WORKING paper

BANQUE DE FRANCE

EUROSYSTÈME

Leverage and the Low-Carbon Transition in Europe

Margherita Giuzio[1], Sujit Kapadia[1], Dilyara Salakhova[2] and Katia Vozian[3]

September 2025, WP #1011

ABSTRACT

Using data on verified carbon emissions from the EU emissions trading system, this paper examines the relationship between leverage and transition performance for highly polluting and mostly non-listed ETS firms over 2013-2019 that are responsible for approximately 20% of total EU emissions. Panel regression analysis indicates that, up to a certain point, firms with higher leverage have lower emissions and improved emission efficiency in subsequent years. But beyond that point, greater leverage is associated with worse transition performance. Exploiting a 2015 policy shock aiming at toughening the emissions regime in a difference-in-differences setup, we also identify a group of firms that appear too indebted to transition towards low-carbon technology.

Keywords: Low-Carbon Transition; Climate Change; Debt Finance; Leverage; Green Investment; EU ETS

JEL classification: C58, E58, G32, Q51, Q56, Q58

[1] European Central Bank; margherita.giuzio@ecb.europa.eu; sujit.kapadia@ecb.europa.eu

[2] Banque de France, IESEG School of Management, dilyara.salakhova@banque-france.fr

[3] Leibniz Institute for Financial Research SAFE, vozian@safe-frankfurt.de

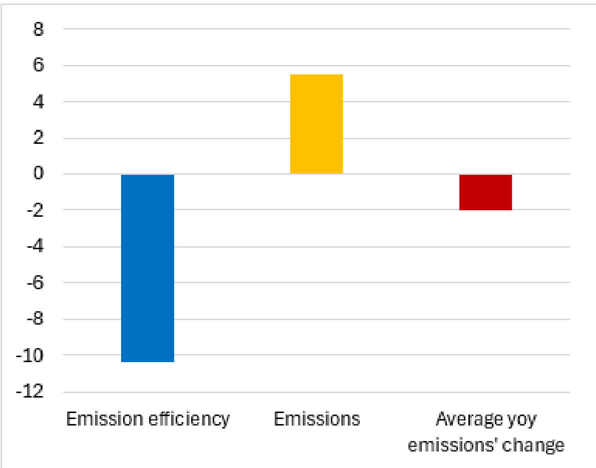
We would like to express tremendous thanks to Olimpia Carradori for outstanding research assistance. We are also grateful to Winta Beyene, Calogero Brancatelli, Martin Brown, Laura Capota, Juliette Desloires, Elias Einiö, Matteo Falagiarda (discussant), Serena Fatica, Emilia Garcia, Sofia Gori, Daniel Kapp, Gustav Martinsson, Jean-Stéphane Mésonnier, Benjamin Mosk, Steven Ongena, Melina Papoutsi, Loriana Pelizzon, Allegra Pietsch, Alexander Popov, Maria Alsina Pujols, Mar Reguant, Glenn Schepens, Luca Taschini, Danilo Vassallo, Ivo Vehviläien, Christian Weistroffer and Soh Young In for their helpful comments, as well as conference and seminar participants at the European Central Bank, the Helsinki Graduate School of Economics, the Helsinki Graduate School of Finance, the Leibniz Institute for Financial Research SAFE, the School of Finance of the University of St. Gallen, the Stanford Precourt Institute for Energy, the 2022 RiskLab/BoF/ESRB Conference on Systemic Risk Analytics, the International Journal of Central Banking (IJCB) 2022 Conference, the 2022 GRASFI Conference, the 2022 Annual Research Conference of the European Commission, the 2022 Annual Research Workshop of the European Banking Authority, the 2023 Energy Finance Italia Conference, the 2023 Young Swiss Economist Meeting, the CEPR Paris Symposium 2024, the 2024 CEBRA Annual Meeting, the Brunel-KCL Conference on Social and Sustainable Finance: Bridging Methods, Policy and Practice, and the 2025 CEPR Climate Change and the Environment Symposium.

NON-TECHNICAL SUMMARY

With the Fit for 55 plan and the European Green Deal, the European Commission set the goal to reduce greenhouse gas emissions by 55% by 2030 and to reach carbon neutrality by 2050. To direct European firms toward the path of the low-carbon transition, the EU introduced in 2005 an economic mechanism of carbon pricing based on an emissions trading system. This system imposes a cap on emissions of fossil-fuel-intensive businesses in Europe, in particular covering firms that are active in industries such as aviation, electricity supply, and manufacturing of chemicals and metals. The system encourages emissions reduction by decreasing the cap every year and by putting a price on tradable emissions. Firms subject to such a cap-and-trade mechanism need adequate financing to adopt clean technologies and reduce their emissions without constraining their economic activity. The EU's 2019 Green Deal acknowledges that financing is central to achieving emission reduction. In particular, European firms subject to a cap on their emissions are mostly non-listed and heavily reliant on debt financing. Therefore, the development of debt markets and the understanding of the debt-emissions nexus is crucial to efficiently reaching carbon neutrality.

We rely on evidence from a sample of approximately 2400 firms subject to the EU emissions trading system (EU ETS) that are responsible for more than 20% of the total EU greenhouse gas emissions to study how European firms' debt finance relates to changes in emissions. Our findings indicate an inverted U-shape relationship between the level of firm leverage and its transition performance. Firms with leverage ratios (debt/assets) above 40% are associated with higher emissions and worse emission efficiency. Specifically, we find that a one standard-deviation increase in leverage – a 21 percentage point rise – from this threshold leads to a 10% decline in emission efficiency (blue bar) and a 5.5% increase in absolute emissions (yellow bar). These economically meaningful effects, particularly when compared to the average annual reduction of 2% in the emissions cap imposed by the EU ETS (red bar), indicate that capital structure constraints can significantly hinder firms' transition efforts. The findings are consistent with theoretical models showing that high indebtedness constraints firms' capacity to undertake profitable – and in our case green – investment opportunities.

Figure 1. Estimated impact of an increase in leverage on transition performance



Note: The bars show the estimated percentage change in transition performance (emissions efficiency and absolute emissions) resulting from a one standard-deviation increase in leverage after the turning point in the U-shape curve. These effects are shown in comparison to the annual average reduction in the EU ETS emissions cap (in red).

In particular, we investigate firms' reaction to a quasi-exogenous regulatory shock that imposed a more stringent cap on emissions. We find that highly indebted firms did not reduce their emissions even when exposed to this growing constraint on their emissions, while other firms successfully did so. The study sheds light on the existence of a group of European firms that are too indebted for transition. While the higher future cost of emissions upon the formal adoption of the reform would have strongly incentivised all firms to invest in low-carbon technology, possibly by taking on more debt, highly leveraged firms suffering from debt overhang may have found it difficult or costly to access the necessary additional finance.

Our findings highlight significant policy implications for enabling firms under the EU Emissions Trading System (EU ETS) to transition to low-carbon operations while maintaining economic viability. They confirm that debt financing is a viable mechanism to support this transition. However, the EU ETS may fall short of its potential in reducing emissions from highly leveraged firms.

For highly indebted firms with limited growth prospects, market exit in favor of more emission-efficient competitors may be inevitable. In contrast, highly indebted firms with strong growth potential could benefit from tailored transition finance solutions to reduce emissions more effectively. This underscores the importance of expanding green bond and green loan markets through measures such as enhanced transparency, international standards, or tax incentives limited to green debt.

Investor demand for green debt is robust and growing. Green debt instruments may allow highly leveraged firms to secure funding at reasonable premiums, provided they commit to investing the proceeds in low-carbon technologies and demonstrate measurable environmental benefits. Lenders may view such financing as a means to enhance firms' medium-term profitability and resilience, even if these firms face challenges in obtaining general financing.

Effet de levier et transition vers une économie à faible émission de carbone en Europe

RÉSUMÉ

En utilisant des données sur les émissions de carbone vérifiées provenant du système d'échange de quotas d'émission de l'UE, cet article examine la relation entre l'effet de levier et la performance de transition pour les entreprises ETS fortement polluantes et majoritairement non cotées en bourse, sur la période 2013-2019, qui sont responsables d'environ 20 % des émissions totales de l'UE. L'analyse de régression en panel indique que, jusqu'à un certain point, les entreprises avec un effet de levier plus élevé ont des émissions plus faibles et une efficacité d'émission améliorée dans les années suivantes. Mais au-delà de ce point, un effet de levier plus important est associé à une moins bonne performance de transition. En exploitant un choc politique de 2015 visant à durcir le régime des émissions dans un cadre de différence-en-différences, nous identifions également un groupe d'entreprises qui semblent trop endettées pour passer à des technologies à faible émission de carbone.

Mots-clés : transition à faible émission de carbone ; changement climatique ; financement par la dette ; effet de levier ; investissement vert ; EU ETS

---

1 Introduction

Drastic reductions in greenhouse gas emissions are essential for mitigating climate change (IPCC, 2021). Firms generally do not internalize the social cost related to the carbon emissions that they generate (Nordhaus, 1991; Common and Stagl, 2005; Perman, Ma, Common, Maddison, and McGilvray, 2011; Nordhaus, 2017). Correcting for this negative externality can be achieved through carbon pricing mechanisms like carbon taxes or cap-and-trade policies such as the EU's emissions trading system (EU ETS).

Faced with such policies, firms are incentivised to direct their corporate investments toward the adoption of greener technologies. This requires adequate financing opportunities; indeed, the European Union's 2019 Green Deal acknowledges that financing is central to achieving emission reduction. This is also confirmed by evidence highlighting the important role of equity financing and stock markets in allocating capital to support the low-carbon transition (De Haas and Popov, 2023). But the vast majority of European firms are not listed on the stock market and debt finance – especially in the form of bank lending – is their primary source of external financing (ECB, 2022). While debt finance may be relatively less well suited for highly risky investments into potential new green technologies (De Haas and Popov, 2023; Philippe, Boneva, Breckenfelder, Laeven, Olovsson, Popov, and Rancoita, 2022), it is still vital in enabling companies to adopt low-carbon technologies that already exist (Polzin and Sanders, 2020). As such, taking on leverage can support green investment and the low carbon transition of European firms. At the same time, when a firm is already highly indebted, it may find it difficult or costly to raise the finance needed to support significant green investment, consistent with debt overhang literature (Myers, 1977; Kalemli-Özcan, Laeven, and Moreno, 2022).

This suggests that there could be an inverted U-shape relationship between the level of transition performance of a firm and its leverage.

In this paper, we use firm-level data over the period from 2013 to 2019 for companies subject to the EU Emissions Trading System (ETS) to examine how European firms' debt finance relates to changes in their emissions. We find that leverage – as measured by the debt-to-assets ratio – is indeed a double-edged sword. Results from our panel regressions indicate that up to a leverage ratio of around 40%, firms in our sample with higher leverage have both lower emissions and higher emission efficiency (i.e. revenues per unit of emission) in subsequent years. But beyond that point, higher leverage is associated with worse transition performance. We also use a difference-in-differences setup which mitigates possible endogeneity concerns to ascribe some causality to the role of high leverage in impeding firms' efforts to reduce their emissions. For this analysis, we exploit a policy shock - the legal adoption of the Market Stability Reserve (MSR) of the EU ETS in 2015 - that imposed a more stringent cap on emissions and later acted as an exogenous shock to carbon prices. In particular, we identify a group of firms that appear too indebted to transition towards low-carbon technology, even if anticipating a steep increase in the cost of their emissions. Finally, we assess whether our results may be driven by carbon leakage, whereby firms could invest to relocate emissions outside the scope of the EU ETS, but find limited evidence to support this possibility. Overall, our results highlight the possible role of debt finance in facilitating firms to lower their carbon emissions but demonstrate that debt overhang in the form of high leverage can be an impediment to firms' ability to transition towards lower carbon technology even if they are subject to a costly constraint on their emissions.

More specifically, we first construct a novel dataset covering yearly verified emissions of approximately 2400 non-financial firms – comprised mostly of non-listed firms and including a large share of small and medium enterprises (SMEs) – subject to the EU ETS. The EU ETS regulates emissions produced by most fossil-fuel-intensive economic activities in the European Economic Area. Its main goal is to reduce the aggregate level of emissions via a cap-and-trade policy, while its longer-term goal is to foster innovation and the adoption of clean technologies (Martin, Muûls, and Wagner, 2020). For this purpose, each installation subject to the EU ETS is allocated yearly a limited amount of allowances (EUAs) to emit a given amount of greenhouse gases for free. For instance, during Phase 3 of the EU ETS (2013–2020), the allocation of free allowances followed a sector-specific schedule designed to balance emissions reduction incentives with concerns over competitiveness. Sectors deemed at risk of carbon leakage (based on trade intensity and emissions exposure) were allocated 100% of their benchmarked allowances for free. In contrast, sectors not on the carbon leakage list started with 80% free allocation in 2013, with the share declining linearly to 30% by 2020. The power sector, in principle, received 0% free allowances, although transitional exemptions were granted to certain member states, such as Poland. If an installation's yearly emissions exceed its total amount of free EUAs, it has to purchase additional EUAs to cover its excess emissions or otherwise faces a penalty. Conversely, operators with a surplus of EUAs may store them for future years or trade them in a system of auctions with those with a deficit of EUAs.[1]

The emissions of each installation subject to the EU ETS are verified by a third party; hence they are more reliable than the self-reported or estimated emissions used in much of

[1]For a history of the EU ETS and further detail on its functioning concerning emissions, allowance prices, the use of offsets, and its overall performance for reducing emissions, see Ellerman, Marcantonini, and Zaklan (2020).

the green finance literature. These emissions data are published annually on the website of the European Union Transaction Log (EUTL). We identify the firm corresponding to each operator that owns installations within the EUTL and we aggregate the verified ETS emissions at the firm level. The emission data collected therefore only refers to firms that can be attributed as being subject to the cap-and-trade climate policy instrument. The final dataset represents more than 20% of total EU GHG emissions.[2]

We also collect firm-specific financial characteristics, such as leverage, revenues, profitability and age. Only a very limited number of firms in the sample relied on green debt between 2013 and 2019, suggesting that debt financing of ETS active firms has been driven so far foremost by means of traditional debt instruments. In addition, market-based debt (bonds, commercial paper, etc.) represents only a small fraction - on average 11% - of total debt for firms across countries and years in our sample (see Figure 10). We additionally collect firm-specific environmental factors, such as cumulative EUA balances which may either be in surplus or deficit. Because both leverage and the free-allowance schedule may vary by sector (e.g. heavy industry vs. power vs. chemicals) but also by country, we include sector–country–year fixed effects throughout our regressions, isolating our estimates on within-group firm variation.

We then test whether there is a a non-linear relationship between debt finance and transition performance, assessing the latter in terms of both absolute emissions and emission efficiency (i.e. revenues relative to emissions). We use both a panel regression over

[2]See Section 3 for a detailed description of the ETS emissions data. ETS emissions relate to the Scope 1 emissions of the firm. To date, there are no EU-wide mandatory reporting requirements in place for firms to report both their ETS and Scope 1 emissions. Under the EU CSRD, firms shall be required to report the share of ETS emissions in Scope 1 emissions. Methodological variations in the computation of Scope 1 and ETS emissions of a firm make these two metrics difficult to compare (e.g. different sets of greenhouse gases, use of different organizational-boundary-setting methodologies, and equity-based approach or control approach — operational control or financial control — in carbon accounting).

the period 2013 to 2019 and a difference-in-differences approach which provides stronger identification of the impact of high leverage on transition performance. The period of examination ends prior to the onset of the Covid-19 pandemic which distorted both firms' emissions and their leverage.

Results from the panel regressions indicate an inverted U-shape relationship between the level of firm leverage and its transition performance. Higher leverage ratios beyond about 40% start to be associated with higher emissions and worse emission efficiency. Specifically, we find that a one standard-deviation increase in leverage (i.e., a 21 percentage point rise) from this threshold leads to a 10% decline in emission efficiency and a 5.5% increase in absolute emissions. These are economically meaningful effects, indicating that capital structure constraints can significantly hinder firms' transition efforts.

To confront endogeneity concerns, we then apply a difference-in-differences setup which exploits the formal adoption of the MSR in 2015.[3] This quasi-exogenous regulatory shock imposed a more stringent cap on emissions. Although it only came into force in 2019, soon after a reform that further strengthened the MSR and set the ground for phase 4 of EU ETS, and although emission allowance prices only started to increase sharply from late 2017 onwards, there are several reasons why 2015 is likely to be the appropriate year for the policy shock in the difference-in-differences analysis. First, it represents the moment when firms began adjusting their behaviour in response to the MSR mechanism since they typically make capital investment or operational decisions in response to policy

[3]The introduction of the Market Stability Reserve followed a process spanning five years. In 2014, the European Commission proposed the MSR to address the surplus of allowances. In 2015, the European Parliament and Council adopted the MSR decision. In 2017, the Commission published the calculation of the total number of allowances in circulation on an annual basis that served as the indicator for determining whether allowances were to be placed in or released from the MSR. In 2018, the MSR was established and further strengthened (e.g., doubling its intake rate from 2019-2023). Finally, in 2019, the MSR became operational, starting to remove surplus allowances from the market. See also Decision (EU) 2015/1814, followed by the Directive (EU) 2018/410.

certainty rather than policy implementation. Delaying the shock year would overlook the adaptation of firms in anticipation of the future regulatory landscape. Second, choosing 2015 avoids contamination from later events of the second wave of policy reforms in 2018. Finally, although emission allowances can be carried over into future years, the policy shock did not translate into a price increase until 2018, giving firms time to adapt without extra costs. The main reason for an immediate price increase in anticipation of future tightening would be if firms decided to stock "cheap" emission allowances for future years. However, this asset brings no return and has no convenience yield. In addition, the policy change was permanent, implying that firms would not be able to accumulate an infinite number of allowances for all future payments. Given the less stringent emission caps during 2015-2018, firms with the financial capacity and technological capability to do so were therefore likely to have undertaken green investments to reduce emissions (or undertaken other profitable investment opportunities) rather than accumulating excess emission allowances with zero return and no convenience yield only in anticipation of a possible future price increase.

While the higher future cost of emissions upon the formal adoption of the MSR would have strongly incentivised all firms to invest in low-carbon technology, possibly by taking on more debt, highly leveraged firms suffering from debt overhang may have found it difficult or costly to access the necessary additional finance. Therefore, our difference-in-differences setup compares the transition performance of highly leveraged firms exposed to the future price increase against less leveraged firms facing the same price increase. We find that the former group saw worse transition performance subsequently than other firms, whether measured in terms of emissions or emission efficiency. As sectoral capital intensity and financing needs differ, we rerun our DiD for electricity firms, highly polluting manufacturers, and all other sectors, finding similar treatment effects across each, indicating no single industry drives our results. In various robustness exercises, we also find that this result is robust to different ways of partitioning firms by leverage, the use of matching estimators, alternative measures of indebtedness, and sub-samples with different characteristics (e.g. the sub-samples of SMEs or large firms and the sub-sample of firms with privately held equity). Overall, these findings suggest that high leverage does hamper firms' efforts to cut their carbon emissions in a causal manner, shedding light on a group of firms that are too indebted to transition, despite being subject to a constraint on their emissions and even when such constraints become more binding.

While our results are consistent with the narrative that firms invest in the adoption of green technologies to reduce their emissions, they may also align with the narrative that carbon pricing encourages firms to invest to relocate emissions outside the EU ETS – often referred to as carbon leakage. To assess this, we exploit a list of firms identified by the European Commission deemed to be at risk of carbon leakage. We find that our main results continue to hold in the sub-sample of firms not deemed to be at risk of carbon leakage as of the beginning of the sample. This suggests that our results are unlikely to be driven by carbon leakage rather than by the adoption of low-carbon technologies. While this does not rule out that some firms in our sample may shift their polluting activity outside the EU ETS, also the existing literature mitigates such concerns as it provides limited evidence of the materialization of carbon leakage risks in the EU ETS.

Our findings have important policy implications. They highlight that the EU ETS may not be effective as it could be in helping to reduce the emissions of highly leveraged firms. While highly indebted firms with low growth prospects may have to leave the market to more emission-efficient firms, highly indebted firms with high growth prospects could benefit from suitable transition finance solutions to enable them to reduce emissions. This points to the potential value of deepening green bond and green loan markets, for example through greater transparency and international standards, or by making the tax advantages of debt financing only applicable to green debt. Investor appetite for green debt is strong and growing, which gives more highly-leveraged companies the chance to borrow at reasonable premiums for their green investments. Green debt instruments may also allow firms with high leverage to still access finance conditional on committing to use the proceeds to invest in low-carbon technology and measuring the positive real-world outcome of these investments, even if they may struggle to increase borrowing more generally. This is because lenders may be more confident that this type of finance will increase the profitability and resilience of the companies over the medium term.

This paper relates to three strands of the literature: (i) the role of (green) finance and financing opportunities in supporting the investment necessary for the low-carbon transition; (ii) the role of firm-level over-indebtedness and financial constraints in hampering (green) investment; and (iii) the EU ETS and other factors as determinants of firms' emissions reduction.

Firstly, finance is vital to support all types of investment and essential to transition to a low-carbon economy (ESA, 2024). As such, raising equity and/or taking on more leverage via borrowing is necessary to support the green investment needed to lower carbon emissions (Polzin and Sanders, 2020). Consistent with this, De Haas and Popov (2023) find that at the country-level, equity finance is important in helping to reduce carbon emissions. The literature on debt financing to support the low-carbon transition has primarily focused so far on the role of green bonds.[4] The firm-level evidence on green bonds' role in reducing emissions is inconclusive, with Flammer (2021), Fatica and Panzica (2021) and Demski, Dong, McGuire, and Mojon (2025) finding that firms that issue green bonds subsequently reduce their greenhouse gas emissions, while Ehlers, Mojon, and Packer (2020) find that this is not the case. Empirical research on green loans is scarce (see e.g., Gilchrist, Yu, and Zhong (2021) for a literature review), partly due to minimal data on green loans.

Secondly, there are theoretical reasons and strong empirical evidence which suggest that high levels of leverage may constrain firm investment (Myers, 1977; Lang, Ofek, and Stulz, 1996; Hennessy, 2004; Kalemli-Özcan, Laeven, and Moreno, 2022). More specifically, financing constraints can act as a barrier to (green) investment. For example, De Haas, Martin, Muûls, and Schweiger (2024) find that credit constraints may affect a firm's green investment decisions while Howell (2017) shows that relief of financial constraints is associated with more patents, especially for firms in industries related to clean energy and clean production. Kaldorf and Shi (2024) show that firms with tighter credit constraints exhibit a relatively smaller emission reduction after a carbon tax increase. A growing literature further documents that financial constraints lead to more pollution (Xu and Kim, 2022; Sfrappini, 2024; Fang, Hsu, and Tsou, 2024; Bellon and Boualam, 2024; Iovino, Martin, and Sauvagnat, 2024). Interestingly Sfrappini (2024) argues that financially-constrained firms tend to favour more profitable dirtier projects. However, if funding access is linked to environmental performance, then firms tend to shift to cleaner projects to relax financial constraints. In related work on Swedish manufacturing, Martinsson,

[4] There is also a broad literature examining whether firms' greenness is priced by banks and capital markets, but this generally does not speak to how finance helps firms to reduce carbon emissions (see, for example, Beyene, De Greiff, Delis, and Ongena (2021); Kacperczyk and Peydró (2021); Degryse, Goncharenko, Theunisz, and Vadasz (2021)).

Sajtos, Strömberg, and Thomann (2024) exploit a high national carbon tax (introduced in 1991 with subsequent rate changes, exemptions, and the late-sample adoption of the EU ETS) to show that a 1% rise in the marginal CO2 tax rate reduces firms' sales-weighted emissions by about 2% over three years, an effect concentrated among firms with low abatement costs and much weaker for financially constrained, high-abatement-cost firms.

The third stream of literature assesses empirically the role of the EU ETS for regulated firms' low-carbon transition. Although distinguishing the effects of the EU ETS on emissions reduction from other factors is not trivial, particularly in the light of concomitant use of other climate policy instruments (e.g. feed-in tariffs, renewable energy obligations), there is robust evidence that the EU ETS had a negative effect on emissions (Ellerman and McGuinness, 2008; Anderson and Di Maria, 2011; Wagner, Muûls, Martin, and Colmer, 2013; Petrick and Wagner, 2014; Ellerman, Marcantonini, and Zaklan, 2020; Colmer, Martin, Muûls, and Wagner, 2024). Clean innovation has also increased since the launch of the EU ETS in 2005 (Martin, Muûls, and Wagner, 2020). Furthermore, ETS-regulated firms showed a larger increase in low-carbon patents compared with non–regulated firms (Calel and Dechezleprêtre, 2016), suggesting that carbon pricing is related to an uptick in green innovation (Känzig, 2021; Martin, Muûls, and Wagner, 2013; Borghesi, Cainelli, and Mazzanti, 2015). Recent evidence adds nuance to this view: Akey, Appel, Bellon, and Klausmann (2024) show that while EU ETS-regulated firms making public climate commitments do reduce their verified emissions (and thus surrender fewer allowances), they simultaneously increase allowance sales on secondary markets. Yet, the proceeds are not used to invest in green innovation or to reduce the firm's emissions outside the EU ETS. Using Italian credit-registry data, Apicella and Fabiani (2023) exploit the 2017–18 EUA price surge to show that banks, anticipating stronger cash-flow prospects and green investment opportunities at firms facing higher carbon costs, reallocate credit toward highly exposed ETS firms, boosting term-loan volumes by roughly 10%. These additional loans are linked to higher capital expenditures and employment at those firms, without an uptick in emissions. Colmer, Martin, Muûls, and Wagner (2024) document that EU ETS induced regulated manufacturing firms to reduce CO2 emissions by 14–16% between 2005 and 2012 via targeted investments to reduce emissions intensity of production and without outsourcing to unregulated firms or markets or contracting their economic activity. Finally, De Jonghe, Mulier, and Schepens (2020) also exploit the tightening of the EU ETS regulation to show that it improved the emission efficiency of highly polluting firms, with this also being supported by the acquisition of green firms.

Relative to the existing literature, our key contribution is to examine how leverage and debt financing may affect the low-carbon transition of firms subject to an explicit constraint on their emissions in a broad sample which also encompasses unlisted firms and SMEs. In this context, we also move beyond inferred or non-verified measures of emissions to develop a novel firm-level dataset with verified disclosed emissions, reducing the risk that we capture greenwashing or other confounding effects that may characterise self-reported or inferred emissions data (Busch, Johnson, and Pioch, 2020; Kalesnik, Wilkens, and Zink, 2020). By contrast, existing research examining the link between firm-level finance, indebtedness or financial constraints and reductions in emissions typically uses non-verified emissions and focuses on listed or large firms, often including those not subject to an explicit climate policy constraint. And while a small number of other studies do examine firms subject to the EU ETS and exploit changes in the ETS regulation, none of these have focussed on the interplay between transition performance and firms' leverage or financing opportunities. By contrast, our analysis provides robust evidence on the existence of a group of firms that are too indebted to abate their emissions. Our results also indicate that the reduction in emissions identified in previous studies examining the EU ETS is likely to be driven by less leveraged firms who have the financial capacity to invest in less polluting technologies. Our findings thereby highlight that while the strengthening of the EU ETS emissions cap is likely to have pushed regulated firms to reduce their emissions, the system alone may not be a sufficient tool to achieve the corporate sector low-carbon transition if not paired with suitable financing opportunities.

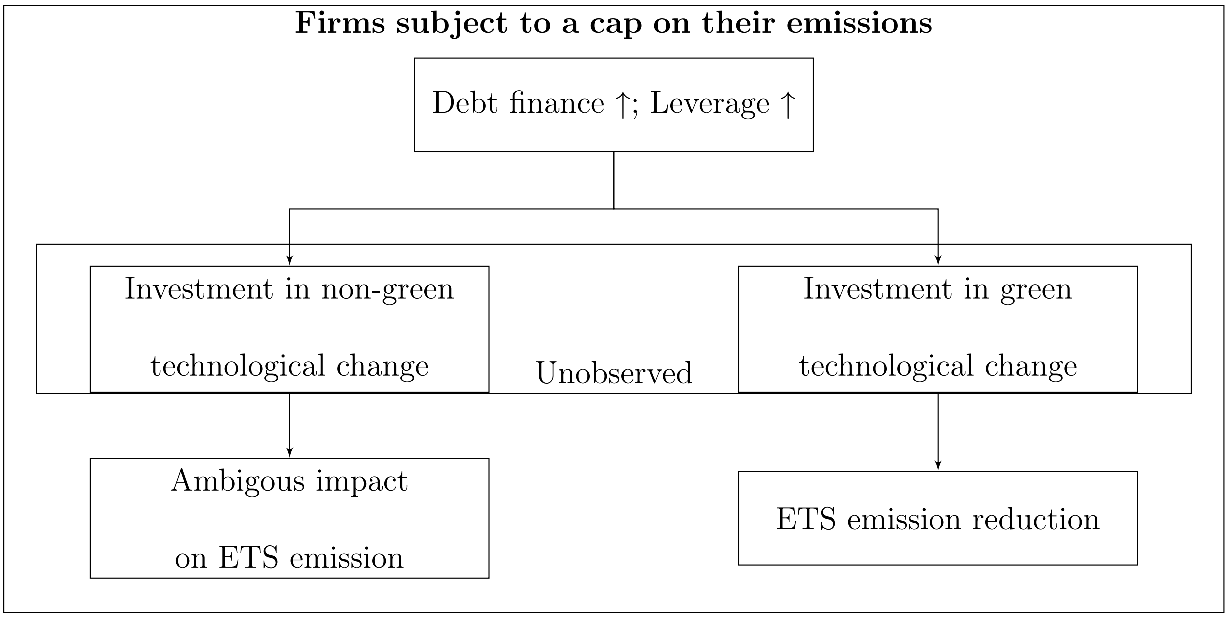
The rest of the paper is structured as follows. Section 2 outlines the conceptual background, our set of hypotheses and empirical strategy. Section 3 describes the data, and Section 4 presents the results. Section 5 concludes and discusses policy implications.

2 Conceptual background and empirical specifications

The EU ETS is designed to tackle negative externalities associated with greenhouse gas emissions (Nordhaus, 1991) which would not otherwise be internalised in the decisions of profit-maximising firms (Helbling, 2017). To comply with the EU ETS cap, firms either need to produce less, purchase additional emission allowances, or invest in substituting emissions-intensive technologies with less polluting ones. Finance to support investment is, therefore, central to enabling firms subject to the ETS to invest in cutting their emissions without reducing their economic activity. Debt financing, particularly from banks, is the primary source of external financing for non-financial firms in Europe (ECB, 2022). The ability of firms to borrow and take on additional leverage may, therefore, be important for investment in the adoption of green technologies and reducing emissions.

Figure 1: Link between debt finance, investment, and transition performance

Notes: The Figure illustrates the theoretical link between external financing, investments and emissions for firms subject to the EU ETS.



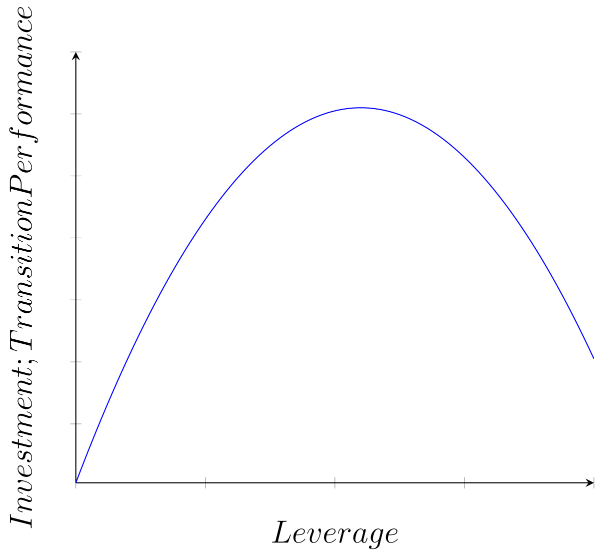
In a simplified illustration of debt-leverage-investment links (Figure 1), firms subject to an emissions cap may increase their debt financing and leverage either to invest in the adoption of green technologies or for any other purpose (e.g., other types of investment or debt servicing). Investing in green technological change allows firms to approach low-carbon transition goals by decreasing their emissions and increasing their emission efficiency over time. Conversely, borrowing for other purposes has an ambiguous effect on the emissions performance of the firm. Highly indebted firms who face challenges in taking on more leverage may be unable to invest in green technologies and reduce their emissions. This highlights the relevance of exploring the firm-level links between leverage and emissions empirically, also recognising that there are limited data which allow firms' green investments to be distinguished from their other investment, especially historically.[5]

[5] De Haas, Martin, Muûls, and Schweiger (2024) analyses the EBRD-EIB-WB Enterprise Surveys data, which collect information on firm-level green management and green investments in 22 Emerging European countries. But most firms subject to the ETS are in developed European countries and are not covered by these survey data.

In examining the potential links between leverage and carbon emissions, it is important to recognise that the literature on corporate debt and investment documents two opposing forces that may influence the relationship between leverage and investment. Firms can benefit from corporate debt financing through tax advantages and reduced agency costs (Modigliani and Miller, 1958, 1963; Ross, 1977; Grossman and Hart, 1982). This incentivises firms to take on more debt to finance investment in profitable opportunities. And for firms subject to the ETS, investing in low-carbon technologies is likely to be a profitable strategy over the medium term. At the same time, high levels of existing indebtedness may hold back a firm's investment. This is because highly leveraged firms may find it more difficult or costly to raise new external financing and because they may need to direct a higher share of any debt financing they receive towards covering debt servicing costs (Myers, 1977). Given these two opposing forces, the static trade-off theory on debt and investment suggests an inverted U-shape relationship between leverage and investment (Figure 2). Empirically, Gebauer, Setzer, and Westphal (2018) and Mosk, Pietsch, Cappiello, and Kapadia (2023) provide evidence of a concave relationship between debt and investment for European firms. And a wider empirical literature finds that high corporate leverage may adversely affect investment (Hernando and Martínez-Carrascal, 2008; Martinez-Carrascal and Ferrando, 2008; Kalemli-Özcan, Laeven, and Moreno, 2022; Barbiero, Popov, and Wolski, 2020).

Figure 2: Conceptual relationship between leverage and investment of a firm

Notes: The figure illustrates the conceptual inverted U-shape relationship between leverage and investment as well as between leverage and transition performance as measured by emission efficiency.



Drawing on these conceptual relationships between leverage, (green) investment and carbon emissions, we hypothesise a non-linear relationship between ETS firms' leverage and transition performance (see Figure 2), with the latter measured by a firm's (future) carbon emissions and emissions efficiency. This is based on the idea that firms subject to the EU ETS which have relatively low leverage can borrow to invest in emissions-reducing technologies, improving transition performance as leverage rises. However, when firms' leverage is already relatively high, they may not be able to invest as much in low-carbon technologies either because external debt finance is less readily available or more costly, or because they cannot channel as high a share of their borrowing towards investments in green technologies due to other financial commitments. Therefore, beyond a certain point, higher firm leverage may lower transition performance. This hypothesis assumes firms do not use investments to shift emissions outside the ETS system, a point we revisit in Section 4.3. More precisely, we first test:

Hypothesis 1. There is an inverted U-shape relationship between the level of transition performance of a firm within the EU ETS and its leverage.

To strengthen identification, we then examine the relationship between the two variables in the context of the 2015 introduction of the MSR. Although the MSR took effect in 2019, its announcement in 2015 significantly strengthened the credibility of the EU ETS by introducing a more stringent cap on emissions and provides a natural setting to exploit variation in firms' responses to a tightening carbon market. We select 2015 as the policy shock year for the difference-in-differences analysis as it marks the point at which firms plausibly began adjusting their behavior in response to the MSR announcement. Firms typically respond to clear policy intentions well before formal implementation of regulations, especially when such policies have significant implications for long-term capital investment and operational planning.[6] Therefore, it is plausible that many firms began adjusting their behaviour in 2015, in anticipation of the future tightening of the carbon market. We take a conservative stance by selecting 2015 as the event year, thereby also avoiding potential contamination from the second wave of EU ETS reforms in 2018. Delaying the shock year to later would likely miss the anticipatory behavioural changes already underway.

It is worth noting that the steep increase in EUA prices only materialised from late 2017 onwards (see Figure 4 left panel), while both spot and futures prices remained relatively stable and near pre-reform levels in the intervening years (Ampudia, Bua, Kapp, and Salakhova, 2022). However, although emission allowances can be carried over into future years, they earn no return. In addition, given that the policy change was permanent, firms

[6]While the 2015 Paris Agreement may represent a potential confounding factor, we argue that its impact was largely complementary, reinforcing existing EU climate policy rather than introducing specific, binding mechanisms. The Agreement articulated broad targets, such as limiting global warming to 1.5C - 2C, without detailing enforcement or sector-specific pathways, thereby strengthening the signal from the MSR rather than confounding it.

would not in any case have been able to accumulate an infinite number of allowances for all future payments, and it would also have been difficult for them to judge how exactly many additional allowances would be required per year until precise calculations were published in 2017. Given the surplus of actual allowances between 2015 and 2018, there was, therefore, no significant reason for spot prices to increase immediately in 2015. And although futures are slightly more expensive to account for the risk-free rate and the credit risk of firms on the EU ETS market, futures prices closely follow spot prices because even though there are no storage costs for carbon allowances, they earn no return and have no convenience yield (Charles, Darné, and Fouilloux, 2013; Bredin and Parsons, 2016; Azzone, Baviera, and Manzoni, 2025). Overall, given the less stringent emission caps during 2015-2018, firms with the financial capacity and technological capability to do so were therefore likely to have undertaken green investments to reduce future emissions (or undertaken other profitable investment opportunities) rather than accumulating emission allowances with zero return and no convenience yield only in anticipation of a possible future price increase. As such, even though it was understood from 2015 that emission allowances would probably become more valuable from 2018 or 2019 onwards, there were reasons why actual emission prices only started to rise materially as implementation became imminent.

Hypothesis 2. Highly leveraged firms exposed to the more stringent emissions cap associated with the MSR are unable to reduce their emissions after 2015, whereas less leveraged firms successfully do so.

Throughout, we measure firm leverage as total debt divided by total assets (as in Gebauer, Setzer, and Westphal, 2018). As noted above and in line with much of the literature (e.g., Bolton and Kacperczyk, 2021b and De Jonghe, Mulier, and Schepens, 2020), we consider two complementary measures of firm-level transition performance: absolute emissions and emission efficiency, defined as how much revenue a firm generates for each unit of emissions (the inverse of emission intensity).[7] The two measures reflect different, yet both important, aspects of a firm's low-carbon transition and are consistent with the targeted metrics of the EU ETS: reducing aggregate emissions and improving emission efficiency. Absolute emissions reflect a firm's contribution to the overall, global level of greenhouse gases. Therefore, reducing absolute emissions is what ultimately matters from a societal perspective in tackling global warming. Absolute emissions are also a simpler measure, not subject to being conflated with other factors that may affect revenues. At the same time, holding all else equal, the higher the level of emission efficiency, the cleaner the production technology of the firm. This may be an important dimension because rapidly growing firms that increasingly adopt ever-lower carbon technologies may displace less emissions-efficient competitors, and so may contribute to the overall transition of the economy even if their absolute emissions are increasing as they grow in size.

Our empirical strategy adopts a panel regression to test hypothesis 1 and a difference-in-differences approach for hypothesis 2. We first estimate the following specification to test hypothesis one:

$$Y_{f,t} = \gamma_1 Leverage_{f,t-x} + \gamma_2 Leverage^2_{f,t-x} + \gamma_3' X_{f,t-1} + \eta_{c,s,t} + \mu_{f,t} \qquad (1)$$

Where $Y_{f,t}$ is a time varying measure of transition performance, either the total emissions of the firm or its emission efficiency. Equation 1 is quadratic in leverage, following the

[7] Our choice to focus on emission efficiency rather than emissions intensity (i.e., Emissions / Revenues) is in line with the practice in the literature on clean production, e.g., De Jonghe, Mulier, and Schepens (2020). Nevertheless, all of our results can also be interpreted identically for emissions intensity.

strategy introduced by Mosk, Pietsch, Cappiello, and Kapadia (2023).[8] This allows for testing the non-linearity of the relationship between leverage and transition performance. In our preferred specification, in an effort to reduce endogeneity concerns, we fix firms' leverage at their levels before the beginning of the sample period, in 2013. We also conduct additional analyses employing a time-varying measure of leverage lagged by either 1 or 2 years relative to the baseline. We consider lags of both 1 year and 2 years to reflect that certain technological changes may result in an improvement in transition performance in the next year (e.g., thermal insulation of a firm's building), while other technological changes are more time-intensive and may only result in an improvement in transition performance over a longer time horizon (e.g., changing to clean cement production).

$X_{i,t-1}$ is a vector of control variables. Our rich set of control variables includes firm-specific economic variables, firm-specific environmental variables and country-specific environmental variables. The firm-specific economic variables include revenues, profitability and the age of the firm (as in De Jonghe, Mulier, and Schepens, 2020; Bolton and Kacperczyk, 2021a; Xu and Kim, 2022; De Haas, Martin, Muûls, and Schweiger, 2024). Although a firm's market-to-book ratio is also a widely used control, we exclude it as 96% of the firms in our sample are non-listed. Regarding firm-specific environmental controls, we include a firm's cumulative balance of free allowances to emit net of ETS emissions and the number of ETS-regulated installations of a firm, where the latter helps to control for the possibility of our results being driven by carbon leakage (see Section 4.3). We cumulate the EUAs balance of a firm to proxy its total number of EUAs in a given year since firms can bank their EUAs. Together, this set of control variables helps to

[8] The idea to estimate debt overhang through a quadratic relationship between leverage and investment was developed by Mosk, Pietsch, Cappiello, and Kapadia (2023). We thank the authors for sharing their ideas at an early stage.

tackle concerns related to omitted variable bias and confront endogeneity concerns by including common factors that may explain both leverage and transition performance, as documented in the literature (see, for example, Gebauer, Setzer, and Westphal, 2018 for the literature on leverage and De Jonghe, Mulier, and Schepens, 2020 for the literature on transition performance).

Lastly, we include $\eta_{c,s,t}$, sector–country–time fixed effects, to net out any average differences in leverage and in emissions across countries, sectors, and years. In practice, this means we identify the effect of leverage on emissions from deviations around the sector–country–year mean. Thus, even if, for example, electricity firms in Country A are on average more leveraged than metals manufacturing firms in Country B, our estimator uses only the contrast between two electricity firms in Country A in the same year (one more leveraged than the other) to determine the leverage–emissions relationship. This within–group variation approach both (i) controls for sector-level financing norms that may vary by country and over time and (ii) isolates firm-level leverage changes from any broad regulatory or macro-shock (e.g., a sector-specific carbon tax or country-wide debt policy). Importantly, this setup also accounts for the foreseen free allocation schedule under the EU ETS, which introduced quasi-exogenous variation in firms' carbon cost exposure based on sector, country and year. Since the schedule was determined in advance and systematically varied by policy design, the sector–country–time fixed effects absorb these differences, ensuring that our estimates are not confounded by expected differences in allowance allocation. This strategy aligns with the wider literature on firm-level emissions determinants (see, e.g., Bolton and Kacperczyk, 2021a). As Figure 5 shows, the distributions of leverage, emissions, and emission efficiency for the full sample and within sectors in 2013 and 2019 exhibit relatively modest shifts in their overall and sectoral profiles over time, alongside substantial firm-level heterogeneity.

The design of this specification allows us to use the estimated coefficients to compute, for a given set of firms, an implied leverage threshold above which the relationship between leverage and transition performance inverts, in line with the hypothesis that we aim to test[9]:

$$threshold = \frac{-\gamma_1}{2 \times \gamma_2} \tag{2}$$

To test hypothesis 2, we proceed in two steps. Firstly, we exploit the following specification in a difference-in-differences approach:

$$Y_{f,t} = \alpha_f + \eta_{s,c,t} + \beta Treatment_f \times Event_t + \gamma' X_{f,t-1} + \epsilon_{f,t} \tag{3}$$

Where $Treatment_f$ is a dummy equal to 1 for firms with an excess of emissions over allowances (i.e., a negative EUA balance) at the beginning of phase 3 of the EU ETS (2013), 0 otherwise. In this first diff-in-diff specification, the coefficient of interest is β, which captures the average difference in transition performance after the 2015 event, relative to the previous period, for treated firms relative to control firms. While firms with an excess of allowances also face a higher opportunity cost of allowances when EUA prices (are expected to) rise, firms with a negative EUA balance face higher *direct* costs. These firms are directly exposed to the tightening of the cap linked to the adoption of

[9]Leverage thresholds may depend on the sector and other economic factors. Banks consider the debt-to-assets ratio alongside other financial indicators, such as profitability, cash flow, and market conditions, when making lending decisions. Thus, there is no universally "ideal" debt-to-assets ratio, since acceptable levels depend on industry norms, economic conditions, and individual company circumstances. Our point is not about the existence of a unique leverage threshold but rather about the U-shape relationship between leverage and transition performance.

the MSR, as they face the legal obligation to pay for their excess emissions.

Secondly, we use an interaction term to study the different responses of firms with low or high leverage relative to the implied threshold estimated in our baseline panel approach (in Equation 2). Therefore, we exploit the following specification:

$$\begin{aligned} Y_{f,t} = & \alpha_f + \eta_{s,c,t} + \beta_1 Treatment_f \times Event_t + \beta_2 LeverageAbove_f \times Event_t + \\ & + \beta_3 Treatment_f \times LeverageAbove_f \times Event_t + \gamma' X_{f,t-1} + \epsilon_{f,t} \end{aligned} \tag{4}$$

In our baseline specification, $LeverageAbove_f$ is a dummy equal to 1 for firms with leverage above the implied leverage threshold computed from Equation 2, before the beginning of the sample period, and 0 for other firms. This allows us to capture firms that were both highly indebted and exposed to rising EUA prices when the new policy was introduced. We conduct robustness tests for alternative constructions of the $LeverageAbove_f$ dummy.

3 Data

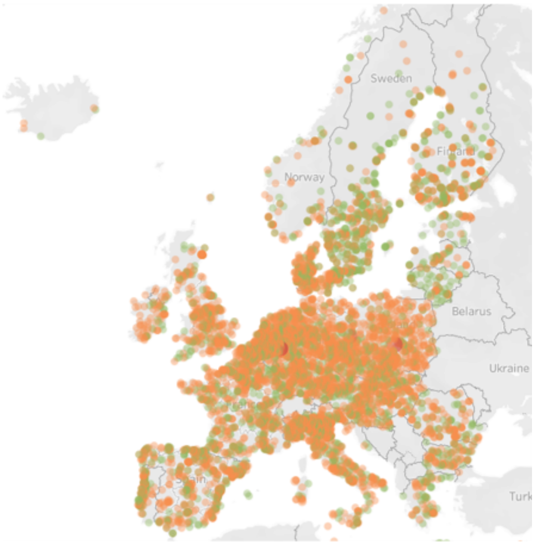
We construct a firm-level dataset based on the EUTL database on the verified greenhouse gas emissions of installations subject to the European Carbon Market (EU ETS), which, in its entirety, reflects approximately 40% of the EU's CO2 emissions. Given the sample period in question, the EU in this context includes the United Kingdom. The EUTL dataset allows for mapping of installations to their owners through national identification and trade registry numbers. Our mapping approach follows closely De Jonghe, Mulier, and Schepens (2020). Through Bureau van Dijk's Orbis database, we identify the non-financial corporations that own most of the installations in the EUTL and we retrieve financial and economic variables that may explain their transition performance. We also obtain further firm and country-level environmental variables as explained in Section 3.2. To construct our key variables, we compute firm-level verified ETS emissions and ETS emission efficiency, measured as revenues relative to emissions[10] as explained in Section 3.1. We obtain an unbalanced dataset covering 3,724 firms over the period from 2013 to 2019, and a balanced sample of 2,421 firms, on which we focus for the majority of our analyses.[11] The period observed is the third phase of emissions trading in the EUTL, which is characterized by a homogeneous ETS regulation. The final dataset covers approximately 20% of the greenhouse gas emissions produced in the EU (including UK) on average between 2013 and 2019.

[10]Data on the share revenues that are attributable to ETS emissions are not available. Therefore, to obtain emission efficiency, we divide ETS emissions by the firm's operating revenues from Orbis.

[11]We favour the balanced sample for the following reasons. First, the seven-year period in our balanced sample allows capturing the gradual impact of ETS-related policies on firms, especially considering the time it takes for technology adoption. By focusing on firms that remained operational throughout the whole period, we ensure that the sample reflects firms with (financial) capacity and time to make such investments and remain operational. This observation period also provides enough time to see the full effects of policy changes, ensuring that the analysis reflects the real-world time lag between policy shifts and actual emission reductions through technology adoption. If firms that exited the market were included, it might reflect some firms failing due to a combination of high leverage and emissions policies (e.g., being unable to afford necessary investments or being acquired due to their emissions profile). This could bias the results in favour of finding a relationship between leverage and transition performance, while also making it harder to isolate the impact of policy on technology adoption among viable firms. Second, Olley and Pakes (1992), who study dynamics of productivity in the US telecommunication equipment industry, argue that the balanced sample gives more consistent results.

Figure 3: Map of installations active within the EU ETS in 2019

Notes: The Figure illustrates the installations owned by the 3724 firms in our EU ETS sample in 2019. Each dot represents one installation. Dots range from green to red, showing the balance of free EUAs versus verified emissions in 2019: green for surplus, red for deficit, with colour intensity indicating the size of the difference.

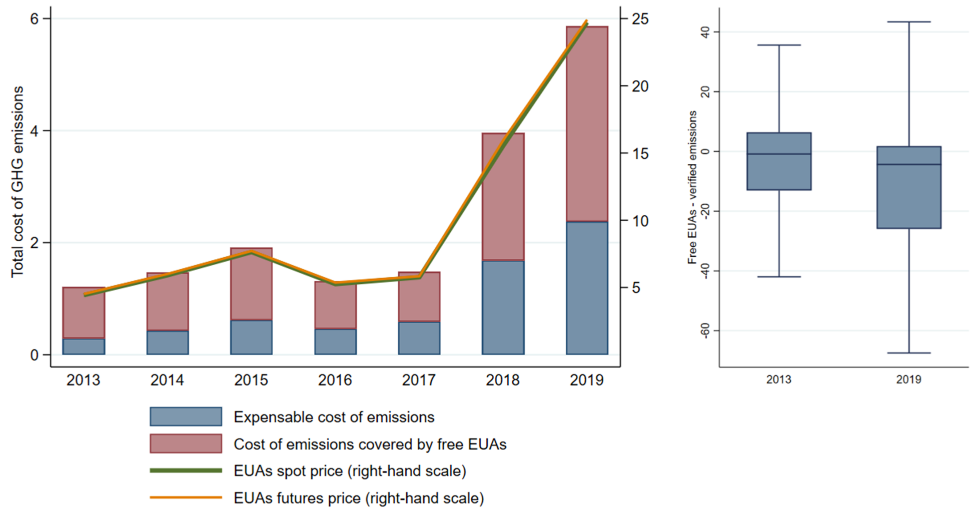


In Figure 3, we show a map of the installations that are owned by the firms in our sample and that produce verified greenhouse gas emissions within the EU ETS. Most observations describe firms with legal registration in the European Economic Area, particularly Germany, Spain, France, and Poland, and entities in the Nace sectors of manufacturing and electricity, gas, and air conditioning supply, metals, manufacturing, and chemicals. The dataset includes small and medium European enterprises (SMEs), which we identify as entities with total assets below 43 million EUR in the year prior to the beginning of the sample period and represent approximately 40% of firms in our sample.[12] Moreover, most of the dataset consists of non-listed companies. Overall, the sample is representative of the structure of the fossil-fuel-intensive section of the European real economy.

[12]We approximate the European Commission's classification of firms into small and medium enterprises (European Commission, 2021).

Figure 4: Cost of ETS emissions, EUA prices and distribution of EUA balance over time.

Notes: Left panel: cost of emissions faced by an average firm in the sample of 3724 firms (in million euros, as shown in the left-hand side scale) and the level of EUA prices over time in phase three of EU ETS trading (in euros, as shown in the right-hand side scales). EUA futures prices reflect 12-month futures' prices. Right panel: distribution of firm-level EUA balance in 2013 and 2019.



Crucially, the sample includes only firms that own installations that are regulated by the EU ETS. Therefore, all firms in our sample are subject to a constraint on their emissions. Figure 4 (left panel) describes the magnitude of this constraint for the sample covered by our analysis. It shows the cost of emissions of the average firm in our sample, including a breakdown between the cost of emissions that must be paid for and the cost of emissions covered by free EUAs. During the sample period, from 2013 to 2019, the total cost and expansible cost of emissions of the firms in our sample increased across time and especially from 2018. This was driven by the increase in the price of EUAs. However, as argued above, it is sensible to take 2015 as the year of the shock for the difference-in-differences setup even though emissions prices only started to increase later. The right panel of Figure 4 shows that comparing the distribution of EUA balances between 2013 and 2019, many more firms were experiencing a deficit of free EUAs in the latter year compared to the former. Our data suggest that the framework of our study is an increasing constraint on firms' emissions from the ETS.

3.1 Measures of transition performance

We consider two measures of transition performance. Consistent with the literature on the topic (see e.g., De Jonghe, Mulier, and Schepens, 2020), we consider firm-level EU ETS verified greenhouse gas emissions and emission efficiency, which we compute as the ratio of firm-level revenues on verified ETS emissions of their plants subject to the EU ETS.[13] To conduct our empirical analyses, we consider the log transformation of the two measures of transition performance, which decreases the skew in their distribution. Firm-level ETS emissions are the sum of the ETS emissions of the firm's installations that are subject to the EU ETS. ETS emissions are disclosed by firms at the installation level and verified by a third party. They compare to Scope 1 emissions of a firm as defined under the GHG protocol, albeit excluding methane (European Parliament and the Council, 2003) and excluding non-ETS eligible installations.

During the sample period, firms show a modest decline in ETS emissions and a general improvement in emission efficiency (Figure 5). On average, firms emit around 200,000 tonnes of CO2e, have an emission efficiency of approximately €500,000 per tonne of CO2e, and a leverage ratio of 18%. Figure 5 also presents breakdowns by sector group and separately for the years 2013 and 2019.

3.2 Determinants of transition performance

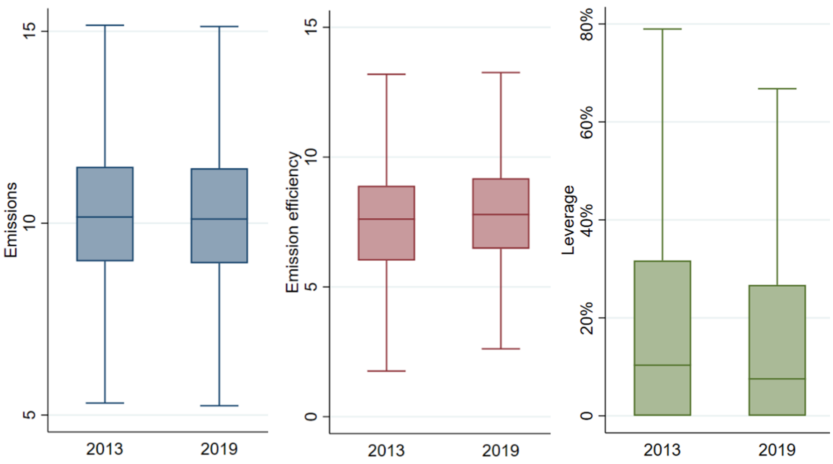
We collect entities' reference data (e.g., NACE Revision 2 codes and country of legal registration) and their yearly financial accounts (including total debt, total assets, return

[13] An ideal metric would be revenues generated by the ETS plants relative to their ETS emissions, but plant-level financial data is not disclosed as ETS plants are not a legal entity, but an asset.

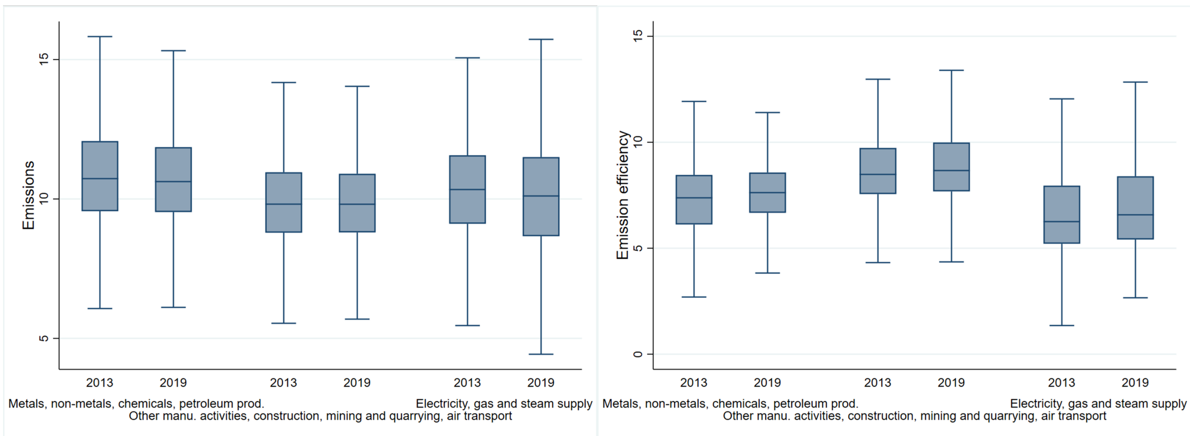
Figure 5: Firm-level distributions of ETS emissions, emission efficiency, and leverage

Notes: Sample: 2,421 firms. Emissions: natural logarithm of verified greenhouse gas emissions (CO2 equivalent tonnes). Emission efficiency: natural logarithm of revenue-to-emissions ratio. Leverage: debt-to-assets ratio. Sector groups by similarity in ETS exposure and emissions profiles: (1) Electricity, gas, steam supply (Energy supply, with the highest direct emissions and policy exposure); (2) Metals, non-metals, chemicals, petroleum products (Emissions-intensive manufacturing); (3) Other manufacturing, construction, mining, quarrying, air transport (Moderate-emitting sectors).

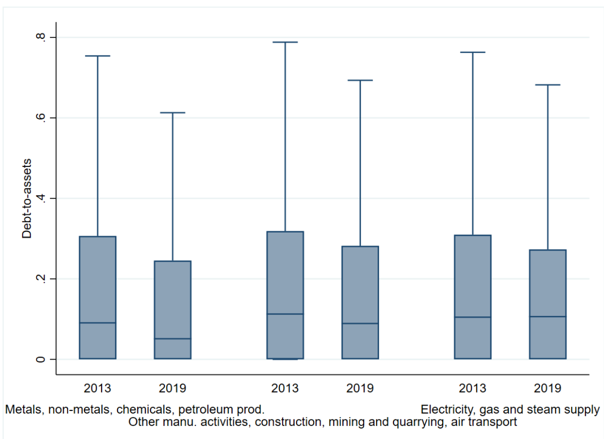
(a) Panel A: Emissions, Efficiency, and Leverage (whole sample)



(b) Panel B: Emissions and Efficiency by Year and Sector Group



(c) Panel C: Leverage by Year and Sector Group



on assets, revenues) from Bureau van Dijk's Orbis. We select financial information at an unconsolidated level. We winsorize all controls at the 1 and 99% levels.

Our main variable of interest is leverage, which we measure by the debt-to-assets ratio. Total assets are equivalent to liabilities and equity, where the latter includes retained earnings; thus, it accounts for other sources of external and internal financing of the firm. We also collect data on whether the firm holds green debt. We find that only a very few firms in our sample have taken a green loan or issued green bonds (see Section 3.3).

The dataset is enriched with firm-specific environmental variables. Relying on the EUTL database, we compute the number of installations subject to the EU ETS owned by each firm and the balance of emission allowances for the firms in the sample. The balance is the difference between the EUAs allocated for free to the firm and its verified emissions. We compute the cumulative sum of this variable to account for firms' possibility to store EUAs across years. Relying on the EUTL regulation, we also build a dummy variable indicating whether a firm is included within the carbon leakage list by the European Commission before and at the beginning of the sample period (European Commission, 2009). These firms are deemed to be at risk of reallocating their production activity outside the EU, the area of coverage of the EU ETS (see Section 4.3).

The full description of the firm financial and environmental variables used in the analysis is in Table 5. The sample composition by country and sector and summary statistics of our key variables of interest are provided in Tables 1 and 2 for the sample of firms observed every year from 2013 to 2019. Table 6 indicates that the summary statistics for the entire unbalanced sample of firms are similar, with the exception of a notably lower average return on assets in the unbalanced sample, consistent with some of those firms failing and dropping out of the sample.

Table 1: Sample composition by year, country and sector

Notes: The table shows the sample composition for firms that appear every year in the sample from 2013 to 2019.

Year	Obs.	Country	Obs.	Sector	Obs.
2013	2,421	Germany	2,436	D 35- Electricity, gas, steam and air conditioning supply	5,068
2014	2,421	Spain	1,890	C 23- Manufacturing of non-metallic mineral products	2,807
2015	2,421	France	1,652	C 17 - Manufacture of paper	1,645
2016	2,421	Poland	1,512	C 20- Manufacture of chemicals	1,358
2017	2,421	Sweden	1,302	C 10- Manufacture of food	1,078
2018	2,421	Other	8,155	C 24- Manufacture of basic metals	847
2019	2,421			Other	4,144
	Obs.				16,947

Table 2: Summary statistics of relevant variables

Notes: The table shows the sample composition for firms that appear every year in the sample from 2013 to 2019.

	Count	Mean	p50	Min	Max	Sd
Log(ETS-Emissions)	16,947	10.37	10.30	0.00	17.44	2.20
Log(Revenues/ETS-Emissions)	16,154	7.64	7.61	-23.61	22.49	2.49
Debt/Assets	16,947	0.18	0.10	0.00	0.89	0.21
Log Revenues	16,240	18.06	18.11	12.99	22.96	2.00
ROA	15,718	3.45	2.87	-31.97	32.35	8.65
Number of ETS-Installations	16,947	1.82	1.00	1.00	13.00	1.90
EUA balance (EUAs-Emissions)	16,947	-0.25	-0.01	-8.62	1.54	1.18
Age	16,937	34.19	23.00	0.00	333.00	29.58
N	16,947					

3.3 Data on green debt

Since 2015, the green debt market has grown significantly, with only the green bond market exceeding USD 1 trillion in 2020 (Pietsch and Salakhova, 2022) and reaching USD 3 trillion of cumulative issuance worldwide in 2025 (Demski, Dong, McGuire, and Mojon, 2025). However, using data on the issuance of green debt, we find that a negligible number of firms in our sample issued green bonds between 2013 and 2019. Only 11 EU ETS firms directly benefited from green debt, while 23 firms benefited from it through their consolidated group structure (see Table 9).[14]

[14]Table 9 does not include sustainability-linked bonds, albeit only a few sustainability-linked bonds have been issued according to our data during the time period of interest.

This is probably largely attributable to the majority of firms in our sample being small and medium enterprises that typically do not use bond markets to raise funding, while the green loan market is still nascent, even at the time of writing and especially so in 2019. In addition, the EU ETS regulates highly polluting industries, and it is possible that polluting firms may have found it difficult to convince investors of the greenness of their projects in the absence of a common regulatory standard for green bonds. Overall, we conclude that the use of different forms of green debt does not explain the transition performance of firms subject to the EU ETS between 2013 and 2019. Therefore, we disregard controlling for green debt throughout our analysis.

4 Results

In this section, we present the results of the fixed-effects regression analysis testing hypothesis 1, followed by the difference-in-differences analysis testing hypothesis 2. We then discuss the robustness of our findings. Throughout the section, we consistently show the results for the two chosen metrics of transition performance - emissions and emission efficiency (see Section 2).

4.1 Fixed-effects regression results on leverage and transition performance

Table 3 presents results from the specification in Equation 1 which examines the relationship between firms' leverage and transition performance. In columns (1) and (2), we report results for our preferred specification where $Leverage_f$ is kept fixed at levels observed in the year before the beginning of the sample period. In columns (3) and (4), we report results for the specification that employs time-varying leverage with a 1-year lag, while in columns (5) and (6), a 2-year lag in leverage is used.

The results in column (1) are consistent with a significant convex relationship between leverage and greenhouse gas emission levels. The coefficients imply that, on average, firms with a leverage ratio below 42% are associated with lower emissions, while firms with levels of leverage above this threshold are associated with higher emissions. The implied leverage threshold of 42% is the minimum of the regression's equation, computed as explained in Equation 2. Results in columns (3) and (5) are aligned with those reported in column (1) showing that the non-linear relationship between leverage and emissions is robust throughout different specifications, although less statistically significant in specification (5). The results are also aligned with hypothesis 1. The coefficients in column (2) imply that, on average, firms with a leverage ratio below 44% are associated with high emission efficiency, while firms with higher levels of leverage are associated with low emission efficiency. Also in this case, we show in columns (4) and (6) that the non-linear relationship between leverage and emission efficiency is robust throughout the different specifications. Due to the use of country-by-sector-by-year fixed effects, the regressions' results should be interpreted as resulting from a cross-sectional study. Indeed, the use of firm fixed effects would not only be econometrically unfeasible due to its collinearity with the $Leverage2012$ dummy, but a within-firm estimator would also fail to capture the non-linearity in the relationship between firms' scarcely time-varying leverage and their transition performance.

The effect of changes in leverage on transition performance can be economically significant. Figure 6 shows the estimated impact of a one standard-deviation change in firm leverage — equivalent to a 21 percentage point (pp) increase — on emission efficiency (blue bar) and absolute emissions (yellow bar). Since the relationship between leverage and transition performance is quadratic, the effect of a one standard-deviation change depends on the firm's starting point. In this case, the effect is calculated as a 21pp movement away from the estimated turning point, i.e. 44% for emission efficiency and 42% for absolute emissions. Using the estimated curve from Table 3 (columns 1 and 2), we compute the marginal effect by comparing transition performance at the threshold to that at a leverage level 21pp higher (i.e., just over 60%). This is derived as follows:

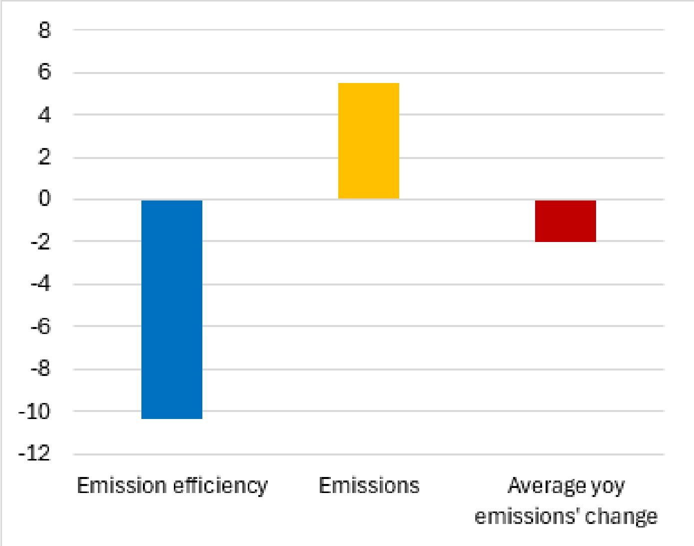
$$
\begin{aligned}
\Delta Y &= Y(L^* + SD_L) - Y(L^*) \\
&= \hat{\gamma}_1 L^* + \hat{\gamma}_1 SD_L + \hat{\gamma}_2 L^{*2} + \hat{\gamma}_2 SD_L^2 + 2\hat{\gamma}_2 L^* SD_L - \hat{\gamma}_1 L^* - \hat{\gamma}_2 L^{*2} \\
&= \hat{\gamma}_1 SD_L + \hat{\gamma}_2 (2L^* SD_L + SD_L^2)
\end{aligned}
$$

where L^* is the leverage threshold and SD_L the standard deviation of leverage. A one standard-deviation increase in leverage from the threshold is associated with a decline of over 10% in emission efficiency and a 5.5% increase in absolute emissions. Conversely, a one standard-deviation decrease implies an improvement in transition performance of the same magnitude. These effects are substantial, particularly when compared to the average annual reduction of 2% in the emissions cap imposed by the EU ETS (red bar).

Throughout the analysis, the coefficients on the controls are broadly stable. Larger firms are associated with higher emission levels, while profitability is negatively correlated with emissions, but positively correlated with emission efficiency. While large firms are almost always mechanically associated with higher emissions due to the size of their economic activity, profitable firms subject to an emission trading system might be able to undertake

Figure 6: Estimated impact of an increase in leverage on transition performance

Notes: The bars show the estimated percentage change in transition performance (emissions efficiency and absolute emissions) resulting from a one standard-deviation increase in leverage, using the sensitivities reported in Table 3 (columns 1 and 2) and relative leverage thresholds of 44% and 42%. These effects are shown in comparison to the annual average reduction in the EU ETS emissions cap (in red).



green investment opportunities to adopt the clean technologies that might enable their transition. Closely related to size, a firm's number of ETS-installations (i.e., installations subject to the EU ETS) is positively correlated with emissions. Moreover, a larger number of ETS installations is correlated with worse emission efficiency.

Firms with a positive (cumulative) EUA balance benefit from an excess of allowances over their emissions. Within a given sector-year, this surplus may suggest that the firm emits less than its peers, receives sufficient allowances to cover a greater share of its emissions, or has reduced its emissions over time, enabling it to accumulate unused allowances. Lastly, a firm's age is not significantly correlated with its emissions, while it is positively correlated with its emission efficiency. Older firms may benefit from longer-standing relationships with suppliers, banks or investors. The stability of this business environment might ease the firm's low-carbon transition process.

Table 3: Panel regression for transition performance and leverage, from 2013 to 2019

Notes: The table shows the result of the panel regression relevant to hypothesis 1 for the two metrics of transition performance: emissions and emissions efficiency. The relationship between transition performance and leverage is tested for the full balanced data sample covering the period from 2013 to 2019. Results for the unbalanced sample are in Table 11. Standard errors are indicated in parentheses, they are clustered at the firm level. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10. All controls are lagged by one year (i.e., taken at time $t-1$) apart from age.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
Leverage 2012	-1.31***	1.78***				
	(0.46)	(0.49)				
Leverage 2012 squared	1.49**	-2.11***				
	(0.72)	(0.76)				
Leverage 1y-lagged			-0.96**	1.35***		
			(0.38)	(0.42)		
Leverage 1y-lagged squared			1.08*	-1.55**		
			(0.61)	(0.65)		
Leverage 2y-lagged					-0.96**	1.29***
					(0.39)	(0.42)
Leverage 2y-lagged squared					0.96	-1.44**
					(0.62)	(0.65)
Size	0.65***		0.65***		0.65***	
	(0.029)		(0.029)		(0.029)	
Profitability	-0.0074**	0.016***	-0.0075**	0.016***	-0.0085***	0.015***
	(0.0031)	(0.0037)	(0.0031)	(0.0038)	(0.0031)	(0.0035)
Number of ETS installations	0.18***	-0.074***	0.18***	-0.074***	0.18***	-0.072***
	(0.024)	(0.023)	(0.024)	(0.024)	(0.024)	(0.024)
EUA balance	-0.40***	0.28***	-0.40***	0.29***	-0.40***	0.28***
	(0.034)	(0.037)	(0.034)	(0.037)	(0.033)	(0.036)
Age	-0.0010	0.0038***	-0.00099	0.0038***	-0.00097	0.0037***
	(0.0012)	(0.0013)	(0.0012)	(0.0013)	(0.0012)	(0.0013)
Constant	-1.54***	7.44***	-1.56***	7.48***	-1.59***	7.52***
	(0.49)	(0.091)	(0.49)	(0.089)	(0.50)	(0.085)
Country-Sector-Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,146	14,033	14,146	14,033	12,112	12,001
R-squared	0.644	0.516	0.643	0.515	0.646	0.531

Standard errors clustered at the firm level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We have also conducted robustness checks by estimating the panel regressions on sub-samples of selected industries (e.g., electricity, chemicals, non-metals) and countries (e.g., France, Germany, Poland) to ensure that our findings are not driven by specific events, such as the European sovereign debt crisis. The results are broadly consistent with the observations on the full sample and are available upon request.

4.2 Baseline difference-in-differences approach

The results in Section 4.1 show a non-linear relationship between leverage and transition performance, with high leverage associated with worse transition performance beyond a certain point. To address omitted variable bias, we include a rich set of controls and fixed effects, and to limit reverse causality concerns, our preferred specification uses highly lagged leverage levels.

To further mitigate potential endogeneity concerns, we adopt the difference-in-differences specification in Equation 4 to test Hypothesis 2 and examine firms' transition performance in response to the 2015 announcement and European Parliament approval of the MSR, taking 2015 as the year of the shock for the reasons discussed above. Throughout our setup, the treatment group includes firms that in 2012 (pre-event) had leverage of above 40% (linked to the threshold in the panel regression results) and a negative cumulative EUA balance, implying a need to buy additional EUAs. The control group includes firms with a surplus of allowances over their emissions. First, we compare treated and control groups along the dimensions of the chosen covariates. Table 7 shows that, unconditionally, treated firms have significantly higher emissions and lower emission efficiency than control firms. The t-test also indicates that they differ significantly in size, profitability, number of ETS installations, EUA balance, and age. To address these differences we adopt two approaches. We saturate our baseline specification with granular fixed effects and controls. And we use a matching estimator in our robustness tests (see Section 4.4).

Figure 7: Visual inspection of validity of parallel trend assumption - emissions

Notes: Impact of the introduction of the first Decision (EU) 2015/1814 addressing the surplus of EUAs in the EU ETS on treated firms' **emissions**—from the beginning of phase 3 of the EU ETS (t=2013) to t.

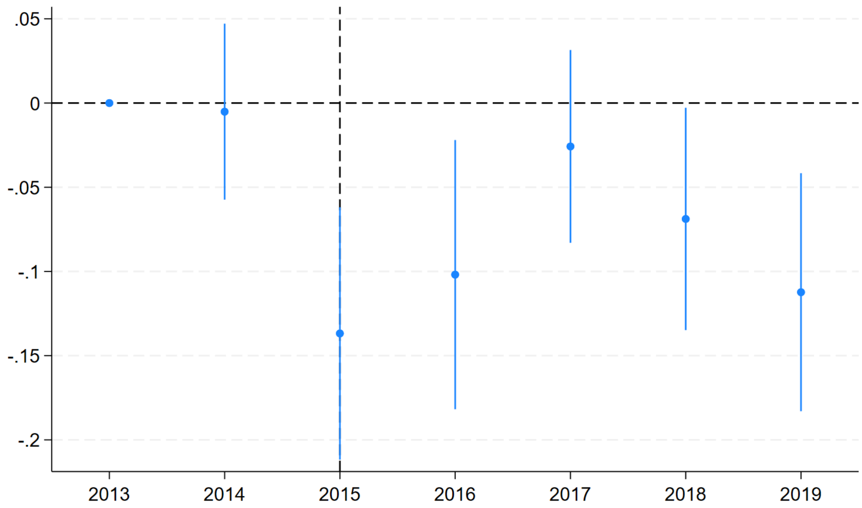
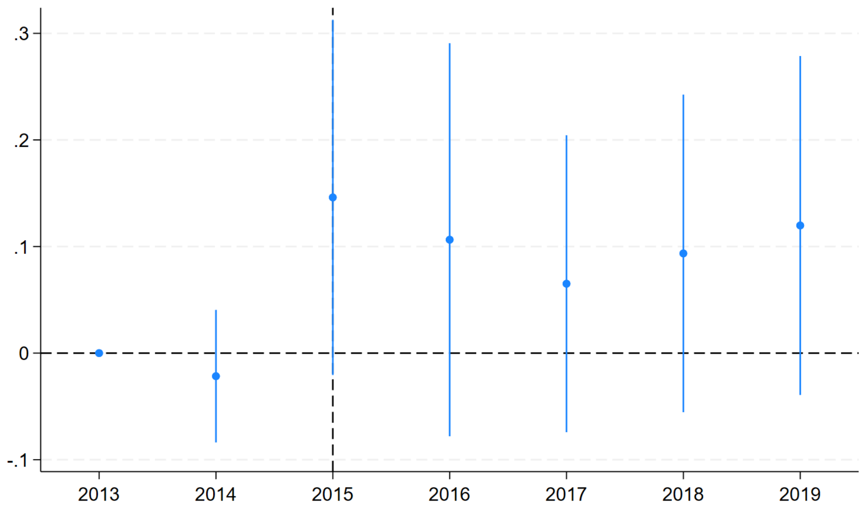


Figure 8: Visual inspection of validity of parallel trend assumption - emission efficiency

Notes: Impact of the introduction of the first Decision (EU) 2015/1814 addressing the surplus of EUAs in the EU ETS on treated firms' **emission efficiency**—from the beginning of phase 3 of the EU ETS (t=2013) to t.



Figures 7 and 8 report the regression coefficients of interest in a dynamic setup, for emissions and emission efficiency respectively. The Figures show that pre-event trends are not significantly different for our treatment and control groups. Moreover, while treated firms significantly reduce their emissions relative to the year prior to the event and relative to the control group, as expected, they do not significantly improve their emission efficiency (although on average the coefficients after the event are positive). The results of the difference-in-differences regression are formally reported in Table 4.

Table 4: Difference-in-differences on emissions and emissions efficiency

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample covering the years 2013 to 2019. Results for the unbalanced sample are in Table 12. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)
$Treated \times Event$	-0.086***	0.12	-0.11***	0.16*
	(0.028)	(0.076)	(0.032)	(0.087)
$LeverageAbove \times Treated \times Event$			0.13*	-0.27**
			(0.080)	(0.11)
$LeverageAbove \times Event$			-0.12**	0.15*
			(0.055)	(0.078)
Size	0.061***		0.062***	
	(0.020)		(0.020)	
Profitability	-0.0017*	0.0070***	-0.0017*	0.0071***
	(0.0010)	(0.0024)	(0.00100)	(0.0025)
Number of ETS installations	0.16***	-0.094	0.16***	-0.096
	(0.042)	(0.078)	(0.042)	(0.078)
Constant	9.04***	7.70***	9.04***	7.68***
	(0.37)	(0.15)	(0.37)	(0.15)
Firm FE	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes
Observations	14,154	14,041	14,154	14,041
R-squared	0.973	0.882	0.973	0.882

Standard errors clustered at the firm level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The coefficients in columns (1) and (2) of Table 4 show that the introduction of the more stringent regulation on emissions within the EU ETS is associated with lower emissions for firms exposed to the rising price of EUAs, relative to the years prior to the event and relative to firms that are not directly exposed to the rising constraints imposed by the EU ETS cap. However, they do not successfully improve their emission efficiency, possibly because this might require undertaking significant green investments, that not every firm in the treated group might be able to promptly undertake.

In columns (3) and (4) we report results for our analysis of interest, where we interact our treatment variable with an indebtedness variable that is equal to 1 for firms with a pre-sample leverage above the implied leverage threshold of 40%, and 0 otherwise. These results are aligned with hypothesis 2: while ETS firms, on average, reduced their emissions following the steep increase in the cost of EUAs, highly indebted firms did not experience such a significant reduction in their emissions. Similarly, while ETS firms, on average, improved their emissions efficiency following the steep increase in the cost of EUAs, highly indebted firms did not experience such a significant improvement. The coefficients on the treatment variable and its interaction with the indebtedness variable are statistically significantly different at the 10% level in column (3), and at the 5% level in column (4). The sign on the coefficients of the control variables is consistent with that obtained in our fixed-effects regression. Larger firms, or a larger number of ETS installations, are correlated with higher emission levels, while firms' profitability is negatively correlated with emissions, but positively correlated with emission efficiency.

A potential concern is that control firms with a positive EUA balance at the 2015 policy announcement may have sold surplus allowances to finance emissions-reducing investments, thereby improving transition performance independently of leverage. While we do not directly test this channel, it is unlikely to bias our results. EUA prices were still low in 2015, limiting incentives to monetize allowances immediately. Firms likely preferred to bank allowances and rely on external finance, including debt, for investments. Recent evidence by Akey, Appel, Bellon, and Klausmann (2024) also finds no support for allowance sales funding abatement investments during Phase 3.

Overall, the set of results suggests that the increased EUA price linked to the event led to worse subsequent transition performance of highly leveraged firms with negative EUA balances, relative to the control group. These results refine the findings of Colmer, Martin, Muûls, and Wagner (2024) by suggesting that reduction in emissions is particularly driven by less leveraged firms who were able to invest in less emitting technologies.

4.3 Carbon leakage

Carbon pricing via a cap-and-trade system such as the ETS may encourage investment in the adoption of green technologies but may also encourage relocation of emissions outside the scope of the scheme, which would also reduce measured ETS emissions. Therefore, it is important to assess whether our results are influenced by such potential carbon leakage.

There are two possible types of EU ETS related carbon leakage practices. Firstly, firms could shut down their active plants and relocate them outside the EU ETS to avoid facing the cost of EUAs. We control for this type of carbon leakage in our setup via the *Installations* variable that controls for the number of EU ETS active plants held by the firms in the sample across time. Secondly, firms could maintain their existing EU ETS plants, while increasing their economic activity outside the ETS (Martin, Muûls, De Preux, and Wagner, 2014). Our results could be consistent with such forms of regulatory arbitrage. Indeed, the use of debt for investment in the adoption of green technologies is not the only possible interpretation of the non-linear relationship between leverage and transition performance, as debt could also be used to finance carbon leakage practices. A key data limitation is the lack of information on plants operating outside the scope of the EU ETS, which prevents a full empirical assessment of this possibility.

At the same time, the existing empirical literature tends to find limited evidence of carbon leakage within the EU ETS, suggesting that our results do reflect firms' improvement of their transition performance via the adoption of clean technologies. Using recent confidential plant-level data, Naegele and Zaklan (2019) show that the emission reduction achieved by French manufacturing firms within the EU ETS is inconsistent with carbon leakage but is mainly driven by their investment in facilities that enable clean production. An earlier study by Naegele and Zaklan (2019) does not find any evidence that the EU ETS induced manufacturing firms to carbon leakage in the initial years of emissions trading.[15] The one exception is De Beule, Schoubben, and Struyfs (2022) who use foreign direct investment data in their examination of Phase 3 of the EU ETS. They find evidence for a statistically significant risk of shifting economic activities outside the EU ETS for firms deemed to be at risk of carbon leakage by the European Commission, although they do not find any evidence of carbon leakage for firms not on the carbon leakage list. Together, this empirical literature suggests that our findings on the relationship between leverage and transition performance are unlikely to be driven by carbon leakage, except possibly for firms on the carbon leakage list.

Given this, we re-run our main specification on the sub-sample of firms that do not belong to sectors included on the first carbon leakage list (that holds valid at the beginning of our sample period, when we select the treatment and control groups). Results in Table 13 are entirely aligned with our main specification, although some coefficients are no longer statistically significant which may be due to the smaller sample size reducing statistical power. In conjunction with the existing empirical literature, this suggests that it is unlikely that the empirical results on the relationships between leverage and transition performance presented in Section 4 can be attributed to carbon leakage.[16]

[15]The latter study is also consistent with Koch and Mama (2019) for the German manufacturing sector, Branger, Quirion, and Chevallier (2016) for the cement and steel sectors, and Dechezleprêtre, Gennaioli, Martin, Muûls, and Stoerk (2022) for multinational firms

[16]Recent literature on the Californian cap-and-trade, which differs from the EU ETS along many di-

4.4 Robustness exercises

4.4.1 Alternative indebtedness dummy

In our baseline analysis, we used the dummy $AboveLeverage_f$ to split the sample into firms with leverage above the implied threshold of 40% and below this threshold. In this robustness test, we set a dummy to 1 when leverage is above or equal to $40\% + \frac{1}{2}\sigma_{leverage}$, and 0 when leverage is below or equal to $40\% - \frac{1}{2}\sigma_{leverage}$, where $\sigma_{leverage}$ is the standard deviation of leverage equal to 21pp. This approach reduces potential confounding effects from firms with leverage near the threshold. The estimated coefficients in Table 14 remain both economically and statistically consistent with the baseline findings.

4.4.2 Matching estimator

In our baseline analysis, we show treated and control firms differ significantly in size, profitability, ETS installations, EUA balance and age. To account for these differences, we saturate our main specification with granular fixed effects and a rich set of controls. For robustness, we also employ a propensity score matching estimator. We match firms exactly on sector, country and equity type (listed or privately held), and apply propensity score weighting for size, profitability and ETS installations. Each treated firm is matched with at least three nearest neighbors using an algorithmic selection. Table 15 shows that the estimated coefficients remain consistent with those from the baseline specification.

mensions including the geographic and the allowance pricing ones, shows that only financially constrained firms are significantly responsible for carbon leakage (Bartram, Hou, and Kim, 2022). While these results cannot be extended to our analysis, they may build an argument for our coefficients constituting a lower bound of the effect of leverage on transition performance. Indeed, were firms with relatively high leverage responsible for carbon leakage, we would observe a reduction in their ETS emissions, in contrast with our results.

4.4.3 Large firms or SMEs

We explore whether our results differ by firm size by comparing large firms with small and medium enterprises (SMEs). Leverage-induced constraints may represent a greater obstacle to low-carbon investments for SMEs than for large firms. For example, SMEs typically have a more limited access to financing, particularly market-based sources, such as bond issuance. Due to data limitations, we cannot observe the composition of firms' debt (market-based versus bank-based), so we use firm size as a proxy for financing access. As shown in Tables 16 and 17, our main results largely hold across both sub-samples.

4.4.4 Firms with listed or privately held equity

We examine whether the effect of leverage on transition performance differs between firms with and without access to public equity markets. As shown by De Haas and Popov (2023), public equity markets tend to reallocate investment towards less emitting firms and may incentivise transition performance. This suggests that listed firms may adopt green technologies through a different economic channel than the one discussed in Section 2. We conduct the difference-in-differences analysis separately for listed and privately held firms. As shown in Table 19, the results are not statistically significant for listed firms, whereas Table 18 confirms robust effects for privately held firms. While this difference may be economically meaningful, it could also reflect the smaller sample size of listed firms.

4.4.5 Sectors

Firms across sectors may differ in their reliance on external financing, and the level threshold indicating over-indebtedness can vary accordingly. Prior research the impact of indebtedness depends on firm characteristics and sector (Rajan and Zingales, 1996). To account for this, we re-estimate our main specifications at the sectoral level. Tables 20, 21 and 22 show that our results are broadly consistent across sectors. Table 20 presents findings for the electricity sector (NACE 2-digit 35); Table 21 covers highly polluting manufacturing sectors (NACE 2-digit 19–25); and Table 22 includes firms in all remaining sectors.

5 Conclusion and policy implications

We study the role of debt as a source of transition finance in supporting the low-carbon transition of non-financial corporations in Europe, focusing on firms regulated under the EU ETS. Using historical data on verified emissions of ETS firms accounting for approximately 20% of total EU emissions, we show that higher debt financing of firms subject to an emission cap is associated with lower emissions and higher emission efficiency, as long as leverage is not above a certain threshold. Beyond this point, additional debt appears to hinder transition performance.

Crucially, our study highlights the existence of a group of firms that are too indebted to transition, although subject to a constraint on their emissions and even when such constraints become more binding. We find that, on average, firms reduced their emissions following the 2015 introduction of the MSR, which signalled a tightening of the ETS emission cap. However, highly indebted firms in the sample did not reduce their emissions. Our results are robust to a wide range of economic and environmental controls and robustness tests. They also hold for firms not at risk of carbon leakage. This helps address concerns that our results might be driven by firms avoiding transition investments by relocating emissions-intensive activities outside the EU ETS. While we cannot fully rule out such behaviour, prior research finds little evidence of significant carbon leakage within the EU ETS during the period analyzed.

These results contribute to two key policy debates. First, in line with existing literature, we show that tightening emission standards under the EU ETS effectively encourages emissions reductions among firms with adequate leverage. This underscores the importance of further strengthening the EU ETS to accelerate emissions reduction in Europe, with the implementation of ETS2 in 2027 being an important step in this direction.

Second, noting the limited use of green debt instruments among the firms in our sample, the development of green debt markets, particularly through the implementation of standards and labels for green bonds and green loans, might be important for the transition of highly indebted European firms. This may also be supported by tax incentives, such as making the tax advantages of debt financing only applicable to green debt. Investor appetite for green debt is strong and growing, which gives more highly-leveraged companies the chance to borrow at reasonable premiums for their green investments. By earmarking funds for green investments, such companies may also find it easier and cheaper to access finance despite struggling to increase borrowing more generally as lenders may be more confident that their finance will increase the profitability of the companies over the medium term. Firms with high leverage and low growth prospects may still have to cede the market to more emission-efficient competitors. But greater availability and stronger standards for green debt instruments could help firms with high leverage and high growth potential to get the necessary financing for the green transition, provided they commit to using the proceeds for environmentally sustainable investments. This is likely to become increasingly important with the forthcoming implementation of EU ETS2.

References

Akey, P., I. Appel, A. Bellon, and J. Klausmann (2024): "Do Carbon Markets Undermine Private Climate Initiatives?", *Darden Business School Working Paper*, (4938460), Available at SSRN.

Ampudia, M., G. Bua, D. Kapp, and D. Salakhova (2022): "The role of speculation during the recent increase in EU emissions allowance prices", Published as part of the ECB Economic Bulletin, Issue 3/2022. [Accessed: 2021 27 06].

Anderson, B., and C. Di Maria (2011): "Abatement and Allocation in the Pilot Phase of the EU ETS", *Environmental and Resource Economics*, 48(1), 83–103.

Apicella, F., and A. Fabiani (2023): "Carbon Pricing, Credit Reallocation and Real Effects", *SSRN Electronic Journal*, Working Paper.

Azzone, M., R. Baviera, and P. Manzoni (2025): "The puzzle of Carbon Allowance spread", *Energy Economics*, 146, 108459.

Barbiero, F., A. Popov, and M. Wolski (2020): "Debt overhang, global growth opportunities, and investment", *Journal of Banking & Finance*, 120, 105950.

Bartram, S. M., K. Hou, and S. Kim (2022): "Real effects of climate policy: Financial constraints and spillovers", *Journal of Financial Economics*, 143(2), 668–696.

Bellon, A., and Y. Boualam (2024): "Pollution-Shifting vs. Downscaling: How Financial Distress Affects the Green Transition", *mimeo*.

Beyene, W., K. De Greiff, M. D. Delis, and S. Ongena (2021): "Too-big-to-strand? Bond versus bank financing in the transition to a low-carbon economy", *CEPR Discussion Paper No. DP16692*.

Bolton, P., and M. Kacperczyk (2021a): “Do investors care about carbon risk?”, *Journal of Financial Economics.*

——— (2021b): “Global pricing of carbon-transition risk”, Discussion paper, National Bureau of Economic Research.

Borghesi, S., G. Cainelli, and M. Mazzanti (2015): “Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry”, *Research Policy*, 44(3), 669–683.

Branger, F., P. Quirion, and J. Chevallier (2016): “Carbon leakage and competitiveness of cement and steel industries under the EU ETS: much ado about nothing”, *The Energy Journal*, 37(3).

Bredin, D., and J. Parsons (2016): “Why is spot carbon so cheap and future carbon so dear? The term structure of carbon prices”, *The Energy Journal*, 37(3), 83–108.

Busch, T., M. Johnson, and T. Pioch (2020): “Corporate carbon performance data: Quo vadis?”, *Journal of Industrial Ecology.*

Calel, R., and A. Dechezleprêtre (2016): “Environmental policy and directed technological change: evidence from the European carbon market”, *Review of economics and statistics*, 98(1), 173–191.

Charles, A., O. Darné, and J. Fouilloux (2013): “Market efficiency in the European carbon markets”, *Energy policy*, 60, 785–792.

Colmer, J., R. Martin, M. Muûls, and U. J. Wagner (2024): “Does pricing carbon mitigate climate change? Firm-level evidence from the European Union Emissions Trading System”, *Review of Economic Studies*, p. rdae055.

Common, M., and S. Stagl (2005): *Ecological Economics: An Introduction.* Cambridge University Press.

De Beule, F., F. Schoubben, and K. Struyfs (2022): "The pollution haven effect and investment leakage: The case of the EU-ETS", *Economics Letters*, p. 110536.

De Haas, R., R. Martin, M. Muûls, and H. Schweiger (2024): "Managerial and Financial Barriers to the Green Transition", *Management Science*, Published online 26 June 2024.

De Haas, R., and A. Popov (2023): "Finance and green growth", *The Economic Journal*, 133(650), 637–668.

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

Dechezleprêtre, A., C. Gennaioli, R. Martin, M. Muûls, and T. Stoerk (2022): "Searching for carbon leaks in multinational companies", *Journal of Environmental Economics and Management*, 112, 102601.

Degryse, H., R. Goncharenko, C. Theunisz, and T. Vadasz (2021): "When green meets green", *Available at SSRN 3724237.*

Demski, J., Y. Dong, P. McGuire, and B. Mojon (2025): "Growth of the green bond market and green house gas emissions", *BIS Quarterly Review.*

ECB (2022): "Financial Integration and Structure in the euro area", Retrievable online at: https://www.ecb.europa.eu/pub/pdf/fie/ecb.fie202204 4c4f5f572f.en.pdf.

Ehlers, T., B. Mojon, and F. Packer (2020): "Green bonds and carbon emissions: exploring the case for a rating system at the firm level", *BIS Quarterly Review, September.*

Ellerman, A. D., C. Marcantonini, and A. Zaklan (2020): "The European Union emissions trading system: ten years and counting", *Review of Environmental Economics and Policy.*

Ellerman, A. D., and M. McGuinness (2008): "CO2 abatement in the UK power sector: evidence from the EU ETS trial period", *MIT Libraries.*

ESA (2024): "Fit-for-55 Climate Scenario Analysis", *European Supervisory Authorities and European Central Bank.*

European Commission (2009): "Commission Decision of 24 December 2009", https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010D0002.

——— (2021): "Commission Staff Working Document Executive Summary of the Evaluation of Commission Recommendation of 6 May 2003 Concerning the Definition of Micro, Small and Medium- Sized Enterprises (2003/361/EC)", [Accessed: 2021 27 06].

European Parliament and the Council (2003): "Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC", https://eur-lex.europa.eu/eli/dir/2003/87/oj/eng.

Fang, M., P.-H. Hsu, and C.-Y. Tsou (2024): "Financial Frictions and Pollution Abatement Over the Life Cycle of Firms", *mimeo.*

Fatica, S., and R. Panzica (2021): "Green bonds as a tool against climate change?", *Business Strategy and the Environment*, 30(5), 2688–2701.

Flammer, C. (2021): "Corporate green bonds", *Journal of Financial Economics*.

Gebauer, S., R. Setzer, and A. Westphal (2018): "Corporate debt and investment: A firm-level analysis for stressed euro area countries", *Journal of International Money and Finance*, 86, 112–130.

Gilchrist, D., J. Yu, and R. Zhong (2021): "The limits of green finance: a survey of literature in the context of green bonds and green loans", *Sustainability*, 13(2), 478.

Grossman, S. J., and O. D. Hart (1982): "Corporate financial structure and managerial incentives", in *The economics of information and uncertainty*, pp. 107–140. University of Chicago Press.

Helbling, T. (2017): "Externalities: Prices do not capture all costs", *Finance & Development*.

Hennessy, C. A. (2004): "Tobin's Q, Debt Overhang, and Investment", *The Journal of Finance*, 59(4), 1717–1742.

Hernando, I., and C. Martínez-Carrascal (2008): "The impact of financial variables on firms' real decisions: evidence from Spanish firm-level data", *Journal of Macroeconomics*, 30(1), 543–561.

Howell, S. T. (2017): "Financing innovation: Evidence from R&D grants", *American Economic Review*, 107(4), 1136–64.

Iovino, L., T. Martin, and J. Sauvagnat (2024): "The Environmental Bias of Corporate Income Taxation", *Available at SSRN 3880057*.

IPCC (2021): "Human Influence on the Climate System: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", *IPCC Sixth Assessment Report*.

Kacperczyk, M. T., and J.-L. Peydró (2021): "Carbon Emissions and the Bank-Lending Channel", *Available at SSRN 3915486*.

Kaldorf, M., and M. Shi (2024): "Do firm credit constraints impair climate policy?", Discussion paper, Deutsche Bundesbank.

Kalemli-Özcan, Ş., L. Laeven, and D. Moreno (2022): "Debt overhang, rollover risk, and corporate investment: Evidence from the European crisis", *Journal of the European Economic Association*, 20(6), 2353–2395.

Kalesnik, V., M. Wilkens, and J. Zink (2020): "Green Data or Greenwashing? Do Corporate Carbon Emissions Data Enable Investors to Mitigate Climate Change?", *SSRN Electronic Journal*.

Känzig, D. R. (2021): "The economic consequences of putting a price on carbon", *Available at SSRN 3786030*.

Koch, N., and H. B. Mama (2019): "Does the EU Emissions Trading System induce investment leakage? Evidence from German multinational firms", *Energy Economics*, 81, 479–492.

Lang, L., E. Ofek, and R. M. Stulz (1996): "Leverage, investment, and firm growth", *Journal of Financial Economics*, 40(1), 3–29.

Martin, R., M. Muûls, L. B. De Preux, and U. J. Wagner (2014): "On the empirical content of carbon leakage criteria in the EU Emissions Trading Scheme", *Ecological Economics*, 105, 78–88.

Martin, R., M. Muûls, and U. Wagner (2013): "Carbon markets, carbon prices and innovation: Evidence from interviews with managers", in *Annual Meetings of the American Economic Association, San Diego*. Citeseer.

Martin, R., M. Muûls, and U. J. Wagner (2020): "The impact of the European Union Emissions Trading Scheme on regulated firms: what is the evidence after ten years?", *Review of environmental economics and policy*.

Martinez-Carrascal, C., and A. Ferrando (2008): *The Impact of Financial Position on Investment: An Analysis for Non-financial Corporations in the Euro-area*. Banco de España.

Martinsson, G., L. Sajtos, P. Strömberg, and C. Thomann (2024): "The Effect of Carbon Pricing on Firm Emissions: Evidence from the Swedish CO_2 Tax", *The Review of Financial Studies*, 37(6), 1848–1886.

Modigliani, F., and M. H. Miller (1958): "The cost of capital, corporation finance and the theory of investment", *The American economic review*, 48(3), 261–297.

——— (1963): "Corporate income taxes and the cost of capital: a correction", *The American economic review*, 53(3), 433–443.

Mosk, B., A. Pietsch, L. Cappiello, and S. Kapadia (2023): "Debt overhang, investment and the role of market-based finance: a micro data approach", *Mimeo*.

Myers, S. C. (1977): "Determinants of corporate borrowing", *Journal of financial economics*, 5(2), 147–175.

Naegele, H., and A. Zaklan (2019): "Does the EU ETS cause carbon leakage in European manufacturing?", *Journal of Environmental Economics and Management*, 93, 125–147.

Nordhaus, W. D. (1991): "To slow or not to slow: the economics of the greenhouse effect", *The economic journal*, 101(407), 920–937.

——— (2017): "Revisiting the social cost of carbon", *Proceedings of the National Academy of Sciences*, 114(7), 1518–1523.

Olley, S., and A. Pakes (1992): "The dynamics of productivity in the telecommunications equipment industry", .

Perman, R., Y. Ma, M. Common, D. Maddison, and J. McGilvray (2011): *Natural resource and environmental economics*. 4th edn.

Petrick, S., and U. J. Wagner (2014): "The impact of carbon trading on industry: Evidence from German manufacturing firms", *Available at SSRN 2389800*.

Philippe, A., L. Boneva, J. Breckenfelder, L. Laeven, C. Olovsson, A. Popov, and E. Rancoita (2022): "Financial Markets and Green Innovation", *ECB Working Paper Series No 2686*.

Pietsch, A., and D. Salakhova (2022): "Pricing of green bonds - drivers and dynamics of the greenium", *ECB Working Paper Series*.

Polzin, F., and M. Sanders (2020): "How to finance the transition to low-carbon energy in Europe?", *Energy Policy*, 147(111863).

Rajan, R., and L. Zingales (1996): "Financial dependence and growth", .

Ross, S. A. (1977): "The determination of financial structure: the incentive-signalling approach", *The bell journal of economics*, pp. 23–40.

Sfrappini, E. (2024): "Financial Constraints and Emission Intensity", *mimeo*.

Wagner, U. J., M. Muûls, R. Martin, and J. Colmer (2013): "An evaluation of the impact of the EU emissions trading system on the industrial sector. Plant-level evidence from France", in *AERE Conference. Banff, Canada*.

Xu, Q., and T. Kim (2022): "Financial constraints and corporate environmental policies", *The Review of Financial Studies*, 35(2), 576–635.

A Appendix

A.1 Additional descriptive statistics

Table 5: List of variables

Variable	Description	Source
Economic Variables		
Debt-to-assets	Ratio of total debt on total assets winsorized at 99% level.	Constructed
(Debt-to-assets)^2	Squared debt to assets.	Constructed
Total debt	Total debt at unconsolidated level.	Orbis
Total assets	Total assets at unconsolidated level.	Orbis
ln(Revenues)	Natural logarithm of sales and other operating revenues.	Orbis
ROA	Ratio of net income on total assets.	Orbis
Green debt	Dummy indicating whether the company has issued green bonds or taken green loans.	Bloomberg
Age	Difference between a given year and year of incorporation.	Orbis
Sector	Sector of economic activity (NACE Revision 2) of the company.	Orbis
Country	Country where the firm is registered and is primarily conducting business.	Orbis
Emission Variables		
ln(Rev./Em.)	Natural logarithm of the ratio of total revenues on ETS emissions of the company.	Constructed
ln(Emissions)	Natural logarithm of the total ETS emissions of the company.	Constructed
ETS emissions	Sum of ETS emissions of the installations owned by the company.	EUTL
EUA balance	Difference between EUAs allocated to the company and its verified emissions.	Constructed
EUA balance cumul.	Difference between EUAs allocated to the company and its verified emissions (cumulative).	Constructed
EUA	Sum of free EU ETS allowances allocated to the installations owned by the company.	EUTL
Installations	Number of EU ETS installations owned by the company.	Constructed - EUTL
Carbon leakage list	Dummy indicating whether the company operates in a sector included within the carbon leakage list in a given year.	EUTL

Table 6: Summary statistics of relevant variables

Notes: The table shows the sample composition for the entire (unbalanced) sample of firms.

	Count	Mean	Median	Min	Max	Sd
Log(ETS-Emissions)	23,966	10.11	10.09	0.00	17.98	2.22
Log(Revenues/ETS-Emissions)	22,271	7.71	7.69	-23.61	22.49	2.71
Debt/Assets	23,961	0.18	0.09	0.00	0.89	0.22
Log Revenues	22,825	17.88	18.01	11.01	22.75	2.09
ROA	22,045	2.94	2.59	-38.34	34.15	9.66
Number of ETS-installations	23,966	1.67	1.00	1.00	11.00	1.64
EUA balance (EUAs-Emissions)	23,966	-0.19	-0.00	-7.52	1.13	0.99
Age	23,938	32.16	23.00	0.00	333.00	29.02
N	23,966					

Table 7: T-test of relevant variables

Notes: The table shows the t-test for firms that appear every year in the sample from 2013 to 2019.

	t-test on differences between control and treated groups. (mean of control - mean of treated)
Log(Emissions)	-1.213***
	(-36.94)
Log(Revenues/Emissions)	1.035***
	(26.80)
EUA balance	0.620***
	(35.08)
Size	-0.216***
	(-6.83)
ROA	-0.454**
	(-3.27)
Number of ETS-installations	-0.00979
	(-0.33)
Age	1.214**
	(2.65)
N	16947

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 9: EUA prices over time

Notes: Price of EUAs (spot and futures) over time. .

Table 8: Correlations between the variables of interest

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. ln(Emissions)	1.00											
2. ln(Rev./Em.)	-0.49	1.00										
3. Debt-to-assets	-0.08	0.09	1.00									
4. $(\text{Debt-to-assets})^2$	-0.09	0.06	0.93	1.00								
5. ln(Revenues)	0.37	0.63	0.02	-0.01	1.00							
6. ROA	0.03	0.07	-0.17	-0.18	0.10	1.00						
7. Carbon tax flag	-0.12	0.03	-0.01	0.01	-0.07	0.04	1.00					
8. EUA balance	-0.25	0.11	0.01	0.01	-0.11	0.02	0.04	1.00				
9. Fossil fuel subsidies	0.03	-0.18	-0.10	-0.09	-0.16	-0.01	-0.10	-0.05	1.00			
10. Age	0.08	0.13	-0.01	-0.04	0.21	0.04	0.03	0.01	-0.03	1.00		
11. Installations	0.26	-0.04	0.00	-0.01	0.20	0.01	0.05	-0.20	-0.05	0.11	1.00	
12. ln(Total assets)	0.44	0.38	0.06	0.03	0.80	0.06	-0.08	-0.15	-0.19	0.25	0.30	1.00

Table 9: NFCs that have contracted green debt

Notes: Unique number of NFCs that have issued a green bond in our sample between 2013 and 2019. We make a distinction between NFCs that have directly contracted green debt and NFCs that have potentially benefited from green debt because a subsidiary or the head of their corporate group has contracted green debt.

	Green Bonds
NFCs in EU ETS with direct contraction of green debt	11
NFCs in EU ETS with possible indirect contraction of green debt	23
NFCs in Europe	162
NFCs in the World	506

Table 10: Matching estimator performance

Notes: Standardised difference in means for variables used in propensity score matching estimator (size, ROA, number of ETS installations). The exact match is performed on sector, country and equity type.

	Before match			After match		
	Treated	Untreated	StdDif	Treated	Untreated	StdDif
Size	18.06096	17.90833	0.0758249	17.76312	17.47155	0.1448516
ROA	3.117778	1.388919	.1965149	1.953915	2.3492	-0.044931
Number of ETS installations	1.783069	1.881279	-0.0506881	1.806156	1.637247	0.0871771

A.2 Additional results

Table 11: Panel regression for transition performance and leverage: unbalanced sample

Notes: The table shows the result of the panel regression relevant to hypothesis 1 for the two metrics of transition performance: emissions and emissions efficiency. The relationship between transition performance and leverage is tested for the unbalanced data sub-sample of ETS-firms covering the period from 2013 to 2019. Results are both economically and statistically consistent with those observed on the balanced sample, suggesting that the sample selection bias in the estimates is negligible. The implied leverage threshold is also broadly consistent with the one obtained on the balanced sample (40%). Standard errors are indicated in parentheses, they are clustered at the firm level. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10. All controls are lagged by one year (i.e., taken at time $t-1$) apart from age.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
Leverage 2012	-1.03**	1.51***				
	(0.41)	(0.46)				
Leverage 2012 squared	1.13*	-1.78**				
	(0.65)	(0.71)				
Leverage 1y-lagged			-1.07***	1.89***		
			(0.30)	(0.38)		
Leverage 1y-lagged squared			1.34***	-2.20***		
			(0.46)	(0.55)		
Leverage 2y-lagged					-1.05***	1.67***
					(0.32)	(0.39)
Leverage 2y-lagged squared					1.29***	-1.98***
					(0.48)	(0.56)
Size	0.59***		0.53***		0.54***	
	(0.026)		(0.023)		(0.025)	
Profitability	-0.0014	0.015***	-0.00056	0.017***	-0.00062	0.014***
	(0.0025)	(0.0031)	(0.0022)	(0.0032)	(0.0023)	(0.0029)
Number of ETS-installations	0.23***	-0.089***	0.26***	-0.092***	0.25***	-0.087***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
EUA balance	-0.49***	0.34***	-0.53***	0.34***	-0.51***	0.34***
	(0.034)	(0.038)	(0.032)	(0.036)	(0.031)	(0.035)
Age	-0.00097	0.0042***	0.00016	0.0036***	0.00034	0.0032***
	(0.0011)	(0.0013)	(0.00099)	(0.0011)	(0.0010)	(0.0012)
Constant	-0.62	7.50***	0.29	7.57***	0.025	7.64***
	(0.44)	(0.082)	(0.40)	(0.083)	(0.43)	(0.081)
Country-Sector-Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,402	15,983	20,153	19,600	16,501	16,050
R-squared	0.626	0.489	0.594	0.431	0.601	0.453

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Difference-in-differences on emissions and emissions efficiency: unbalanced sample

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on an unbalanced sample covering the years 2013 to 2019. Results on emissions are both economically and statistically consistent with those observed in the same analysis on the balanced sample, suggesting that the sample selection bias in these estimates is negligible. Results on emission efficiency in column (4) show a lower statistical significance than those observed in the baseline analysis on the balanced sample. After the event, some highly indebted firms might drop out of the sample due to bankruptcy. This would be accompanied by a decreasing economic activity, characterized by both low emissions and low revenues resulting in higher emission efficiency for some and lower for other firms, in turn, introducing a confounding effect in the analysis. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
$Treated \times Event$	-0.059**	0.021	-0.072***	0.048	-0.12***	0.12
	(0.026)	(0.077)	(0.027)	(0.087)	(0.036)	(0.077)
$Leverageabovethreshold \times Event$			-0.083	0.057		
			(0.051)	(0.075)		
$Leverageabovethreshold \times Treated \times Event$			0.078	-0.17		
			(0.075)	(0.11)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					-0.13*	0.11
					(0.076)	(0.095)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.20*	-0.32**
					(0.10)	(0.13)
Size	0.057***		0.057***		0.072***	1.02***
	(0.014)		(0.014)		(0.020)	(0.16)
Profitability	0.0014	0.0084***	0.0014	0.0085***	0.0020*	-0.0039**
	(0.00089)	(0.0025)	(0.00088)	(0.0025)	(0.0010)	(0.0016)
Number of ETS-installations	0.19***	-0.099	0.19***	-0.100	0.18***	-0.18***
	(0.038)	(0.077)	(0.038)	(0.077)	(0.041)	(0.069)
Constant	8.81***	7.82***	8.81***	7.82***	8.75***	-10.5***
	(0.25)	(0.13)	(0.25)	(0.13)	(0.37)	(2.88)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,968	19,410	19,968	19,410	13,528	13,150
R-squared	0.968	0.848	0.968	0.848	0.968	0.885

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Difference-in-differences on emissions and emissions efficiency: firms that are excluded from the first carbon leakage list

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample covering the years 2013 to 2019, for firms excluded from the first carbon leakage list produced by the European Commission. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
Treated $\times Event$	-0.067**	0.055	-0.087***	0.098**	-0.085***	0.093**
	(0.029)	(0.037)	(0.029)	(0.039)	(0.030)	(0.044)
Leverage above threshold $\times Treated \times Event$			0.12	-0.24**		
			(0.083)	(0.11)		
Leverage above threshold $\times Event$			-0.076	0.19**		
			(0.068)	(0.098)		
Leverage above threshold $+ \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.14	-0.31**
					(0.10)	(0.15)
Leverage above threshold $+ \frac{1}{2}\sigma_{leverage} \times Event$					-0.092	0.25*
					(0.090)	(0.14)
Size	0.073*		0.074*		0.065	
	(0.038)		(0.039)		(0.040)	
Profitability	-0.00011	0.0053**	-0.00015	0.0053**	0.0010	0.0043
	(0.0010)	(0.0026)	(0.0010)	(0.0026)	(0.00091)	(0.0030)
Number of ETS-installations	0.12**	-0.099	0.12**	-0.096	0.13**	-0.11
	(0.056)	(0.10)	(0.056)	(0.10)	(0.055)	(0.11)
Constant	8.91***	8.13***	8.91***	8.10***	9.15***	7.99***
	(0.71)	(0.17)	(0.72)	(0.17)	(0.74)	(0.19)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,861	7,787	7,861	7,787	6,340	6,280
R-squared	0.979	0.932	0.979	0.933	0.982	0.923

Standard errors clustered at the firm level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: Difference-in-differences on emissions and emissions efficiency: robustness to the use of a different implied leverage threshold measure.

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
Treated $\times Event$	-0.086***	0.12	-0.11***	0.16*	-0.12***	0.18*
	(0.028)	(0.076)	(0.032)	(0.087)	(0.035)	(0.10)
Leverage above threshold $\times Treated \times Event$			0.13*	-0.27**		
			(0.080)	(0.11)		
Leverage above threshold $\times Event$			-0.12**	0.15*		
			(0.055)	(0.078)		
Leverage above threshold + $\frac{1}{2}\sigma_{leverage}$ $\times Treated \times Event$					0.20*	-0.40**
					(0.11)	(0.16)
Leverage above threshold + $\frac{1}{2}\sigma_{leverage}$ $\times Event$					-0.13	0.19*
					(0.079)	(0.11)
Size	0.061***		0.062***		0.045**	
	(0.020)		(0.020)		(0.018)	
Profitability	-0.0017*	0.0070***	-0.0017*	0.0071***	-0.00058	0.0070**
	(0.0010)	(0.0024)	(0.00100)	(0.0025)	(0.00095)	(0.0029)
Number of ETS installations	0.16***	-0.094	0.16***	-0.096	0.17***	-0.10
	(0.042)	(0.078)	(0.042)	(0.078)	(0.044)	(0.088)
Constant	9.04***	7.70***	9.04***	7.68***	9.39***	7.56***
	(0.37)	(0.15)	(0.37)	(0.15)	(0.34)	(0.17)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,154	14,041	14,154	14,041	11,673	11,583
R-squared	0.973	0.882	0.973	0.882	0.974	0.866

Standard errors clustered at the firm level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 15: Difference-in-differences on emissions and emissions efficiency: robustness to the use of a matching estimator.

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced and matched sample covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

Variables	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
Treated $\times Event$	-0.068**	0.14	-0.10***	0.12	-0.10***	0.13
	(0.029)	(0.095)	(0.033)	(0.094)	(0.035)	(0.11)
LeverageAbove $\times Treated \times Event$			0.19**	-0.28**		
			(0.079)	(0.12)		
LeverageAbove $\times Event$			-0.063	0.025		
			(0.054)	(0.076)		
LeverageAbove + $\frac{1}{2}\sigma_{leverage}$ $\times Treated \times Event$					0.24**	-0.30**
					(0.11)	(0.15)
LeverageAbove + $\frac{1}{2}\sigma_{leverage}$ $\times Event$					-0.079	-0.0067
					(0.077)	(0.10)
Size	0.048***		0.050***	1.14***	0.044**	1.20***
	(0.018)		(0.018)	(0.26)	(0.017)	(0.27)
Profitability	-0.00079	0.0049*	-0.00089	-0.0031*	-0.00096	-0.0029
	(0.0011)	(0.0029)	(0.0011)	(0.0019)	(0.0011)	(0.0020)
Number of ETS-installations	0.15***	-0.054	0.15***	-0.14*	0.17***	-0.15*
	(0.057)	(0.095)	(0.057)	(0.076)	(0.050)	(0.077)
Constant	9.17***	7.37***	9.15***	-12.5***	9.29***	-13.7***
	(0.33)	(0.18)	(0.33)	(4.53)	(0.32)	(4.84)
Matched sample	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,964	10,891	10,964	10,881	9,181	9,113
R-squared	0.971	0.846	0.971	0.870	0.972	0.859

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: Difference-in-differences on emissions and emissions efficiency: sub-sample of SMEs.

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample of SMEs covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) SMEs ln(Emissions)	(2) SMEs ln(Revenues/Emissions)	(3) SMEs ln(Emissions)	(4) SMEs ln(Revenues/Emissions)	(5) SMEs ln(Emissions)	(6) SMEs ln(Revenues/Emissions)
$Treated \times Event$	-0.16**	0.41**	-0.19***	0.47**	-0.20**	0.52**
	(0.063)	(0.18)	(0.068)	(0.19)	(0.076)	(0.22)
$Treated \times LeverageAbove \times Event$			0.13	-0.38		
			(0.18)	(0.26)		
$LeverageAbove \times Event$			-0.23*	0.24		
			(0.13)	(0.16)		
$LeverageAbove + \frac{1}{2}\sigma_{leverage} \times Event$					-0.29	0.23
					(0.22)	(0.27)
$Treated \times LeverageAbove + \frac{1}{2}\sigma_{leverage} \times Event$					0.28	-0.55
					(0.24)	(0.38)
Size	0.12**		0.12**		0.068**	
	(0.049)		(0.048)		(0.034)	
ROA	-0.0044	0.013**	-0.0043	0.014**	-0.0022	0.017**
	(0.0028)	(0.0063)	(0.0027)	(0.0064)	(0.0027)	(0.0084)
Number of ETS installations	0.33***	-0.14	0.33***	-0.15	0.36***	-0.16
	(0.12)	(0.25)	(0.12)	(0.25)	(0.12)	(0.27)
Constant	7.01***	6.80***	7.04***	6.77***	7.95***	6.64***
	(0.80)	(0.37)	(0.79)	(0.37)	(0.58)	(0.41)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,833	4,787	4,833	4,787	4,102	4,067
R-squared	0.953	0.804	0.953	0.804	0.954	0.782

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 17: Difference-in-differences on emissions and emissions efficiency: sub-sample of large firms.

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample of large firms covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) Large ln(Emissions)	(2) Large ln(Revenues/Emissions)	(3) Large ln(Emissions)	(4) Large ln(Revenues/Emissions)	(5) Large ln(Emissions)	(6) Large ln(Revenues/Emissions)
$Treated \times Event$	-0.068**	-0.00043	-0.092***	0.037	-0.10***	0.045
	(0.030)	(0.092)	(0.034)	(0.11)	(0.038)	(0.12)
$Treated \times LeverageAbove \times Event$			0.12*	-0.19		
			(0.073)	(0.13)		
$LeverageAbove \times Event$			-0.021	0.071		
			(0.045)	(0.096)		
$Treated \times LeverageAbove + \frac{1}{2}\sigma_{leverage} \times Event$					0.18*	-0.35**
					(0.094)	(0.17)
$LeverageAbove + \frac{1}{2}\sigma_{leverage} \times Event$					-0.017	0.13
					(0.056)	(0.13)
Size	0.057***		0.057***		0.058***	
	(0.019)		(0.019)		(0.020)	
ROA	-0.00079	0.0029	-0.00085	0.0029*	-0.00032	0.0018
	(0.00092)	(0.0018)	(0.00092)	(0.0018)	(0.00087)	(0.0020)
Number of ETS installations	0.085**	-0.021	0.084**	-0.021	0.089**	-0.021
	(0.037)	(0.054)	(0.037)	(0.054)	(0.038)	(0.060)
Constant	9.78***	8.04***	9.79***	8.03***	9.84***	7.93***
	(0.36)	(0.11)	(0.36)	(0.11)	(0.38)	(0.13)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,637	8,587	8,637	8,587	6,997	6,956
R-squared	0.979	0.927	0.979	0.927	0.980	0.918

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 18: Difference-in-differences on emissions and emissions efficiency: sub-sample of firms with privately held equity

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) Private firms ln(Emissions)	(2) Private firms ln(Revenues/Emissions)	(3) Private firms ln(Emissions)	(4) Private firms ln(Revenues/Emissions)	(5) Private firms ln(Emissions)	(6) Private firms ln(Revenues/Emissions)
$Treated \times Event$	-0.078***	0.11	-0.11***	0.17*	-0.11***	0.18*
	(0.029)	(0.079)	(0.032)	(0.091)	(0.035)	(0.11)
$LeverageAbove \times Treated \times Event$			0.16**	-0.30***		
			(0.075)	(0.11)		
$LeverageAbove \times Event$			-0.11**	0.15*		
			(0.056)	(0.080)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.19*	-0.40**
					(0.11)	(0.16)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					-0.13	0.19
					(0.080)	(0.11)
Size	0.053***		0.054***		0.043**	
	(0.020)		(0.020)		(0.019)	
ROA	-0.0014	0.0069***	-0.0014	0.0070***	-0.00077	0.0072**
	(0.00097)	(0.0025)	(0.00097)	(0.0025)	(0.00098)	(0.0029)
Number of ETS installations	0.17***	-0.12	0.17***	-0.12	0.18***	-0.13
	(0.046)	(0.086)	(0.046)	(0.086)	(0.048)	(0.096)
Constant	9.13***	7.70***	9.13***	7.68***	9.36***	7.57***
	(0.37)	(0.16)	(0.37)	(0.16)	(0.35)	(0.18)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,478	13,368	13,478	13,368	11,178	11,089
R-squared	0.974	0.879	0.974	0.879	0.974	0.865

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 19: Difference-in-differences on emissions and emissions efficiency: sub-sample of firms with listed equity

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sample covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) Listed ln(Emissions)	(2) Listed ln(Revenues/Emissions)	(3) Listed ln(Emissions)	(4) Listed ln(Revenues/Emissions)	(5) Listed ln(Emissions)	(6) Listed ln(Revenues/Emissions)
$Treated \times Event$	-0.97	1.03*	-1.17*	1.25*	-1.56	1.76
	(0.59)	(0.61)	(0.69)	(0.70)	(1.24)	(1.30)
$LeverageAbove \times Treated \times Event$			1.55**	-1.37**		
			(0.73)	(0.67)		
$LeverageAbove \times Event$			-0.67	0.79		
			(0.57)	(0.50)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.61	-0.87*
					(0.58)	(0.49)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					0.17	0.27
					(0.11)	(0.22)
Size	-0.029		0.034		0.016	
	(0.062)		(0.043)		(0.031)	
ROA	-0.0019	0.017	-0.0022	0.015	-0.0078	0.024
	(0.0068)	(0.014)	(0.0077)	(0.014)	(0.0091)	(0.018)
Number of ETS installations	0.023	0.19	0.036	0.19	0.075**	0.20
	(0.070)	(0.25)	(0.059)	(0.25)	(0.028)	(0.27)
Constant	12.7***	7.18***	11.6***	7.04***	12.5***	6.89***
	(1.37)	(0.88)	(0.97)	(0.91)	(1.10)	(1.23)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	317	311	317	311	211	204
R-squared	0.986	0.978	0.986	0.979	0.980	0.967

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 20: Difference-in-differences on emissions and emissions efficiency: sub-sample of firms in electricity sector

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sub-sample of firms in the electricity sector (NACE 2-digits 35) covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
$Treated \times Event$	-0.11	0.24*	-0.15*	0.30**	-0.16**	0.36**
	(0.067)	(0.14)	(0.077)	(0.15)	(0.083)	(0.17)
$LeverageAbove \times Treated \times Event$			0.15	-0.30		
			(0.19)	(0.21)		
$LeverageAbove \times Event$			-0.17	0.20		
			(0.12)	(0.14)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.34	-0.42
					(0.26)	(0.28)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					-0.23	0.21
					(0.18)	(0.21)
Size	0.053		0.055*		0.020	
	(0.034)		(0.034)		(0.023)	
ROA	-0.0019	0.0076	-0.0019	0.0077	-0.00025	0.0095
	(0.0024)	(0.0053)	(0.0024)	(0.0053)	(0.0023)	(0.0063)
Number of ETS installations	0.22***	-0.14	0.22***	-0.15	0.25***	-0.15
	(0.067)	(0.12)	(0.068)	(0.12)	(0.075)	(0.15)
Constant	8.83***	6.94***	8.82***	6.92***	9.44***	6.78***
	(0.58)	(0.32)	(0.58)	(0.32)	(0.43)	(0.37)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,682	4,662	4,682	4,662	3,987	3,970
R-squared	0.966	0.845	0.966	0.845	0.967	0.833

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 21: Difference-in-differences on emissions and emissions efficiency: sub-sample of firms in the sectors of metals, non-metals, chemicals and petroleum products

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sub-sample of firms in the sectors of metals, non-metals, chemicals and petroleum products (NACE 2-digits 19 to 25) covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
$Treated \times Event$	-0.084***	0.058**	-0.099***	0.081***	-0.11***	0.082**
	(0.025)	(0.029)	(0.028)	(0.031)	(0.030)	(0.035)
$LeverageAbove \times Treated \times Event$			0.085	-0.14*		
			(0.056)	(0.074)		
$LeverageAbove \times Event$			-0.026	-0.00056		
			(0.035)	(0.037)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.099	-0.21*
					(0.077)	(0.12)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					-0.059	0.0036
					(0.042)	(0.049)
Size	0.13***		0.13***		0.12***	
	(0.044)		(0.044)		(0.045)	
ROA	0.00078	0.00088	0.00072	0.00096	0.0013	-0.00030
	(0.0010)	(0.0016)	(0.0010)	(0.0016)	(0.00092)	(0.0016)
Number of ETS installations	0.085***	-0.025	0.085***	-0.025	0.095***	-0.037
	(0.029)	(0.024)	(0.029)	(0.024)	(0.029)	(0.025)
Constant	8.55***	7.40***	8.54***	7.40***	8.77***	7.36***
	(0.81)	(0.042)	(0.80)	(0.043)	(0.82)	(0.044)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,179	5,135	5,179	5,135	4,334	4,299
R-squared	0.986	0.972	0.986	0.972	0.985	0.971

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 22: Difference-in-differences on emissions and emissions efficiency: sub-sample of firms with other sectors

Notes: The table shows the result of the difference-in-differences regression. The analysis is performed on a balanced sub-sample of firms in all sectors excluding (NACE 2-digits from 19 to 25 and 35) covering the years 2013 to 2019. Standard errors are clustered at the firm level, they are indicated in parentheses. All controls are lagged by 1 year. Due to the firm fixed effects the age control drops from the analysis. The statistical significance of the estimated parameters is indicated by *** for a p-value of less than 0.01, ** for a p-value of less than 0.05, and * for a p-value of less than 0.10.

VARIABLES	(1) ln(Emissions)	(2) ln(Revenues/Emissions)	(3) ln(Emissions)	(4) ln(Revenues/Emissions)	(5) ln(Emissions)	(6) ln(Revenues/Emissions)
$Treated \times Event$	-0.12**	0.21	-0.15***	0.27	-0.15***	0.26
	(0.050)	(0.19)	(0.054)	(0.23)	(0.058)	(0.26)
$LeverageAbove \times Treated \times Event$			0.18*	-0.35		
			(0.11)	(0.25)		
$LeverageAbove \times Event$			-0.23**	0.23		
			(0.10)	(0.18)		
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Treated \times Event$					0.097	-0.31
					(0.15)	(0.30)
$Leverageabovethreshold + \frac{1}{2}\sigma_{leverage} \times Event$					-0.22*	0.26
					(0.13)	(0.22)
Size	0.026		0.028		0.023	
	(0.026)		(0.026)		(0.027)	
ROA	-0.0029*	0.013***	-0.0028*	0.013***	-0.0016	0.014**
	(0.0017)	(0.0049)	(0.0017)	(0.0050)	(0.0018)	(0.0057)
Number of ETS installations	0.18***	-0.18	0.17***	-0.18	0.16**	-0.18
	(0.059)	(0.18)	(0.059)	(0.18)	(0.064)	(0.20)
Constant	9.27***	8.89***	9.27***	8.86***	9.48***	8.77***
	(0.48)	(0.30)	(0.48)	(0.31)	(0.50)	(0.35)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,775	4,734	4,775	4,734	3,965	3,932
R-squared	0.965	0.810	0.965	0.811	0.966	0.793

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 10: Market-Based Debt as a Share of Total Debt for Non-Financial Corporations by Country and Year

Notes: Ratio of total market-based debt to total debt of NFCs, by country of registration and year. Market-based debt includes bonds and other tradable instruments, while non-market-based debt primarily reflects bank lending. While European firms predominantly rely on non-market-based debt, variation in the use of market-based debt provides insights into firms' exposure to financial market conditions and potential investor pressure. The red line shows the trend for the respective country, while grey lines represent all other countries. The average market-based debt share across countries and years is approximately 11%; Maximum value is approximately 20%, observed in France.The countries with the most observations in our sample are France, Germany, Poland, Spain, and Sweden.