31).

Finally, firms are also engaging in lobbying to render their businesses more competitive: "the Company has lobbied the European Commission to introduce a carbon border adjustment mechanism to the safeguard measures on steel imports in order to ensure that imports into Europe face the same carbon costs as producers in Europe." (ArcelorMittal, 2020, p. 32).

Academic evidence also points to some of these coping mechanisms. De Beule et al., (2022a) and De Beule et al., (2022b) provide evidence of carbon and investment leakage, with a flight towards less carbon-strict regions (see also Misch and Wingender, 2021). De Jonghe et al., (2020) report a green transition of business models through green acquisitions, whereas Alexeeva-Talebi (2011) find a pass-through of the EU ETS costs to customers. In another study, Compagnie et al., (2023) demonstrate that price increases under the EU ETS are responded to by increasing corporate tax avoidance by listed firms.

In summary, from the aforementioned anecdotes and papers, listed firms appear to possess considerable flexibility in coping with the cost of emission allowances. Techniques such as risk hedging, shifting production abroad, and even engaging in R&D may be less likely to occur in private firms, as they are often more resource constrained and limited in such possibilities. Thus, the absence of a statistically significant effect of the EC's intervention on listed firms may be an artifact of firms using an amalgamation of different strategies to cope with these costs, thereby not triggering an aggregate shock in unemployment.

In addition to the anecdotal evidence mentioned above, we empirically test whether our listed firms significantly resort to some alternative coping mechanisms. We examine four potential responses in Table 8.[28] In Panel A, we consider all listed firms and in Panel B, we interact our variable of interest *RANK* × *POST* with an indicator taking the value of one if a firm is lower than median in terms of size and has lower than median cash levels (*LOW_CASH_SIZE*). Model (1) investigates whether listed firms increase their R&D investments (measured by the R&D expenditure over sales) to become more environmentally efficient. Model (2) investigates whether the listed firms reduce their dividends (measured as the dividend yield) to retain cash. Model (3) focuses on increases in listed firms' debt levels (measured as the natural logarithm of total debt), while Model (4) focuses on whether listed firms raise new capital (measured as the natural logarithm of the number of shares) to ensure adequate funds are available to cope with the unexpected cost increase. In none of the model specifications across both panels, however, do we find any significant response. While the anecdotal evidence highlights that listed firms do take the carbon cost increase into account, the results in Table 8 support the notion of a wide array of coping mechanisms available for listed firms. This variety of strategies implies that no single, uniform response is necessary, allowing these firms to tailor their approaches based on their specific circumstances.

< Insert Table 8 about here. >

V. Discussion and Conclusion

This study explores the influence of the EU ETS on employment, productivity, and emission outcomes during its third phase. While warnings about job losses as a consequence of the EU ETS are consistently raised by stakeholders, academic research (e.g., Anger and Oberndorfer, 2008) found little tangible evidence for such claims. Nevertheless, these studies were conducted in the first and second phases of the emissions trading system characterized by an underwhelming carbon price.

[28] These models employ the same control variables and fixed effects as our baseline models.

We exploit 2017 as the pivotal year in which the European Council undertook measures to reduce excess emission allowances in the system and find evidence that corporate downsizing did occur post-intervention. While the economic significance of the decrease in employment is non-negligible but modest after the intervention (an average of approximately 3.5% of the total workforce for the most polluting private firms relative to the least polluting firms), it is important to note that the carbon price also did not peak during our sample period. Our sample ended in 2020 with the end of phase III of the scheme at a price of €32.57. Since then, emission prices have increased sharply with peak values of around €100 per ton in 2023. Thus, it is likely that EU ETS-related transition costs have further increased in magnitude.

Upon closer examination, we find that not all firms are equally affected by this shock. When compared to a control group of uncovered firms, as well as intra-EU ETS, workforce reductions are stronger and more pronounced in the subset of private firms, whereas no direct effect was found in the subset of publicly listed enterprises. This downsizing response also tends to be more pronounced for private firms operating in non-leakage sectors as firms' emission intensity increases.

After investigating three strategic settings in which firms are expected to downsize as a response to safeguard their profit margins and shield them from the carbon cost increase, we find that financial constraints drive this result within the EU ETS-covered sample. When examining why cash constrained private firms downsize as their emission intensity increases, we observe that this is owing to divestment. Thus, cash constrained private firms downscale in response to increasing carbon costs, thereby requiring fewer personnel and lowering their emissions. We also find that smaller cash constrained listed firms engage substantially more in downsizing, which does not stem from a divestment response but rather appears to be targeted at reducing their operating leverage as they do not appear to reduce their emission output and production asset levels. In both cases, the downsizing firms become leaner as reflected by a positive change in productivity. Finally, we interpret and attribute the absence of statistical evidence of more general corporate responses in listed firms to the availability of a wide variety of techniques to cope with carbon cost increases.

Collectively, our findings add to the growing body of literature examining the impact of environmental regulation on corporate outcomes (e.g., Bellon, 2020, and Dechezleprêtre, Nachtigall, and Venmans, 2022). We provide evidence that when the price of carbon is sufficiently high, it affects employment levels in the pursuit of productivity gains, particularly for cash constrained private firms and cash constrained smaller listed firms. This finding is relevant for policymakers involved in intervening in and developing emissions trading schemes. Governmental efforts to combat climate change resulted in the number of emissions trading systems mushrooming across the globe (ICAP, 2022). However, with the exception of a few schemes—among which the EU ETS—the emission prices remain underwhelmingly low and are often insufficient to stimulate emission abatement (Bel and Joseph, 2015, Black et al., 2022). Although higher carbon prices may stimulate a green transition, this study cautions that sudden interventions to boost emission prices may indeed trigger a reduction in emission output levels, it also brings about transition costs, namely downscaling.

Policymakers may draw inspiration from our findings to understand how sudden interventions can engender important societal side-effects, in particular regarding employment reallocation. We provide important insights for targeted initiatives that aim to balance abatement and social costs. To smoothen transition costs within the EU ETS, policymakers should target cash constrained private firms because these firms are limited by the extent to which they can internalize and absorb price increases. For instance, the development of special (green) loan investment programs or subsidies to facilitate green transitions could help firms realize productivity gains while sustaining the current workforce size and reducing divestment incentives. Furthermore, while the EC has implemented relief mechanisms for leakage sectors, non-leakage sectors are not grandfathered (i.e., given for free) as many allowances, such that they could particularly benefit from transition aid.

Building on this notion of smoothing the social costs of the green transition, the profits of the EU ETS auctioning currently go towards an innovation fund from which carbon-reducing projects can be financed, thereby potentially engendering job creation as well. However, this may need to be calibrated against the characteristics and competencies of the laid-off workers. If the created green jobs target high-skilled white-collar workers and if EU ETS-related downsizing predominantly affects lower-skilled blue-collar workers, trading schemes may compound inequality in employment opportunities. Policymakers may opt to reallocate (part of) the emissions revenue to furnish special training opportunities, thereby rendering employees more equipped and competitive for the nascent green economy. We leave the question of mapping the profiles of lost jobs and the potential creation of jobs through innovation funds for future research.

Our findings provide other interesting avenues for future research. It would be interesting to pay special attention to voluntary turnover. Prior evidence has highlighted that financially distressed firms lose more talented employees (Baghai, Silva, Thell, and Vig, 2021), which rising emission prices could exacerbate. Consequently, an interesting research topic could be to examine whether there exists a cost of environmental distress and to identify whether a shift in talent exists between strongly and weakly environmentally performing firms within the EU ETS. Finally, as our findings are situated at the beginning of the carbon price surge, future research endeavors could investigate the persistence of the job losses mapped in this study and attempt to understand if and to what extent the magnitude further increased in the long run.

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Table 1. Descriptive Statistics

The table shows the descriptive statistics of the main variables used in this study and reports the number of observations, mean, standard deviation (St. dev), first and third quartiles (Q1 and Q3) and median value over the sample period from Jan 2013 to Dec 2020. All continuous variables are winsorized at the 2.5%. Variables are defined in the appendix, Table A1. The emission intensity variable (RANK) is reported before its decile transformation for interpretation purposes. Panel A reports the full matched sample of EU ETS-covered firms and matched non-EUETS-covered firms, Panel B focuses on the EU ETS-covered firms, while Panels C and D focus on the listed and private subsamples of EU ETS-covered firms.

PANEL A: All EU ETS firms and matched non-EU ETS firms

	Obs.	Mean	St. Dev	Q1	Median	Q3
Dependent variable						
DOWNSIZING	22,222	0.136	0.343	0.000	0.000	0.000
Variable of interest						
EU_ETS	22,222	0.497	0.500	0.000	0.000	1.000
Firm level controls						
LTD	22,222	0.110	0.158	0.000	0.034	0.169
GROWTH	22,222	0.025	0.214	-0.090	-0.004	0.104
SIZE	22,222	11.484	1.582	10.328	11.234	12.415
ROA	22,222	4.587	7.892	0.515	3.631	8.128
COST_OF_EMPLOYMENT	22,222	14.789	9.671	7.837	13.058	19.789
ASSETS_PER_EMPLOYEE	22,222	6.183	1.088	5.449	6.097	6.790
CURRENT_RATIO	22,222	1.976	2.121	0.995	1.430	2.191
AGE	22,222	34.262	25.630	17.000	26.000	45.000
TANGIBILITY	22,222	0.486	0.242	0.303	0.480	0.677

PANEL B: All EU ETS firms

	Obs.	Mean	St. Dev	Q1	Median	Q3
Dependent variable						
DOWNSIZING	12,308	0.143	0.350	0.000	0.000	0.000
Variable of interest						
RANK (Untransformed)	12,308	0.472	1.234	-0.075	0.234	0.823
Firm level controls						
ETC	12,308	0.877	4.890	-0.394	-0.149	0.171
LTD	12,308	0.112	0.160	0.000	0.026	0.175
GROWTH	12,308	0.023	0.206	-0.098	-0.012	0.103
SIZE	12,308	11.772	1.681	10.657	11.675	12.844
ROA	12,308	5.051	8.900	0.445	4.069	8.969
COST_OF_EMPLOYMENT	12,308	13.962	8.595	7.622	12.428	18.615
ASSETS_PER_EMPLOYEE	12,308	6.265	1.020	5.581	6.223	6.881
CURRENT_RATIO	12,308	1.871	1.622	0.953	1.396	2.140
AGE	12,308	34.833	27.313	16.000	26.000	46.000
INSTALLATIONS	12,308	1.512	1.164	1.000	1.000	2.000
TANGIBILITY	12,308	0.539	0.220	0.377	0.545	0.716

PANEL C: Listed EU ETS firms

	Obs.	Mean	St. Dev	Q1	Median	Q3
Dependent variable						
DOWNSIZING	4,535	0.146	0.354	0.000	0.000	0.000
Variable of interest						
RANK (Untransformed)	4,535	0.453	0.971	-0.055	0.267	0.862
Firm level controls						
ETC	4,535	0.322	1.737	-0.352	-0.142	0.143
LTD	4,535	0.093	0.154	0.000	0.002	0.134
GROWTH	4,535	0.020	0.200	-0.099	-0.013	0.098
SIZE	4,535	12.674	1.647	11.526	12.547	13.718
ROA	4,535	5.986	9.706	1.038	5.067	10.216
COST_OF_EMPLOYMENT	4,535	14.567	8.922	7.967	12.941	19.471
ASSETS_PER_EMPLOYEE	4,535	6.372	0.968	5.728	6.285	6.907
CURRENT_RATIO	4,535	1.884	1.587	0.948	1.411	2.175
AGE	4,535	41.270	32.496	18.000	28.000	57.000
INSTALLATIONS	4,535	1.750	1.523	1.000	1.000	2.000
TANGIBILITY	4,535	0.551	0.207	0.398	0.562	0.714

PANEL D: Private EU ETS firms

	Obs.	Mean	St. Dev	Q1	Median	Q3
Dependent variable						
DOWNSIZING	7,773	0.141	0.348	0.000	0.000	0.000
Variable of interest						
RANK (Untransformed)	7,773	0.483	1.365	-0.087	0.215	0.788
Firm level controls						
ETC	7,773	1.201	5.985	-0.420	-0.156	0.186
LTD	7,773	0.123	0.163	0.000	0.050	0.193
GROWTH	7,773	0.024	0.210	-0.098	-0.011	0.105
ROA	7,773	4.505	8.346	0.296	3.463	8.216
COST_OF_EMPLOYMENT	7,773	13.609	8.379	7.434	12.108	18.163
ASSETS_PER_EMPLOYEE	7,773	6.203	1.029	5.493	6.179	6.869
CURRENT_RATIO	7,773	1.863	1.642	0.956	1.391	2.117
AGE	7,773	31.078	22.955	16.000	25.000	42.000
INSTALLATIONS	7,773	1.373	0.861	1.000	1.000	1.000
TANGIBILITY	7,773	0.531	0.227	0.363	0.532	0.719

Table 2. Main Results

The table presents the regression results of the linear probability models examining the relationship between green pressure and downsizing. Panel A tests the relationship between being covered by the EU ETS (*EU_ETS*) in the post-intervention period (*POST*) and the indicator variable reflecting the corporate downsizing decision (*DOWNSIZING*). Model (1) focuses on our full matched sample, Model (2) examines the subsample of matched firms that are listed or have a listed owner, while Models (3) to (5) focus on the subsample of matched private firms. Models (1) to (3) include the *POST* variable, while Models (4) and (5) include year fixed effects. Model (5) estimates a dynamic model using year dummies *ECt* reflecting three years prior (2014) until two years after the intervention (2019). Panel B examines the relationship between emission intensity (*RANK*) for EU ETS-covered firms in the post-intervention period. Models (1) through (4) are similar in specification as in Panel A. Model (5) provides the results of a nearest neighbor propensity score matched sample of high-*RANK* (>5) and low-*RANK* (≤ 5) firms, based on country, industry, growth, return on assets, current ratio, long term debt, size, age, cost of employment, and assets per employee. Model (6) estimates a dynamic model using year dummies *ECt* reflecting three years prior (2014) until two years after the intervention (2019). N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: Matched sample

	Full sample	Listed	Private	Private	Private
	1	2	3	4	5
VARIABLES	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*
POST	-0.004	0.002	-0.001		
	(0.013)	(0.025)	(0.017)		
EU_ETS×POST	0.034***	0.001	0.052***	0.052***	
	(0.011)	(0.021)	(0.014)	(0.014)	
$EU\_ETS \times EC_{2014}$					0.001
					(0.027)
$EU\_ETS \times EC_{2015}$					0.004
					(0.027)
$EU\_ETS \times EC_{2016}$					-0.018
					(0.026)
$EU\_ETS \times EC_{2017}$					0.045*
					(0.027)
$EU\_ETS \times EC_{2018}$					0.046*
					(0.026)
$EU\_ETS \times EC_{2019}$					0.054**
					(0.028)
ETC	0.000	-0.004	0.000	0.000	0.000
	(0.001)	(0.010)	(0.001)	(0.001)	(0.001)
LTD	0.025	-0.065	0.073	0.082*	0.082*
	(0.037)	(0.064)	(0.048)	(0.048)	(0.048)
GROWTH	-0.073***	-0.060**	-0.083***	-0.066***	-0.066***
	(0.014)	(0.026)	(0.018)	(0.020)	(0.020)
ROA	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
SIZE	0.307***	0.318***	0.3037***	0.291***	0.291***
	(0.018)	(0.031)	(0.024)	(0.024)	(0.024)
COST_OF_EMPLOYMENT	0.005***	0.008***	0.003**	0.003**	0.003**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
ASSETS_PER_EMPLOYEE	-0.346***	-0.349***	-0.349***	-0.351***	-0.351***
	(0.016)	(0.027)	(0.021)	(0.021)	(0.021)
CURRENT_RATIO	-0.001	0.004	-0.002	-0.002	-0.002
	(0.002)	(0.005)	(0.003)	(0.003)	(0.003)
AGE	-0.005**	-0.001	-0.009***	0.002	0.002
	(0.002)	(0.004)	(0.003)	(0.012)	(0.012)
INSTALLATIONS	-0.096***	-0.051	-0.116**	-0.1163**	-0.116**
	(0.028)	(0.072)	(0.057)	(0.056)	(0.057)
TANGIBILITY	-0.062	-0.015	-0.064	-0.065	-0.065
	(0.040)	(0.072)	(0.050)	(0.050)	(0.050)
YEAR FE	NO	NO	NO	YES	YES
FIRM FE	YES	YES	YES	YES	YES
N	22,222	8,520	13,822	13,822	13,822

Table 2. Main Results (Continued)

PANEL B: Intra-EU ETS sample

	Full sample	Listed	Private	Private	Private PSM	Private
	1	2	3	4	5	6
VARIABLES	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*
RANK	-0.005	-0.006	-0.003	-0.005	-0.002	-0.007
	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
POST	0.016	0.024	0.016			
	(0.019)	(0.030)	(0.024)			
RANK×POST	0.005*	-0.001	0.008***	0.008***	0.006*	
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	
RANK×EC$_{2014}$						0.009
						(0.005)
RANK×EC$_{2015}$						0.003
						(0.006)
RANK×EC$_{2016}$						0.001
						(0.005)
RANK×EC$_{2017}$						0.012**
						(0.005)
RANK×EC$_{2018}$						0.011**
						(0.005)
RANK×EC$_{2019}$						0.010*
						(0.005)
ETC	0.000	-0.002	0.000	0.000	0.000	0.000
	(0.002)	(0.011)	(0.002)	(0.002)	(0.002)	(0.002)
LTD	0.016	-0.079	0.088	0.094*	0.051	0.094*
	(0.044)	(0.071)	(0.056)	(0.056)	(0.058)	(0.056)
GROWTH	-0.093***	-0.078**	-0.108***	-0.091***	-0.100***	-0.090***
	(0.018)	(0.031)	(0.022)	(0.025)	(0.027)	(0.025)
ROA	-0.002***	-0.003***	-0.002**	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SIZE	0.276***	0.309***	0.252***	0.241***	0.303***	0.241***
	(0.021)	(0.035)	(0.027)	(0.027)	0.031	(0.027)
COST_OF	0.006***	0.010***	0.003	0.003*	0.003	0.003*
_EMPLOYMENT	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
ASSETS_PER	-0.298***	-0.324***	-0.285***	-0.286***	-0.332***	-0.286***
_ EMPLOYEE	(0.018)	(0.030)	(0.023)	(0.023)	(0.027)	(0.023)
CURRENT_RATIO	0.003	0.006	-0.000	-0.000	-0.002	-0.000
	(0.004)	(0.007)	(0.005)	(0.005)	(0.006)	(0.005)
AGE	-0.010***	-0.006	-0.013***	0.004	-0.001	0.004
	(0.003)	(0.006)	(0.004)	(0.016)	(0.016)	(0.016)
INSTALLATIONS	-0.009	0.048	-0.058	-0.056	-0.061	-0.056
	(0.040)	(0.057)	(0.055)	(0.055)	(0.056)	(0.055)
TANGIBILITY	-0.041	-0.077	-0.012	-0.014	0.039	-0.016
	(0.047)	(0.078)	(0.059)	(0.059)	(0.064)	(0.059)
YEAR FE	NO	NO	NO	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES
N	12,308	4,535	7,773	7,773	6,778	7,773

Table 3. Moderating Employment and Sectoral Conditions

The table presents the regression results of the linear probability models examining the potential moderating influence of employment and sectoral characteristics on the relationship between green pressure and downsizing. Panel A tests the relationship between being covered by the EU ETS (*EU_ETS*) in the post-intervention period (*POST*) and the indicator variable reflecting the corporate downsizing decision (*DOWNSIZING*), for a set of matched private firms (Models (1) to (4)) and listed firms (Models (5) to (8)). Models (1) and (5) report the moderating impact of regional unemployment. *UNEMPLOYMENT* is an indicator variable equal to one if the firm is headquartered in a location with a higher than median unemployment at the NUTS2-level, zero otherwise. Models (2) and (6) report the moderating impact of employee protection. *BARGAINING* is an indicator variable equal to one if the number of employees covered by a collective bargaining agreement as a proportion to the total workforce size is higher than the sample median, zero otherwise. Models (3) and (7) report the moderating impact of regulatory strength, as approximated by the rule of law index from the World Bank. *RULE_OF_LAW* is an indicator variable equal to one if the rule of law index is higher than the sample median, zero otherwise. Models (4) and (8) consider whether or not the firm is active in a leakage sector (*LEAKAGE*), based on the carbon leakage classification by the European Commission. Panel B examines the relationship between emission intensity (*RANK*) for EU ETS-covered firms in the post-intervention period for the private (Models (1) to (4)) and listed firms (Models (5) to (8)). Models (1) through (8) test the same settings as Models (1) through (8) in Panel A. The control variables are the same as those represented in Table 2, omitted for parsimony. N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: Matched sample

	Private firms				**Listed firms**			
VARIABLES	1	2	3	4	5	6	7	8
POST	0.007	-0.020	0.001	-0.007	0.075	0.091**	-0.010	0.000
	(0.021)	(0.023)	(0.021)	(0.019)	(0.050)	(0.043)	(0.035)	(0.033)
EU_ETS×POST	0.049**	0.075***	0.064***	0.047***	-0.032	-0.049	0.025	0.010
	(0.021)	(0.023)	(0.020)	(0.018)	(0.036)	(0.043)	(0.034)	(0.032)
UNEMPLOYMENT	-0.004				0.029			
	(0.025)				(0.042)			
EU_ETS×UNEMPLOYMENT	-0.037				-0.022			
	(0.030)				(0.047)			
POST×UNEMPLOYMENT	-0.006				-0.087*			
	(0.027)				(0.045)			
EU_ETS×POST×UNEMPLOYMENT	-0.007				0.084*			
	(0.032)				(0.052)			
BARGAINING		-0.016				0.162**		
		(0.037)				(0.084)		
EU_ETS×BARGAINING		0.094**				-0.126		
		(0.043)				(0.096)		
POST×BARGAINING		0.004				-0.048		
		(0.029)				(0.052)		
EU_ETS×POST×BARGAINING		-0.016				0.015		
		(0.034)				(0.058)		
RULE_OF_LAW			-0.048				-0.376	
			(0.034)				(0.280)	
EU_ETS×RULE_OF_LAW			0.109***				0.101	
			(0.040)				(0.136)	
POST×RULE_OF_LAW			-0.005				0.021	
			(0.020)				(0.039)	
EU_ETS×POST×RULE_OF_LAW			-0.030				-0.044	
			(0.028)				(0.044)	
LEAKAGE				-0.019				-0.024
				(0.022)				(0.030)
EU_ETS×LEAKAGE				0.011				-0.001
				(0.025)				(0.033)
POST×LEAKAGE				0.018				-0.000
				(0.027)				(0.039)
EU_ETS×POST×LEAKAGE				0.004				-0.013
				(0.031)				(0.045)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES	YES	YES
N	13,390	10,214	13,822	13,822	7,560	5,947	8,517	8,520

Table 3. Moderating Employment and Sectoral Conditions (Continued)

PANEL B: Intra-EU ETS sample

	Private firms				**Listed firms**			
VARIABLES	1	2	3	4	5	6	7	8
RANK	0.003	0.003	-0.005	-0.003	-0.004	-0.007	-0.003	-0.005
	(0.006)	(0.007)	(0.006)	(0.005)	(0.007)	(0.008)	(0.007)	(0.006)
POST	0.053*	0.012	-0.008	-0.027	0.039	0.063	0.062	0.047
	(0.031)	(0.034)	(0.033)	(0.031)	(0.040)	(0.045)	(0.040)	(0.052)
RANK×POST	0.002	0.008*	0.011***	0.013***	-0.004	-0.002	-0.006	-0.005
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)	(0.007)
UNEMPLOYMENT	0.002				0.033			
	(0.037)				(0.047)			
RANK×UNEMPLOYMENT	-0.006				-0.003			
	(0.005)				(0.007)			
POST×UNEMPLOYMENT	-0.053				-0.033			
	(0.044)				(0.055)			
RANK×POST×UNEMPLOYMENT	0.007				0.005			
	(0.006)				(0.008)			
BARGAINING		-0.025				0.057		
		(0.065)				(0.074)		
RANK×BARGAINING		0.012				0.002		
		(0.009)				(0.010)		
POST×BARGAINING		0.012				-0.032		
		(0.044)				(0.056)		
RANK×POST×BARGAINING		-0.001				-0.000		
		(0.007)				(0.009)		
RULE_OF_LAW			0.015				0.064	
			(0.049)				(0.069)	
RANK×RULE_OF_LAW			0.005				-0.003	
			(0.007)				(0.009)	
POST×RULE_OF_LAW			0.032				-0.065	
			(0.038)				(0.048)	
RANK×POST×RULE_OF_LAW			-0.007				0.010	
			(0.006)				(0.007)	
LEAKAGE				-0.007				-0.042
				(0.027)				(0.033)
RANK×LEAKAGE				0.001				0.001
				(0.004)				(0.005)
POST×LEAKAGE				0.081**				-0.030
				(0.041)				(0.057)
RANK×POST×LEAKAGE				-0.010*				0.004
				(0.006)				(0.009)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES	YES	YES
N	7,497	5,633	7,773	7,773	4,159	3,165	4,535	4,535

Table 4. Understanding the Underlying Downsizing Drivers

The table presents the regression results of the linear probability models examining the underlying downsizing drivers of green pressure. Panel A tests the relationship between being covered by the EU ETS (*EU_ETS*) in the post-intervention period (*POST*) and the indicator variable reflecting the corporate downsizing decision (*DOWNSIZING*), for a set of matched private firms (Models (1) to (3)) and listed firms (Models (4) to (6)). Models (1) and (4) test for the role of financial constraints. *CASH* is an indicator variable equal to one if the cash divided by total assets of the firm is higher than the sample median, zero otherwise. Models (2) and (5) test for the extent to which firms can pass through the cost increase in emission allowances to customers. We rely on an indicator variable (*HHI*) equal to one if the within-industry Herfindahl-Hirschman Index is larger than the sample median and equals zero otherwise to this end. Models (3) and (6) test for the role of employment efficiency. *VALUE_ADDED* is an indicator variable equal to one if the firm's industry-adjusted natural logarithm of value added per employee, is higher than the sample median, zero otherwise. Panel B examines the relationship between emission intensity (*RANK*) for EU ETS-covered firms in the post-intervention period for the private (Models (1) to (3)) and listed firms (Models (4) to (6)). Models (1) through (6) test the same settings as Models (1) through (6) in Panel A. The control variables are the same as those represented in Table 2, omitted for parsimony. N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: Matched sample

	Private firms			**Listed firms**		
VARIABLES	1	2	3	4	5	6
POST	-0.071	-0.022	-0.072	0.001	-0.005	0.019
	(0.076)	(0.024)	(0.081)	(0.036)	(0.035)	(0.034)
EU_ETS×POST	0.058***	0.077***	0.075***	0.002	0.002	0.013
	(0.022)	(0.023)	(0.022)	(0.035)	(0.034)	(0.034)
CASH	-0.002			-0.036		
	(0.023)			(0.042)		
EU_ETS×CASH	-0.000			0.037		
	(0.027)			(0.047)		
POST×CASH	-0.000			-0.005		
	(0.026)			(0.041)		
EU_ETS×POST×CASH	-0.004			0.004		
	(0.031)			(0.047)		
HHI		0.003			-0.052	
		(0.026)			(0.032)	
EU_ETS×HHI		-0.002			0.052	
		(0.032)			(0.037)	
POST×HHI		0.029			0.004	
		(0.025)			(0.039)	
EU_ETS×POST×HHI		-0.035			0.009	
		(0.030)			(0.044)	
VALUE_ADDED			-0.030			0.005
			(0.029)			(0.044)
EU_ETS×VALUE_ADDED			-0.000			0.003
			(0.034)			(0.048)
POST×VALUE_ADDED			0.005			-0.022
			(0.027)			(0.040)
EU_ETS×POST×VALUE_ADDED			-0.034			-0.016
			(0.033)			(0.046)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES
N	12,259	13,822	11,968	6,724	8,520	7,562

Table 4. Understanding the Underlying Downsizing Drivers (Continued)

PANEL B: Intra-EU ETS sample

	Private firms			**Listed firms**		
VARIABLES	1	2	3	4	5	6
RANK	-0.006	-0.000	0.004	-0.005	-0.007	-0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
POST	-0.027	0.003	0.045	-0.011	0.022	0.033
	(0.033)	(0.030)	(0.035)	(0.039)	(0.039)	(0.042)
RANK×POST	0.015***	0.007*	0.007*	0.000	-0.004	-0.003
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)
CASH	-0.076**			-0.011		
	(0.035)			(0.043)		
RANK×CASH	0.011**			0.010		
	(0.005)			(0.006)		
POST×CASH	0.087**			0.065		
	(0.041)			(0.052)		
RANK×POST×CASH	-0.016***			-0.008		
	(0.006)			(0.008)		
HHI		0.018			-0.024	
		(0.042)			(0.043)	
RANK×HHI		-0.004			0.003	
		(0.006)			(0.007)	
POST×HHI		0.053			-0.009	
		(0.039)			(0.048)	
RANK×POST×HHI		-0.002			0.011	
		(0.006)			(0.007)	
VALUE_ADDED			0.033			-0.013
			(0.043)			(0.046)
RANK×VALUE_ADDED			-0.005			0.000
			(0.006)			(0.007)
POST×VALUE_ADDED			-0.039			-0.001
			(0.043)			(0.053)
RANK×POST×VALUE_ADDED			-0.001			-0.001
			(0.006)			(0.008)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES
N	7,498	7,773	6,749	4,162	4,535	3,969

Table 5. Economic Channels Explaining the Downsizing Response in Cash Constrained Firms

The table presents the regression results of the linear probability models examining the economic channels underlying the downsizing decision of cash constrained firms following green pressure. Panel A tests the relationship between being covered by the EU ETS (*EU_ETS*) in the post-intervention period (*POST*) and the indicator variable reflecting the corporate downsizing decision (*DOWNSIZING*) for a set of matched private (Models (1) to (3)) and listed firms (Models (4) to (6)). Models (1) and (4) test for an alternative explanation that the observed downsizing response in cash constrained firms is not driven by financial constraints, but rather by associated agency conflicts within the firm. To examine agency conflicts, we rely on the level of outside ownership concentration, measured as the Herfindahl Hirschman Index of all outside shareholders. We create an indicator variable equal to one if the ownership concentration of all outside shareholders is higher than the sample median, zero otherwise (*OWNERSHIP_CONCENTRATION*). Models (2) and (5) test whether these cash constraints are a corollary of firm size. To that end, we exploit an indicator variable equal to one if the firm has a lower than median cash level and a lower than median firm size (*LOW_CASH_SIZE*). Models (3) and (6) test whether the downsizing in cash constrained firms stems from divestments, which is approximated by an indicator variable equal to one if the firm has a lower than median cash level and if the percentage change in industry-adjusted fixed assets between the downsizing year and the previous one is smaller than the sample median, zero otherwise (*LOW_CASH_Δ_FIXED_ASSETS*). Panel B examines the relationship between emission intensity (*RANK*) for EU ETS-covered firms in the post-intervention period for a set of private (Models (1) to (3)) and listed firms (Models (4) to (6)). Models (1) to (3) and Models (4) to (6) test the same settings as in Models (1) to (3) and Models (4) to (6) of Panel A, respectively. The control variables are the same as those represented in Table 2, omitted for parsimony. N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: Matched sample

	Private firms			Listed firms		
VARIABLES	1	2	3	4	5	6
POST	-0.053	-0.006	0.016	-0.004	0.005	-0.004
	(0.078)	(0.022)	(0.024)	(0.030)	(0.029)	(0.036)
EU_ETS×POST	0.050**	0.042**	0.046**	0.010	-0.001	0.007
	(0.023)	(0.021)	(0.023)	(0.030)	(0.027)	(0.036)
OWNERSHIP_CONCENTRATION	-0.014			-0.017		
	(0.027)			(0.039)		
EU_ETS×OWNERSHIP_CONCENTRATION	0.007			0.020		
	(0.032)			(0.044)		
POST×OWNERSHIP_CONCENTRATION	-0.004			0.016		
	(0.025)			(0.039)		
EU_ETS×POST×OWNERSHIP_CONCENTRATION	-0.000			-0.020		
	(0.030)			(0.045)		
LOW_CASH_SIZE		0.008			0.002	
		(0.034)			(0.073)	
EU_ETS×LOW_CASH_SIZE		-0.002			0.026	
		(0.043)			(0.082)	
POST×LOW_CASH_SIZE		-0.000			-0.029	
		(0.025)			(0.045)	
EU_ETS×POST×LOW_CASH_SIZE		0.035			0.028	
		(0.031)			(0.050)	
LOW_CASH_Δ_FIXED_ASSETS			-0.007			-0.014
			(0.018)			(0.028)
EU_ETS×LOW_CASH_Δ_FIXED_ASSETS			0.001			-0.011
			(0.021)			(0.032)
POST×LOW_CASH_Δ_FIXED_ASSETS			-0.047			-0.025
			(0.030)			(0.048)
EU_ETS×POST×LOW_CASH_Δ_FIXED_ASSETS			0.050			0.044
			(0.035)			(0.052)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES
N	13,475	12,259	11,598	8,447	6,724	6,386

Table 5. Economic Channels Explaining the Downsizing Response in Cash Constrained Firms (Continued)

PANEL B: Intra-EU ETS sample

	Private firms			Listed firms		
VARIABLES	1	2	3	4	5	6
RANK	-0.000	0.004	0.003	-0.008	0.003	-0.000
	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
POST	0.044	0.030	0.053**	-0.009	0.053	0.036
	(0.034)	(0.026)	(0.026)	(0.046)	(0.034)	(0.034)
RANK×POST	0.002	0.003	0.001	0.004	-0.008*	-0.004
	(0.004)	(0.003)	(0.003)	(0.006)	(0.004)	(0.004)
OWNERSHIP_CONCENTRATION	0.016			-0.025		
	(0.040)			(0.042)		
RANK×	-0.003			0.005		
OWNERSHIP_CONCENTRATION	(0.006)			(0.006)		
POST×	-0.054			0.047		
OWNERSHIP_CONCENTRATION	(0.041)			(0.052)		
RANK×POST×	0.008			-0.008		
OWNERSHIP_CONCENTRATION	(0.006)			(0.008)		
LOW_CASH_SIZE		0.075*			0.046	
		(0.043)			(0.054)	
RANK×LOW_CASH_SIZE		-0.017***			-0.017**	
		(0.006)			(0.008)	
POST×LOW_CASH_SIZE		-0.041			-0.136**	
		(0.050)			(0.062)	
RANK×POST×LOW_CASH_SIZE		0.011			0.021**	
		(0.007)			(0.009)	
LOW_CASH_Δ_FIXED_ASSETS			0.094***			-0.013
			(0.033)			(0.040)
RANK×LOW_CASH_Δ_FIXED_ASSETS			-0.016***			-0.003
			(0.005)			(0.006)
POST×LOW_CASH_Δ_FIXED_ASSETS			-0.127***			-0.062
			(0.048)			(0.057)
RANK×POST×			0.022***			0.007
LOW_CASH_Δ_FIXED_ASSETS			(0.007)			(0.009)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES	YES	YES
N	7,315	7,498	7,434	4,492	4,162	4,157

Table 6. Downsizing Outcomes: Intra-EU ETS Sample

The table presents the regression results examining the relationship between corporate downsizing (*DOWNSIZER*) in the post-intervention period (*POST*) on emission changes and firm productivity for our sample of intra-EU ETS private firms (Models (1) and (2)) and listed firms (Models (3) and (4)). *ΔEMISSIONS* are the logarithmic change in emissions in year *t+1* relative to year *t*. *ΔTFP* is the difference in the total factor productivity of the firm in year *t+1* relative to year *t*. The total factor productivity is measured as the residual of a logarithmic transformed Cobb-Douglas function regressing the net sales on the firm's number of employees and the firm's property, plant, and equipment, for each two-digit sic industry segment (see Equation (6)). *DOWNSIZER* is an indicator variable equal to one if the firm downsized in year *t*, zero otherwise. The control variables are the same as those represented in Table 2, omitted for parsimony N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

	Private firms		**Listed firms**	
	1	2	3	4
VARIABLES	*ΔEMISSIONS*	*ΔTFP*	*ΔEMISSIONS*	*ΔTFP*
DOWNSIZER	0.005	-0.018	-0.002	-0.024
	(0.007)	(0.013)	(0.007)	(0.019)
POST	-0.009	-0.070	0.002	-0.078
	(0.008)	(0.015)	(0.007)	(0.021)
DOWNSIZER ×POST	-0.020*	0.085***	-0.004	0.090**
	(0.012)	(0.031)	(0.011)	(0.043)
FIRM CONTROLS	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES
N	7,748	6,433	4,531	3,819

Table 7. Robustness Tests

The table presents the regression results of alternative models examining the relationship between green pressure and downsizing. Panel A tests the relationship between being covered by the EU ETS (*EU_ETS*) in the post-intervention period (*POST*) and dependent variables reflecting the corporate downsizing decision (*DOWNSIZING*) for a set of matched listed firms (Models (1), (3), (5), (7), (9), and (11)) and private firms (Models (2), (4), (6), (8), (10), and (12)). Models (1) and (2) examine a random effects logit model, while Models (3) and (4) examine a fixed effects logit model. Models (5) through (10) use a linear probability model with country, industry and year fixed effects (Models (5) and (6)), country × year × industry fixed effects (Models (7) and (8)), and a balanced panel data sample (Models (9) and (10)). While Models (1) through (10) use the binary *DOWNSIZING* variable as dependent variable, Models (11) and (12) employ the natural logarithm of the number of employees (*EMPLOYEES*) as per Filatotchev et al. (2000). Panel B examines the relationship between emission intensity (*RANK*) in the post-intervention period (*POST*) and dependent variables reflecting the corporate downsizing decision for listed (Models (1), (3), (5), (7), (9), (11), and (13)) and private firms (Models (2), (4), (6), (8), (10), (12), and (14)). Models (1) through (10) test the same settings as Models (1) through (10) in Panel A. Models (11) and (12) fix the emission intensity levels of the firm to that in the year of the EC intervention (*RANK2017*). Models (13) and (14) employ the natural logarithm of the number of employees (*EMPLOYEES*) as per Filatotchev et al. (2000), in line with Models (11) and (12) of Panel A. The control variables are the same as those represented in Table 2, omitted for parsimony. N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: Matched sample

	Listed RE logit	Private RE logit	Listed FE logit	Private FE logit	Listed Country+industry+ year	Private Country+industry+ year
VARIABLES	1 *DOWNSIZING*	2 *DOWNSIZING*	3 *DOWNSIZING*	4 *DOWNSIZING*	5 *DOWNSIZING*	6 *DOWNSIZING*
EU_ETS	0.183	0.128			0.036***	0.022*
	(0.127)	(0.124)			(0.014)	(0.012)
POST	0.212**	0.008	0.090	0.138		
	(0.101)	(0.086)	(0.285)	(0.208)		
EU_ETS×POST	-0.028	0.285***	-0.046	0.506***	-0.004	0.025**
	(0.139)	(0.115)	(0.024)	(0.175)	(0.014)	(0.011)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
YEAR FE	NO	NO	NO	NO	YES	YES
FIRM FE	NO	NO	YES	YES	NO	NO
COUNTRY FE	NO	NO	NO	NO	YES	YES
INDUSTRY FE	NO	NO	NO	NO	YES	YES
N	8,520	13,822	2,482	4,066	8,520	13,822

	Listed Country×year ×industry	Private Country×year ×industry	Listed Balanced panel	Private Balanced panel	Listed	Private
VARIABLES	7 *DOWNSIZING*	8 *DOWNSIZING*	9 *DOWNSIZING*	10 *DOWNSIZING*	11 *EMPLOYEES*	12 *EMPLOYEES*
EU_ETS	0.051***	0.011				
	(0.016)	(0.012)				
POST			0.082**	0.021	-0.023**	-0.010
			(0.038)	(0.025)	(0.011)	(0.008)
EU_ETS×POST	-0.022	0.029***	-0.033	0.047**	-0.000	-0.019***
	(0.017)	(0.011)	(0.033)	(0.021)	(0.011)	(0.006)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES
YEAR FE	NO	NO	YES	NO	NO	NO
FIRM FE	NO	NO	YES	YES	YES	YES
COUNTRY FE	NO	NO	NO	NO	NO	NO
INDUSTRY FE	NO	NO	NO	NO	NO	NO
COUNTRY × YEAR × INDUSTRY FE	YES	YES	NO	NO	NO	NO
N	8,520	13,822	4,127	7,250	8,520	13,815

Table 7. Robustness Tests (Continued)

PANEL B: Intra-EU ETS sample

	Listed RE logit	Private RE logit	Listed FE logit	Private FE logit	Listed Country+ Industry+ Year	Private Country+ Industry+ Year	Listed Country×year ×industry
	1	2	3	4	5	6	7
VARIABLES	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*
RANK	0.012	-0.019	-0.072	-0.037	-0.005	-0.003	-0.003
	(0.035)	(0.022)	(0.059)	(0.053)	(0.003)	(0.002)	(0.006)
POST	0.003	-0.047	0.203	0.312			
	(0.217)	(0.177)	(0.301)	(0.241)			
RANK×POST	-0.018	0.045*	-0.016	0.068**	0.002	0.005*	-0.005
	(0.025)	(0.027)	(0.039)	(0.029)	(0.004)	(0.003)	(0.007)
FIRM CONTROLS	YES	YES	YES	YES	YES	YES	YES
YEAR FE	NO	NO	NO	NO	YES	YES	NO
FIRM FE	NO	NO	YES	YES	NO	NO	NO
COUNTRY FE	NO	NO	NO	NO	YES	YES	NO
INDUSTRY FE	NO	NO	NO	NO	YES	YES	NO
COUNTRY × YEAR × INDUSTRY FE	NO	NO	NO	NO	NO	NO	YES
N	4,535	7,773	2,332	3,683	4,535	7,773	4,535

	Private Country× Industry× Year	Listed Balanced panel	Private Balanced panel	Listed RANK2017	Private RANK2017	Listed	Private
	8	9	10	11	12	13	14
VARIABLES	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*DOWNSIZING*	*EMPLOYEES*	*EMPLOYEES*
RANK	-0.003	-0.004	0.001			0.002	-0.002
	(0.003)	(0.007)	(0.007)			(0.003)	(0.003)
POST		0.028	0.033	0.004	0.015	-0.036	-0.003
		(0.036)	(0.029)	(0.030)	(0.024)	(0.014)	(0.012)
RANK×POST	0.010**	0.002	0.007**			0.001	-0.004**
	(0.004)	(0.005)	(0.035)			(0.002)	(0.002)
RANK2017				0.033	0.001		
				(0.046)	(0.061)		
RANK2017×POST				0.001	0.008***		
				(0.004)	(0.003)		
FIRM CONTROLS	YES	YES	YES	YES	YES	YES	YES
YEAR FE	NO	NO	NO	NO	YES	NO	NO
FIRM FE	NO	YES	YES	YES	YES	YES	YES
COUNTRY × YEAR × INDUSTRY FE	YES	NO	NO	NO	NO	NO	NO
N	7,773	2,884	4,802	4,535	7,773	4,535	7,773

Table 8. Alternative Responses From Listed Firms

The table presents the regression results examining the relationship between emission intensity (*RANK*) in the post-intervention period (*POST*) and alternative potential responses from the EU ETS-covered listed firms. Panel A reports the results for the full sample of listed firms. Model (1) uses the R&D expenditures divided by the sales as a dependent variable (*R&D*). Model (2) uses the dividend yield, measured as the size of the dividend divided by the share price (*DIVIDEND*). Model (3) takes the natural logarithm of the total long-term debt of the company (*DEBT*), while Model (4) examines the natural logarithm of the number of shares of the firm (*NUMBER_OF_SHARES*). Panel B interacts our variable of interest with an indicator variable taking the value of one if the firm has a lower than median cash level and a lower than median firm size, zero otherwise (*LOW_CASH_SIZE*). The control variables are the same as those represented in Table 2, omitted for parsimony. N represents the number of firm-year observations. *, ** and *** represent significance at the 10%, 5% and 1% level respectively. Variables are defined in the appendix, Table A1.

PANEL A: All listed firms

	1	2	3	4
VARIABLES	*R&D*	*DIVIDEND*	*DEBT*	*NUMBER OF SHARES*
RANK	-0.001	0.023	-0.013	-0.001
	(0.008)	(0.017)	(0.008)	(0.003)
POST	0.056	0.438	0.146	0.014
	(0.036)	(0.095)	(0.035)	(0.016)
RANK×POST	-0.009	-0.007	0.006	0.002
	(0.006)	(0.015)	(0.006)	(0.002)
FIRM CONTROLS	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES
N	2,784	4,128	4,066	4,134

PANEL B: Moderating role of lower than median cash and lower than median size

	1	2	3	4
VARIABLES	*R&D*	*DIVIDEND*	*DEBT*	*NUMBER OF SHARES*
RANK	-0.002	0.011	0.002	0.007
	(0.009)	(0.025)	(0.009)	(0.004)
POST	0.088	0.077	-0.026	-0.002
	(0.046)	(0.140)	(0.049)	(0.003)
RANK×POST	-0.015	-0.008	0.005	0.001
	(0.007)	(0.019)	(0.006)	(0.003)
LOW_CASH_SIZE	-0.029	-0.048	-0.124	-0.056
	(0.081)	(0.022)	(0.079)	(0.035)
RANK× LOW_CASH_SIZE	0.001	0.015	0.011	0.005
	(0.013)	(0.034)	(0.012)	(0.005)
POST× LOW_CASH_SIZE	-0.025	-0.016	-0.053	0.002
	(0.097)	(0.026)	(0.091)	(0.040)
RANK×POST× LOW_CASH_SIZE	0.011	-0.011	-0.005	-0.002
	(0.015)	(0.040)	(0.015)	(0.006)
FIRM CONTROLS	YES	YES	YES	YES
FIRM FE	YES	YES	YES	YES
N	2,514	3,777	3,713	3,783

Figure 1. Dynamic Models: Matched Sample

Figure 1 represents the results of a dynamic model for the sample of EU ETS matched firms with yearly coefficients loading on the interaction of the decile rank of emission intensity (*RANK*) and year dummies reflecting three years prior (2014) until two years after the EC's intervention (2019). This analysis is performed relative to the baseline year 2013 as per Nguyen and Phan (2020). Figure 1a presents the results of the full sample of matched firms, Figure 1b presents the results for the matched listed firms and Figure 1c presents the results for the matched private firms. The underlying results of Figure 1c are reported in Model (5) of Panel A in Table 2.

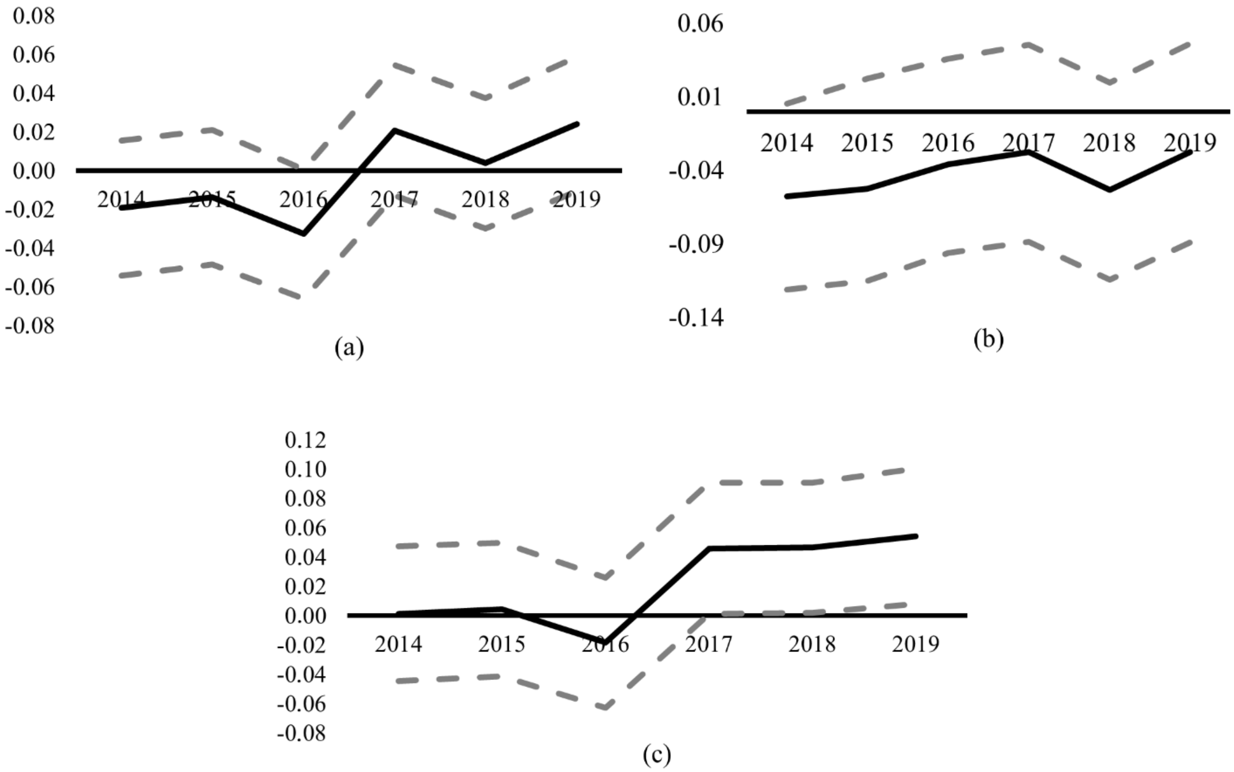


Figure 2. Dynamic Models: Intra-EU ETS

Figure 2 represents the results of a dynamic model of the intra-EU ETS sample with yearly coefficients loading on the interaction of the decile rank of emission intensity (*RANK*) and year dummies reflecting three years prior (2014) until two years after the EC's intervention (2019). This analysis is performed relative to the baseline year 2013 as per Nguyen and Phan (2020). Figure 2a presents the results of the total sample of EU ETS-covered firms, Figure 2b the results for the subset of EU ETS-covered listed sample, and Figure 2c the results for the EU ETS-covered private sample. The underlying results of Figure 2c are reported in Model (6) of Panel B of Table 2.

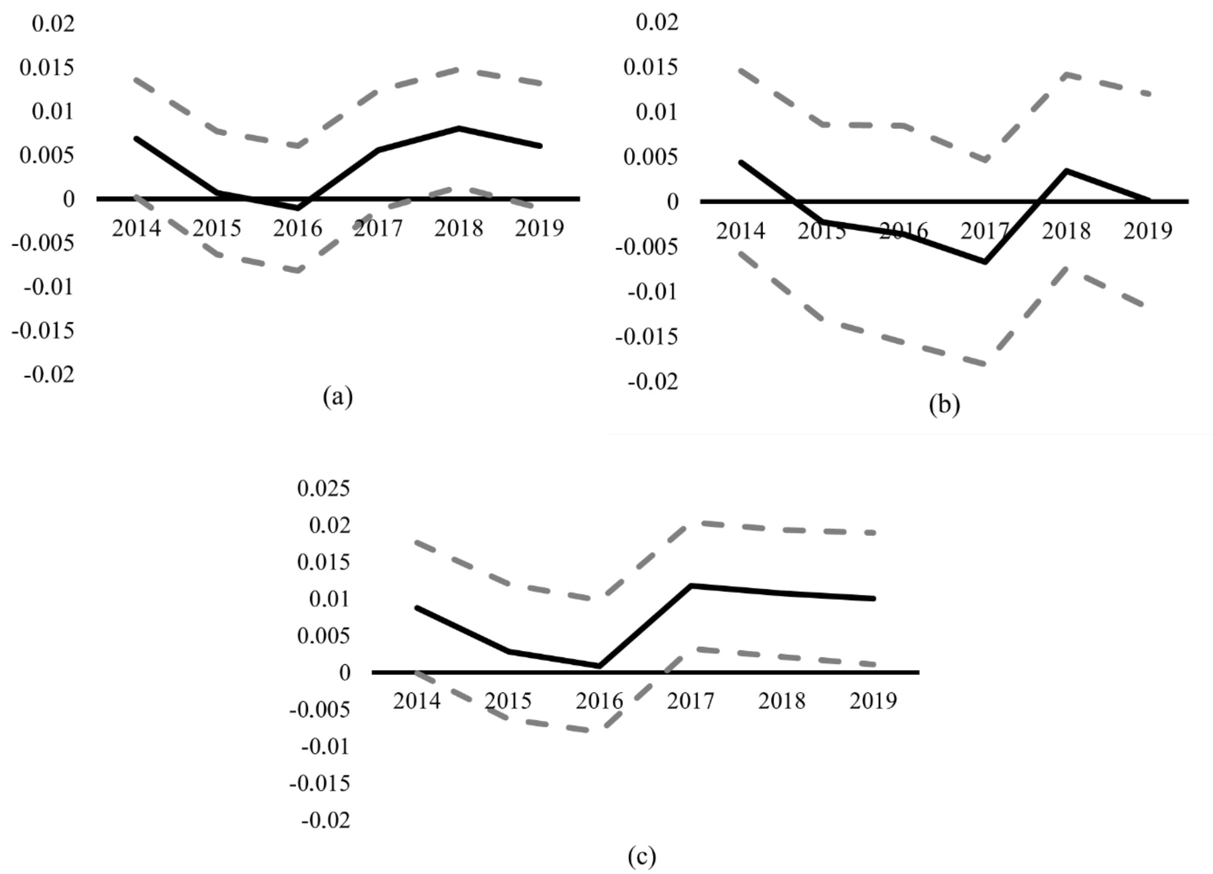
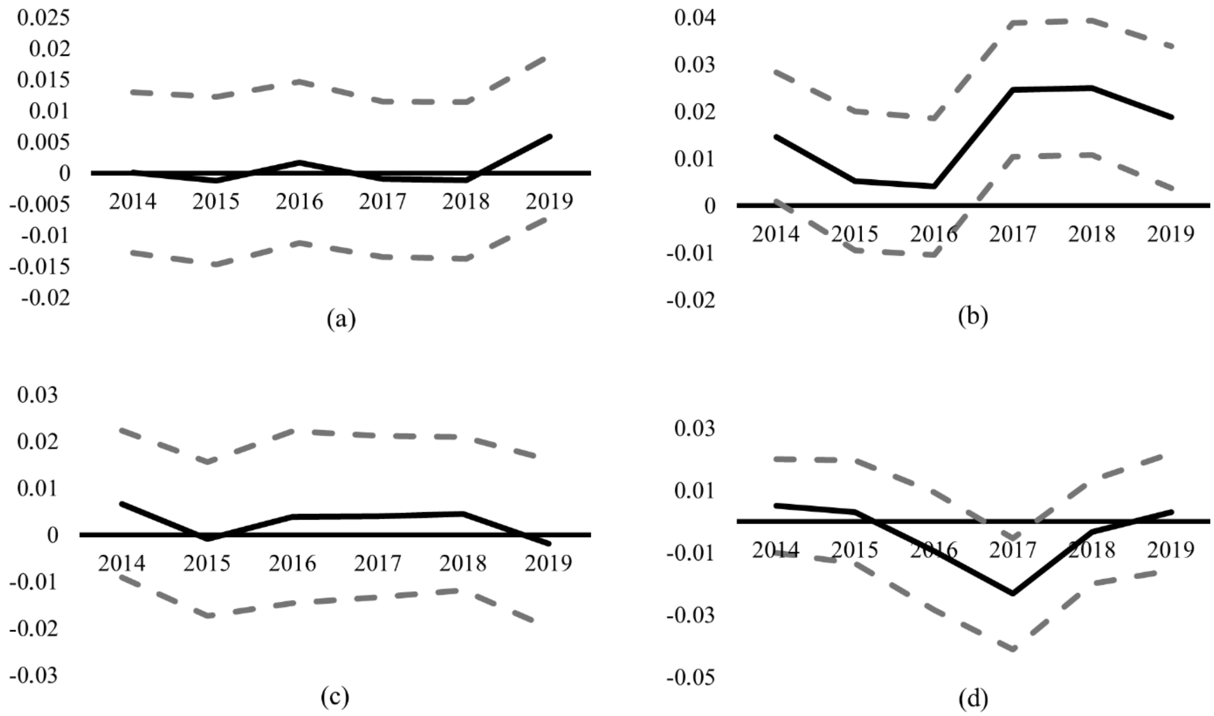


Figure 3: Dynamic Model for Intra-EU ETS Private (top) and Listed (bottom) Unconstrained (left) vs. Cash Constrained (right) Firms.

Figure 3 represents the results of a dynamic model of the intra-EU-ETS sample partitioned on their financial constraints with yearly coefficients loading on the interaction of the decile rank of emission intensity (*RANK*) and year dummies reflecting three years prior (2014) until two years after the EC's intervention (2019). This analysis is performed relative to the baseline year 2013 as per Nguyen and Phan (2020). Figure 3a (3c) presents the results for unconstrained EU ETS-covered private (listed) firms and Figure 3b (3d) presents the results for cash constrained private (listed) firms.



APPENDIX

Appendix A1. Variable Definitions

Variable	Definition	Source
DOWNSIZING	Indicator variable equal to one if the firm's number of employees has reduced by at least 5% in the year *t+1* relative to year *t*.	Orbis Global
POST	Indicator variable equal to one from 2017 onwards.	/
EU_ETS	Indicator variable equal to one if the firm is subject to the EU ETS, zero otherwise.	EUTL
RANK	A decile ranked industry-corrected (at the four-digit NACE codes) verified emissions over sales.	EUTL
ETC	The difference between the allocated emission allowances and the verified emissions made by the firm, scaled by the verified emissions.	EUTL
LTD	The long-term debt scaled by total assets.	Orbis Global
GROWTH	The total sales of the firm scaled by the total sales of the previous year.	Orbis Global
SIZE	The natural logarithm of the total assets.	Orbis Global
ROA	The return on assets, calculated as the net income divided by the total assets.	Orbis Global
COST_OF_EMPLOYMENT	The total employment cost scaled by the total revenue.	Orbis Global
ASSETS_PER_EMPLOYEE	The natural logarithm of the total assets scaled by the number of employees.	Orbis Global
CURRENT_RATIO	The current assets scaled by current liabilities.	Orbis Global
AGE	The difference between the current year and the incorporation year.	Orbis Global
INSTALLATIONS	The number of EU ETS-covered installations owned by the firm.	EUTL
TANGIBILITY	The fixed assets scaled by total assets.	Orbis Global
NUTS_UNEMPLOYMENT	Indicator variable equal to one if the firm is headquartered in a location with a higher than median percentage of unemployment at the NUTS2-level, zero otherwise.	Eurostat
BARGAINING	Indicator variable equal to one if the number of employees covered by a collective bargaining agreement as a proportion to the total workforce size is higher than the sample median, zero otherwise.	OECD Trade Union Dataset
RULE_OF_LAW	Indicator variable equal to one if the rule of law index is higher than the sample median, zero otherwise.	Worldwide Governance Indicators
LEAKAGE	Indicator variable equal to one if the firm is considered at risk of leaving the EU based on the carbon leakage classification at the 4-digit NACE level.	European Commission
CASH	Indicator variable equal to one if the total cash scaled by total assets is higher than the sample median, zero otherwise.	Orbis Global
HHI	Indicator variable equal to one if the within-industry Herfindahl-Hirschman Index is higher than the sample median, zero otherwise.	Orbis Global
VALUE_ADDED	Indicator variable equal to one if the firm's industry-adjusted natural logarithm of value added per employee is higher than the sample median, zero otherwise.	Orbis Global

OWNERSHIP_ CONCENTRATION	Indicator variable equal to one if the ownership concentration of all outside shareholders (measured as the Herfindahl Hirschman Index of all outside shareholders) is higher than the sample median, zero otherwise.	Orbis Global
LOW_CASH_SIZE	Indicator variable equal to one if the firm has a lower than median cash level and a lower than median firm size, zero otherwise.	Orbis Global
LOW_CASH_Δ_FIXED_ASSETS	Indicator variable equal to one if the firm has a lower than median cash level and if the percentage change in industry-adjusted fixed assets between the downsizing year and the previous one is smaller than the sample median, zero otherwise.	Orbis Global
ΔEMISSIONS	The logarithmic change in emissions between year *t+1* and to year *t*.	EUTL
ΔTFP	The change in the total factor productivity between year *t+1* and to year *t*. Total factor productivity is measured as the error term of a logarithmic transformation of a Cobb-Douglas function that assumes that the net sales (*NET_SALES*) are generated by the number of employees (*NUMBER_OF_EMPLOYEES*) and the firm's property, plant, and equipment (*PPE*) as follows: $NET\_SALES_{it} = A \times NUMBER\_OF\_EMPLOYEES_{it}^{\beta} \times PPE_{it}^{\gamma}$, estimated at the two-digit SIC industry level.	Orbis Global
DOWNSIZER	Indicator variable equal to one if the firm downsized in year *t*, zero otherwise.	Orbis Global
RANK2017	The decile-ranked industry-corrected (at the four-digit NACE codes) verified emissions over sales measured in 2017 (the year of the EC intervention).	EU ETL
EMPLOYEES	Natural logarithm of the number of employees.	Orbis Global
R&D	Total R&D expenditures, divided by the firms' sales.	Orbis Global
DIVIDEND	The dividend yield, measured as the size of the dividend divided by the share price.	Orbis Global
DEBT	The natural logarithm of the total long-term debt of the company.	Orbis Global
NUMBER_OF_SHARES	The natural logarithm of the number of shares of the firm.	Orbis Global

Appendix A2. EUA Futures Price

The figure presents the EUA futures price from the ICE ECX platform. The sample period of this paper (phase III) is indicated by a white background.