EUROPEAN CENTRAL BANK

EUROSYSTEM

# Working Paper Series

Margherita Giuzio, Bige Kahraman,
Jasper Knyphausen

## Climate change, bank liquidity and systemic risk

No 3168

**Abstract**

This paper examines the relevance of banks' exposure to climate transition risk in the interbank lending market. Using transaction-level data on repo agreements, we first establish that banks with higher exposure to transition risk face significantly higher borrowing costs. This premium is a combination of a risk premium, compensating lenders for increased credit risk, and an inconvenience premium, reflecting the sustainability preferences of key dealer banks. We also find that the transition risk premium intensifies during periods of financial stress, indicating that climate-induced risks amplify existing vulnerabilities in financial markets. Furthermore, the rate segmentation caused by transition risk premium has implications for the transmission of monetary policy. Transition risk is an important factor in financial stability and policy design.

KEYWORDS: CLIMATE FINANCE, TRANSITION RISK, REPO MARKETS, RISK PREMIUM, FINANCIAL STABILITY
JEL CLASSIFICATION: Q54, G21, G32, Q58.

## Non-technical summary

This paper examines how climate transition risks — particularly banks' exposure to carbon-intensive borrowers — affect short-term funding costs in the European repo market. The repo market is the backbone of bank liquidity and a core channel for transmitting central bank policy rates. It is generally considered one of the safest financial markets, given the short maturities and collateralized nature of transactions. Our findings show, however, that even here climate risks are priced in, with meaningful consequences for financial stability and monetary policy.

Using transaction-level data from 2019–2022, we combine information on European banks' repo borrowing with data on their "financed emissions," that is, the greenhouse gas emissions of the firms they lend to. We find that banks with higher financed emissions consistently pay higher borrowing rates in the repo market. Quantitatively, a one standard deviation increase in financed emissions translates into repo rates that are 7–12% higher, on average. This "carbon premium" cannot be explained by usual drivers of repo pricing, such as collateral quality, transaction maturity, or counterparty relationships.

To understand why this premium arises, we explore three possible explanations: compensation for higher credit risk, greater demand for cash from carbon-intensive borrowers, and dealer banks' sustainability preferences. Our evidence points to a mix of both a risk premium and what we term an "inconvenience premium," reflecting the reluctance of climate-committed banks to extend cheap funding to more carbon-exposed peers.

We also assess the broader implications. First, the carbon premium amplifies during times of market stress, tripling in size. This suggests that climate risks interact with existing vulnerabilities to heighten systemic risk. Second, transition risks alter the transmission of monetary policy: repo rates for high-emission banks adjust more quickly to central bank rate hikes, indicating uneven pass-through across the banking sector.

In sum, our study provides the first evidence that climate risks affect the pricing of bank liquidity in Europe's core funding market and highlights how climate transition risks can amplify financial fragilities and interplay with monetary policy transmission.

## 1 Introduction

Climate change presents a profound global risk with potential implications for financial markets. Financial market participants and policymakers are increasingly concerned that climate change related risks may disrupt financial stability and inflict negative economic consequences (Acharya et al., 2023). While a growing body of research has explored how climate risk affects asset prices and corporate financing, its impact on systemic risk remains less understood despite these concerns. As (Acharya et al., 2023) highlight, climate change can increase market risk through multiple channels, potentially depressing property and corporate values, reducing corporate profits, and eroding household wealth. These effects, in turn, can exacerbate credit, market, and liquidity risks across the financial system.[1]

In this paper, we explore a critical, yet understudied, channel: whether and how climate transition risks —those arising from climate policies, regulations, or technological shocks—may threaten liquidity in the banking sector. We specifically investigate three key questions:

- Does increased exposure to transition risk affect a bank's refinancing needs and alter the pricing of short-term interbank loans, known as repos?
- Does exposure to transition risk amplify other exogenous shocks in financial markets, making banks with higher climate risk exposure more vulnerable during periods of financial stress?
- Does exposure to transition risk impact monetary policy transmission?

By addressing these questions, our research contributes to the academic literature on climate finance by shedding light on the interplay between **climate risk** and both **systemic risk** and **monetary policy transmission**. Our findings have implications for policymakers, as climate risk-induced frictions in the repo market could hinder the effectiveness of financial stability measures and monetary policy.

When the literature discusses climate risk, it typically considers two distinct types of risk relevant to financial markets: transition risk and physical risk. We focus on transition risk as it is more likely than physical risk to affect firms and financial institutions in the near future (Krueger et al., 2020; Acharya et al., 2023). Although physical risks, such as extreme weather events, have become more prevalent in recent years, their financial impact has been relatively

[1] See Figure 7.

contained due to ample insurance coverage and liquidity buffers. In contrast, recent research shows that transition risk is already materializing, with investors increasingly taking this risk into account when making portfolio choices (e.g., Kacperczyk and Bolton (2021); Bolton and Kacperczyk (2024)).

Our analysis employs high-frequency, trade-level data for the European repo market from 2019 to 2022. This market is the primary venue for managing funding and collateral for European banks, with daily transaction volumes ranging between EUR 500 and EUR 1,500 billion. It is also the main venue through which the European Central Bank implements its policy rate. Given this central role for financial intermediaries, any disruption in the functioning of the repo market could have serious implications for liquidity across the European financial system. Our data source is the Money Market Statistical Reporting (MMSR) dataset from the European Central Bank, which covers all transactions in the repo market by the 46 biggest European banks. For each transaction, we observe the trade date, maturity, volume, loan rate, haircut, collateral (identified by a unique ISIN), lender, borrower, and transaction type. Our analysis focuses on reverse repo transactions conducted by the 46 MMSR-reporting banks (which we refer to as "lenders") with 223 other banks in our sample (their cash-seeking trading partners, referred to as "borrowers").

We find that exposure to higher transition risk, proxied by banks' financed GHG emissions, is significantly linked to a premium in repo rates. Specifically, our baseline regressions show that a one standard deviation increase in transition risk exposure is associated with a 7–12% increase in repo rates, on average. This finding is particularly notable because the repo market is generally considered very safe due to its short-term nature and the fact that loans are collateralized. To ensure the robustness of this result, we control for a variety of deal- and bank-specific characteristics that are typically associated with risk factors in the repo market. Our findings remain stable even in extended tests where we also account for borrower as well as borrower-lender fixed effects. To further validate our findings, we conduct a natural experiment using exogenous shocks to transition risk. Specifically, we use the staggered increases in carbon prices that occurred when the EU reduced the supply of carbon allowances traded on its Emissions Trading System (ETS) market as exogenous shocks. We find both statistically and economically significant transition risk premium after the supply shock introduced in 2022.

Next, we aim to understand the source of the risk premium, and to this end, we consider three hypotheses. First, the transition risk premium may reflect a genuine risk premium, compensating lenders for the increased risk associated with carbon-intensive exposures. Second, it could be related to the preferences of dealer banks, particularly large European institutions that have committed to various climate initiatives. In this case, higher rates charged to carbon-intensive banks may reflect a loss of convenience or a misaligned with these banks' sustainability goals. Finally, the premium might be a result of increased funding demand from carbon-intensive firms, which their banks must support by raising funds in the money market. This greater funding demand could, in equilibrium, lead to higher borrowing costs.

Taken altogether, our findings suggest that the results can be understood as a combination of a risk and an inconvenience premium that reflects the preferences of dealer banks. First, we find that the premium is more pronounced in less-standardized transactions and when the collateral is generally considered riskier, such as in the non-government sector. Risk premium is associated with longer maturities and higher haircuts, but not with higher trading volumes. Risk premium is associated with higher *lagged* financed emissions, but not with contemporaneous ones. Finally, the premium becomes particularly noticeable after dealer banks joined voluntary climate commitments.

If repo rates are associated with banks' transition risk exposure, and the repo market is the core channel for both funding and monetary policy transmission, what are the implications for financial stability and monetary policy? Focusing first on financial stability question, we examine the pricing of the transition risk in the repo market during periods of heightened financial stress. Using various different measures of market stress, we find that transition risk premium significantly increases (three-fold) during periods of heightened financial stress. This finding further supports the earlier interpretation of a risk premium and highlights that the real dangers of climate change for financial stability may not be from direct exposure, which currently seems contained, but rather from its compounding effect with broader financial vulnerabilities. This finding underscores the need for policymakers to consider these interactions when designing new regulations.

For monetary policy, the key concern is whether interest rate changes set by the central bank are passed on quickly and fully to market participants, a process which is called the transmission of monetary policy. In reality, this is necessarily the case, partly because the repo market is highly segmented and influenced by various factors that blur the direct effect of policy changes. When the level of repo rates is affected by transition risk exposure, does this mean that transmission is also impacted? Our data shows that during half of the rate hikes in our sample, borrowing rates for "brown" banks (those with high financed emissions) adjusted approximately 7% faster to new policy rates than those for "green" banks. This suggests that the transmission of monetary policy is quicker to brown banks during rate hikes, possibly because dealer banks are less willing to offer them favorable terms after a rate increase due to risk concerns or their own preferences.

### 1.1 Related literature

This study makes a two-fold contribution to the literature on climate finance and to policy discussions. First, to the best of our knowledge, this study provides the first empirical evidence on the dynamic relationship between **climate risks** and **bank liquidity**. In doing so, the analysis offers new insights into how climate risks can amplify existing financial vulnerabilities and affect the transmission of monetary policy, filling a key gap in the literature identified by Acharya et al. (2023). Second, our findings offer guidance for policymakers and central banks. They highlight the need for a new policy paradigm that integrates climate risk into systemic risk assessments, especially given the repo market's vital role in the financial system. Policies aimed at mitigating the climate risk's impact on interbank markets, along with enhanced climate risk disclosure and the implementation of robust stress testing frameworks, would help assessing and reducing transition-related systemic risk.

Much of the existing research examines how climate risks affect individual asset classes in isolation. Equity markets, in particular, have been extensively studied, with most findings suggesting a positive risk premium for carbon-intensive or "brown" stocks. For example, Kacperczyk and Bolton (2021, 2022); Faccini et al. (2023); Ramelli et al. (2021); Hong et al. (2019); Hsu et al. (2020); Barnett (2020) document that investors demand higher expected returns for holding brown stocks, reflecting compensation for regulatory, reputational, or transition risks. Engle et al. (2020) provide insight into how news about climate change could potentially be hedged in the equity market.

Similar patterns emerge in fixed income markets. Studies on corporate bonds suggest that firms with higher carbon footprints face higher borrowing costs, consistent with the idea that climate risks influence credit spreads and bond yields (Bua et al., 2024; Painter, 2020; Huynh and Xia, 2020; Goldsmith-Pinkham et al., 2019; Baker et al., 2018). Government bond markets also exhibit climate-related pricing effects, with sovereign debt instruments reflecting exposure to climate vulnerabilities or policy shifts (Collender et al., 2023).

Climate risks extend beyond equities and fixed income. In corporate loan markets, Altavilla et al. (2024) show that transition risk affects loan pricing, with lenders adjusting credit terms based on borrowers' climate-related exposures. Short-term options markets are also influenced, as Ilhan et al. (2020) find that options on firms with high carbon exposure tend to exhibit higher implied volatility, reflecting uncertainty about climate policies and stranded asset risks. Even very long-term assets, such as real estate (Foerster et al., 2025), are impacted. Research indicates that climate risks influence property valuations, with coastal properties exposed to sea level rise experiencing price discounts, while more resilient locations see price premia (Giglio et al., 2021; Bernstein et al., 2019; Bakkensen and Barrage, 2017; Baldauf et al., 2020).

Finally, our paper also contributes to the literature on repo markets. Several studies provide insights into key determinants of repo market dynamics. For example, Julliard et al. (2022) offer an in-depth analysis of the factors driving haircuts in the UK repo market, while Ballensiefen et al. (2023) highlight the strong segmentation between collateral-driven and funding-driven repo markets. Eisenschmidt et al. (2024) demonstrate that oligopolistic effects play a crucial role in shaping interbank borrowing rates, and Duffie and Krishnamurthy (2016) provide a foundational explanation of how the US repo market functions, including the role of liquidity demand and collateral quality.

# 2 Institutional background and hypothesis development

## 2.1 Climate risks

The finance literature typically categorises climate-related risks into two broad types: physical risks (e.g., climate disasters, rising sea levels) and transition risks (e.g., policy changes, market shifts, technological innovations). In its essence, transition risk refers to the financial risks associated with the process of shifting towards a low-carbon economy. [2]

Transition risk could manifest through multiple channels, including through (1) Regulatory risk: Stricter carbon pricing mechanisms (e.g., carbon taxes, cap-and-trade systems) increase operational costs for high-emitting firms; (2) Market risk: Shifts in investor sentiment and

[2] The Task Force on Climate-related Financial Disclosures (TCFD) defines transition risk as the potential financial losses that firms, investors, and financial institutions may face due to changes in policies, regulations, technologies, and consumer preferences aimed at mitigating climate change (Task Force on Climate-related Financial Disclosures, 2017).

consumer preferences lower the valuation of carbon-intensive assets; (3) Technological risk: Disruptive clean technologies (e.g., electric vehicles, renewable energy) erode the market share of fossil-fuel-based industries; (4) Legal risk: Climate litigation against polluting firms raises liability costs and insurance risks.

Our analysis focuses on the regulatory risk channel of transition risk. This is motivated by two factors. First, regulatory risk has a direct and quantifiable impact on financial institutions and markets. Unlike market or technological risks, which evolve gradually, policy changes such as carbon taxes, cap-and-trade systems, and disclosure mandates can immediately alter firms' cost structures, profitability, and creditworthiness. This makes regulatory risk a more tangible and measurable potential driver of financial instability, particularly in the interbank lending market, where liquidity constraints and risk assessments are highly sensitive to sudden policy shifts. Secondly, large institutional investors see transition risk as the more immediate consequence of climate change for their portfolios. While they believe that physical risk will only really start to materialise in their portfolios in the long-term, the impact of transitioning to a net-zero economy is already felt today (Krueger et al., 2020).

While greenhouse gas emissions are a widely used proxy for transition risk, physical risk exposure is more difficult to measure. In the euro area, physical risk can to some extent be proxied by country or region, but it is important to consider how much of the risk is borne by firms and households versus insurance corporations and the public sector. This makes it more complex to estimate the share of risk ultimately held by banks.

### 2.2 Carbon markets

The European Union Emissions Trading System (EU ETS) is the world's largest and most established carbon market, designed to help the EU meet its climate targets by reducing greenhouse gas (GHG) emissions in a cost-effective manner. It was established in 2005 as a central policy instrument to meet the EU's obligations under the Kyoto Protocol and has since been a key part of the region's strategy to achieve carbon neutrality by 2050.

The EU ETS operates as a cap-and-trade system, meaning that a maximum limit (or cap) is set on the total amount of GHG emissions allowed from covered sectors. This cap is progressively reduced over time, aligning with the EU's long-term climate goals. Companies within these sectors are allocated a certain number of emission allowances (EUAs), which represent

**Figure 1: EUA futures prices and MSR event dates**

The graph shows the EU carbon price as measured by the price of the first EUA futures contract over the different phases of the EU ETS together with key events regarding the market stability reserve (MSR). Dotted lines indicate the announcement of each supply reduction, and solid lines indicate the actual start of the supply reduction.


the right to emit one ton of CO2 or its equivalent in other GHGs. If a company emits more than its allocated allowances, it must buy additional permits from others, incentivising emissions reductions. Conversely, firms that reduce emissions below their allocation can sell surplus allowances, creating a financial incentive to lower emissions.

The EU ETS covers emissions from over 11,000 power plants, industrial facilities, and airlines operating within the EU, as well as a growing number of sectors under its new expansion. The system initially focused on energy-intensive industries, such as power generation, cement, steel, and chemicals, but its coverage has expanded over time, now including aviation and potentially extending to maritime shipping and other sectors in the future. Collectively, the EU ETS accounts for around 40% of the EU's total GHG emissions.

A key reform to enhance the system's efficiency is the Market Stability Reserve (MSR), introduced in 2019. The MSR was designed to address the surplus of allowances in the market and ensure that carbon prices remain at levels that incentivize genuine emissions reductions. Around 57% of the allowances in the EU ETS are auctioned, with auctions held about three times a week, while the remainder is allocated for free to sectors at risk of carbon leakage. If the surplus of allowances in the market exceeds a threshold of 833 million, excess allowances are removed from future auctions. This mechanism automatically sets aside unused allowances in the MSR, tightening supply and supporting higher carbon prices. As a result, the market price for allowances has nearly quadrupled over the observation period from 2019 to 2022.

### 2.3 The interbank lending market

A repurchase agreement (repo) is a short-term financial transaction in which one party sells securities to another with the agreement to repurchase them at a set price and date. Essentially, it functions as a secured loan, where the securities serve as collateral. Repos are widely used for short-term funding and liquidity management in financial markets.

The repo market plays a crucial role for financial institutions in sourcing funding or specific securities through short-term, secured transactions. With an average daily trading volume of approximately EUR 700 billion and an outstanding stock of EUR 2.15 trillion (European Central Bank, 2025), it is vital to the functioning of monetary policy, as it "ensures an even distribution of central bank liquidity and a homogeneous level of short-term interest rates" (European Central Bank, 2011).

For this paper it will be particularly important to understand *why* participants trade. There are roughly three reasons: (1) *funding-driven*: cash-borrowers seek short term funding, (2) *return-driven:* cash-lenders seek to collect a return on their excess liquidity, and (3) *collateral-driven:* cash-lenders seek to source specific asset. While a significant share of the transactions are initiated because of the latter two reasons, the secured market remains the predominant source of short-term funding and in this paper, we will therefore entirely focus on the funding-driven segment of the market. Throughout this paper, we will refer to the borrower as the cash-borrower and to the lender as the cash-lender on the first leg of the transaction.

Repos can be further sub-classified into general collateral (GC) repos and special collateral (SC) repos. In a GC repo, the collateral is selected from a predefined basket of eligible securities, meaning the specific ISIN is not known to the cash lender in advance. These transactions are primarily funding-driven, focusing on liquidity rather than a particular security. In contrast, a SC repo involves a predefined ISIN as collateral, making it the preferred option for collateral-driven transactions. These transactions are typically used when a specific security is in demand, such as for short-covering or settlement purposes.

Repos can be traded through three main channels. The first is via a central clearing counterparty (CCP), which, under the European Markets Infrastructure Regulation (EMIR), acts as an intermediary by becoming the buyer to the repo seller and the seller to the repo buyer (open order). By assuming counterparty risk, the CCP also determines the haircut, making it an exogenous factor for the original contracting parties. The second method is trading through a tri-party agent, a financial intermediary that assists with administrative tasks and settlement but does not assume counterparty risk. Lastly, repos can be traded bilaterally in the OTC segment, where transactions occur directly between financial institutions without an intermediary. In the EU, the tri-party segment is relatively small, representing only 10% of the market. Around 70% of transactions in a dataset covering 46 major European commercial banks are cleared via a CCP, with 90% of these being SC repos, reflecting the demand for specific securities (European Central Bank, 2025). However, many financial institutions lack direct access to a CCP and are therefore restricted to trading in the OTC market

### 2.4 Testable hypotheses

We now list the hypotheses on if and how climate change impacts the repo market which we aim to assess in out empirical analysis. A substantial body of research indicates that transition risk associated with climate change permeates most markets studied to date. In most cases, firm's GHG emissions have been used a a proxy for transition risk and a price premium for securities of low GHG-intensive firms has been discovered (Kacperczyk and Bolton, 2021; Bua et al., 2024; Ilhan et al., 2020). On the other hand, we are looking at mostly short-term transactions in a market that is perceived as being very liquid and secure. If transition risk does not play a role in this market, the null hypothesis should find some support:

**Hypothesis 1** *A bank's exposure to transition risk, as measured by financed GHG emissions, has no impact on the pricing of their funding-driven repo transactions.*

Transition risk undoubtedly impacts the risk profile, cash demand, and potentially the profitability of firms. This effect could spill over to banks with higher financed GHG emissions, leading to increased risk premiums in their refinancing transactions, or driving greater demand for borrowing, which they may source from the interbank market. If either of these scenarios holds true, we would expect to find support for the following alternative hypothesis.

**Hypothesis 2** *A bank's exposure to transition risk, as measured by financed GHG emissions, leads to higher rates on its funding-driven repo transactions.*

# 3 Data

## 3.1 Data on European repo transactions

For our analysis we employ high-frequency, trade-level data for the European repo market for the time span from 2019 to 2022. Our data source is the Money Market Statistical Reporting (MMSR) data set from the European Central Bank, which covers all transactions in the repo market made by the 46 biggest European banks.[3] For each transaction we observe the trade date, the maturity, the trade volume, the loan rate, the haircut, the collateral identified by a unique ISIN, the lender, the borrower and the transaction type. Unless stated otherwise, our analysis focuses on *reverse* repo transactions conducted by the 46 MMSR-reporting banks with 223 banks in our sample, which act as cash borrowers in these transactions. For simplicity, we refer to the 46 MMSR-reporting banks as *lenders* and their cash-seeking trading partners as *borrowers*.

As we are interested in cash-driven transactions, i.e., transactions which were initiated because the borrower needed cash, we only consider a part of the transactions from the MMSR dataset. First, we focus on bilateral transactions and exclude those cleared by Central Counterparties (CCPs) for three key reasons: (1) To assess counterparty risk, it is essential to observe the bank-counterparty pair directly; (2) CCPs often determine rates at the portfolio level, which can introduce noise that makes it difficult to attribute specific risk to collateral alone; (3) Many CCP transactions are primarily used by banks to manage collateral demands rather than cash demands, which reduces their relevance to our analysis.[4] Second, we are excluding special collateral transactions and all transactions made with haircuts below zero as both are most likely collateral-driven. Third, we focus on transactions between deposit-taking financial institutions for the simple reason that we cannot observe loan-portfolios for other market participants like money-market funds, hedge funds or pension funds. We end up with a sample of 2.3 million transactions, with an average transaction volume of EUR 7.8 million.

All rates, volumes and haircuts are winsorised at the 1% and 99% level. This was done to clean the dataset from flawed data points, but it has no impact on the qualitative nature of our findings. Figure 2 shows the maturity and collateral sector distribution in our sample. While most repos are typically collateralised by a government bond, our sample features also

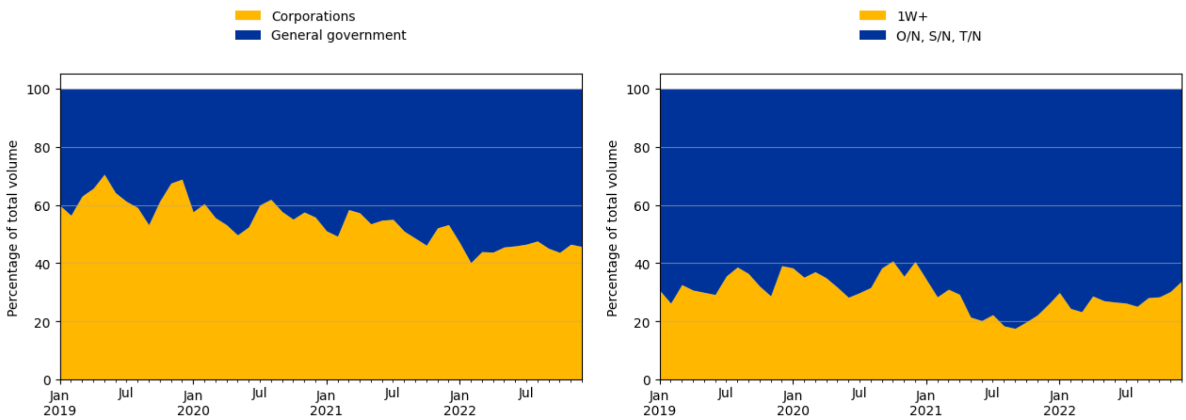
[3] For a detailed list of the reporting banks see European Central Bank (2025).

[4] About 90% of the cleared transactions are SC repos which tend to be collateral-driven (European Central Bank, 2025).

a significant share of transactions that is collateralised with corporate sector bonds.

**Figure 2: Collateral sector and maturity distribution of transactions in our sample**

The left graph illustrates the relative volume-weighted share of transactions collateralized by securities across the two primary collateral sectors in our sample. Meanwhile, the right graph displays the relative volume-weighted share of transactions within the two main maturity buckets in our sample.




**(a) Collateral sector distribution** **(b) Maturity distribution**

We also note that our classification into funding- and collateral driven transactions may not be perfect for two reasons. One is that the transaction type classifier (whether it was a generic or a specific transaction) is voluntary and hence missing in many cases. The second reason is that even GC transactions are used for collateral purposes in some rare cases. However, including collateral-driven transactions in our sample would only go against us as these transactions are neither reflective of the demand for cash, nor about the counterparty-risk of the cash-borrower. As a consequence, by including some of the collateral-driven transactions in our sample, we would be underestimating the true effect.

The average borrowing rate of our sample is plotted in Figure 3. It is very similar to the average GC rate which is a close proxy for the cost of money (Ballensiefen et al., 2023).

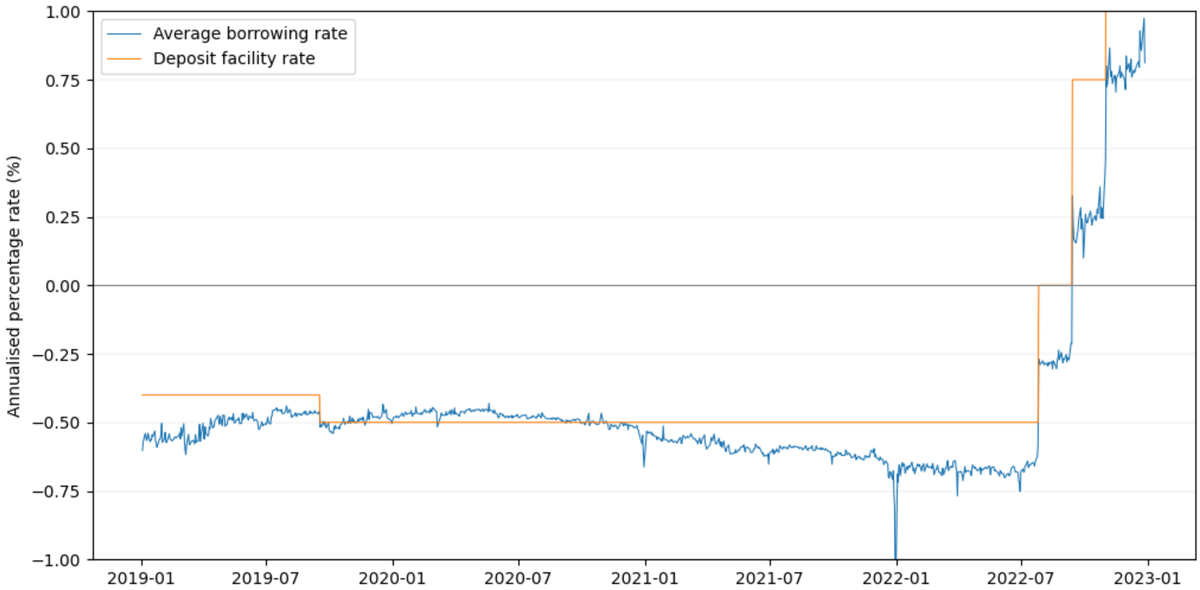
## 3.2 Data on financed GHG emissions

Our primary proxy for transition risk will be the financed GHG emissions of each bank, calculated as follows. For each year and each bank, we examine all outstanding corporate loans with a value exceeding EUR 25,000.[5] These loans are paired with Scope 1 GHG intensity data

[5]These loans include credit card debt, credit lines, deposits (excluding reverse repurchase agreements), reverse repurchase agreements, trade receivables, loans, revolving credit (excluding overdrafts and credit card debt), overdrafts, and finance leases.

**Figure 3: Average borrowing rate**

The graph shows the average daily borrowing rate and the ECB's deposit facility rate. The average daily borrowing rate is calculated as the volume weighted average rate of all borrowing transactions made by 223 counterparty banks in our sample with the 46 MMSR reporting banks.




from Urgentem. We use Scope 1 emissions as it is the most likely level subject to regulatory measures.[6] Additionally, we focus on intensity rather than absolute emissions, as firms with lower revenues relative to emissions will likely face greater regulatory burden. This approach aligns with the climate finance literature (e.g., Ilhan et al. (2020)).

Next, we calculate the volume-weighted Scope 1 intensity for each year and bank, then divide it by the bank's revenues. This method is motivated by the fact that banks with relatively low revenues are most likely to face challenges in accommodating the borrowing demand arising from transition risks.

Table 1 summarises the key variables used in the following empirical analysis.

# 4 The climate premium

In this section, we establish the existence of a strong correlation between repo rates and financed GHG emissions. We then proceed to investigate *why* this carbon premium arises. A common explanation in the climate finance literature is that it reflects compensation for risk,

[6]The aggregate time series is published in European Central Bank (2024).

**Table 1: Summary statistics and correlation matrix**

For all repo loan rates we show the difference of the actual loan rate minus the ECB's deposit facility rate (DFR). The collateral rating is a mapping from Moody's rating into integer numbers from 1 to 20, with 20 representing AAA-quality.

**Panel A: Summary Statistics**

| Variable | N | Mean | Std. Dev. | Min | 1% | 25% | 50% | 75% | 99% | Max |
|---|---|---|---|---|---|---|---|---|---|---|
| $Rate$ | 2,334,623 | -0.53 | 0.83 | -6.17 | -6.10 | -0.55 | -0.35 | -0.20 | 0.35 | 8.50 |
| $FinancedEmissions$ | 2,334,623 | 0.03 | 0.02 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 | 0.10 | 0.43 |
| $Haircut$ | 2,334,623 | 0.37 | 1.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 100.00 |
| $Volume$ | 2,334,623 | 7.88 | 30.61 | 0.00 | 0.02 | 0.53 | 1.10 | 3.68 | 111.60 | 6,755.21 |
| $Rating$ | 1,959,710 | 17.29 | 2.81 | 11.00 | 12.00 | 16.00 | 18.00 | 20.00 | 20.00 | 20.00 |
| $Maturity$ | 2,334,623 | 2.88 | 16.61 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 30.00 | 365.00 |
| $TotalAssets$ | 2,006,742 | 721.49 | 840.19 | 0.64 | 26.82 | 101.98 | 348.87 | 1,299.70 | 2,766.39 | 2,766.39 |
| $LeverageRatio$ | 2,006,742 | 0.05 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.12 | 0.42 |
| $LiquidityRatio$ | 2,006,742 | 24.74 | 4,787.70 | 1.01 | 1.20 | 1.36 | 1.49 | 1.71 | 9.28 | 999,999 |
| $CapitalRatio$ | 2,006,742 | 0.17 | 0.04 | 0.06 | 0.13 | 0.15 | 0.17 | 0.18 | 0.38 | 1.37 |
| $ROA$ | 2,006,742 | 0.01 | 0.01 | -0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.03 | 0.11 |

**Panel B: Correlation Matrix**

| | $FinancedEmissions$ | $TotalAssets$ | $LeverageRatio$ | $LiquidityRatio$ | $CapitalRatio$ | $ROA$ |
|---|---|---|---|---|---|---|
| $FinancedEmissions$ | 1.00 | -0.13 | -0.02 | 0.00 | -0.06 | -0.12 |
| $TotalAssets$ | -0.13 | 1.00 | -0.39 | 0.00 | -0.45 | 0.06 |
| $LeverageRatio$ | -0.02 | -0.39 | 1.00 | 0.01 | 0.46 | 0.06 |
| $LiquidityRatio$ | 0.00 | 0.00 | 0.01 | 1.00 | 0.00 | 0.00 |
| $CapitalRatio$ | -0.06 | -0.45 | 0.46 | 0.00 | 1.00 | 0.10 |
| $ROA$ | -0.12 | 0.06 | 0.06 | 0.00 | 0.10 | 1.00 |

i.e., a risk premium. We assess this hypothesis against alternative explanations based on investor preferences or demand shocks, using additional panel regressions and identification strategies.

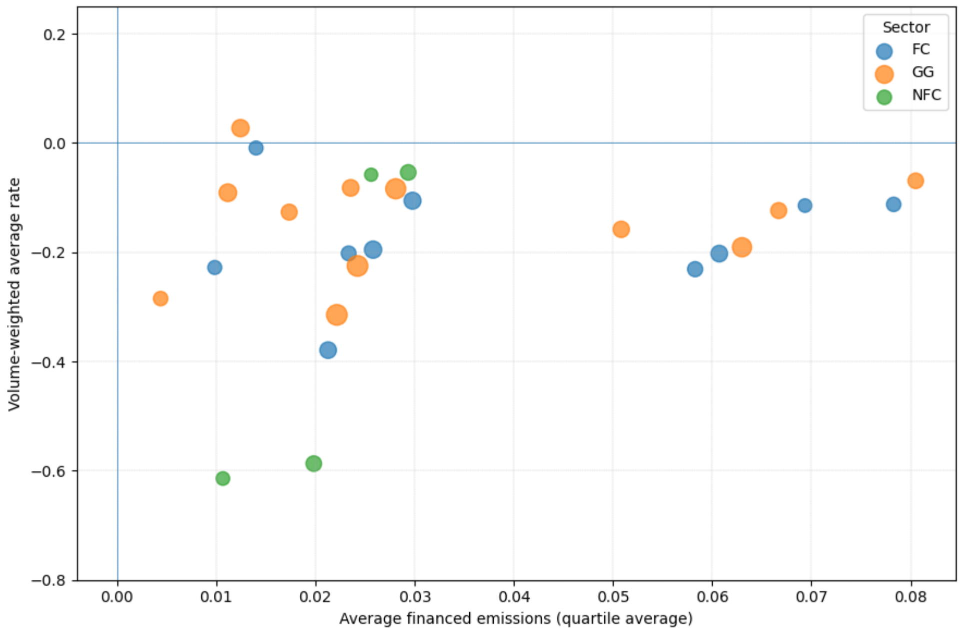
## 4.1 Panel regressions of interbank borrowing rates on financed emissions

We begin by presenting our main findings on the pricing of emissions in the European repo market. We first report results for the full set of available collateral assets, and then examine how the carbon premium varies across different collateral classes. At a high level, Figure 4 illustrates the distribution of financed GHG emissions and repo rates, even before controlling for repo-specific characteristics or borrower fixed effects. Across all collateral sectors, the figure suggests that banks with lower financed GHG emissions tend to receive more favourable rates.

Our main analysis of the carbon premium relies on two fixed-effects specifications. The first controls for all time-series variation in rates, allowing us to focus on cross-sectional heterogeneity in banks' financed emissions. The second controls for bank-specific heterogeneity,

**Figure 4: Financed emissions and average borrowing rates**

The chart shows the volume-weighted yearly average loan rate in cash-borrowing transactions of 223 banks against their financed GHG-emissions, subdivided by collateral issuer sector. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25k, divided by the bank's revenues and lagged by one year. Only O/N, S/N and T/N transactions are included.




**(a) Distribution across collateral types**

thereby emphasizing time-series variation. Given that our sample spans only four years, there is substantially more variation across banks than over time. As a result, the second specification generally yields weaker, though still largely significant results.

Even though most studies focus on general firms rather than banks (e.g., Kacperczyk and Bolton (2021, 2022)), several characteristics are particularly relevant when using carbon emissions as the main dependent variable. These include total assets or bank size, risk measures such as the liquidity and leverage ratios, capital ratios, and return on assets as a proxy for profitability. We also note considerable cross-sectional heterogeneity in repo rates, which largely depends on deal-specific characteristics such as the ISIN used as collateral, maturity, volume, haircut, and dealer-specific factors.

We begin by linking bank's borrowing rates, to their corresponding financed emissions intensities and other characteristics, all lagged by one year. Specifically, we estimate the following specification:

$$Rate_{l,b,t,i} - DFR_t = \beta_1 \times FinancedEmissions_{b,t-365} + \beta_2 \times DealControls_i + \beta_3 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i}, \quad (1)$$

where $\delta_t$ and $\gamma_{l,b}$ are time and borrower-lender fixed effects. The index $i$ represents the transaction level on which this regression is executed which – strictly speaking – makes the indices $l$ for lender, $b$ for borrower and $t$ for the specific day obsolete. As deal controls, we include the collateral ISIN, the transaction maturity, volume and haircut. As borrower controls, we include total assets to proxy for the borrower's size, the return on assets to proxy for its profitability and the leverage ratio, the liquidity ratio as well as the capital ratio to proxy for the the riskiness of the borrower. In all specifications, standard errors are clustered at the lender-borrower level, as we expect errors to be correlated at this level due to the strong impact of relationships within this market (Eisenschmidt et al., 2024). The results are reported in Table 2.

**Table 2: Transition risk premia**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | DFR-adjusted rate (%) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $FinancedEmissions$ | 0.066*** | 0.058*** | 0.031*** | 0.048*** |
| | (0.006) | (0.005) | (0.004) | (0.006) |
| $Haircut$ | | −0.148*** | −0.054*** | 0.006 |
| | | (0.017) | (0.009) | (0.007) |
| $Volume$ | | 0.104*** | 0.075*** | 0.051*** |
| | | (0.005) | (0.004) | (0.003) |
| $Maturity$ | | 0.003*** | 0.002*** | 0.002*** |
| | | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | No | No | Yes | No |
| FE: Lender | No | No | Yes | No |
| FE: Lender × Borrower | No | No | No | Yes |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.16 | 0.33 | 0.43 | 0.50 |

Across all specifications, we find a positive and significant effect of financed GHG emissions on a bank's interbank borrowing rate. Most importantly, this effect cannot be explained by individual deal characteristics or lender-borrower relationships—both of which are known to be key determinants of repo rates. Isolating the time-series variation in financed GHG emissions yields larger positive coefficients than focusing on cross-sectional differences. This may reflect the growing salience of transition risk over the observation period.

The presence of a carbon premium in generally safe and short-term loans is both novel and surprising. Taken at face value, our results suggest that a one standard deviation increase in a bank's financed GHG emissions is associated with an average increase of 3–5 basis points in its borrowing rate. To put this into perspective, the overall standard deviation of adjusted rates in our sample is 83 basis points. However, this figure includes substantial heterogeneity driven by deal-specific characteristics. After controlling for such factors, the standard deviation of the residual loan rates is 0.43, implying that a one standard deviation increase in financed emissions is associated with a rate increase equivalent to approximately 7–12% of this residual variation.

As the scatter plot in Figure 4 indicates, there may be significant differences between the collateral sectors. Collateral management is highly relevant for banks and one of the key reasons why repos are so often used next to its funding purpose. We repeat the above regression 1 for each collateral class separately. The results are reported in Table 3.

The differences between collateral classes are economically meaningful and, depending on the specification, range from around 4 basis points for transactions collateralised by government bonds and financial corporations, to up to 21 basis points in the case of non-financial corporate collateral. Two potential factors may explain this variation. First, repos backed by general government bonds tend to be more standardised and liquid instruments compared to those involving non-financial corporate bonds. As a result, their contractual terms are less flexible, and climate-related risks may be less directly reflected in pricing. Second, transactions involving general government collateral are more commonly used for collateral management purposes, rather than strictly for funding. In such cases, the pricing of borrower-specific risks (such as financed emissions exposure) may be less relevant, which could weaken the observed relationship in this segment. We also find that the results become stronger once lender-borrower fixed effects are included. This specification isolates time variation within individual lending relationships, suggesting that dealers may have increasingly priced in climate transition risks over time. One possible explanation is that awareness and salience of climate-related

**Table 3: Transition risk premia by collateral sector**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. Regressions are based on the subset of transactions from three different collateral sectors: Non-financial corporations (NFC), Financial corporations (FC), and General government (GG). All continuous variables are standardised. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. Standard errors are clustered at the bank-counterparty-month level. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | DFR-adjusted rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | NFC | | FC | | GG | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $FinancedEmissions$ | 0.055*** | 0.209*** | 0.025*** | 0.039*** | −0.004 | 0.043*** |
| | (0.012) | (0.029) | (0.005) | (0.006) | (0.004) | (0.005) |
| $Haircut$ | 0.015* | 0.025*** | −0.005 | 0.003 | −0.013*** | −0.022*** |
| | (0.009) | (0.009) | (0.004) | (0.002) | (0.004) | (0.004) |
| $Volume$ | 0.010 | 0.021*** | 0.091*** | 0.080*** | 0.029*** | 0.025*** |
| | (0.006) | (0.005) | (0.007) | (0.006) | (0.003) | (0.003) |
| $Maturity$ | 0.005*** | 0.000 | 0.003*** | 0.002*** | 0.001*** | 0.002*** |
| | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| FE: Lender | Yes | No | Yes | No | Yes | No |
| FE: Date | Yes | No | Yes | No | Yes | No |
| FE: Lender × Borrower | No | Yes | No | Yes | No | Yes |
| $N$ | 466 410 | 466 410 | 1 095 577 | 1 095 577 | 434 832 | 434 832 |
| $R^2$ | 0.50 | 0.54 | 0.31 | 0.45 | 0.49 | 0.54 |

financial risks grew between 2019 and 2022, leading to a gradual incorporation of such premia into repo rates.

## 4.2 Mechanism analysis

The panel regression in the previous section provides suggestive evidence that transition risk leads to higher borrowing rates for affected banks. But we have not identified the transition risk yet and cannot say anything yet about the origin of this premium. There are three main hypotheses as to where this premium comes from.

The first one is that it reflects *credit risk*. If firms with higher emissions get hit by climate policies, for instance by rising carbon prices, then these firms face higher thresholds for profitability and and thus getting more risky for its lenders. The risk that these lenders carry if there are highly exposed to the brown sector, could be internalised into the lending rates by other peer banks in the interbank lending market.

The second hypothesis is that the observed effect reflects an *equilibrium adjustment* in rates driven by increased demand for cash. When carbon-intensive (or "brown") firms are impacted by regulation, they face higher production costs due to new climate policies. To cover these costs, they may draw more heavily on their credit lines. Banks that lend to these firms therefore experience a surge in credit demand, prompting them to seek additional liquidity in the interbank repo market. As a result, banks with greater exposure to carbon-intensive borrowers face increased refinancing needs, which raises their demand for cash in the interbank market. This heightened demand, in turn, drives up the price of liquidity, reflected in higher repo rates.

A third hypothesis relates to *institutional preferences*. Most dealer banks in the euro area have joined at least one major sustainability initiative, such as the Net-Zero Banking Alliance (NZBA) or the Science Based Targets initiative (SBTi).[7] These frameworks typically involve commitments to reducing financed emissions or excluding carbon-intensive sectors from lending portfolios. Joining such initiatives not only reflects a strategic orientation towards climate-aligned finance but also signals the bank's broader preferences, whether driven by regulation, stakeholder pressure, or internal values. As a result, it is plausible that dealer banks with these commitments may have been less willing to extend funding to counterparties with high exposure to carbon-intensive sectors.

In the following sections we will look at various different variables and event to differentiate between these three hypothesis and eventually answer the question where this premium really comes from.

#### 4.2.1 Maturities

Even in this ultra short-term market, maturities matter and are priced in, as evidenced by the consistently positive and significant coefficients on maturity across all panel regressions in subsection 4.1. Longer maturities amplify credit risk: the longer a bank is exposed to its counterparty through a loan contract, the more relevant the assessment of counterparty risk becomes. This finding is particularly relevant for our second hypothesis. If the observed rate premium were driven primarily by a demand-side explanation—for example, a surge in repo demand due to climate transition pressures—then maturity should not systematically affect pricing. In such a case, the resulting rate adjustment would affect transactions uniformly, regardless of their term. A reasonable null hypothesis would therefore be to expect no amplification effect.

[7] The NZBA and SBTi are voluntary initiatives through which financial institutions commit to aligning their lending and investment portfolios with net-zero greenhouse gas emissions by 2050 (NZBA), or to setting emission reduction targets consistent with climate science and the goals of the Paris Agreement (SBTi).

We are testing this by estimating a modified version of regression 1:

$$
\begin{aligned}
Rate_{l,b,t,i} - DFR_t = \beta_1 \times FinancedEmissions_{b,t-365} \\
+ \beta_2 \times LongMaturity + \beta_3 \times LongMaturity \times FinancedEmissions_{b,t-365} \\
+ \beta_4 \times DealControls_i + \beta_5 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i},
\end{aligned}
\tag{2}
$$

where $\delta_t$ and $\gamma_{l,b}$ are time and borrower-lender fixed effects. The variable $LongMaturity$ is a dummy variable assuming the value 1 whenever the maturity of the repo was longer than one month. As deal controls, we include the collateral ISIN, volume and haircut. As borrower controls, we include total assets to proxy for the borrower's size, the return on assets to proxy for its profitability and the leverage ratio, the liquidity ratio as well as the capital ratio to proxy for the the riskiness of the borrower. In all specifications, standard errors are clustered at the lender-borrower level. The results are reported in Table 4.

**Table 4: Transition risk premia and longer maturities**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. The variable $LongMaturity$ is a dummy indicating if the repo has a maturity greater than one month. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | DFR-adjusted Rate (%) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $FinancedEmissions$ | 0.064*** | 0.057*** | 0.030*** | 0.048*** |
| | (0.006) | (0.005) | (0.004) | (0.006) |
| $LongMaturity$ | 0.526*** | 0.352*** | 0.343*** | 0.156*** |
| | (0.033) | (0.039) | (0.030) | (0.022) |
| $FinancedEmissions \times LongMaturity$ | 0.061** | 0.054** | 0.065*** | −0.010 |
| | (0.025) | (0.026) | (0.022) | (0.014) |
| $Haircut$ | | −0.146*** | −0.052*** | 0.008 |
| | | (0.017) | (0.009) | (0.007) |
| $Volume$ | | 0.107*** | 0.078*** | 0.055*** |
| | | (0.005) | (0.004) | (0.003) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | No | No | Yes | No |
| FE: Lender | No | No | Yes | No |
| FE: Lender × Borrower | No | No | No | Yes |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.16 | 0.32 | 0.43 | 0.50 |

While the coefficient on $FinancedEmissions$ remains largely unchanged relative to the baseline reported in Table 2, and the coefficient on $LongMaturity$ is positive and significant as expected, the interaction term between the two depends on the specification. In the cross-sectional analysis, there is a strong additional premium of approximately 7 basis points for longer-term loans issued to borrowers with high financed emissions. However, in the time-series specification the interaction term is insignificant and close to zero. This suggests that within stable lending relationships, longer maturities do not amplify the pricing of transition risk, whereas such interactions do matter across borrowers. One possible explanation is that within lender-borrower pairs, repo contracts tend to become more stable over time, partly due to operational convenience, and partly because lenders develop a better understanding of their counterparties. Nevertheless, the fact that longer maturities are associated with higher rates in the cross-section, and that they interact positively with financed emissions, is consistent with a credit risk channel. It may also indicate that dealers exhibit a preference for lower-emission counterparties, particularly when their exposure spans longer durations.

#### 4.2.2 Haircuts

When investigating credit risk, the haircut is another natural variable to look at. Julliard et al. (2022) show that counterparties matter for haircut determination: riskier clients such as hedge funds are charged significantly higher haircuts, whereas larger borrowers with higher ratings receive lower haircuts. One important caveat is that haircuts in repo markets change much less frequently than rates and are set to zero in more than 80% of the transactions in our sample. Nevertheless, we still see that haircuts spike around important macroeconomic events such as the onset of the Covid crisis in 2020, indicating that it still captures some degree of credit risk. That there is a premium for additional credit risk originating from transition risk in these ultra-short term and secured loans is surprising so a reasonable null hypothesis would be for the financed emissions to not have any effect on the haircut.

We are testing this hypothesis in two ways. First, we use the haircut itself as the dependent variable in the following regression:

$$\begin{aligned} Haircut_{l,b,t,i} &= \beta_1 \times FinancedEmissions_{b,t-365} \\ &\quad + \beta_1 \times DealControls_i + \beta_5 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i}. \end{aligned} \tag{3}$$

Second, because of the limited variation in our dataset, we are using a dummy indicating whether the haircut has been strictly positive with the regression

$$D_{l,b,t,i}^{Haircut>0} = \beta_1 \times FinancedEmissions_{b,t-365} + \beta_1 \times DealControls_i + \beta_5 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i}. \quad (4)$$

In both cases $\delta_t$ and $\gamma_{l,b}$ are used as time and borrower-lender fixed effects. As deal controls, we include the collateral ISIN, volume and the rate. As borrower controls, we include total assets to proxy for the borrower's size, the return on assets to proxy for its profitability and the leverage ratio, the liquidity ratio as well as the capital ratio to proxy for the the riskiness of the borrower. In all specifications, standard errors are clustered at the lender-borrower level. The results are reported in Table 5.

**Table 5: Transition risk impact on haircuts**

The dependent variable in the left two regressions is the transaction haircut, and a dummy indicator in the two right hand side regressions indicating whether or not the transaction has had a positive haircut. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | Haircut (%) | | $D^{Haircut>0}$ | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $FinancedEmissions$ | 0.043*** | −0.012 | 0.008*** | 0.006*** |
| | (0.011) | (0.008) | (0.001) | (0.002) |
| $Rate$ | −0.087*** | 0.006 | −0.020*** | 0.004*** |
| | (0.014) | (0.006) | (0.002) | (0.001) |
| $Volume$ | 0.043*** | 0.046*** | 0.011*** | 0.012*** |
| | (0.016) | (0.014) | (0.002) | (0.002) |
| $Maturity$ | 0.005*** | 0.005*** | 0.001*** | 0.001*** |
| | (0.001) | (0.001) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | Yes | No | Yes | No |
| FE: Lender | Yes | No | Yes | No |
| FE: Lender × Borrower | No | Yes | No | Yes |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.41 | 0.70 | 0.74 | 0.84 |

In the first specification, we observe a pattern consistent with earlier regressions. While the effect is present and significant in the cross-sectional analysis, the coefficient diminishes once we focus on within lender–borrower pair variation – likely for the same reasons discussed above.

The coefficients for $FinancedEmissions$ in the second specification are positive and statistically significant. They suggest that a one standard deviation increase in a borrower's financed emissions raises the probability of receiving a positive haircut by approximately 1%. While this may seem modest, it should be viewed in the context of haircuts being generally rigid and often zero.

#### 4.2.3 Identification via ETS-prices

In this section, we aim to identify transition risk through shocks to carbon prices. The core idea is that an unexpected increase in the price of emissions allowances represents a direct realization of transition risk. For carbon-intensive ("brown") firms, such shocks raise production costs. Given nominal rigidities, these cost increases are likely to compress short-term profits, which can in turn increase funding needs and, in more severe cases, contribute to financial distress if sufficient external financing is not secured.

If we can use carbon price shocks as an instrument and demonstrate that they are associated with rising repo rates, this would provide compelling evidence that credit risk or demand-side channels are active in this market.

One potential concern, however, is that MSR-related supply reductions (i.e., cuts in the Market Stability Reserve) are announced well in advance, typically in May or June before being implemented on September 1st. As a result, these events may not constitute truly "unexpected" shocks. Yet for our purposes, what matters is not the surprise element of the supply announcement, but rather the actual shock to carbon prices. While the reduction in allowance supply is anticipated, the market's reaction in the form of price changes is an equilibrium outcome that unfolds around the implementation date. Due to the ultra-short-term nature of the repo market, much of this price effect is revealed only after September 1st. That said, firms anticipating tighter supply may warehouse allowances in advance, which could mute the price adjustment on the implementation date and potentially weaken the predictive power of our identification strategy.

Another potential concern with this approach is serial correlation. If we would be using transaction level data, the number of observations per treated unit are much more granular than the level on which the intervention takes place. As a consequence, results will be highly significant (and indeed positive) but no longer trustworthy (Angrist and Pischke, 2004). Hence, we are doing two things to reduce this problem: The first is that we don't do this estimation on a transaction level, but rather average transactions by counterparty-week. As there is important heterogeneity in repo contracts that we need to control for, we are first stripping repo rates off fundamental factors that are know to influence repo rates such as the collateral ISIN, the maturity, and the haircut. To fix ideas, we are computing residual repo rates as in

$$Rate_{l,b,i,t} - DFR_t = \beta_1 Haircut_{i,t} + \beta_2 Maturity_{i,t} + \beta_3 CollISIN_{i,t} + \delta_t + \varepsilon_{l,b,i,t}, \tag{5}$$

where $\delta_t$ are month-year fixed effects. We average these residuals as in

$$Rate^{resid}_{b,w} \equiv \frac{\sum_{i \in \mathcal{T}_{b,w}} LoanVolume_{i,t} \times \hat{\varepsilon}_{l,b,i,t}}{\sum_{i \in \mathcal{T}_{b,w}} LoanVolume_{i,t}}, \tag{6}$$

where $\mathcal{T}_{b,w}$ denotes all borrowing transactions made by counterparty $b$ in week $w$.

The second important step is to cluster the standard errors at the counterparty level to account for errors being correlated across time for each borrower. For each year in our sample for which we have MSR-related supply reductions, we are estimating the following specification

$$Rate^{resid}_{b,w} = \beta^{IV} D^{IV}_w \times FinancedEmissions_{w-52,b} + X_{b,w} + \delta_w + \gamma_b + \varepsilon_{b,w}, \tag{7}$$

were $D^{IV}_w$ is a dummy taking the value 1 for all weeks after the supply reduction in a given year. The results are reported in Table 6.

In three out of four cases, we reject the claim that MSR supply reductions directly increased repo rates for banks more heavily exposed to the brown sector. The year 2022 stands out: the MSR supply reduction can be causally linked to a 7 basis point increase in repo rates over 12 weeks. Why was this intervention different from the others? There are several potential reasons. First, climate awareness has grown over the years, so while earlier transactions did not carry a climate premium, later interventions may have reflected stronger premia. Second, energy prices soared in the second half of 2022 due to the war in Ukraine, meaning that high emitting companies already facing elevated input costs were hit even harder by higher carbon prices. Third, carbon prices themselves increased substantially over the years and were generally much higher in 2022 than before. Firms that might have coped with 20 Euros per ton of carbon previously faced prices up to 90 Euros per ton in 2022, which likely posed a differ-

**Table 6: Identification via ETS-supply shocks**

The dependent variable is the loan rate residual as defined in equation 6. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the borrower-level and reported in parentheses. Controls include total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | $Rate^{resid}$ (%) | | | |
|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 |
| $Post \times FinancedEmissions$ | 0.022 | 0.000 | 0.000 | 0.070** |
| | (0.018) | (0.010) | (0.007) | (0.030) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Counterparty | Yes | Yes | Yes | Yes |
| FE: Week | Yes | Yes | Yes | Yes |
| Num.Obs. | 1343 | 1139 | 1321 | 1439 |
| R2 | 0.605 | 0.677 | 0.713 | 0.788 |

ent challenge. Fourth, successive interest rate hikes in the second half of 2022 driven by rising prices may confound our estimates. This is why we used adjusted rates and included month-year fixed effects when calculating residuals. The DiD-plot in Figure 5 for this year shows almost no pre-trend and a sharp incline right after the introduction which alleviates this concern. Lastly, warehousing carbon allowances or the expectation of supply reductions may have erased our effects in the first three years.

#### 4.2.4 Voluntary climate commitments

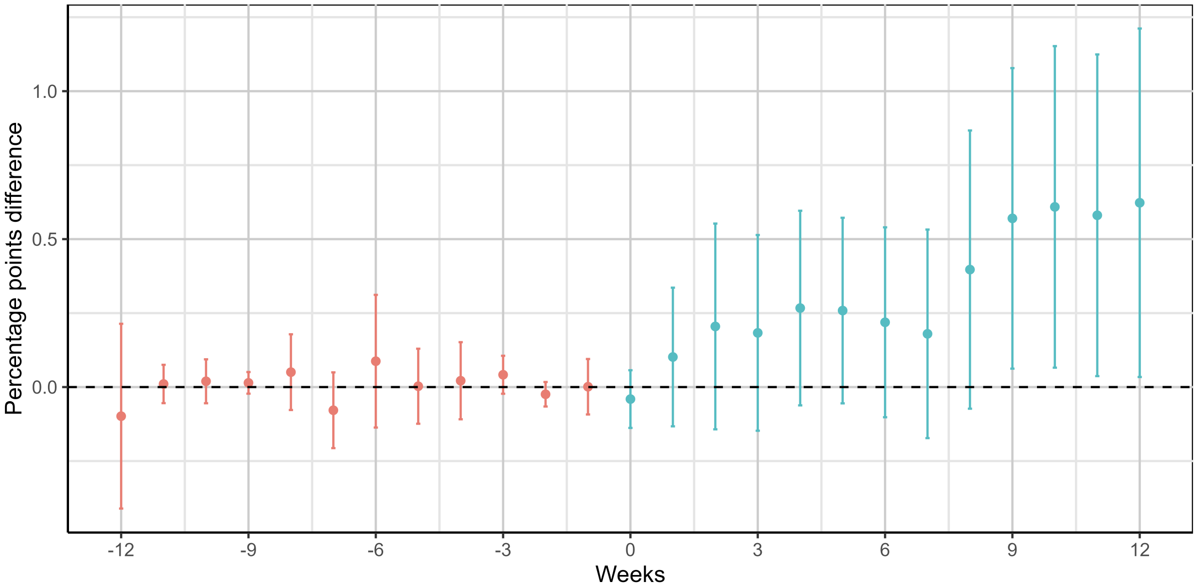
A third explanation could be that the premium is due to preferences, i.e., banks could have a preference for borrowers with lower financed GHG-emissions, and hence they charge lower rates for green banks, or higher rates to brown banks to compensate themselves for the loss in convenience.

Often introduced due to stakeholder pressure, voluntary climate commitments offer insight into each bank's preferences. To the extent that banks genuinely follow through on these commitments — and there is ongoing debate about whether they do[8] — we can examine whether

[8] Kacperczyk and Peydró (2022) and Ye (2023), for instance, find that banks reduce exposure to high emitters or coal-related sectors in syndicated loans following voluntary climate commitments. Additionally, Altavilla et al. (2024), Delis et al. (2018), and Degryse et al. (2023) find that banks charge higher interest rates to polluting firms, suggesting a risk-based pricing response aligned with climate goals. On the other hand, Giannetti et al. (2025) and Sastry et al. (2024) show that banks highlighting the sustainability of their lending practices in public disclosures do not necessarily reduce their environmental impact and in fact, may extend more credit to brown borrowers.

**Figure 5: Estimated coefficients of the 2022 MSR treatment indicator**

The graph plots the estimated coefficients on interactions of the treatment indicator variable with year-week fixed effects. We drop the interaction for the last week of August in 2022 (week 35, which started on Monday, August 29, 2022, and ended on Sunday, September 4, 2022) and thus the effect is normalized to zero for that week. We control for deal maturity, haircut, collateral ISIN, and bank-counterparty relationships. Standard errors are clustered at the borrower-level.




banks' preferences influence pricing in repo markets.

There are two main types of climate commitments we could use in our analysis: SBTi and NZBA. The SBTi distinguishes between the date of commitment, when a bank formally requests a decarbonization timeline, and the date when concrete targets are actually set and implementation can begin. While some dealer banks in our sample do make SBTi commitments, most had not established specific targets by the end of the sample period. Therefore, we should not expect observable changes in behavior based solely on initial SBTi commitments.

In contrast, NZBA includes a signing date that is directly linked to specific decarbonization targets. Most dealer banks in our sample committed to NZBA during the sample period,[9] which is the key reason we rely on NZBA commitments rather than SBTi to conduct our empirical tests.

[9] A striking number of banks have since exited the NZBA, but this occurred only after the end of our sample period.

We specify our test in the following form:

$$
\begin{aligned}
Rate_{l,b,t,i} - DFR_t = \beta_1 \times FinancedEmissions_{b,t-365} & \\
+ \beta_2 \times VCC_{b,t} + \beta_3 \times FinancedEmissions_{b,t-365} \times VCC_{b,t} & \\
+ \beta_4 \times DealControls_i + \beta_5 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i}, &
\end{aligned} \tag{8}
$$

where $\delta_t$ and $\gamma_{l,b}$ are time and borrower-lender fixed effects. The variable $VCC$ is a dummy variable assuming the value 1 whenever the transaction day of the specific repo is on or after the day on which the bank committed to their Specific NZBA targets. As deal controls, we include the collateral ISIN, volume and haircut. As borrower controls, we include total assets to proxy for the borrower's size, the return on assets to proxy for its profitability and the leverage ratio, the liquidity ratio as well as the capital ratio to proxy for the the riskiness of the borrower. In all specifications, standard errors are clustered at the lender-borrower level. The results are reported in Table 7.

The coefficients of interest, $\beta_1$ and $\beta_3$, are both significantly positive across all specifications. Relative to the baseline results in Table 2, the isolated effect of higher financed emissions captured by $\beta_1$ is somewhat smaller but remains statistically significant. This suggests that voluntary climate commitments account for a substantial part of the observed carbon premium, though they do not fully explain it.

#### 4.2.5 Volumes

In theory, the climate premium that we are observing could be due to an equilibrium effect and not really a risk premium. For instance, brown firms may have more demand for funding which means that banks lending to these firms have to source the money from somewhere. The most popular way to source cash for commercial banks is the repo market. Consistent with this hypothesis would be if there is a positive correlation coefficient of *contemporaneous* financed emissions on volumes after controlling for counterparty specific characteristics.

To test this idea we are estimating the following regression:

$$
\begin{aligned}
Volume_{l,b,t,i} = \beta_1 \times FinancedEmissions_{b,t-365} & \\
+ \beta_2 \times DealControls_i + \beta_3 \times BorrowerControls_{b,t} + \delta_t + \gamma_{l,b} + \varepsilon_{l,b,t,i}, &
\end{aligned} \tag{9}
$$

**Table 7: Transition risk premia and preferences**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. $VCC$ stands for voluntary climate commitments and assumes the value one whenever the respective has committed to follow the NZBA guidelines. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | DFR-adjusted Rate (%) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $FinancedEmissions$ | 0.048*** | 0.033*** | 0.015*** | 0.023*** |
| | (0.007) | (0.005) | (0.005) | (0.007) |
| $VCC$ | −0.039** | −0.046*** | 0.004 | −0.040** |
| | (0.018) | (0.013) | (0.021) | (0.017) |
| $FinancedEmissions \times VCC$ | 0.036*** | 0.055*** | 0.039*** | 0.088*** |
| | (0.012) | (0.010) | (0.009) | (0.016) |
| $Haircut$ | | −0.151*** | −0.055*** | 0.006 |
| | | (0.017) | (0.009) | (0.007) |
| $Volume$ | | 0.104*** | 0.076*** | 0.052*** |
| | | (0.005) | (0.004) | (0.003) |
| $Maturity$ | | 0.003*** | 0.002*** | 0.002*** |
| | | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | No | No | Yes | No |
| FE: Lender | No | No | Yes | No |
| FE: Lender × Borrower | No | No | No | Yes |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.16 | 0.33 | 0.43 | 0.50 |

where $\delta_t$ and $\gamma_{l,b}$ are time and borrower-lender fixed effects. As deal controls, we include the collateral ISIN, the transaction maturity, adjusted rate and haircut. As borrower controls, we include total assets to proxy for the borrower's size, the return on assets to proxy for its profitability and the leverage ratio, the liquidity ratio as well as the capital ratio to proxy for the the riskiness of the borrower. The results are reported in Table 8.

While coefficients for the first two specifications are not significant, the coefficients for regressions where we control for borrower fixed effects are actually negative and significant, which is inconsistent with the demand side channel.

**Table 8: Transition risk premia and volumes**

The dependent variable is the transaction volume. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | Volume (EUR mln) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $FinancedEmissions$ | 0.916 | 0.781 | $-0.799^{***}$ | $-1.076^{***}$ |
| | (0.849) | (0.879) | (0.166) | (0.274) |
| $Haircut$ | 0.549 | 0.863 | 1.264 | 1.255 |
| | (1.645) | (1.261) | (1.336) | (1.355) |
| $Maturity$ | $0.437^{***}$ | $0.357^{***}$ | $0.315^{***}$ | $0.314^{***}$ |
| | (0.122) | (0.094) | (0.084) | (0.084) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | No | Yes | No | Yes |
| FE: Lender | No | Yes | No | No |
| FE: Lender × Borrower | No | No | Yes | Yes |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.28 | 0.39 | 0.64 | 0.64 |

# 5 Consequences to market stability and monetary policy

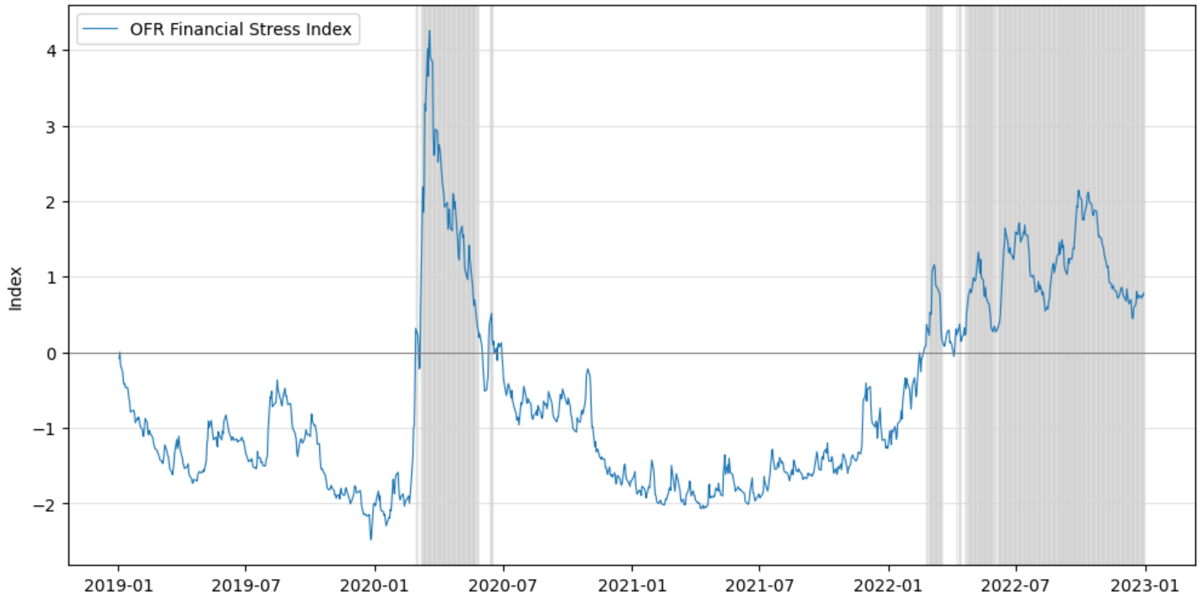
In the main body of this paper, we established a strong relationship between a bank's financed greenhouse gas (GHG) emissions and the repo rates it faces. As we argued, this relationship can be partly attributed to a risk premium and partly to investor preferences. With financed emissions likely to become an increasingly important focus of future policy, this pricing premium is poised to become even more significant. This raises an important question: what are the implications for the repo market when a factor seemingly exogenous to it is associated with such pricing differences? We explore this question along two key dimensions. First, we examine whether this relationship poses concerns for market stability or systemic risk. Second, we consider its implications for the transmission of monetary policy.

## 5.1 Amplification of liquidity risks

In this part of the paper, we want to examine whether this rate-sensitivity to transition risk has implications for market stability. More precisely we are asking: *Are banks that have higher financed GHG emissions disproportionally affected by market stress?* Our null hypothesis would

**Figure 6: OFR Financial Stress Index**

This graph shows the OFR financial stress index over time. Shaded areas indicate days where the index has been in its top tercile regarding all values contained in the time span from 2019 to 2022.




be that transition risk, to the extent that it can be measured by financed GHG emissions, is independent of other exogenous liquidity risks in the funding-driven repo market. The alternative hypothesis would mean that the rate premium is exacerbated or even driven by stressed times, meaning that banks with higher emissions tend to quicker get into funding stress than less-heavily exposed banks.

To measure financial stress we first use the OFR Financial Stress Index (Office of Financial Research, 2024), which measures systemic financial stress using 33 market variables across five categories: credit, equity valuation, funding, safe assets, and volatility. It applies a dynamic factor model, standardizing each indicator and weighting them based on co-movement to capture overall market stress. Positive values indicate above-average stress, while negative values suggest calmer conditions. This way, the index provides a real-time gauge of financial stress, and helps to identify periods of market strain. Figure 6 shows the index values over our observation period. For the sake of interpretation, we interact the financed GHG emissions with a dummy variable indicating whether the Financial Stress index was in the top tercile of observations over the observation window from 2019 to 2022. Specifically, the regression, will be

$$Rate_{l,b,t,i} - DFR_t = \beta_1 \times FinancedEmissions_{b,t-365} + \beta_2 \times FinRisk_t + \beta_3 \times FinRisk_t \times FinancedEmissions_{b,t-365} + \beta_4 \times DealControls_i + \beta_5 \times BorrowerControls_{b,t} + \delta_t + \gamma_l + \varepsilon_{l,b,t,i}, \quad (10)$$

where $\delta_t$ and $\gamma_l$ are date and lender fixed effects. The results are reported in Table 9.

**Table 9: The amplification effect of financed GHG-emissions.**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Individual regressions are based on the sub-samples of transactions collateralised by bonds issued in the sectors shown. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. The variable $FinRisk$ is a dummy taking the value one whenever the OFR Financial Stress Index is in its top tercile. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-level and reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | DFR-adjusted rate (%) | | | |
|---|---|---|---|---|
| | **All collateral** | **NFC** | **FC** | **GG** |
| $FinancedEmissions$ | 0.020*** | 0.019* | 0.014*** | −0.007* |
| | (0.004) | (0.011) | (0.005) | (0.004) |
| $FinancedEmissions \times FinRisk$ | 0.052*** | 0.159*** | 0.049*** | 0.016* |
| | (0.010) | (0.029) | (0.010) | (0.010) |
| $Haircut$ | −0.083*** | 0.011 | −0.037*** | −0.031*** |
| | (0.009) | (0.017) | (0.012) | (0.006) |
| $Volume$ | 0.079*** | 0.010* | 0.095*** | 0.030*** |
| | (0.004) | (0.006) | (0.008) | (0.003) |
| $Maturity$ | 0.002*** | 0.004*** | 0.003*** | 0.001*** |
| | (0.000) | (0.001) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes |
| FE: Date | Yes | Yes | Yes | Yes |
| FE: Lender | Yes | Yes | Yes | Yes |
| N | 1 968 692 | 457 400 | 1 074 985 | 426 563 |
| $R^2$ | 0.44 | 0.51 | 0.32 | 0.49 |

We first note that all coefficients for the interaction term as well as for the financed emissions are positive and significant. This is inconsistent with the previous hypothesis of complete independence. Moreover, the coefficients for the financed emissions term is slightly lower than those of our baseline regression in Table 2 suggesting that the coefficient for financed emissions is to some extent driven by the observation from stressed financial conditions. Yet they are still mostly positive and significant which indicates that if there is an amplification effect, a one standard deviation difference in finance emissions adds another 2 to 16 bps to rates in times of financial stress to an already existing but low premium of 0 to 2 bps. Again, the results for transactions collateralised by government bonds are weaker. Several factors could explain why we do not observe an effect in this segment. First, repos backed by government bonds are more standardised and conventional than those in other segments, meaning market standards may play a larger role. Second, government bond repos are more likely to be used for collateral purposes, which could obscure the true effect. Lastly, in times of financial stress, there may be stronger incentives to use high-quality government bonds specifically to avoid higher rates.

As a robustness test we are also conducting the same regressions with the (European) VIX index as a measure for financial stress and alternative fixed effects specifications which can be found in the appendix.

### 5.2 Implication for monetary policy

The repo market serves as the primary channel through which the ECB's monetary policy rates are transmitted. We have shown that banks with higher financed GHG emissions face a rate premium, paying more for repo funding. A natural follow-up question is whether this carbon exposure also affects the transmission of policy rate changes. Specifically, when the ECB raises rates, do high emission banks adjust to the new borrowing rate more slowly or more quickly than their peers?

There are four rate hikes in our sample that we could look at.[10] In a first specification we are testing the the rate response of brown firms following each of these policy events in a tight 6 weeks window around the decision. Specifically, we are testing

$$Rate_{b,w}^{resid} = \beta^{IV} D_w^{IV} \times FinancedEmissions_{w-52,b} + X_{b,w} + \delta_w + \gamma_b + \varepsilon_{b,w}, \tag{11}$$

where $\delta_w$ and $\gamma_b$ are bank and week fixed effects. $D_w^{IV}$ is an indicator which is 1 after the monetary policy announcement. We cluster at the borrower level and by using only three pre/post weekly aggregated loan rate residuals per bank we are mitigating concerns about serial correlation. The results are reported in Table 10.

The coefficients for all policy events are positive, ranging between 3 and 6 basis points, though only two are statistically significant. While it is difficult to pinpoint exactly what dif-

[10] In 2022, the ECB raised its key policy rates four times - by 50 basis points in July, 75 in both September and October, and another 50 in December - in response to rising inflation.

**Table 10: Monetary policy shocks**

The dependent variable is the loan rate rate residual as defined in equation 6. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the borrower-level and reported in parentheses. Controls include the collateral ISIN, total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | $Rate^{resid}$ (%) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $Jul27 \times FinancedEmissions$ | 0.049** | | | |
| | (0.022) | | | |
| $Sep14 \times FinancedEmissions$ | | 0.027 | | |
| | | (0.024) | | |
| $Nov2 \times FinancedEmissions$ | | | 0.056*** | |
| | | | (0.021) | |
| $Dec21 \times FinancedEmissions$ | | | | 0.052 |
| | | | | (0.044) |
| FE: Counterparty | X | X | X | X |
| FE: Week | X | X | X | X |
| N | 338 | 340 | 351 | 216 |
| R2 | 0.862 | 0.898 | 0.922 | 0.938 |
| R2 Adj. | 0.814 | 0.858 | 0.890 | 0.900 |

ferentiates the significant events from the others, the results do not allow us to reject the null hypothesis of no effect on policy transmission. That said, the estimates suggest that brown banks, on average, adjust more quickly to higher rates following a hike, by around 5 basis points.

We complement this regression with an alternative approach measuring the passthrough directly as in Eisenschmidt et al. (2024). First, we consider loan rate residuals as in 6 to be able to average rates across dates while respecting the transaction heterogeneity. We then measure the passthrough as

$$Passthrough_{b,t}^{DFR\_OTC} = \frac{Rate_{b,t}^{resid,\ post} - Rate_{b,t}^{resid,\ pre}}{DFR_t^{post} - DFR_t^{pre}}, \tag{12}$$

where $Rate_{b,t}^{resid,\ pre}$ denotes the average pre-announcement rate per counterparty banks from the week before the the policy decision, and $Rate_{b,t}^{resid,\ post}$ denotes the average post-implementation rate from the week after the new rate was implemented. The distribution for banks divided into above and below median financed emissions groups is given in Table 11. The table shows that brown banks adjust *quicker* to the new higher rate than green banks. This observation is also

**Table 11: Passthrough by financed emissions group**

| Emission Group | Mean | P10 | P25 | P50 | P75 | P90 |
|---|---|---|---|---|---|---|
| High emissions | 64.01 | 16.58 | 41.95 | 72.15 | 91.67 | 96.68 |
| Low emissions | 54.75 | 2.71 | 22.15 | 60.00 | 86.33 | 94.44 |

confirmed again with the following regression

$$Passthrough_{b,t}^{DFR\_OTC} = \beta_1 \times FinancedEmissions_{t-52,b} + X_b + \delta_w + \varepsilon_{b,w}, \quad (13)$$

where $X_b$ are borrower-level controls and $\delta_w$ are time fixed effects. As all rate hikes happened in the same year 2022 for our sample, we cannot use borrower fixed-effects, as this would make financed emissions obsolete which also vary only on the year level. The coefficient on pass-

**Table 12: Monetary policy shocks**

The dependent variable is the Passthrough as defined in equation 12. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. The variable $FinancedEmissions$ is standardised. Standard errors are clustered at the counterparty-level and reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | $Passthrough^{DFR\_OTC}$ (%) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| $FinancedEmissions$ | 4.625** | 7.196** | 7.435** |
| | (2.175) | (3.163) | (3.132) |
| $Assets$ | | 0.000 | 0.000 |
| | | (0.000) | (0.000) |
| $ROA$ | | 595.256 | 736.065 |
| | | (978.246) | (983.308) |
| $Leverage$ | | | 137.709 |
| | | | (258.111) |
| $Liquidity$ | | | −2.617 |
| | | | (2.658) |
| $Capital$ | | | 65.801 |
| | | | (144.769) |
| FE: Month | Yes | Yes | Yes |
| $N$ | 278 | 195 | 195 |
| $R^2$ | 0.01 | 0.02 | 0.03 |

through is positive across all specifications, indicating that a one standard deviation increase in financed GHG emissions is associated with a roughly 7% faster adjustment to the new policy rate in the first week after implementation. This suggests that brown banks experience quicker rate pass-through following a hike. Whether this reflects dealers' preferences for greener counterparties or the pricing in of a brown risk premium, the evidence points to a consistent pattern: dealers appear to be less accommodating toward brown banks, while green banks tend to face a more gradual adjustment to higher rates.

# 6 Conclusion

How is climate change affecting financial stability? This is a fundamental question not only for the emerging field of climate change and finance but also for policymakers who are striving to design stress tests that adequately capture all potential factors impacting the financial system.

To address this question, we conduct a detailed cross-sectional and time-series analysis of interbank lending rates, haircuts, and volumes, using financed carbon emissions as a key bank characteristic. We find robust evidence that financed carbon emissions significantly and positively affect borrowing rates in the funding-driven repo market which can be rationalised in part as a result of bank's preferences for greener counterparties and in part also as a carbon risk premium.

This provides clear evidence of a link between transition risk, financial stability, and monetary policy. Transition risk raises firms' production costs and puts downward pressure on profits, increasing the risk of default. As a result, banks lending to these firms face higher credit risk. In the repo market, brown banks are penalised with higher rates, and during periods of rate hikes, this also leads to a faster transmission of new policy rates. The repo market is a key source of daily liquidity for both banks and non-banks, and its importance is likely to grow as excess liquidity declines.

Additionally, our findings suggest that transition risk could amplify other exogenous financial risks. While transition risk alone might not induce immediate stress in the repo market, its mere presence implies that banks are subject to differential treatment in terms of their cost of funding. This dynamic suggests that, in the presence of significant market shocks, such amplification could indeed exacerbate broader financial instability.

## References

Acharya, V. V., Berner, R., Engle, R., Jung, H., Stroebel, J., Zeng, X., and Zhao, Y. (2023). Climate stress testing. *Annual Review of Financial Economics*, 15:291–326.

Altavilla, C., Boucinha, M., Pagano, M., and Polo, A. (2024). Climate risk, bank lending and monetary policy. *ECB Working Paper No 2969*.

Angrist, J. D. and Pischke, J.-S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics*, 119(1):249–275.

Baker, M., Bergstresser, D., Serafeim, G., and Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of us green bonds. Technical report, National Bureau of Economic Research.

Bakkensen, L. A. and Barrage, L. (2017). Flood risk belief heterogeneity and coastal home price dynamics: Going under water? Technical report, National Bureau of Economic Research.

Baldauf, M., Garlappi, L., and Yannelis, C. (2020). Does climate change affect real estate prices? only if you believe in it. *The Review of Financial Studies*, 33:1256–1295.

Ballensiefen, B., Ranaldo, A., and Winterberg, H. (2023). Money Market Disconnect. *The Review of Financial Studies*, 36(10):4158–4189.

Barnett, M. (2020). Estimated impacts of climate policy risk. Working paper.

Bernstein, A., Gustafson, M. T., and Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, 134:253–272.

Bolton, P. and Kacperczyk, M. (2024). Are carbon emissions associated with stock returns? comment? *Review of Finance*, 28(1):107–109.

Bua, G., Kapp, D., Ramella, F., and Rognone, L. (2024). Transition versus physical climate risk pricing in european financial markets: a text-based approach. *The European Journal of Finance*, 30(17):2076–2110.

Collender, S., Gan, B., Nikitopoulos, C. S., Richards, K.-A., and Ryan, L. (2023). Climate transition risk in sovereign bond markets. *Global Finance Journal*, 57:100868.

Degryse, H., Goncharenko, R., Theunisz, C., and Vadasz, T. (2023). When green meets green: Do environmentally conscious banks reward environmentally conscious firms? *Journal of Corporate Finance*, 78:102355.

Delis, M. D., de Greiff, K., Iosifidi, M., and Ongena, S. R. G. (2018). Being Stranded with Fossil Fuel Reserves? Climate Policy Risk and the Pricing of Bank Loans. Technical Report Research Paper No. 18-10, Swiss Finance Institute (also EBRD and CEPR Working Paper).

Duffie, D. and Krishnamurthy, A. (2016). Pass-through efficiency in the fed's new monetary policy setting. In *Designing Resilient Monetary Policy Frameworks for the Future*, pages 21–102, Jackson Hole. Federal Reserve Bank of Kansas City.

Eisenschmidt, J., Ma, Y., and Zhang, A. L. (2024). Monetary policy transmission in segmented markets. *Journal of Financial Economics*, 151.

Engle, R. F., Giglio, S., Kelly, B., Lee, H., and Stroebel, J. (2020). Hedging climate change news. *The Review of Financial Studies*, 33(3):1184–1216.

European Central Bank (2011). *The Monetary Policy of the ECB*. European Central Bank. Accessed: 2025-03-29.

European Central Bank (2024). Analytical indicators on carbon emissions. https://www.ecb.europa.eu/stats/all-key-statistics/horizontal-indicators/sustainability-indicators/data/html/ecb.climate_indicators_carbon_emissions.en.html. European Central Bank website — updated April 2024; accessed Jul 2025.

European Central Bank (2025). Money market statistics. Available at: https://www.ecb.europa.eu/stats/financial_markets_and_interest_rates/money_market/html/index.en.html (Accessed: 2025-03-09).

Faccini, R., Matin, R., and Skiadopoulos, G. (2023). Dissecting climate risks: Are they reflected in stock prices? *Journal of Banking and Finance*, 155:106948.

Foerster, K., Ryan, E., and Scheid, B. A. (2025). Pricing or panicking? commercial real estate markets and climate change. ECB Working Paper 2025/3059, European Central Bank. Available at SSRN: https://ssrn.com/abstract=5265614.

Giannetti, M., Jasova, M., Loumioti, M., and Mendicino, C. (2025). "Glossy Green" Banks: The Disconnect Between Environmental Disclosures and Lending Activities. Technical Report 5357407, SSRN Electronic Journal.

Giglio, S., Maggiori, M., Rao, K., Stroebel, J., and Weber, A. (2021). Climate change and long-run discount rates: Evidence from real estate. *The Review of Financial Studies*, 34(8):3527–3571.

Goldsmith-Pinkham, P. S., Gustafson, M., Lewis, R., and Schwert, M. (2019). Sea level rise and municipal bond yields. *SSRN Electronic Journal*. Available at SSRN.

Hong, H., Li, F. W., and Xu, J. (2019). Climate risks and market efficiency. *Journal of Econometrics*, 208:265–281.

Hsu, P.-H., Li, K., and Tsou, C.-Y. (2020). The pollution premium. *SSRN Electronic Journal*. Available at SSRN 3578215.

Huynh, T. and Xia, Y. (2020). Climate change news risk and corporate bond returns. *Journal of Financial and Quantitative Analysis*. Forthcoming.

Ilhan, E., Sautner, Z., and Vilkov, G. (2020). Carbon tail risk. *The Review of Financial Studies*, 34(3):1540–1571.

Julliard, C., Pinter, G., Todorov, K., Wijnandts, J.-C., and Yuan, K. (2022). What drives repo haircuts? evidence from the uk market. *BIS Working Papers*, 1027.

Kacperczyk, M. and Bolton, P. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2):517–549.

Kacperczyk, M. and Bolton, P. (2022). Global Pricing of Carbon-Transition Risk. *Journal of Finance (forthcoming)*.

Kacperczyk, M. T. and Peydró, J.-L. (2022). Carbon emissions and the bank–lending channel. Technical Report 3915486, SSRN Electronic Journal. European Corporate Governance Institute – Finance Working Paper No. 991/2024; CEPR Discussion Paper No. DP16778.

Krueger, P., Sautner, Z., and Starks, L. T. (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies*, 33(3):1067–1111.

Office of Financial Research (2024). OFR Financial Stress Index. Available at: https://www.financialresearch.gov/financial-stress-index/ (Accessed: 2024-03-24).

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 135:468–482.

Ramelli, S., Ossola, E., and Rancan, M. (2021). Stock price effects of climate activism: Evidence from the first global climate strike. *Journal of Corporate Finance*, 69:102018.

Sastry, P. R., Verner, E., and Marques Ibanez, D. (2024). Business as usual: Bank net zero commitments, lending, and engagement. Technical Report NBER Working Paper No. w32402, National Bureau of Economic Research.

Task Force on Climate-related Financial Disclosures (2017). Final report: Recommendations of the task force on climate-related financial disclosures. Technical report, Financial Stability Board.

Ye, Z. (2023). Bank Divestment and Green Innovation. Technical Report 4324996, SSRN Electronic Journal.

# A Tables and figures

**Figure 7: Climate risk channels**

Source: Acharya et al. (2023) .

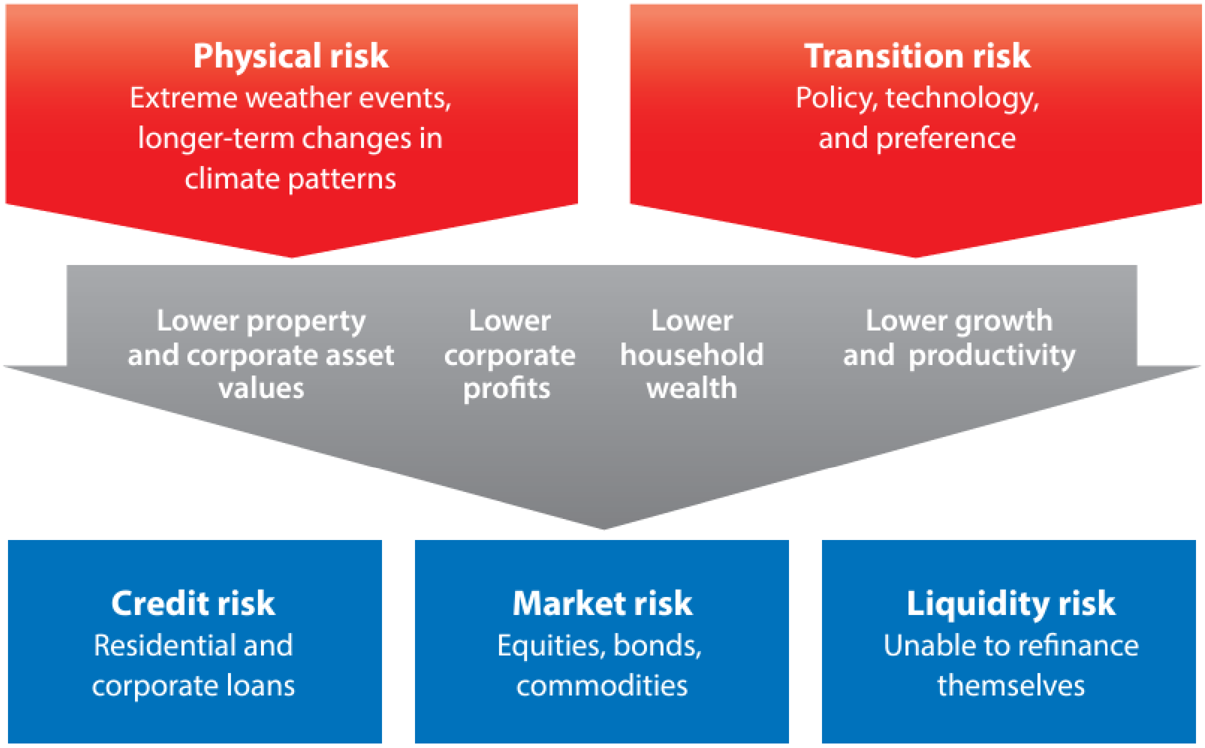


**Table 13: Transition risk premia dependent on collateral sector.**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Individual regressions are based on the sub-samples of transactions collateralised by bonds issued in the sectors shown. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **Panel A: Non-financial corporations** | | | | | |
| $FinancedEmissions$ | 0.066** | 0.062*** | 0.055*** | 0.187*** | 0.209*** |
| | (0.030) | (0.013) | (0.012) | (0.030) | (0.029) |
| $Haircut$ | | | 0.015* | | 0.025*** |
| | | | (0.009) | | (0.009) |
| $Volume$ | | | 0.010 | | 0.021*** |
| | | | (0.006) | | (0.005) |
| $Maturity$ | | | 0.005*** | | 0.000 |
| | | | (0.001) | | (0.001) |
| $N$ | 466 410 | 466 410 | 466 410 | 466 410 | 466 410 |
| $R^2$ | 0.20 | 0.45 | 0.50 | 0.51 | 0.54 |
| **Panel B: Financial corporations** | | | | | |
| $FinancedEmissions$ | 0.064*** | 0.029*** | 0.025*** | 0.039*** | 0.039*** |
| | (0.005) | (0.005) | (0.005) | (0.006) | (0.006) |
| $Haircut$ | | | −0.005 | | 0.003 |
| | | | (0.004) | | (0.002) |
| $Volume$ | | | 0.091*** | | 0.080*** |
| | | | (0.007) | | (0.006) |
| $Maturity$ | | | 0.003*** | | 0.002*** |
| | | | (0.000) | | (0.000) |
| $N$ | 1 095 577 | 1 095 577 | 1 095 577 | 1 095 577 | 1 095 577 |
| $R^2$ | 0.07 | 0.22 | 0.31 | 0.40 | 0.45 |
| **Panel C: General government** | | | | | |
| $FinancedEmissions$ | 0.020*** | −0.003 | −0.004 | 0.035*** | 0.043*** |
| | (0.007) | (0.007) | (0.004) | (0.005) | (0.005) |
| $Haircut$ | | | −0.013*** | | −0.022*** |
| | | | (0.004) | | (0.004) |
| $Volume$ | | | 0.029*** | | 0.025*** |
| | | | (0.003) | | (0.003) |
| $Maturity$ | | | 0.001*** | | 0.002*** |
| | | | (0.000) | | (0.000) |
| $N$ | 434 832 | 434 832 | 434 832 | 434 832 | 434 832 |
| $R^2$ | 0.02 | 0.16 | 0.49 | 0.36 | 0.54 |
| Controls | X | X | X | X | X |
| FE: Collateral ISIN | | | X | | X |
| FE: Lender | | X | X | | |
| FE: Date | | X | X | | |
| FE: Lender × Borrower | | | | X | X |

**Table 14: Size and leverage effects of banks with high financed GHG emissions.**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include the leverage ratio, the liquidity coverage ratio, and the capital ratio for the size regressions, and the returns on assets as well as the size for the capital ratio and the liquidity coverage ratio regressions. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $FinancedEmissions$ | 0.067*** | 0.044*** | 0.073*** | 0.064*** | 0.079*** |
| | (0.007) | (0.006) | (0.006) | (0.007) | (0.007) |
| $D^{LargeSize}$ | 0.040*** | −0.033*** | | | −0.003 |
| | (0.011) | (0.011) | | | (0.011) |
| $D^{LargeSize} \times FinancedEmissions$ | −0.050*** | −0.027*** | | | −0.021** |
| | (0.010) | (0.009) | | | (0.010) |
| $D^{LowCapital}$ | | | 0.088*** | 0.136*** | 0.089*** |
| | | | (0.012) | (0.013) | (0.012) |
| $D^{LowCapital} \times FinancedEmissions$ | | | −0.066*** | −0.071*** | −0.056*** |
| | | | (0.009) | (0.009) | (0.009) |
| $Volume$ | 0.073*** | 0.076*** | 0.073*** | 0.073*** | 0.073*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| $Maturity$ | 0.002*** | 0.002*** | 0.002*** | 0.002*** | 0.002*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $N$ | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 | 2 006 742 |
| $R^2$ | 0.41 | 0.43 | 0.41 | 0.41 | 0.41 |
| Controls | | X | | X | |
| FE: Lender | X | X | X | X | X |
| FE: Date | X | X | X | X | X |
| FE: Collateral ISIN | X | X | X | X | X |

**Table 15: The amplification effect of financed GHG-emissions.**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Individual regressions are based on the sub-samples of transactions collateralised by bonds issued in the sectors shown. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. The variable $FinRisk$ is a dummy taking the value one whenever the OFR Financial Stress Index is in its top quartile. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-level and reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | All collateral | All collateral | Non-financial corporations | Non-financial corporations | Financial corporations | Financial corporations | General government | General government |
|---|---|---|---|---|---|---|---|---|
| $FinancedEmissions$ | 0.020*** | 0.036*** | 0.019* | 0.187*** | 0.014*** | 0.030*** | −0.007* | 0.034*** |
| | (0.004) | (0.006) | (0.011) | (0.030) | (0.005) | (0.006) | (0.004) | (0.005) |
| $FinancedEmissions \times FinRisk$ | 0.052*** | 0.017** | 0.159*** | 0.043** | 0.049*** | 0.013* | 0.016* | 0.008 |
| | (0.010) | (0.007) | (0.029) | (0.022) | (0.010) | (0.007) | (0.010) | (0.007) |
| $Haircut$ | −0.083*** | 0.007 | 0.011 | 0.035* | −0.037*** | 0.007* | −0.031*** | −0.032*** |
| | (0.009) | (0.006) | (0.017) | (0.018) | (0.012) | (0.004) | (0.006) | (0.005) |
| $Volume$ | 0.079*** | 0.052*** | 0.010* | 0.022*** | 0.095*** | 0.082*** | 0.030*** | 0.026*** |
| | (0.004) | (0.003) | (0.006) | (0.005) | (0.008) | (0.005) | (0.003) | (0.004) |
| $Maturity$ | 0.002*** | 0.001*** | 0.004*** | 0.000 | 0.003*** | 0.001*** | 0.001*** | 0.002*** |
| | (0.000) | (0.000) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| N | 1 968 692 | 1 968 692 | 457 400 | 457 400 | 1 074 985 | 1 074 985 | 426 563 | 426 563 |
| $R^2$ | 0.44 | 0.50 | 0.51 | 0.54 | 0.32 | 0.45 | 0.49 | 0.54 |
| Controls | X | X | X | X | X | X | X | X |
| FE: Collateral ISIN | X | X | X | X | X | X | X | X |
| FE: Date | X | | X | | X | | X | |
| FE: Lender | X | | X | | X | | X | |
| FE: Lender × Borrower | | X | | X | | X | | X |

**Table 16: The amplification effect of financed GHG-emissions - Robustness test using VIX instead of OFR index**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Individual regressions are based on the sub-samples of transactions collateralised by bonds issued in the sectors shown. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. The variable $VIX$ is a dummy taking the value one whenever the VIX Index is in its top tercile. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-level and reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | All collateral | All collateral | Non-financial corporations | Non-financial corporations | Financial corporations | Financial corporations | General government | General government |
|---|---|---|---|---|---|---|---|---|
| $FinancedEmissions$ | 0.011** | 0.038*** | 0.023** | 0.209*** | 0.006 | 0.031*** | −0.012*** | 0.030*** |
| | (0.005) | (0.006) | (0.011) | (0.029) | (0.006) | (0.006) | (0.004) | (0.005) |
| $FinancedEmissions \times VIX$ | 0.039*** | 0.015*** | 0.066*** | −0.020 | 0.039*** | 0.013*** | 0.018*** | 0.022*** |
| | (0.006) | (0.004) | (0.016) | (0.014) | (0.007) | (0.004) | (0.005) | (0.004) |
| $Haircut$ | −0.083*** | 0.009 | 0.010 | 0.039** | −0.037*** | 0.008* | −0.030*** | −0.032*** |
| | (0.009) | (0.006) | (0.017) | (0.018) | (0.012) | (0.004) | (0.006) | (0.005) |
| $Volume$ | 0.079*** | 0.052*** | 0.011* | 0.020*** | 0.095*** | 0.083*** | 0.030*** | 0.026*** |
| | (0.004) | (0.003) | (0.006) | (0.005) | (0.008) | (0.006) | (0.003) | (0.004) |
| $Maturity$ | 0.002*** | 0.001*** | 0.004*** | 0.000 | 0.003*** | 0.001*** | 0.001*** | 0.002*** |
| | (0.000) | (0.000) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| N | 2 006 740 | 2 006 740 | 466 409 | 466 409 | 1 095 577 | 1 095 577 | 434 831 | 434 831 |
| $R^2$ | 0.44 | 0.50 | 0.51 | 0.54 | 0.32 | 0.45 | 0.49 | 0.54 |
| Controls | X | X | X | X | X | X | X | X |
| FE: Collateral ISIN | X | X | X | X | X | X | X | X |
| FE: Date | X | | X | | X | | X | |
| FE: Lender | X | | X | | X | | X | |
| FE: Lender × Borrower | | X | | X | | X | | X |

**Table 17: Robustness test: Transition risk premia including specific collateral transactions.**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-level and reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $FinancedEmissions$ | 0.090*** | 0.060*** | 0.043*** | 0.070*** | 0.008 |
| | (0.023) | (0.013) | (0.015) | (0.021) | (0.020) |
| $Haircut$ | | −0.237*** | −0.187*** | −0.046 | −0.046 |
| | | (0.087) | (0.069) | (0.042) | (0.044) |
| $Volume$ | | 0.098*** | 0.080*** | 0.052*** | 0.046*** |
| | | (0.015) | (0.011) | (0.010) | (0.009) |
| $Maturity$ | | 0.003*** | 0.003*** | 0.002*** | 0.002*** |
| | | (0.001) | (0.001) | (0.000) | (0.000) |
| $N$ | 2 523 574 | 2 523 574 | 2 523 574 | 2 523 574 | 2 523 574 |
| $R^2$ | 0.01 | 0.24 | 0.31 | 0.45 | 0.47 |
| FE: Collateral ISIN | | X | X | X | X |
| FE: Date | | | X | | X |
| FE: Lender | | | X | | |
| FE: Lender × Borrower | | | | X | X |

**Table 18: Robustness test: Lagged vs. Non-lagged GHG-exposure**

The dependent variable is the loan rate minus the ECB's deposit facility rate expressed in percentage points. Financed GHG emissions are calculated as the volume-weighted GHG-intensities per bank-year from all commercial loans over EUR 25,000, divided by the bank's revenues. All continuous variables are standardised. Standard errors are clustered at the bank-counterparty-month-level and reported in parentheses. Controls include total assets, the leverage ratio, the liquidity coverage ratio, the capital ratio, and the return on assets. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

| | (1) | (2) |
|---|---|---|
| $FinancedEmissions(lag)$ | 0.031*** | |
| | (0.004) | |
| $FinancedEmissions$ | | −0.006 |
| | | (0.004) |
| $Haircut$ | −0.050*** | −0.089*** |
| | (0.009) | (0.010) |
| $Volume$ | 0.073*** | 0.073*** |
| | (0.004) | (0.004) |
| $Maturity$ | 0.002*** | 0.003*** |
| | (0.000) | (0.000) |
| $N$ | 2 006 742 | 1 571 265 |
| $R^2$ | 0.43 | 0.57 |
| Controls | X | X |
| FE: Lender | X | X |
| FE: Date | X | X |
| FE: Collateral ISIN | X | X |

**Acknowledgements**

We thank Dimitrios P. Tsomocos, Anthony Limburg, and participants at the University of Oxford FAME seminar, the CCC Green Seminar Series at the ECB, and the ECB Monetary Policy Strategy Division for their helpful comments. Jasper Knyphausen acknowledges support from the Saïd Business School Fund (SBSF).

**Margherita Giuzio**
European Central Bank, Frankfurt am Main, Germany; email: margherita.giuzio@ecb.europa.eu

**Bige Kahraman**
Saïd Business School, University of Oxford, Oxford, United Kingdom; email: bige.kahraman@sbs.ox.ac.uk

**Jasper Knyphausen**
Saïd Business School, University of Oxford, Oxford, United Kingdom; email: jasper.knyphausen.dphil@said.oxford.edu



Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu



PDF ISBN 978-92-899-7623-7 ISSN 1725-2806 doi:10.2866/0413357 QB-01-26-011-EN-N