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Climate Risk and Firm Financial Performance: The Case of Slovenia

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Abstract

This paper explores how climate transition risk relates to firm financial performance and the cost of financing, using firm-level data in Slovenia for the 2014–2021 period. The effect of climate transition risk as a driver of financial performance is expected to increase in the forthcoming energy transition. Our results show that there is a negative effect of emissions and emission intensity on profit ratios, though the overall magnitude is small. The results also show that there are some segments that have so far been shielded from these effects. This is due to confounding factors such as market power or productivity. Finally, we find that climate transition risk were not priced into firms' financing costs in the 2014–2021 period, as the spread on newly approved loans for high-emitters was not higher than the spread for low emitters. The results show that firms may already have an incentive to decarbonise today, as climate risk affects financial performance negatively. Tighter financing conditions for high-emitters may increase the risks for these firms in the green transition.

Povzetek

V članku analiziramo vpliv podnebnih tranzicijskih tveganj na poslovanje in stroške financiranja nefinančnih družb (NFD) na podlagi mikro podatkov NFD v Sloveniji v obdobju 2014-2021. Pričakujemo lahko, da se bo vpliv podnebnih tveganj na poslovanje NFD v prihajajočem zelenem prehodu povečal. Ugotovitve kažejo, da je vpliv emisij in emisijske intenzitete NFD na njihovo poslovanje negativen, vendar je velikost vpliva majhna. Rezultati prav tako kažejo, da nekateri segmenti NFD, tem učinkom niso bili izpostavljeni, predvsem zaradi vpliva dejavnikov, kot npr. tržna moč ali produktivnost. V raziskavi ugotavljamo tudi, da podnebna tveganja v obdobju 2014-2021 še niso bila vključena v stroške financiranja NFD, npr. z višjim pribitkom za novoodobrena posojila NFD, ki bolj onesnažujejo okolje, v primerjavi s pribitkom NFD, ki okolje onesnažujejo manj. Rezultati kažejo, da lahko že danes obstaja spodbuda za razogljičevanje poslovanja NFD, saj lahko podnebna tveganja negativno vplivajo na finančni rezultat NFD. S strožjimi pogoji financiranja za NFD, ki bolj onesnažujejo okolje se lahko tekom zelenega prehoda tveganja za te NFD dodatno povečajo.

1 Introduction

Moving towards a low-carbon economy and meeting the goals of the Paris Agreement, which are to substantially reduce global greenhouse gas (GHG) emissions and limit the global temperature increase to 1.5 degrees by 2050, is one of the most important tasks we face today. Global carbon dioxide (CO2) emissions are following a decade-long upward trend. While emissions shrank by more than 5% in 2020, as the Covid-19 pandemic cut energy demand, they continued to rise by more than 6% in 2021 and by 0.9% in 2022, reaching a new all-time high of 36.8 Gt (IEA, 2023). In recent years, the need to contain climate risks has brought many regulatory responses, placing increasing social and economic pressure on all economic agents: firms, the financial system, consumers and governments. The carbon performance of firms has become increasingly important and there is an ever-greater need for firms to properly identify, measure and manage climate risks, and disclose their risks to the public. The regulatory pressure on the banking sector has also increased, since banks play an important role in the transition towards a greener economy through the support they provide firms in their investment decisions and growth. It is vital for banks to integrate climate and environmental risks into their risk management frameworks. Climate-related and environmental risks are at the core of global risks today, and will remain so over the next decade. However, as the window for transition to a low-carbon economy is shrinking (World Economic Forum, 2023), more effort will need to be made to align firms' business operations with the Paris Agreement.

This paper focuses on climate risks from the perspective of transition risks. Climate risks fall broadly into two categories: physical risks (including severe or more frequent weather disruptions, such as floods, storms and droughts) and transition risks, which arise from the uncertainty of the path towards a low-carbon economy. Transition risks bring many challenges to firms, particularly to those operating in high-carbon sectors as they can erode valuations, increase operating expenses (due to carbon pricing and regulation), and lead to balance-sheet deterioration as a result of the lower value of collateral, or even stranded assets (Eren et al., 2022). In the literature, carbon risk refers to the impact of the transition to a low-carbon economy on firm values arising from uncertainty in the transition process from a brown to a green economy and includes policy and legal, technology, market and reputational factors (Fulton and Weber, 2015; Görgen et al., 2020; Wang et. al, 2022). Trinks et al. (2022) refer to carbon risk as regulatory and market risk incurred by high-emission firms during the transition from a high-carbon to a low-carbon economy. Nevertheless, it is crucial to also assess the risks stemming from physical risks, which are arguably more contentious to estimate, while studies on the link between physical risks and financial performance remain scarce.

This paper aims to contribute to a growing body of literature on climate finance that explores the relationship between climate transition risk and financial performance. Studies have found that reducing carbon emissions increases firms' financial performance (Busch and Lewandowski, 2017; van Emous et. al., 2021). Various studies have also found that firms in high-polluting activities or those with higher emission intensity have higher debt financing costs and a higher interest rate spread for new bank loans (Nandy and Lodh, 2012; Jung et al., 2018; Ehlers et al., 2022). Carbon risk may also subsequently lead to higher credit risks, considering a negative impact of emissions on financial performance. Studies find a firm with greater exposure to climate transition risk is more likely to default on its debt (Kabir et al., 2021a; Capasso et al., 2020), which implies that financial markets are increasingly pricing climate change risks in. However, the literature on the link between climate risk and financial performance is subject to various caveats. Data providers may differ in their definitions of environmental score, leading to potential inconsistencies in climate risk measurements, while data on emissions may differ substantially across various data providers and studies.

The purpose of this paper is to study the impact of firm climate transition risk on financial performance by using firm carbon emissions data to proxy for climate transition risk and firm-level financial statements and bank loans data to capture firms' financial performance. To study the relationship between firm climate transition risk and financial performance, we construct a granular dataset that includes information on firm-level carbon emissions, data from firms' financial statements and loan-level data reported by monetary financial institutions in Slovenia. One of the challenges in measuring climate transition risk is obtaining firm-level carbon emissions data, since it not is included in firms' financial statements. In the paper, we use information on firm-level carbon emissions from the EU Emissions Trading System (ETS) for the firms included in the register, while for the rest of the firms, we estimate their carbon emissions at firm-level. To measure firm financial performance, we use annual firm-level data from the Slovenian business register and the annual financial statements of companies collected by AJPES, which cover all firms operating in Slovenia. Furthermore, we use loan-level data from Banka Slovenije, which covers all bank lending in Slovenia. Our comprehensive matched dataset covers the period from 2014 to 2021.

The main contributions of this paper are the following. First, we explore the relationship between firm climate transition risk and financial performance by using comprehensive firm-level data in Slovenia, while most of the existing studies use small samples of listed firms or shorter sample periods. Second, we explore whether firm access to credit is affected by their emissions and find that firm emissions have almost no effect on loan spread. The main findings of this paper are that a change in firm carbon emissions has a positive impact and the stock of carbon emissions a negative impact on financial performance, as measured through ROA and ROE. This is in line with a positive short-term effect and a negative long-term effect of emissions on financial performance (Delmas et al, 2015). The results also suggest that, in the period analysed, banks did not consider credit risks of high emitters, as they did not associate high emissions with higher credit costs. To understand the impacts of climate risk, policymakers, firms and banks need to consider the relationship between climate risk and firm financial performance. Policymakers need to consider incentives for firms to reduce carbon emissions, as reducing emissions may contribute to lower borrowing costs at banks and therefore better access to finance. However, tighter financing conditions for firms in high-polluting activities may also further increase the risks for these firms in the transition towards a greener economy.

The paper is structured as follows. The literature review is presented in the next section. Section 3 presents the data and variables used in the analysis, with summary statistics. Section 4 outlines the methodological approach taken in the paper. Section 5 presents the results of the analysis. Finally, Section 6 concludes.

2 Literature Review

Higher carbon emissions increase risks in the economy and the financial system due to an inefficiency and an (unpriced) negative externality stemming from excess production and pollution. Corrective policies such as taxes or pollution permits serve to lower emissions through a carbon price which internalizes the carbon externality. Recent studies suggest that financial markets have started to price in carbon risks (Ilhan et al., 2021), which is also evident from higher rates of return associated with a climate risk factor or carbon emissions (Alessi et al., 2020; Bolton and Kacperzyk, 2021). Pastor et al. (2020) for instance posit a theoretical model of asset pricing which includes a green factor, also known as the PST model. In equilibrium, green assets have lower expected returns as they hedge climate risks. This suggests the existence of a carbon risk premium (Bolton and Kacperzyk, 2021), or a negative Greenium, i.e. a risk premium linked to firms' greenness and environmental transparency (Alessi et al., 2020), as investors accept lower returns for carbon risk hedging.

Empirical studies suggest the existence of a carbon risk premium across various geographies. Bolton and Kacperzyk (2022) examine a sample of stock returns for firms across three continents (North America, Europe, Asia), and find a carbon risk premium for both short- and long-term carbon risk, estimated through the effect on stock returns of the change or the level of carbon emissions respectively. Alessi et al. (2020) estimate the CAPM adding a green factor, based on the difference in returns of a green and brown portfolio, and find a lower return for holding assets, which correlate positively with the green factor of around 7–10% p.a., which suggests the existence of a Greenium. In other words, investors are willing to forego returns for holding assets, which correlate positively with the green factor, based on greenness and transparency indicators. Pastor et al. (2022) posit a carbon risk premium, though they also find that green assets outperform brown assets with an increase in the underlying ESG factor in an empirical study of the PST model (Pastor et al, 2020), which suggests a difference between expected and realised returns. In a recent study, Jung et al. (2021) also find positive climate betas estimated by adding a climate risk factor to the CAPM model based on the returns of a stranded asset portfolio.

The results are driven by various factors, as carbon risk hedging implies a higher carbon risk premium, as investors are willing to accept lower returns on green assets to hedge carbon risks. Conversely, growing demand for green assets due to shifts in investor preferences implies a lower carbon risk premium. Gorgen et al. (2020) study the stock returns of a global sample of firms by extending the CAPM for a brown-minus-green (BMG) factor and find no significant outperformance for a portfolio which correlates positively with the BMG factor. The factor is constructed as the difference in returns between a brown and a green portfolio, based on firms' BGS score, which accounts for various aspects of carbon risks, such as value chain, public perception and firms' adaptability to transition-related issues. This suggests the existence of various factors, which affect the pricing of carbon risks in financial markets at present.

Beyond the asset pricing literature, there is a sizeable body of literature that aims to estimate the link between environmental and financial performance. The growing body of literature on the link between carbon and financial performance includes the return on assets (ROA) and Tobin's Q as the most commonly used ratios (Busch and Lewandowski, 2017), in addition to other variables such as the return on equity (ROE) and return on sales (ROS) indicators. An early study by Matsumura et al. (2014) finds that firms with higher emissions have lower firm values. Delmas et al. (2015), for example, analyse the effect of carbon emissions on ROA and Tobin's Q for a sample of US firms and posit that changes in ROA reflect the short-term effect of carbon emissions, while changes in Tobin's Q reflect the long-term effects of carbon emissions on financial performance. Namely, while the ROA is an accounting profitability measure, Tobin's Q reflects the expectations of the stock market on the future profitability and growth of firms (van Emous et al., 2021). Delmas et al. (2015) find a positive short-term effect of carbon emissions on ROA and a negative long-term effect on Tobin's Q, which could explain corporate inertia in undertaking more ambitious carbon emission reductions. A recent replication study (Busch et al., 2022) corroborates the positive short-term effect of carbon emissions on ROA, but finds no effect on Tobin's Q. Van Emous et al. (2021) also find that carbon emissions reduction increases ROA, ROE and ROS, while it has no effect on Tobin's Q or liquidity, measured as a current ratio. Furthermore, an extended analysis (Busch et al., 2022) which includes a broader sample and emission intensity as the carbon risk variable, finds a positive effect of emission intensity on Tobin's Q, suggesting a positive effect of carbon risk on financial performance in both the short and long term.

In addition to measuring horizon effects through the impact on accounting ratios, which are associated with short or long-term changes such as ROA or Tobin's Q respectively, some authors have also assessed the short and long-term effects of carbon risk by distinguishing between the changes and levels of the carbon variable (Lewandowski, 2017; Bolton and Kacperzyk, 2021). Moreover, Lewandowski (2017) finds that the link between carbon performance and financial performance depends on the initial carbon performance. The author estimates a U-shaped relationship between carbon intensity and financial performance as measured through various indicators, including ROA and Tobin's Q. This corroborates the hypothesis of a non-linear relationship between carbon and financial performance, which posits that payoffs are highest at the extremes (Brammer and Millington, 2008). In turn, there is a linear relationship between changes in carbon intensity for ROS and Tobin's Q, with a positive effect of carbon mitigation on ROS and a negative effect on Tobin's Q. Thus, even though improvements in carbon performance may lead to enhancements in financial performance, they are also negatively related to firm value as measured through Tobin's Q. More broadly, the results suggest that improvements in carbon performance would improve financial performance for firms with superior carbon performance (lower emission intensity) to begin with.

Conversely, Ferrat (2021) distinguishes between the short- and long-term effects of carbon performance on financial performance in high- and low-materiality industries, and finds positive effects of improving carbon performance for firms in industries which are more exposed to transition risks. Namely, improving carbon performance, as measured through a composite indicator accounting for emissions and mitigation strategies, leads to worse financial performance in the short term and improved financial performance in the long term solely for firms in high-materiality industries. In a recent study, Bolton and Kacperzyk (2022) analyse stock returns for a global sample of firms, and find evidence for a positive effect of both the level and changes in emissions on firms' stock returns. This indicates a carbon risk premium related to both the short- and long-term element of climate risk, captured by the change and level of emissions, respectively.

Another strand of the literature has examined the effect of carbon risk on the cost of debt financing and credit risk. Various studies find a positive effect on the loan spread for firms in high-polluting activities. Nandy and Lodh (2012) find lower spreads for a sample of loans to US firms with a higher environmental score, based on firms' environmental ranking. Subsequent studies examine the effect of carbon emissions on the cost of debt financing. Jung et al. (2018) examine a sample of Australian firm loan data and find that high emitters have a higher cost of debt financing ranging from 38 and 62 basis points. This is also corroborated in a later study by Kleimeier and Viehs (2018) for a global sample of firms, with the effect driven by environmental risks rather than investor preferences. Ehlers et al. (2022) also find higher spreads for syndicated loans to firms with higher emission intensity primarily in terms of Scope 1 emissions, though the effect is small in magnitude (up to 7 bps).

The cost of debt financing may increase due to climate risks stemming from higher physical risks and exposure to weather-related hazards, beyond the climate risk from higher emissions, which are largely related to transition risks. Javadi and Masum (2021) also find higher spreads for loans to firms in the US with higher exposure to climate risk, specifically drought risk, in the magnitude of around 4.4 percentage points. The effect is driven by firms with poorer credit ratings, particularly over the long run. Kabir et al. (2021b) also find a negative impact of carbon risks expressed through higher carbon emissions or emission intensity on credit ratings for a sample of US firms. The effect is driven by higher cash flow uncertainty, which is broadly aligned with an emission-financial performance channel for climate risks.

Carbon risk may subsequently lead to higher credit risks, considering a negative impact of emissions on financial performance. Several recent studies examine the effect of carbon risk on credit risk expressed through PDs, although the literature on carbon and credit risk remains scarce. Kabir et al. (2021a) find that higher emissions reduce the distance-to-default (DD) in a Merton setting for PDs for a sample of US firms, through a ROA and cash flow volatility channel. They suggest that a firm with greater exposure to climate transition risk is more likely to default on its debt and find results stronger for firms operating in more carbon-intensive industries. Capasso et al. (2020) also find a negative impact of carbon emissions and intensity on the distance to default for a sample of European firms, with an increasing effect following the Paris agreement. This suggests that climate change risks are increasingly priced in by financial markets. Huang et al (2021) find that default rates increased by 80% for a sample of Chinese firms loan data following the introduction of the Clean Air environmental regulation. Umar et al. (2021) also find lower PDs and NPL ratios for banks in the eurozone with higher exposures to carbon-neutral financing. Jung et al. (2021) find that exposures to "brown" industries are positively correlated with the climate betas for a sample of US banks, based on an extension of the CAPM model including a climate factor. Higher climate betas in turn increase climate risk metrics, estimated based on banks' debt, equity exposures and climate betas.

Most of the studies in the growing body of literature on climate finance assess the link between carbon and financial performance in terms of transition risks primarily, while estimates of the link between physical risks and financial performance remain scarce. A few studies have provided early estimates of the financial effects of physical risks. For example, Giglio et al. (2021) posit that real estate is exposed to consumption and climate risk, with real estate prices subject to declines during economic downturns or weather-related hazards. They estimate a price decline of between 2% and 3% for US coastal properties located in a flood zone given an increase in the Climate Risk Attention index, which is constructed based on the frequency of climate change-related words in property listings. Javadi and Masum (2021) find that loan spreads increase for firms, which are more exposed to drought risk. Bolton and Kacperzyk (2022) supplement their analysis of the carbon risk premium by estimating the interaction effects of physical and transition risks on stock returns, measured through a country-level index based on the frequency of climate-related damages and firm emissions. They find that the carbon risk premium cannot be explained by the interaction of physical and transition risks, which may suggest that transition risks are currently more salient to investors than physical risks.

While there has been a proliferation of studies on the link between ESG and financial performance, the body of literature on the link between carbon risk and financial performance is nascent and subject to various caveats. First of all, data providers may differ in their definitions of an environmental score or dimension, thus leading to potential inconsistencies in the construction and measurement of the climate risk factor in asset pricing. Second, emission data may differ substantially across the various data providers used across studies. Third, studies differ in terms of their coverage in terms of emission scope (direct and indirect emissions), time period and geographies. Fourth, it is also crucial to assess the risks stemming from physical risks, which are arguably more contentious to estimate. The growing literature seems to suggest the existence of a carbon risk premium in the stock market, with mixed evidence on the link between carbon and financial performance in terms of accounting ratios. We aim to add to the existing literature by estimating the link between carbon and financial performance of Slovene firms in the 2014–2021 period, specifically by assessing the effects on corporate financial performance (financial ratios) and their access to credit (loan spreads). The latter is revealing of perceived credit risks by banks in relation to climate risk exposure.

3 Data

3.1 Sample and variables

To study the relationship between firm climate risk and financial performance, we construct a granular dataset that combines confidential and public data for Slovene firms between 2014 and 2021. To the best of our knowledge, this is the first paper to explore the link between climate risk and financial performance for Slovene firms, including granular data on emissions and firm loans. We use annual firm-level data from the Slovenian business register and the annual financial statements of companies collected by AJPES, which cover all firms operating in Slovenia. We also use loan-level data from the reporting by monetary financial institutions to Banka Slovenije, which covers all bank lending in Slovenia. Finally, to add a climate risk component, we use public information on emissions and emission intensity at the NACE 2 activity level from Eurostat and firm-level GHG emissions from the EUTL, as information on firm-level carbon emissions is not included in firms' annual reports.

The paper employs a granular as well as a sectoral approach to studying the link between climate risk and financial performance. We follow Battiston et al. (2017) in classifying economic activities into climate policy relevant sectors (CPRS) with the main five climate policy relevant sectors: energy intensive, fossil fuels, utilities, transport and housing. The CPRS classification is regarded as a reference for climate transition risk assessment at EU level. Moreover, we also use a definition of climate-sensitive activities, based on the structure of carbon emissions in Slovenia (Sokolovska, 2020), with climate-sensitive activities defined as activities with the largest share in total carbon emissions. In addition, we also define highly emission-intensive activities, following the approach in the EBA pilot exercise on assessing climate risks (EBA, 2021). Firms in highly emission-intensive (high-polluting) activities are defined as those firms classified in activities with an emission intensity higher than the 75th percentile of the distribution of emission intensity at the NACE 2 activity level in a given year, while firms in other activities are firms that are, in all other activities, defined as less emission-intensive (less-polluting) activities.

The EUTL contains the verified firm-level GHG emissions of firms included in the EU Emissions Trading System (ETS), which sets a cap on the total amount of certain greenhouse gases that can be emitted each year by the entities covered by the system, and is reduced in time so that total emissions fall. The ETS register covers 40% of all emissions in Slovenia. For firms included in the ETS register, we use data on emissions from the ETS register, while for firms that are not included in the ETS register, we estimate the emissions at firm level. For these firms, we impute the value of the emissions across firms using the average emissions per FTE employee for the non-ETS segment of the specific sector and the number of employees for a specific firm. The emissions of the non-ETS segment are calculated as the difference between the emissions reported in Eurostat and the EU ETS emissions at the NACE 2 activity level.

We match carbon emissions data and firm financial data at firm level, where we use annual firm balance sheet data and data from monetary financial institutions. Our matched dataset covers between 34,662 and 41,397 annual observations on firms over the period between 2014 and 2021. The number of observations may vary depending on the regression model. Emissions are defined at firm level, expressed in thousands of tonnes CO2 eq. (expressed in logs). Emission intensity is defined in terms of emissions relative to sales (in grams per euro, expressed in logs) at the NACE 2 activity level. Since policies are typically designed at the sectoral level, this is arguably more representative of firms' transition risks. We use data on firm size, profitability ratios, liquidity, sales, firm leverage, firm productivity and tangibility based on firms' balance sheet data. Firm size is defined across four groups (micro, small, medium-sized and large) based on number of employees, annual turnover and value of assets. Profitability is defined in terms of profit ratios, such as return on assets (ROA), measured as the ratio of net operating profit to total assets, as well as the return on equity (ROE), measured as the ratio of net operating profit to total equity (both in %). The sales variable is defined in terms of the volume of annual turnover (in thousands of EUR, expressed in logs) and not by using net operating profit, which is already used in ROA and ROE, to avoid multicollinearity. Firm leverage is measured as debt-to-asset ratio (in %) and liquidity is measured as the ratio of cash (and cash equivalents) to total assets (in %), where a higher ratio means a firm has more funds available for investments. Finally, we include total factor productivity (TFP) which we estimated using the Levinsohn-Petrin (2003) method (expressed in logs), using a commonly observable variable (costs of material) to control for unobserved productivity. In some specifications, we also include asset tangibility, defined as the ratio of tangible fixed assets to total assets (in %). In the paper, we focus on accounting-based firm characteristics, such as ROA, ROE, etc., and not also on market-based characteristics, such as stock returns or Tobin's Q (also documented in the literature), as the majority of Slovene firms are not listed on the stock exchange.

From reports provided by monetary financial institutions, we use loan-level data on newly approved bank loans to firms, with information on the volume of the loan, the interest rate at origination and the interest rate spread on new loans, to explore the relationship between climate risk and firms' financing costs. The volume of the loan is defined as the total loan amount approved, regardless of how many tranches were drawn. The loan amount was put into dummy for the quartiles of the loan amount of each loan (e.g., loan amount 25 is a dummy for operations in the first quartile of the distribution of loan amounts). Loan maturity is defined at origination and corresponds to the due date of the last loan instalment. Maturity is put into classes (less than 1 year, 1–5 years, over 5 years) and introduced into the regression as a dummy variable. The interest rate is defined at the origination for each loan (fixed or variable rate). We calculate the interest rate spread for new loans only. For variable rate loans, the loan spread is reported, while for the fixed rate loans we calculate loan spread as the difference between the contractual interest rate of the loan and the average value of the 6-month EURIBOR in the month of loan approval.

In our matched firm carbon emission, balance sheet and bank dataset, we reduced the effect of outliers on the regression results by excluding firms with no FTE employees and firms of the 1st and 99th percentile of the distribution of dependent variables ROA and ROE, as well as two other variables, liquidity and total assets in the 1st percentile. We also excluded all firms that have less than 0.5 full-time employees. Table 1 shows the summary statistics for firm balance sheet, bank loan and carbon emissions data for the variables included in the model.

Table 1: **Variables included in the analysis**

Variable	Obs.	Mean	Median	Std. Dev.
A: Firm emission (firm-level)	275,158	162.2	75.2	366.5
B. Firm financial performance (firm-level)				
ROE	309,820	14.3	9.5	49.4
ROA	309,820	0.7	2.9	25.9
Liquidity	309,820	16.1	7.7	19.8
Sales	307,400	5.5	5.4	1.8
Debt-to-assets	309,340	68.8	55.5	140.7
Productivity	257,521	26.0	21.9	16.1
Tangibility	309,820	25.7	15.8	26.8
C. Newly approved bank loans (loan-level)				
Interest rate spread on new loans	226,857	2.9	2.4	1.7

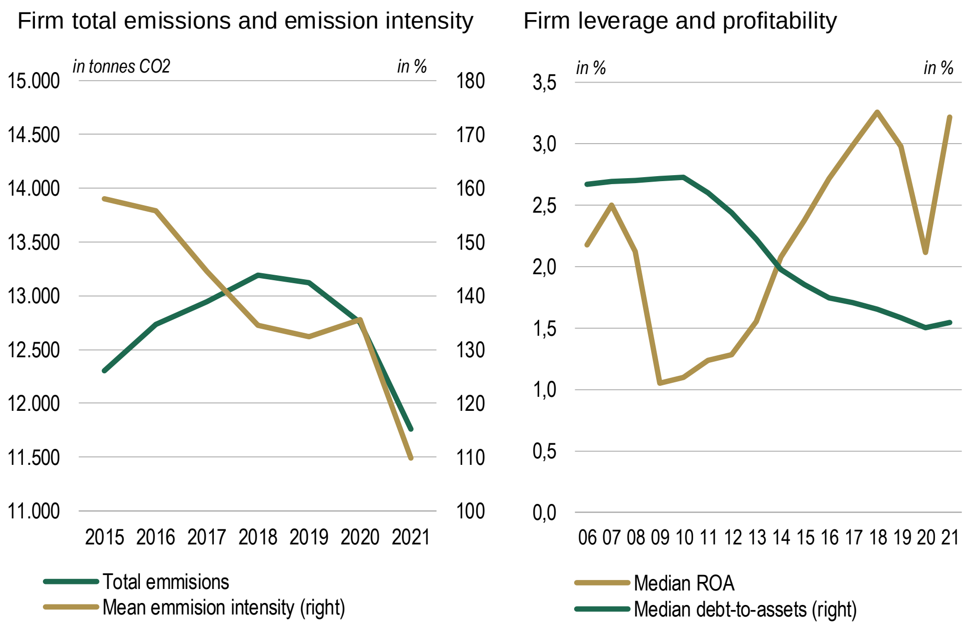
Sources: AJPES, Banka Slovenije, ETS

3.2 Summary statistics

In this section we focus first on firm financial performance and the evolution of firm emissions for firms in climate-sensitive activities (Clim_sens), CPRS firms (CPRS), and firms in high-polluting and less-polluting activities (Emit_int) in the 2006–2021 period. Second, we explore the allocation of bank loans to climate-sensitive firms, CPRS firms and firms in high-polluting and less-polluting activities, while focusing on firm financial performance. Last, we look into the relationship between climate risk and firm financing costs by using interest rate spread on newly approved bank loans to firms in the 2014–2021 period.

Figure 1 (left) shows that firm emissions decreased in the 2015–2021 period, and amounted to 11,761 of tonnes CO2 eq. in 2021. Average firm emission intensity, measured as emissions relative to sales, decreased from 158 grams per euro in 2015 to 110 grams per euro in 2021, while total firm-level emissions decreased by 4.4% in the same period. Figure 1 (right) shows that firm leverage has declined sharply over the last decade in Slovenia, and has remained significantly smaller than during the global financial crisis of 2008. The firm median debt-to-asset ratio decreased from 67.3% in 2010 to 55.5% in 2021. Firm profitability, measured as median ROA, increased to 3.3% in the 2009–2018 period, falling to 2.1% in 2020 and increasing again to 3.2% in 2021. However, firm leverage and profitability can differ greatly between firms in different sectors. For example, construction, which is a climate-sensitive sector, recorded some of the highest figures for median leverage in the period observed (59.7% in 2021), although the figures were down significantly on more than a decade ago (73.6% in 2009). The median ROA for construction firms stood at 2.3% in 2021 (0.7% in 2010).

Figure 1: **Firm total emissions and emission intensity and firm leverage and profitability**



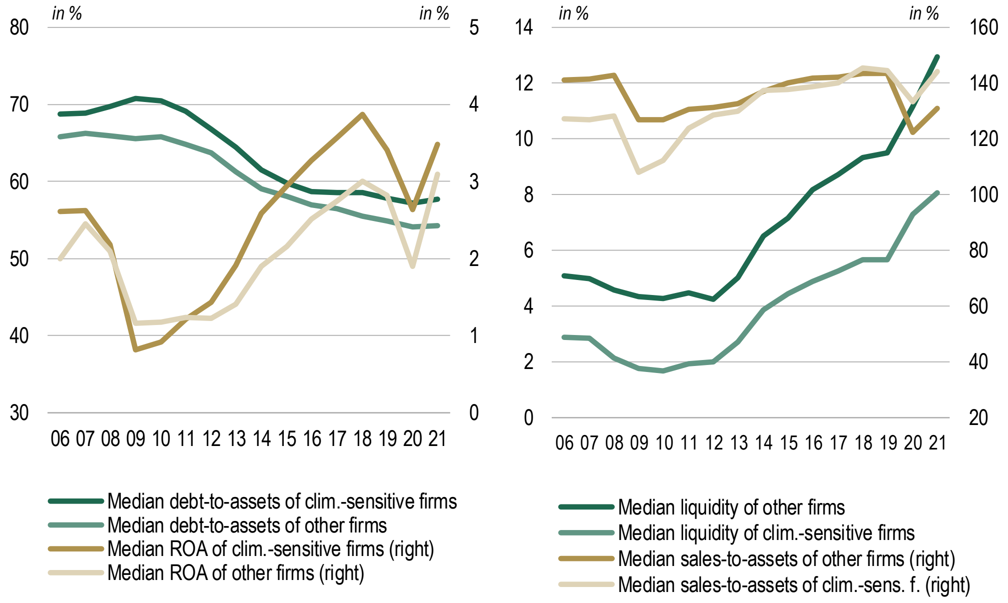
Source: AJPES, ETS

The share of climate-sensitive sectors stood at a third of GDP in 2021, with the share in industry well above the EU average. Figure 2 (left) shows that firms in climate-sensitive sectors were more indebted in the 2006–2021 period than firms in non-climate-sensitive sectors, but that they have had higher profitability since 2011. In 2021 the median debt-to-assets ratio stood at 57.8% at climate-sensitive firms and 54.2% at other firms, while median ROA stood at 3.5% at climate-sensitive firms and 3.1% at other firms. Firms in CPRS were more indebted than other firms in the 2006–2021 period (58.4% and 54.5% respectively, in 2021), while CPRS firms had lower profitability than other firms (3% and 3.3% respectively in 2021). By contrast, firms in high-polluting activities were less indebted than firms in less-polluting activities in the 2015–2021 period (except in 2017), and more profitable in the 2015–2019 period, while their median ROA declined in the last two years and was lower than that of less-polluting firms.

Figure 2: **Firm leverage and profitability and firm liquidity and sales-to-assets**

Firms leverage and profitability in climate-sensitive sectors and other sectors

Firm liquidity and sales-to-assets in climate-sensitive sectors and other sectors



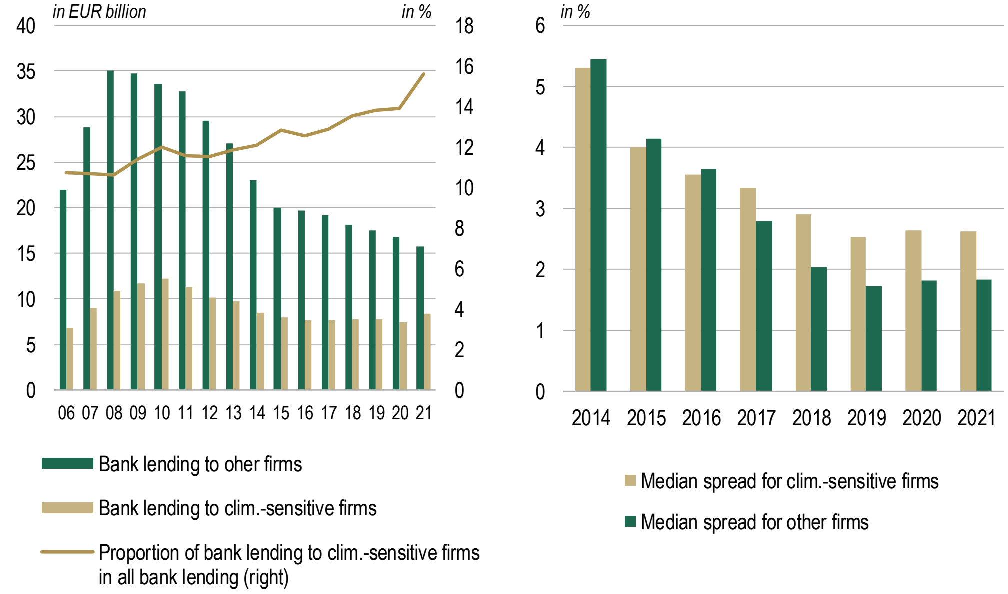
Source: AJPES, ETS

Figure 2 (right) shows that firms in climate-sensitive sectors had lower liquidity than other firms in the 2014–2021 period, with liquidity standing at 8% at climate-sensitive firms and 12.9% at other firms. The median sales-to-assets ratio was similar in both groups for most of the period observed, with the ratio falling at other firms in 2020 and 2021 relative to climate-sensitive firms. CPRS firms were also less liquid than other firms (8.5% and 12.2%, respectively, in 2021), while CPRS firms had a lower sales-to-assets ratio than non-CPRS firms (123.9% and 138%, respectively, in 2021). By contrast, firms in high-polluting activities had a higher median liquidity ratio than other firms in the 2015–2021 period, except in 2017 (11.7% and 11.4%, respectively, in 2021), while their median sales-to-assets ratio was lower (108.9% and 136.3%, respectively, in 2021).

Figure 3: **The volume of bank loans to firms and median spread**

The volume of bank loans to firms in climate sensitive sectors and to other firms

Median spread for climate-sensitive firms and other firms



Source: AJPES, ETS

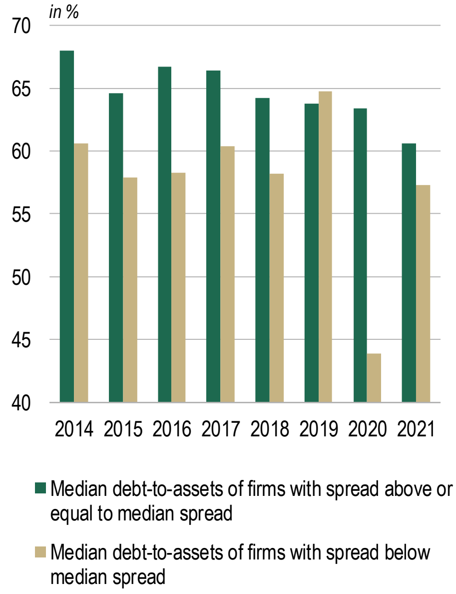
Note: The data on the volume of bank loans in Figure 3 is taken from AJPES and may differ from data on bank loans, used further in the paper, where data is taken from Banka Slovenije bank reporting.

This paper explores bank loans to climate-sensitive firms, CPRS firms and firms in high-polluting and less-polluting activities in the 2014–2021 period. Figure 3 (left) shows that the volume of bank lending (from within and outside Slovenia, based on AJPES data) to firms in climate-sensitive activities remained at a similar level through the period observed, while bank lending to other firms decreased. In 2021 the volume of bank loans stood at EUR 3.8 billion to firms in climate-sensitive activities and EUR 7.1 billion to other firms. The proportion of bank lending to firms in climate-sensitive activities in all bank lending therefore increased from 23.8% in 2006 to 34.7% in 2021. The same applies to bank lending to CPRS firms, with bank lending to CPRS firms increasing from 31% of all bank lending in 2006 to 38.1% of all bank lending in 2021. The volume of bank lending to firms in high-polluting activities stayed at almost the same level from 2015 to 2021, at around EUR 1.7 billion (except in 2017, when it increased to EUR 2.5 billion). However, the proportion of bank lending to firms in high-polluting activities increased over the period observed, from 14.9% in 2014 to 16.1% in 2021. This was due to a fall in bank lending to firms in less-polluting activities. Nevertheless, firms in climate-sensitive activities and firms in other activities both saw a decrease in bank debt between 2014 and 2021, with median firm bank debt-to-assets falling from 19.6% to 4.8% and from 21.9% to 6.4%, respectively.

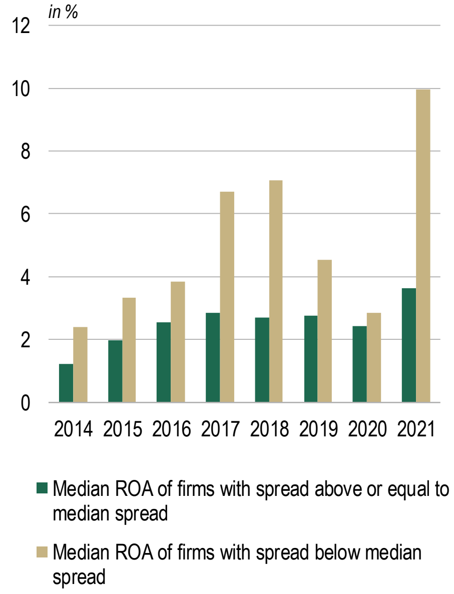
This paper also explores the relationship between climate risk and firm financing costs by using loan-level data contained in reports published by monetary financial institutions, with data on the interest rate spread on newly approved bank loans. Figure 3 (right) shows that the median spread for firms in climate-sensitive activities has been higher than the spread for other firms since 2017, while the median spread was slightly higher for other firms before 2017. In 2021 the median spread was 2.5% for firms in climate-sensitive activities and 2% for other firms. The median spread for firms in high-polluting and less-polluting activities also shows that the spread has been higher for firms in high-polluting activities than for other firms since 2017 (2.5% and 2%, respectively, in 2021). However, the median spread has been higher for CPRS firms than for non-CPRS firms only since 2020 (2.5% and 1.8%, respectively, in 2021).

Figure 4: **Leverage and profitability of firms regarding their spread**

Leverage of firms with spread above or equal and below to median spread



Profitability of firms with spread above or equal and below to median spread



Source: AJPES, ETS

Figure 4 (left) shows firm leverage in the 2014–2021 period was higher for firms with a spread above or equal to the median spread than for firms with a spread below the median spread in a specific year. This suggests that banks charge higher spreads to more indebted firms. Figure 4 (right) shows that banks also charge higher spreads for less profitable firms, since, in the period observed, median ROA was higher for firms with a spread below or equal to the median spread than for firms with a spread higher than the median spread in a specific year. When looking at emissions relative to assets, banks appear to charge higher spreads for firms with higher emissions-to-assets. In 2021 the median emissions-to-assets for firms with a spread above or equal to the median stood at 1.7%, while median emissions-to-assets for firms with a spread below the median spread stood at 0.1%.

This paper explores climate risk in relation to firm financial performance, as well as firm financing costs, based on our matched firm carbon emission, balance sheet and bank dataset. We find that, in recent years, firms in climate-sensitive sectors have been more indebted, more profitable and less liquid. The results also suggest that banks charge a higher spread for more indebted and less profitable firms, although we find there was almost no effect of a higher interest rate spread for newly approved bank loans for firms in climate-sensitive sectors in the 2014–2021 period.

4 Methodology

We describe the estimation approach in the following section. We estimate fixed effects regressions for ROA and ROE, depending on various firm characteristics, including emissions. The main equation is therefore:

$$Profit\_ratio_{it} = \beta_0 + \beta_1 * X_{it} + \beta_2 * E_{it} + Z_i + v_t + \varepsilon_{it}$$

where Xij is a vector of time-varying firm-specific variables, liquidity, debt assets, sales, firm size, productivity, Eit is a climate variable, emissions or emission intensity, and Zi is a vector of controls for industry effects (at the NACE 2 level) and vt stands for year dummies. We estimate the main equation for the total sample, as well as across various climate-sensitivity subsets. These include subsets of firms in highly emission-intensive activities, climate policy-relevant sectors and climate-sensitive activities, as defined based on the structure of emissions in the EU and overall climate policy relevance (Battiston et al., 2017) or the structure of emissions in Slovenia. The regression includes dummies for industry and year effects since running a fixed effects regression would omit the climate sensitivity identification variable, which is constant over time.

We also test for interaction effects between leverage and emissions, as high emissions may impact highly leveraged firms disproportionately in the event of higher transition risks, as these firms are already financially vulnerable to an extent. We add tangibility to the main equation as firms’ fixed assets may also be an important determinant of profit ratios, as these are key for the production capacity of the firm. We also test for the interaction effect between tangibility and emissions, as firms with higher emissions might have higher fixed assets which may affect profit ratios.

The main equation includes an emission variable which is defined as emissions or emission intensity. Emissions are defined at the firm-level, while emission intensity is defined at the sectoral level. Thus, the regression coefficient on emission intensity would reflect the effect on profit ratios of belonging to/operating in a certain industry.

Following Bolton and Kacperzyk (2021), we test for the difference in short- and long-term effects of emissions. This is done by testing the effect of the change in emissions versus the stock of emissions in a given year. The effect of the stock of emissions on profit ratios should reflect the long-term effects of higher emissions, while the effect on profit ratios due to changes in emissions should reflect short-term profit determinants. In addition, emissions and emission intensity might have non-linear effects on profit ratios (Lewandovski, 2017), which may also differ due to market structures. Thus, we test for the existence of non-linear effects by including a square term of emissions or emission intensity in the main equation, which is essentially an (inverse) U-shape curve effect. We specify the main equation for the profit ratio of firm i as follows:

$$Profit\_ratio_{it} = \beta_0 + \beta_1 * X_{it} + \beta_2 * E_{it} + \beta_3 * E_{it}^2 + Z_i + v_t + \varepsilon_{it}$$

Moreover, we test for the existence of non-linear effects across various segments, which would enable us to test whether the effect of emission intensity or emissions on profit ratios is related to confounding factors such as market power or productivity. Market power would for example enable firms to pass on higher transition risks to consumers, while higher productivity would enable firms to offset negative effects on profit ratios from higher transition risks. To model market power, we use a variable which reflects the share of revenues generated by a specific firm in a given industry, defined at NACE 2 level. To test for the effects of market power and productivity, we divide the sample into four quartiles and define segments of high market share and high productivity as segments which include firms whose market shares and productivity in a given year are above the 75th percentile of the distribution of the respective variable.

In addition, we examine the effect of climate variables on firm financing conditions by modelling the effect of firm-specific financial characteristics and climate variables on the spread of loans granted to firms. The equation for the effect of carbon risk on the spread of the loan j is specified as follows:

$$Spread_{jt} = \beta_0 + \beta_1 * X_{it} + \beta_2 * E_{it} + \beta_3 * E_{it}^2 + Z_i + v_t + \varepsilon_{it}$$

5 Results

5.1 Climate risk and firm profitability

The estimates show compelling evidence of a negative effect of emissions on profit ratios (ROE, ROA), albeit modest. The effect ranges from 0.1 to 0.028 unit decline in ROE or between -0.02 to -0.04 unit decline in ROA in case of a 1% increase in emissions. The effect is statistically significant and economically meaningful, as it indicates that a 10% increase in emissions on an annual level could reduce profit ratios by up to

0.4 units. Nevertheless, the estimate shows limited incentive for firms to reduce emissions drastically so far. In addition, the estimates show a positive effect of emissions for firms in highly emission-intensive sectors, with a 1% increase in emissions associated with an increase on average ceteris paribus of 0.01 units in both profit ratios.

Table 2. **Effect of climate risk on ROA**

Model variables/ model	(1) Main	(2) Emit_int	(3) Emit_int_no	(4) CPRS	(5) CPRS_no	(6) Clim_sens	(7) Clim_sens_no	(8) Int1	(9) Int2
Liquidity	0.106***	0.109***	0.109***	0.0882***	0.108***	0.0644***	0.111***	0.102***	0.104***
	(0.00247)	(0.00859)	(0.00251)	(0.00536)	(0.00276)	(0.00460)	(0.00289)	(0.00245)	(0.00258)
Sales	6.301***	6.122***	4.785***	5.175***	6.498***	5.495***	6.372***	6.272***	6.295***
	(0.0639)	(0.358)	(0.0772)	(0.129)	(0.0729)	(0.116)	(0.0752)	(0.0634)	(0.0640)
Debt/assets	-0.0547***	-0.0672***	-0.0587***	-0.128***	-0.0491***	-0.164***	-0.0471***	-0.201***	-0.0547***
	(0.000487)	(0.00184)	(0.000492)	(0.00164)	(0.000516)	(0.00161)	(0.000524)	(0.00232)	(0.000487)
Productivity	0.329***	0.348***	0.304***	0.321***	0.333***	0.362***	0.322***	0.331***	0.329***
	(0.00324)	(0.0146)	(0.00352)	(0.00647)	(0.00369)	(0.00573)	(0.00384)	(0.00320)	(0.00324)
Emissions	-3.963***	0.981***	0.739***	-3.048***	-4.160***	-3.426***	-4.035***	-2.011***	-3.993***
	(0.0820)	(0.226)	(0.0650)	(0.155)	(0.0955)	(0.136)	(0.100)	(0.0868)	(0.0918)
Leverage_emit								-0.0317***	
								(0.000490)	
Tangibility									-0.000813
									(0.00556)
Tangibility_emit									0.00136
									(0.00136)
Constant	-24.06***	4.226***	3.411***	-29.87***	-25.24***	-31.41***	-25.07***	-14.49***	-24.03***
	(1.275)	(1.156)	(1.264)	(6.192)	(1.294)	(1.953)	(1.327)	(1.281)	(1.301)
Observations	196,751	13,534	196,720	39,954	156,797	53,722	143,029	196,751	196,751
Number of firms	43,115	4,355	43,102	9,050	34,153	11,660	31,529	43,115	43,115
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.236	0.261	0.222	0.268	0.232	0.313	0.229	0.236	0.236

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Column 1 shows the results from the main specification for the whole sample, column 2 shows the results for the subsample consisting of firms in highly emission-intensive activities, column 3 shows the results for the subsample of all other activities (excluding highly emission-intensive activities) as defined in section 3.1, column 4 shows the results for the subsample of firms in CPRS activities, column 5 shows the results for the subsample of firms in all other (non-CPRS) activities, column 6 shows the results for the subsample of firms in climate-sensitive activities, and column 7 shows the results for the subsample of firms in all other (excluding climate-sensitive) activities. Columns 8 and 9 show the results of the main specification extended for interaction effects of emissions and leverage or tangibility respectively.

In terms of the effects of other variables, an increase in the liquidity ratio by 1 p.p. is associated with a 0.1 p.p. increase in profit ratios. An increase in sales by 1% is associated on average ceteris paribus with a 0.06 p.p. increase in profit ratios. The effect of leverage, expressed in terms of debt-to-assets, is ambiguous and depends on the profit ratio, which follows from the definition of the ratios. A 1 p.p. increase in the debt-to-asset ratio is associated ceteris paribus within a 0.02 p.p. increase in ROE, or a 0.05 p.p. decline in ROA. Productivity has an unambiguously positive effect on profit ratios, with an increase in the productivity index by 1% being associated on average ceteris paribus with a 0.03 p.p. to 0.06 p.p. increase in ROA and ROE respectively. The effects of other variables on profit ratios are consistent across different segments of climate sensitivity in terms of the direction and magnitude of the effect, which indicates model robustness. In terms of magnitude, the effect of leverage is more pronounced for climate-sensitive activities, defined either based on the structure of emissions in Slovenia or the EU, with a smaller negative effect of emissions on profit ratios in these activities. These differences are also statistically significant. In terms of leverage, this is also corroborated by the sign on the interaction term of leverage and emissions, which is positive in the case of ROE and negative in the case of ROA. The effect could be due to differences in debt financing conditions and debt structure of firms in climate-sensitive activities (which have greater leverage), leading to greater effects on ROA and ROE respectively. The effect of tangibility is in turn negative in the case of ROE, while there is no evidence for an effect of tangibility on ROA.

As further checks, we test for the short- and long-term effects of emissions and the effect of emission intensities. The effect of the change in emissions on profit ratios reflects a short-term effect of emissions, while the effect of the stock of emissions on profit ratios reflects a long -term effect of emissions, as in Bolton and Kacperzyk (2022). The results indicate that there is a positive effect of a change in emissions on profit ratios, while the stock of emissions has a negative effect on profit ratios. An increase in the growth rate of emissions by 1 p.p. is associated ceteris paribus on average with an increase in ROA and ROE of 0.01 p.p. and 0.08 p.p., respectively. In turn, an increase in emissions by 1% is associated, on average ceteris paribus with a 0.02 p.p. to 0.04 p.p. decrease in profit ratios. This indicates that while higher emissions may be associated with higher profits in the short term, a higher stock of emissions may be a drag on profit ratios, as it could be associated with an energy-intensive production process which could lead to higher costs overall (due to various excise duties, higher energy costs, etc.).

Thus, there is already some incentive for firms to reduce emissions, despite the fact that the energy transition is still in its early stages. The effects are economically meaningful as well, as a substantial increase in emissions could lead to a significant/non-negligible effect on profit ratios. Thus, while changes in emissions are not the main driver of profit ratios, they could be an important channel in understanding the dynamics of profit ratios. This is also particularly relevant in the context of the energy crisis.

Table 3: **Short run,long term and non-linear effects of climate risk on ROA**

Model variables/ model	(1) Emit	(2) Emit_square	(3) Emit_delta	(4) Emit_int	(5) Emit_int_square
Liquidity	0.106***	0.106***	0.112***	0.107***	0.107***
	(0.00247)	(0.00247)	(0.00264)	(0.00250)	(0.00250)
Sales	6.301***	6.300***	4.247***	4.851***	4.848***
	(0.0639)	(0.0639)	(0.0533)	(0.0768)	(0.0768)
Debt_assets	-0.0547***	-0.0547***	-0.0567***	-0.0588***	-0.0588***
	(0.000487)	(0.000487)	(0.000526)	(0.000492)	(0.000492)
Productivity	0.329***	0.329***	0.361***	0.301***	0.301***
	(0.00324)	(0.00324)	(0.00346)	(0.00350)	(0.00350)
Emissions	-3.963***	-3.936***			
	(0.0820)	(0.178)			
Emissions_square		0.00380			
		(0.0221)			
Emissions_delta			1.281***		
			(0.0969)		
Emission_intensity				-1.570***	-3.557***
				(0.248)	(0.702)
Emission_intensity_square					0.248***
					(0.0820)
Constant	-24.06***	-24.12***	-17.60***	18.96***	16.07***
	(1.275)	(1.315)	(1.301)	(2.638)	(2.806)
Observations	196,751	196,751	171,787	197,299	197,299
Number of firms	43,115	43,115	41,519	43,140	43,140
Year dummies	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes
R-squared	0.236	0.236	0.229	0.219	0.219

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Columns 1 and 4 show the results from the main specification for the whole sample using the stock of emissions and emission intensity respectively as the climate transition risk variable (long-term effects) , while column 3 shows the results of the main specification using the annual change in emissions as the climate transition risk variable (short-term effects). Columns 2 and 5 show the results of the inverse-U curve specification (non-linear effects) for the stock of emissions and emission intensity respectively.

Emission intensity has a negative effect on both profit ratios. The effect ranges from -0.03 p.p. to -0.016 p.p. for ROE and ROA, respectively on average ceteris paribus for a 1% increase in the emission intensity of the sector the firm operates in. Nevertheless, the results also indicate the existence of a U-shaped curve for emission intensity, while there is no compelling evidence for a U curve in the case of emissions. In fact, the coefficients on both the linear and the square terms are negative for emissions in the case of ROE, while only the linear term is negative and statistically significant in the case of ROA. We explore the U shaped curve in more detail further on.

There is a U shaped curve for the effect of emission intensity on profit ratios, which is driven by particular segments with high productivity and high market shares. Namely, the effect of emission intensity on profit ratios is in general negative, though it turns positive after a certain threshold in the case of firms with high market shares or high productivity. This likely implies that firms with higher market power and greater productivity are able to either pass on the negative effects of emission intensity or offset/withstand the negative effect of emission intensity through higher productivity. The turning points for both segments occur at relatively lower ends of the distribution of emission intensity. The effect is driven by segments with high productivity and high market shares for both profit ratios.

Table 4: **Non-linear effects of climate risk on ROA**

Model variables/ model	(1) Emit	(2) Emit_ low_ms	(3) Emit_ high_ms	(4) Emit_ low_prod	(5) Emit_ high_prod	(6) Emit_int	(7) Emit_int_ low_ms	(8) Emit_int_ high_ms	(9) Emit_int_ low_prod	(10) Emit_int_ high_prod
Liquidity	0.106***	0.0869***	0.102***	0.0426***	0.0829***	0.107***	0.106***	0.101***	0.0532***	0.0817***
	(0.00247)	(0.00700)	(0.00356)	(0.00759)	(0.00288)	-0.0025	-0.00715	-0.00352	-0.00774	-0.00283
Sales	6.300***	9.597***	3.471***	8.307***	0.930***	4.848***	5.274***	2.517***	5.064***	2.991***
	(0.0639)	(0.197)	(0.117)	(0.178)	(0.0937)	-0.0768	-0.208	-0.115	-0.221	-0.108
Debt_assets	-0.0547***	-0.0282***	-0.0889***	-0.0507***	-0.0902***	-0.0588***	-0.0310***	-0.0895***	-0.0536***	-0.0921***
	(0.000487)	(0.000743)	(0.00139)	(0.000827)	(0.00160)	-0.000492	-0.000757	-0.00136	-0.000841	-0.00158
Productivity	0.329***	0.454***	0.260***	0.666***	0.184***	0.301***	0.422***	0.245***	0.496***	0.154***
	(0.00324)	(0.0116)	(0.00384)	(0.0160)	(0.00288)	-0.0035	-0.0127	-0.00409	-0.0178	-0.00309
Emissions	-3.936***	-9.849***	-2.466***	-9.813***	-1.329***					
	(0.178)	(1.501)	(0.176)	(0.889)	(0.154)					
Emissions_square	0.00380	-0.267*	-0.114***	-0.0489	-0.0540***					
	(0.0221)	(0.158)	(0.0270)	(0.100)	(0.0208)					
Emission intensity						-3.557***	-7.934**	-3.409***	-1.027	-2.267***
						-0.702	-3.227	-0.709	-2.635	-0.755
Emission intensity square						0.248***	0.328	0.209***	-0.102	0.316***
						-0.082	-0.433	-0.0776	-0.322	-0.0848
Constant	-24.12***	-38.77*	-7.651***	-26.29***	7.955***	16.07***	25.03	21.87***	21.12**	4.785
	(1.315)	(21.17)	(1.270)	(2.825)	(1.504)	-2.806	-26.09	-2.592	-9.86	-3.034
Observations	196,751	37,081	54815	43126	51476	197,299	37,066	55,240	43,169	51,695
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	43,115	12,130	12,659	18,237	15,288	43,140	12,122	12,692	18,240	15,319
R-squared	0.236	0.221	0.205	0.229	0.212	0.219	0.194	0.212	0.198	0.23

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Columns 1 to 5 show the results of the inverse-U curve specification (non-linear effects) for the stock of emissions for: the whole sample (column 1); the subsample of low market share firms (column 2); the subsample of high market share firms (column 3); the subsample of low productivity firms (column 4); and the subsample of high productivity firms (column 5). Columns 6 to 10 show the results of the inverse-U curve specification (non-linear effects) for: the emission intensity for the whole sample (column 6); the subsample of low market share firms (column 7); the subsample of high market share firms (column 8); the subsample of low productivity firms (column 9); and the subsample of high productivity firms (column 10).

Overall, the results indicate a negative effect of emissions and emission intensity on profit ratios, which reflects transition risks, with some ameliorating effects of productivity and market shares. The magnitude of the effect ranges from up to 0.2 and 0.4 p.p. decline in ROE and ROA for a 10% increase in emissions, and 0.16 to 0.3 p.p. decline in ROA and ROE respectively for a 10% increase in emission intensity. While the estimates show some incentive for firms to reduce emissions, the effect is limited. Nevertheless, it provides a channel for understanding further the dynamics of profit ratios and how they may be affected during the energy transition. Namely, the sample includes data on firms up to 2021, while energy prices increased starkly during 2022. Despite an overall limited effect, it is expected that the effect will increase and persist due to structural changes during the green transition, which would presumably increase the cost of pollution. Moreover, the effect is smaller or even positive for firms in sectors with very high emission intensity. In fact, further checks show a U-curve effect for emission intensity for firms with high market shares and high productivity. Thus, emission intensity may affect firms' profit ratios negatively on average, though there are segments which have so far been shielded from these negative effects, possibly due to market power or the offsetting effects due to high productivity.

Our results contribute to the literature on the link between carbon performance and environmental performance. We find a negative impact of the stock of carbon emissions and a positive impact of the change in carbon emissions on firm financial performance, as measured through ROA and ROE. This is in line with a positive short-term effect and a negative long-term effect of emissions on financial performance (Delmas et al., 2015). A positive short-term effect of emissions is also found in a subsequent study by Busch et al. (2022). Conversely, Bolton and Kacperzyk (2021) find both a negative short and long run effect of carbon risk on stock returns. This could be explained by market efficiency, as financial markets could already be pricing in carbon risk (thus incorporating forward-looking information). The results also corroborate earlier findings in the literature of a U-shaped curve as in Lewandowski (2017). Moreover, we explore the U-shaped curve further and find that it is driven largely by segments of firms with high productivity and market share.

There are various limitations to these results. First of all, the emission estimates themselves do not take firm efficiency into account, thus emission intensity could be overestimated for some firms, which could explain the positive effect of emission intensity in the case of firms with higher productivity. Second, the definition of firms' market shares might be inaccurate as a market is a broad term which need not reflect the share of revenues of a firm in the total revenues generated by firms with the same NACE industrial code. Nevertheless, since emission intensity estimates are provided at the sectoral level and these are arguably the basis for climate policy, high market shares as defined in this paper could reflect concentration in a particular sector which could affect sectoral policies through various exemptions etc. Environmental policy stringency is therefore an additional avenue to explore. Third, our sample does not include the period of the most recent energy crisis, which could reveal greater vulnerabilities of firms in climate-sensitive activities, particularly energy or emission-intensive firms. Fourth, we focus on the effects on profits so far which is backward-looking. It would also be highly relevant to explore the effect of emissions on other firm characteristics, which would reveal firms' adaptation to transition risks, such as investments in renewable energy or diversification of firms' product mix. Going forward, competitiveness effects in case of policy divergences at the international level are also highly relevant in this context. Moreover, access to credit and financing conditions are also important dimensions, as they may enable firms to adapt to the transition more easily. Conversely, tighter financing conditions for firms in high-polluting activities may further compound the risks for these firms in the transition. The paper explores this aspect in the next section. We proceed further by examining the effect of climate risk on firms' financing costs.

5.2 Climate risk and firm financing costs

We use loan-level data from reports by monetary financial institutions that provide data on the interest rate spread on newly approved bank loans, matched with firm-level data on emissions and firm financial statements. The results indicate that there was almost no effect of firm emissions on loan spread in the 2014–2021 period. Table 5 shows we find that a 1 p.p. increase in emissions at an annual level is associated with an increase in the loan spread of 0.00023 p.p. We also find that a 1 p.p. increase in emissions at an annual level for CPRS and climate-sensitive sectors is associated with an increase in the loan spread (0.00484 p.p. and 0.00548 p.p., respectively). For firms in high-polluting activities, a 1 p.p. increase in emissions at an annual level is associated with an increase in the loan spread of 0.00023 p.p., as with firms overall. We also find almost no effect of firm emissions on loan spread for firms that are not in CPRS and climate-sensitive sectors (-0.00318 p.p. and -0.00185 p.p., respectively).

The results further indicate that firm leverage has a positive but small effect on loan spreads. Table 5 shows that a 1 p.p. increase in the debt-to-asset ratio is associated, all things being equal, with a 0.007 p.p. increase in loan spread. The estimates also show that firm leverage has a slightly larger positive effect on loan spreads for CPRS and climate-sensitive sectors (alternative definition), with a 1 p.p. increase in the debt-to-asset ratio associated with a 0.012 p.p. and 0.015 p.p. increase in loan spread, respectively.

An increase in sales of 1% is associated, on average and all things being equal, with a 0.170 p.p. decrease in loan spread. Asset tangibility has a negative effect on loan spread, as a 1 p.p. increase in the tangibility ratio decreases the loan spread by 0.003 p.p. The results indicate that having higher sales and more tangible assets (e.g. buildings, land, plant) reduces borrowing costs at banks. The results also show that the higher the loan amount, the lower the spread, most significantly when comparing the quartile of the largest operations with the remainder (loan amount 100 is omitted from the regression). Spreads increase with maturity and spreads at maturity over five years (omitted from the regression) differ significantly from spreads at shorter maturity.

In terms of magnitude, the effects of sales on loans spreads are more pronounced for CPRS and climate-sensitive sectors, as well as firms in high-polluting activities, than for other firms (the spread decreases more). The effects of tangibility on loan spreads are less pronounced for firms in high-polluting and climate-sensitive activities than for other firms (the spread decreases less). However, the results indicate that firm tangibility has a positive but small effect on loan spreads for CPRS firms. The effects of maturity on loan spreads are also more pronounced for firms in CPRS and climate-sensitive activities, as well as firms in high-polluting activities, than for firms in other activities. The results in Table 6 show that higher emission intensity has almost no effect on loan spread (-0.00167 p.p. for loan spread, on average and all things being equal, for a 1% increase in emission intensity).

Table 5: **Effect of climate risk (through stock of provisions) on loan spread for different segments**

Model variables/ model	**(1) Main**	**(2) Emint**	**(3) Emint_no**	**(4) CPRS**	**(5) CPRS_no**	**(6) Clims_sens**	**(7) Clims_sens_no**
Debt-to-assets	0.00710***	0.00710***	0.00432***	0.0121***	0.00615***	0.0149***	0.00511***
	(0.000120)	(0.000120)	(0.000698)	(0.000282)	(0.000130)	(0.000331)	(0.000122)
Sales	-0.170***	-0.170***	-0.234***	-0.420***	-0.112***	-0.343***	-0.134***
	(0.00268)	(0.00268)	(0.0172)	(0.00671)	(0.00297)	(0.00867)	(0.00264)
Tangibility	-0.00279***	-0.00279***	-0.00329***	0.00158***	-0.00322***	-0.00167***	-0.00256***
Loan amount (quartiles)							
loan amount 25	0.119***	0.119***	0.0900	0.157***	0.140***	0.00919	0.131***
	(0.00978)	(0.00978)	(0.0605)	(0.0182)	(0.0115)	(0.0232)	(0.0105)
loan amount 50	0.306***	0.306***	0.232***	0.274***	0.352***	0.210***	0.315***
	(0.00898)	(0.00898)	(0.0459)	(0.0168)	(0.0105)	(0.0221)	(0.00955)
loan amount 75	0.431***	0.431***	0.270***	0.355***	0.451***	0.383***	0.431***
	(0.00790)	(0.00790)	(0.0363)	(0.0153)	(0.00908)	(0.0176)	(0.00865)
Maturity							
less than 1 year	0.287***	0.287***	0.226***	0.426***	0.233***	0.337***	0.271***
	(0.0101)	(0.0101)	(0.0413)	(0.0193)	(0.0116)	(0.0202)	(0.0116)
from 1 to 5 years	0.186***	0.186***	0.413***	0.431***	0.128***	0.409***	0.114***
	(0.0107)	(0.0107)	(0.0472)	(0.0203)	(0.0123)	(0.0225)	(0.0120)
Emissions	0.0232	0.0232	-0.506***	0.484***	-0.318***	0.548***	-0.185***
	(0.0307)	(0.0307)	(0.191)	(0.0396)	(0.0549)	(0.106)	(0.0313)
Constant	4.646***	4.646***	9.507***	3.875***	6.987***	3.416***	6.087***
	(0.237)	(0.237)	(1.447)	(0.174)	(0.414)	(0.375)	(0.240)
Observations	200,106	200,106	7,493	60,847	139,259	46,226	153,880
R-squared	0.634	0.634	0.589	0.674	0.631	0.552	0.658
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Sources: Banka Slovenije, AJPES, ETS, own calculations.
Note: Column 1 shows the results from the main specification for the whole sample, column 2 shows the results for the subsample consisting of firms in highly emission-intensive activities, column 3 shows the results for the subsample of all other activities (excluding highly emission-intensive activities) as defined in section 3.1, column 4 shows the results for the subsample of firms in CPRS activities, column 5 shows the results for the subsample of firms in all other (non-CPRS) activities, column 6 shows the results for the subsample of firms in climate-sensitive activities, and column 7 shows the results for the subsample of firms in all other (excluding climate-sensitive) activities.

Table 6: **Non-linear effects of climate risk on loan spread**

Model variables/ model	**(1) original**	**(2) emitsq**	**(3) emint**	**(4) emintsq**
Debt-to-assets	0.00710***	0.00710***	0.00712***	0.00712***
	(0.000120)	(0.000120)	(0.000120)	(0.000120)
Sales	-0.170***	-0.169***	-0.169***	-0.169***
	(0.00268)	(0.00268)	(0.00267)	(0.00267)
Tangibility	-0.00279***	-0.00278***	-0.00279***	-0.00279***
	(0.000138)	(0.000138)	(0.000138)	(0.000138)
Maturity				
less than 1 year	0.287***	0.287***	0.287***	0.287***
	(0.0101)	(0.0101)	(0.0101)	(0.0101)
from 1 to 5 years	0.186***	0.187***	0.185***	0.185***
	(0.0107)	(0.0107)	(0.0107)	(0.0107)
Loan amount (quartiles)				
loan amount 25	0.119***	0.119***	0.121***	0.121***
	(0.00978)	(0.00978)	(0.00978)	(0.00978)
loan amount 50	0.306***	0.306***	0.307***	0.307***
	(0.00898)	(0.00898)	(0.00898)	(0.00898)
loan amount 75	0.431***	0.431***	0.432***	0.432***
	(0.00790)	(0.00790)	(0.00790)	(0.00790)
Emissions	0.0232	-0.385***		
	(0.0307)	(0.102)		
Emissions square		0.0509***		
		(0.0121)		
Emission intensity			-0.167***	-0.235***
			(0.0239)	(0.0624)
Emission intensity square				0.0100
				(0.00861)
Constant	4.646***	4.820***	6.379***	6.137***
	(0.237)	(0.240)	(0.231)	(0.310)
Observations	200,106	200,106	200,106	200,106
R-squared	0.634	0.634	0.634	0.634
Year dummies	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes
Bank dummies	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Sources: Banka Slovenije, AJPES, ETM, own calculations.
Note: Columns 1 and 3 show the results from the main specification for the whole sample using the stock of emissions and emission intensity (respectively) as the climate transition risk variable (long-term effects). Columns 2 and 4 show the results of the inverted U curve specification (non-linear effects) for the stock of emissions and emission intensity, respectively.

The results contribute to the literature on the link between climate risk and financial performance. The results suggest banks have not considered the credit risks of firms in high-polluting activities because they do not associate high emissions with higher credit costs. Various studies have also found that firms in high-polluting activities or those with higher emission intensity have higher debt financing costs and a higher interest rate spread for new bank loans (Nandy and Lodh, 2012; Jung et al., 2018; Ehlers et al., 2022). The results therefore do not indicate that, in the 2014–2021 period, banks considered firms with high emissions to be exposed to larger physical and transition climate risks that could bring additional costs and therefore a higher credit risk. However, reducing emissions may contribute to lower borrowing costs at banks and therefore better access to finance in the future. This may provide further incentive for firms to reduce carbon emissions.

6 Conclusions

This paper analyses the relationship between firm climate risk on financial performance in Slovenia between 2014 and 2021. We construct a granular dataset that combines confidential and public data for Slovene firms, using information on firm-level carbon emissions, data from firms' financial statements and loan-level data reported by monetary financial institutions in Slovenia.

Our results indicate that emissions and emission intensity have a negative impact on profit ratios (which largely reflects transition risks), although the overall magnitude is small. The results show that firms already have some incentive to reduce emissions today. This is likely to increase going forward with the onset of the energy transition. We also find a U-curve effect for the effect of emission intensity on profit ratios for firms with high market shares and productivity, which indicates that some segments have so far been shielded from the effect of transition risks. Overall, the results contribute to an understanding of the dynamics of profit ratios and how they may be affected during the energy transition.

Last, we explore the relationship between climate risk and firm financing costs by using interest rate spread on newly approved bank loans to firms in the 2014–2021 period, and find that firm emissions have almost no effect on loan spread. The results suggest banks did not consider credit risks of high emitters as they did not associate high emissions with higher credit costs. Various studies have found that firms in high-polluting activities or those with higher emission intensity have higher debt financing costs and a higher interest rate spread for new bank loans (Nandy and Lodh, 2012; Jung et al., 2018; Ehlers et al., 2022). We also find that having higher firm indebtedness is associated with higher loan spread, as the results indicate that firm leverage has a positive but small effect on loan spreads, and that firm leverage has a slightly greater positive effect on loan spreads for CPRS and climate-sensitive sectors. Furthermore, having higher sales and more tangible assets (e.g. buildings, land, plants) reduces firms' borrowing costs at banks.

The results of the paper are important for policymakers, as they shed light on the relationship between climate risk and firm financial performance, which is relevant in terms of understanding the potential impact of climate related financial risks. Moreover, the results show that firms already have some incentive to reduce emissions today, as higher emissions are associated with deterioration in financial performance. In the future, tighter financing conditions for high-polluting firms may increase the risks for these firms in the transition towards a greener economy.

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8 Appendix

Table 2: **Variable definitions**

Variables	Definitions
A: Emission variables (source: ETS)	
Emissions	Defined at the firm level, expressed in thousands of tonnes CO2 eq. (expressed in logs)
Emission intensity	Defined in terms of emissions relative to sales (in grams per euro, expressed in logs) at the NACE 2 activity level
B. Firm characteristics variables (source: AJPES)	
Firm size	Classified into four groups (micro, small, medium-sized and large) on the basis of satisfying any two of the three criteria on number of employees, annual turnover and value of assets
Profitability	Return on assets (ROA), measured as the ratio of net operating profit to total assets. Return on equity (ROE), measured as the ratio of net operating profit to total equity (in %)
Liquidity	Measured as the ratio of cash (and cash equivalents) to total assets (in %)
Sales	Measured as the volume of annual turnover (in thousands of EUR, expressed in logs)
Leverage	Measured as the debt-to-asset ratio (in %)
Productivity	Total factor productivity (TFP) estimated using the Levinsohn-Petrin method (in logs)
Asset tangibility	Measured as the ratio of tangible fixed assets to total assets (in %)
C. Bank loan variables (source: Banka Slovenije)	
Volume of the loan	Measured as the total loan amount approved regardless of how many tranches were drawn
Interest rate	The interest rate is defined at the origination for each loan (fixed or variable rate).
Interest rate spread	We calculate the interest rate spread for new loans only. For variable rate loans, the loan spread is reported, while for the fixed rate loans we calculate loan spread as the difference between the contractual interest rate of the loan and the average value of the 6-month EURIBOR in the month of loan approval.
Loan amount	The volume of the loan is defined as the total loan amount approved, regardless of how many tranches were drawn.
Loan maturity	Loan maturity is defined at origination and corresponds to the due date of the last loan instalment. Maturity in put into classes (less than 1 year, 1-5 years, over 5 years) and introduced into the regression as a dummy variable. Maturity over 5 years was omitted from the regressions.

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Table 2: **ROE main specification**

Model variables/ model	(1) Main	(2) Emit_int	(3) Emit_int_no	(5) CPRS	(4) CPRS_no	(7) Clim_sens	(6) Clim_sens_no	(8) Int1	(9) Int2
Liquidity	0.114***	0.0715***	0.110***	0.114***	0.115***	0.109***	0.118***	0.115***	0.118***
	(0.00652)	(0.0219)	(0.00652)	(0.0156)	(0.00716)	(0.0139)	(0.00738)	(0.00652)	(0.00681)
Sales	5.796***	13.40***	8.723***	6.132***	5.758***	5.854***	5.872***	5.803***	5.811***
	(0.159)	(1.025)	(0.225)	(0.357)	(0.177)	(0.331)	(0.181)	(0.158)	(0.159)
Debt/assets	0.0220***	0.0119***	0.0173***	0.0439***	0.0198***	0.0709***	0.0181***	0.0710***	0.0220***
	(0.00131)	(0.00441)	(0.00130)	(0.00424)	(0.00138)	(0.00461)	(0.00138)	(0.00576)	(0.00131)
Productivity	0.597***	0.585***	0.493***	0.589***	0.598***	0.671***	0.573***	0.596***	0.597***
	(0.00975)	(0.0429)	(0.0105)	(0.0213)	(0.0110)	(0.0190)	(0.0114)	(0.00975)	(0.00975)
Emissions	-2.165***	1.050*	2.268***	-1.494***	-2.411***	-1.108***	-2.689***	-2.821***	-1.638***
	(0.206)	(0.545)	(0.155)	(0.428)	(0.235)	(0.387)	(0.245)	(0.219)	(0.231)
Leverage_emit								0.0107***	
								(0.00123)	
Tangibility									-0.0588***
									(0.0140)
Tangibility_emit									-0.0182***
									(0.00342)
Constant	-20.86***	6.913***	4.163*	-50.10***	-20.18***	-28.33***	-20.84***	-24.02***	-18.06***
	(2.621)	(2.505)	(2.529)	(13.15)	(2.619)	(4.825)	(2.640)	(2.644)	(2.704)
Observations	196,751	13,534	196,720	39,954	156,797	53,722	143,029	196,751	196,751
Number of firms	43,115	4,355	43,102	9,050	34,153	11,660	31,529	43,115	43,115
Year dummies	Yes	Yes	Yes	Yes	Yes				
Activity dummies	Yes	Yes	Yes	Yes	Yes				
R-squared	0.042	0.060	0.045	0.046	0.042	0.051	0.041	0.043	0.043

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Column 1 shows the results from the main specification for the whole sample, column 2 shows the results for the subsample consisting of firms in highly emission-intensive activities, column 3 shows the results for the subsample of all other activities (excluding highly emission-intensive activities) as defined in section 3.1, column 4 shows the results for the subsample of firms in CPRS activities, column 5 shows the results for the subsample of firms in all other (non-CPRS) activities, column 6 shows the results for the subsample of firms in climate-sensitive activities, and column 7 shows the results for the subsample of firms in all other (excluding climate-sensitive) activities. Columns 8 and 9 show the results of the main specification extended for interaction effects of emissions and leverage or tangibility respectively.

Table 3: **ROE short run, long term and non-linear effects**

Model variables/ model	(1) Emit	(2) Emit_square	(3) Emit_delta	(4) Emit_int	(5) Emit_int_square
Liquidity	0.114***	0.114***	0.116***	0.104***	0.104***
	(0.00652)	(0.00652)	(0.00672)	(0.00651)	(0.00651)
Sales	5.796***	5.764***	4.182***	8.985***	8.980***
	(0.159)	(0.159)	(0.123)	(0.224)	(0.224)
Debt_assets	0.0220***	0.0220***	0.0208***	0.0164***	0.0164***
	(0.00131)	(0.00131)	(0.00134)	(0.00130)	(0.00130)
Productivity	0.597***	0.598***	0.647***	0.483***	0.483***
	(0.00975)	(0.00975)	(0.0103)	(0.0105)	(0.0105)
Emissions	-2.165***	-3.607***			
	(0.206)	(0.421)			
Emissions_square		-0.205***			
		(0.0521)			
Emissions_delta			7.764***		
			(0.283)		
Emission_intensity				-2.966***	-6.702***
				(0.739)	(2.098)
Emission_intensity_square					0.467*
					(0.245)
Constant	-20.86***	-17.76***	-15.09***	34.45***	28.93***
	(2.621)	(2.737)	(2.586)	(7.361)	(7.912)
Observations	196,751	196,751	171,787	197,299	197,299
Number of firms	43,115	43,115	41,519	43,140	43,140
Year dummies	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes
R-squared	0.042	0.042	0.050	0.042	0.042

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Columns 1 and 4 show the results from the main specification for the whole sample using the stock of emissions and emission intensity respectively as the climate transition risk variable (long-term effects), while column 3 shows the results of the main specification using the annual change in emissions as the climate transition risk variable (short-term effects). Columns 2 and 5 show the results of the inverted U curve specification (non-linear effects) for the stock of emissions and emission intensity respectively.

Table 4: **ROE Non-linear effects**

Model variables/ Model	(1) Emit	(2) Emit_ low_ms	(3) Emit_ high_ms	(4) Emit_ low_prod	(5) Emit_ high_prod	(6) Emit_int	(7) Emit_int_ low_ms	(8) Emit_int_ high_ms	(9) Emit_int_ low_prod	(10) Emit_int_ high_prod
Liquidity	0.114***	0.0369**	0.154***	-0.00728	0.128***	0.104***	0.0363**	0.145***	-0.0202	0.118***
	(0.00652)	(0.0174)	(0.0113)	(0.0195)	(0.00831)	-0.00651	-0.0174	-0.0112	-0.0195	-0.00817
Sales	5.764***	4.504***	6.272***	0.509	2.653***	8.980***	5.236***	10.37***	4.986***	9.947***
	(0.159)	(0.476)	(0.350)	(0.452)	(0.265)	-0.224	-0.556	-0.402	-0.6	-0.32
Debt_assets	0.0220***	0.0154***	0.0223***	0.0284***	0.0428***	0.0164***	0.0137***	0.0153***	0.0287***	0.0359***
	(0.00131)	(0.00199)	(0.00401)	(0.00217)	(0.00454)	-0.0013	-0.00198	-0.00397	-0.00216	-0.00448
Productivity	0.598***	0.578***	0.586***	0.417***	0.422***	0.483***	0.476***	0.470***	0.230***	0.312***
	(0.00975)	(0.0325)	(0.0138)	(0.0434)	(0.00864)	-0.0105	-0.035	-0.0147	-0.0474	-0.00926
Emissions	-3.607***	3.513	-3.491***	2.522	-2.848***					
	(0.421)	(3.697)	(0.497)	(2.235)	(0.431)					
Emissions_square	-0.205***	0.358	-0.181**	0.0380	-0.185***					
	(0.0521)	(0.391)	(0.0752)	(0.252)	(0.0578)					
Emission intensity						-6.702***	-0.768	-9.601***	-10.86	-5.878***
						-2.098	-8.844	-2.561	-7.233	-2.277
Emission intensity square						0.467*	-1.195	0.683**	0.78	0.795***
						-0.245	-1.187	-0.281	-0.888	-0.256
Constant	-17.76***	91.42**	-23.23***	-1.412	4.236	28.93***	210.5***	37.26***	36.19	0.206
	(2.737)	(45.43)	(3.331)	(6.553)	(4.089)	-7.912	-60.29	-9	-26.8	-8.976
Observations	196,751	37,081	54,815	43,126	51,476	197,299	37,066	55,240	43,169	51,695
Number of firms	43,115	12,130	12,659	18,237	15,288	43,140	12,122	12,692	18,240	15,319
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Activity dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.042	0.024	0.067	0.018	0.089	0.042	0.024	0.077	0.019	0.115

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Columns 1 to 5 show the results of the inverted U curve specification (non-linear effects) for the stock of emissions for: the whole sample (column 1); the subsample of low market share firms (column 2); the subsample of high market share firms (column 3); the subsample of low productivity firms (column 4); and the subsample of high productivity firms (column 5). Columns 6 to 10 show the results of the inverted U curve specification (non-linear effects) for: the emission intensity for the whole sample (column 6); the subsample of low market share firms (column 7); the subsample of high market share firms (column 8); the subsample of low productivity firms (column 9); and the subsample of high productivity firms (column 10).