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GREEN GRANULAR BORROWERS

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Abstract

We examine how a bank's lending policies are affected when its large (granular) borrowers unexpectedly reduce their emissions. First, we document that these borrowers are valuable to the bank and, when their emissions fall below the expected levels, they are rewarded with lower interest rates on short-term loans. Second, we show that, when aggregated at the bank-sector level, these emission shocks significantly affect the returns on banks' loan portfolios, but only when they capture a reduction in emissions. Finally, we find that, following a negative emission shock by large borrowers, banks increase their lending to non-granular borrowers in sectors more engaged in the green transition, which are likely to offset lost margins. Overall, these results suggest that banks allow negative emission shocks from large borrowers to spill over into loan supply to green sectors, facilitating the green transition.

JEL Classification: G21, G32, Q54.

Keywords: granular borrower, climate, green lending, spillover.

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1 Introduction[1]

Credit concentration is a well-known aspect of credit risk for banks, reflecting the non-insurability of bank credit exposures when they are heavily concentrated in a single sector or with a single borrower (Asberg Sommar et al. (2006)). Recent banking literature has introduced new evidence on credit concentration risk by applying the concept of "granularity" to credit markets (Galaasen et al. (2020); Baena et al. (2022)), as defined by Gabaix (2011). Broadly speaking, a "granular" agent is a large entity whose idiosyncratic shocks effectively become aggregate due to the agent's size, connectedness, or influence. In credit markets,"granular borrowers" refer to individual borrowers who hold a significant share of a bank's portfolio. Leveraging this concept and the corresponding instrumental variable methodology (referred to as "granular" IV or GIV), which enables the establishment of a causal link between shocks to granular agents and aggregate outcomes, it has been demonstrated that idiosyncratic risks to granular borrowers are a key driver of intermediaries' performance (Galaasen et al. (2020); Baena et al. (2022)).

An open question remains as to whether the presence of granular borrowers has implications beyond credit risk transmission. Specifically, one might ask whether granular borrowers can influence bank decisions and outcomes by transmitting other types of shocks. In this study, we explore the possibility that idiosyncratic shocks to large borrowers' greenhouse gas (GHG) emissions may spur an aggregate response by banks, potentially influencing their financing of climate-conscious companies. In other words, we investigate whether shocks that make granular borrowers "greener" lead to changes in credit supply to non-granular firms. In particular, we investigate if these shocks improve lending especially to (non-granular) firms active in green sectors. In doing so, we first document that banks look favorably upon unexpected reductions in emissions and offer a lower cost of credit, however only when these shocks occur at large firms and when they indicate lower than expected emissions. When

[1]We thank Paolo Angelini, Luca Citino, Antonio Di Cesare, Giuseppe Ferrero, Sigurd Galaasen, Gil Nogueira, Andrea Polo, Andrea Tiseno and two anonymous referees for helpful comments.

this discount is applied to granular borrowers, it results in a reduction in the returns on the whole loan portfolio, for a given sector. In reaction to this, banks expand their credit supply to non-granular borrowers, especially to those active in green sectors.

While the credit supply expansion plausibly is motivated by the objective to recover the lost profits, and is targeted to smaller borrowers reflecting the greater bargaining power that banks have over them, why this expansion is targeted to climate-conscious firms is less clear. Several mechanisms could explain this spillover effect. First, there is a reputation mechanism. Green borrowers, particularly those newly committed to climate goals, may prefer not to be associated with "brown" banks and may leverage their significance to influence the lending banks' credit policies, steering them toward greener sectors. Reputation may also play a role at a higher level. As banks acknowledge the inevitability of participating in the green transition, they may use the nudge from large green borrowers as an opportunity to shift their overall lending toward less polluting sectors. Second, we propose a specialization motive. As a large borrower adopts greener production processes, the lending bank may develop specialized knowledge while supporting this transition. The bank could then seek to capitalize on this expertise by applying it to the screening and monitoring of borrowers in other markets. Finally, large firms that become greener may substitute bank credit with bond financing, freeing up capital for lenders to redirect toward other green firms.

We establish causality by adapting the granular instrumental variable (GIV) approach of Gabaix and Koijen (2020), as applied by Galaasen et al. (2020) and Baena et al. (2022), to our empirical question. Following these works, we proceed in steps. First, given the Pareto distribution of loan shares in our sample, we observe that most firms for which we can calculate green shocks fall within the right tail, above the 95th percentile. These empirical findings establish the preconditions for the rest of our analysis. If there were no granular borrowers in Italy during the 2014-19 period, or if emission data were unavailable for all these large borrowers, we would not be able to perform a sensible GIV analysis and properly identify our effects.

Second, we calculate the idiosyncratic shocks to firms' emissions. We define these shocks as the unexplained component in a linear model of a firm's GHG emissions. The idea is that a firm's emissions can be predicted by factors such as the nature of its production process, funding structure, sector, age, geographical location, and other time-varying and time-invariant observable and unobservable characteristics. After accounting for all these determinants in a comprehensive fixed effects model, the remaining residual can be interpreted as a shock to a firm' emissions, potentially, though not necessarily for our identification purposes, serving as a proxy for a shift in a firm's climate preferences. When the residual is positive, the firm's actual emissions are higher than predicted, indicating a "brown" shock. Conversely, when the residual is negative, the shock is "green", meaning the firm is emitting less than expected.

Third, we estimate whether and how these shocks affect the interest rates charged to firms, accounting for bank-level supply and sector-level demand dynamics, in addition to time-invariant observed and unobserved firm characteristics. A statistically significant impact would support the idea that banks are concerned about firms' emissions and respond to unexpected changes by adjusting the cost of their short-term loans, which is the most immediate margin to adjust. Indeed, we find a positive association between higher than predicted emissions and the cost of short-term credit. This positive relation appears to be driven by larger borrowers.

Fourth, we aggregate the individual shocks at the bank level. This process combines the shocks for each bank's borrowers, weighting them by their respective share of loans in the bank's sector-level portfolio. This approach highlights granularity, as shocks to larger borrowers carry more weight. We find that aggregated emissions shocks positively impact the return on the bank's sector-level portfolio. This effect is asymmetrical as it is concentrated in negative shocks, i.e. when emissions are overall lower than expected. This suggests that banks value the "greenification" of their borrowers' activities, all else being equal.

Finally, we assess whether banks attempt to recover lost profitability by expanding their loan supply to other borrowers. We focus on this intensive margin to evaluate whether green granular shocks spill over to other borrowers and explore the implications for banks' role in supporting the green transition. We do not examine other possible ways of recovering margins, such as issuing more new loans or adjusting their financial portfolio. Moreover, we do not investigate adjustments in the cost of credit to other (non-granular) borrowers. Increasing the interest rates on a given borrower would deteriorate its repayment capacity, making the price adjustment a sub-optimal way to recover profitability, especially if compared to extending new - appropriately priced - credit. Our findings indicate that after receiving a green shock in year t, banks extend more credit to non-granular, green borrowers in the following year. We establish this result using a standard Khwaja and Mian (2008) framework, which accounts for contemporaneous demand dynamics and supply factors beyond the emission shock. Notably, this effect is entirely driven by medium- to long-term loans, rather than credit lines, suggesting that banks are strengthening their relationships with the greener segment of their borrower base. Additionally, we find that this effect is concentrated among borrowers outside the sector of the granular borrowers affected by the green shock, indicating that the spillover extends more broadly than what would be expected from a specialization motive.

2 Literature Review

Within the banking literature, scholars have examined extensively the intricate relationship between banks and the green transition from two distinct angles. On one hand, researchers have investigated the potential risks and challenges posed by the green transition to banks and for overall financial stability (see Giglio et al. (2021) and Daumas (2023) for recent reviews). This strand of literature assesses the vulnerabilities of banks to the evolving landscape of environmentally conscious policies and explores the potential disruptions that may arise from the reallocation from "brown" to "green" sectors (Bolton and Kacperczyk, 2021; Carbone et al., 2021).

On the other hand, a parallel stream of research investigates the proactive role that banks can play in fostering the green transition. Several papers have examined, with mixed results, how banks' commitment to climate policies results in banks favoring firms in less carbon-emissive sectors (Degryse et al., 2023; Kacperczyk and Peydró, 2021; Giannetti et al., 2023). This perspective also delves into how banks can contribute to sustainability efforts by supporting green investments and aligning their operations with environmental objectives (Haas and Popov, 2023). Accetturo et al. (2022) show, for example, that a positive credit supply impulse may induce firms to invest in green technologies.

In a spirit similar to Polo et al. (2023), this paper contributes to bridging the gap between these two streams of literature and analyzes the role of a climate risk-taking channel in banks' lending policies and credit allocation.

In addition to engaging with the broader debate on banks and the green transition, our paper also draws upon recent research concerning granular borrowers, individual firms that play a substantial role in the credit market as large borrowers. Unlike the existing literature (Galaasen et al., 2020; Baena et al., 2022) that focuses on estimating the effect of a granular risk shock on bank lending behavior, our contribution lies in the novel exploration of the green shock impact, first on bank portfolio returns and, consequently, on banks' credit supply choices.

3 Data

We combine data from three sources. First, we use ISS-Climate Solution[2] to obtain company-level GHG emissions at a yearly frequency for the period 2014-2019. We end the sample before the Covid-19 pandemic, which likely blurred the relationship between production, GHG emissions, and credit dynamics. We then merge these data with information on companies' balance sheets from the Company Accounts Data Service database and with detailed

[2] https://www.issgovernance.com/esg/climate-solutions/

data on their outstanding credit relations from the Bank of Italy Credit Register. We discuss each of these sources in turn. Summary statistics for the variables used in the paper are presented in Table 1.

3.1 Emissions and firm balance sheet data

Emission data are retrieved from ISS-Climate Solution, which collects information on scope 1, 2, and 3 emissions for a sample of companies active globally. Scope 1 emissions are those directly coming from the company's production activities; Scope 2 are indirect emissions created by the production of energy that the company is using. Finally, Scope 3 emissions are those produced by the suppliers in the production of the inputs that the company uses or by its customers when they use the company's products. The indicators are computed at the activity level (stocks, bonds, and loan book) and then aggregated at the company level, where a company is defined as the holding company plus all of its controlled subsidiaries. For the purpose of this paper, we define emissions as "total" emissions, i.e., the sum of scope 1 and 2 emissions, consistent with most definitions of emission intensity. Considering only companies that are resident in Italy, the dataset contains information on GHG emissions for about 200 entities, of which about 50 percent are active in the manufacturing sector, 10 percent in the construction sector, and the remaining 40 percent in services. Credit-wise, these companies are the recipients of about 3 percent of total credit (to firms).

To the above emissions data, we merge information on the company and its activity using yearly data from Company Accounts Data Service (CADS), a proprietary database owned by Cerved Group S.p.A. that includes detailed information on balance sheets and income statements for almost all Italian limited liability non-financial companies.[3] As these data are collected at the subsidiary level, we group them at the company level using the ownership structure available in the Orbis database.[4] Firm balance sheet data allow us to

[3]The CADS is the source from which data for Italian companies are inputted in the Orbis database.

[4]Due to data-access limitation on credit exposures, we do not consider foreign subsidiaries. In this sense, we tolerate a minimum discrepancy between the emissions, calculated globally, and balance sheet and credit exposure data, calculated within Italy.

model emissions as a function of productive inputs and sectoral characteristics. This exercise has a twofold aim. First, by modeling emissions on all their determinants, the residual will capture a company's idiosyncratic "climate shock", i.e. an unexpected event that prompted the company to emit less (or more) than what was foreseen by the model. Second, the model will produce estimates of the various drivers of emissions that allow us to back-test the reliability of the ISS emissions data (see Appendix B).

With this in mind, we collect data on firm size, measured by its log assets, profitability, and the level of activity (measured by cash flow, trade credit, leverage, and investments). Besides these variables, we consider each firm's production sector (bucketing 2-digit NACE sectors in 25 bundles) and the province of its headquarters.

3.2 Credit registry data

To determine the evolution of credit supply in response to an emission shock, we draw information from the Bank of Italy Credit Registry. For each company for which we have emission data, we collect information on all outstanding credit exposures. We separate utilized from granted credit, and for each category we distinguish between short and medium-long term credit. We merge information on interest rates applied to short-term revolving credit from the Bank of Italy TAXIA database. We focus on interest rates for short-term credit (specifically overdrafts) for two reasons. First, these rates respond more quickly to bank-level shocks. Second, they provide a clearer measure of the cost of outstanding credit facilities compared to term loan rates, which account for varying maturities and collateral. We then recover the same information for all other firms that are borrowing from banks lending to a firm for which we have emissions data. In this way, we can study how idiosyncratic shocks to granular borrowers affect banks' behavior by spilling over to lending policies toward non-granular borrowers. As with the balance sheet data, we collapse information at the company level. Further, we exclude branches of foreign banks as we would not be able to access firm-level information on loans outside Italy. In addition, as GHG emission data and firm balance sheet data are yearly, we monitor the evolution of credit variables at the same frequency, although data are recorded monthly. In particular, we compute the standardized growth rate in firm credit by using the methodology in Chodorow-Reich (2014), which allows us to study the intensive and the extensive margin jointly.

4 Green shocks

The robust identification of unforeseeable changes in emissions is key to our argument, as we want to determine if these idiosyncratic changes, when occurring at large borrowers, are able to produce externalities for the lenders' overall attitudes toward green lending.

To do so, we rely on the procedure in Galaasen et al. (2020) and define as "green shock" the residual component e_{fy} of a regression where the yearly level of emissions is explained by a number of observable and unobservable firm characteristics in a fixed-effect setup.

More precisely, we estimate the following equation:

$$Emission_{fy} = \beta FirmChar_{fy} + \alpha_{sy} + \alpha_f + e_{fy} \tag{1}$$

where $Emission_{fy}$ is the level in total emissions for firm f in year y and $FirmChar_{fy}$ are the following contemporaneous firm controls: log(assets), squared log(assets), profitability, cash flow, trade credit, leverage, investments and a dummy for whether the firm is financing itself via the bond market. In our preferred specification, we also include the following set of fixed effects: sector×year[5] (sy) and company (f). In our view, this combination of FEs is restrictive enough to control for unobservables that may affect emissions in a certain year in a given sector and for a firm's trend in emissions over time, while leaving enough variation in the data to capture something that may meaningfully surprise banks[6]. A higher residual

[5]Sector is here a 25 sectors definition based on two-digit NACE2. See Table C.1 for the complete list of sectors considered.

[6]Emission shocks appear to be not autocorrelated: Regressing the residuals on their lagged values leads to statistically not significant coefficients, clustering at firm level

indicates higher realized emissions than what is predicted by the model, so the shock is actually "green" when the value is negative. Thus, to ease the explanation of the narrative around the results, we will refer to the emissions shocks as "green" shocks when they take a negative sign. Chart 1 plots the residuals obtained from the estimation of 1, pooled across all firms and years.

While other definitions of green shock are certainly possible, we consider ours fairly robust, as it moves from the measurable GHG emissions, which are generally considered the main parameter for evaluating the climatic impact of a company's production.[7]

To corroborate this interpretation, we put forward two additional exercises. First, we test if these shocks are autocorrelated. Second, we investigate if the effect of green shocks is persistent, coherently with the idea that they are the byproduct of a green transition and not just a statistical artefact which banks would not account for in their lending decisions.

As for autocorrelation, we show in Table 2 the absence of evidence of autocorrelation of emission shocks, with past and future values. Persistence of the effect is documented in Table 3, where we regress dynamically the shock computed for firm f in year t on the cost of credit from *t-1* to *t+2*. Reassuringly, we document that shocks in t have no effect on the cost of credit charged to the firm in *t-1.* The effect is instead positive and statistically significant in the same year, reflecting the flexibility in the repricing of short-term credit; it remains so in the following year. After two years, the effect is still positive, but loses statistical significance.

Green shocks or risk shocks? Are green shocks just another risk shock? As the green transition takes place, firms' ability to reduce emissions and reconvert their activities to more climate-friendly processes is becoming a key parameter in banks' lending decisions. Looking forward, lending to brown firms will progressively become less unprofitable, though at different speeds across sectors, depending on regulation and also on individual firms'

[7] As one would expect, larger shocks provide a better explanation of emission levels. When we regress total emissions on the emission shock and split the sample into larger shocks (1st and 4th quartiles of their distribution) and smaller shocks (2nd and 3rd quartiles), the R^2 for the larger shocks is 0.0574, compared to just 0.0060 for the smaller shocks.

contractual power with the bank.[8]

To support our argument, it is essential that green shocks are not "just" shocks to a firm's riskiness. Indeed, we aim to understand whether a reduction in a firm's emissions is valuable for banks, *holding risk constant*, and if so, whether such shocks, when occurring at granular borrowers, can steer banks' lending policies in a way that spills over to smaller borrowers.

We test this directly in the data, showing that the occurence of green shocks does not causally impact a firm's z-score, which is a comprehensive measure of its risk. This is true when we control for firm and sector×year dummies (see Table 4).

5 The impact of granular green shocks on lending

5.1 The impact of green shocks on the cost of credit at the firm level

In this section, we estimate the impact of firms' emission shocks on the price of the loans they receive. More precisely, we investigate whether shocks to firms' emissions affect the loan interest rate charged by bank b in year y for that firm. While we are agnostic about the sign of the effect, we expect it to be statistically significant. Statistical significance underscores the idea that banks observe and respond to this shock in terms of loan-level returns.

In practice, we estimate:

$$R_{fby} = \alpha_{by} + \alpha_{sy} + \alpha_f + \beta e_{fby} + \varepsilon_{fby}. \tag{2}$$

The specification above implies that the impact of shocks is identified by comparing loan-level returns across firms that, in the same year y, borrow from the same bank b (α_{by}) and

[8] See the ad hoc question "The impact of climate change on bank lending to enterprises" in the Q2 2023 round of the euro area Bank Lending Survey.

are active in the same sector s (α_{sy}).[9] We also include firm dummies to take into account differences in firm's average loan rate in the sample period (α_f).

Results are displayed in Table 5.[10] We find that shocks are positively and significantly associated with the cost of credit granted to a company. This is true under a wide set of fixed effects, progressively tighter going from column (1) to (3).[11] Intuitively, green (negative) shocks are thus associated with a lower cost of credit, and, vice versa, brown (positive) shocks are linked to a higher cost of credit.

Economically, the results above imply that a standard deviation increase in the idiosyncratic green shock (the residual; min = -1.8, $\mu = 0$, max = 1.8 and $\sigma = 0.4$) has on average about one-tenth of a standard deviation of the short-term interest rate (i.e. 40 pbs; min = 0.003 $\mu = 6.2$, max = 17 and $\sigma = 4.4$).

We want to test now if this positive effect of green shocks on the cost of credit is indeed driven by large borrowers. We do so by estimating a modified version of Equation 2 in which we interact our green shock with a dummy $D95$ that equals one if in year t the bank-firm relationship fb stands above the 95th percentile of the amount distribution (see Section 3). For a better interpretation of the results we interact the shock with the dummy $D95^c := 1 - D95$. The results in Table 6 show that the positive coefficients of Table 5 are driven, as expected, by very granular borrowers.[12]

5.2 The impact of granular firms' idiosyncratic shocks on the cost of credit at the bank portfolio level

We now want to explore if, when a granular borrower receives a negative emissions shock (a green shock), the reduction in the price applied to their loan, as documented earlier, is

[9] Here we consider the 25 sectors displayed in Table C.1 to capture as much confounding factors as possible.

[10] As the independent variable is a generated regressor, we also check whether the reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. All robustness tests confirm the validity of the results. Detailed findings are available upon request.

[11] Results clustered at the firm level remain broadly unchanged and are available upon request.

[12] Appendix A provides more detail on the granularity of the Italian credit market.

large enough to result in a reduction in the return of the overall sector-level portfolio.[13] This would imply that no contemporaneous shocks of opposite sign are taking place to offset its overall effect on the sector-level portfolio.

To this end, we sum the emissions shocks at the bank×sector×year level, weighting each shock by the firm's share of the portfolio of loans to firms active in the same sector ("sectorial level").[14] Note that we do not consider the banks' overall loan portfolio, but instead compute granularity at the level of the portfolio of loans to the macro-sectors of activity.

Empirically, we aim to estimate via OLS a regression equation that, in its most demanding version, appears as:

$$R_{sby} = \alpha_b + \alpha_{sy} + \beta_{OLS}\overline{e}_{sby} + \varepsilon_{sby}. \tag{3}$$

Here ${w^s}_{fby}$ is the loan share for firms f in sector s-portfolio of b in y, R_{sby} is the return on bank b's portfolio of loans in sector s and year y,

$$R_{sby} = \sum_{f \in s} w^s_{fby} R_{fby} \tag{4}$$

and $\overline{e}_{sby}$ is the aggregation of the firms' emissions shocks e_{fby}

$$\overline{e}_{sby} = \sum_{f \in s} w^s_{fby} e_{fby} \tag{5}$$

To control for bank supply confounding in this regression (where we cannot include bank×time fixed effects, which vary at the same frequency as the aggregate shock), we follow Galaasen et al. (2020) and adopt an IV strategy, where we instrument our possibly

[13] We focus on sector-level portfolios, as it seems unlikely—based on the propagation mechanisms discussed earlier—that green granular shocks would affect the bank's entire portfolio, which is more common with other types of granular shocks, such as risk shocks (Galaasen et al. (2020)).

[14] At this stage, we carry out our analysis on 4 macro-sectors as a trade-off between not considering any sectorial heterogeneity in portfolios, as in Galaasen et al. (2020) and Baena et al. (2022), and exploiting the 25-sector-level variability used in the estimation of Equation 1.

endogenous $\overline{e}_{sby}$ with a "supply-exogenous" $\hat{u}_{sby}$.

More formally, we assume that firm shocks can be decomposed into an unobservable supply factor, specific to each s-portfolio and not captured by the specification in Equation 1, and a genuine shock component:

$$e_{fby} = \gamma_{sb}\eta_{sbt} + u_{fby}. \tag{6}$$

Then we use the Granular Instrumental Variable (GIV) proposed by Gabaix and Koijen (2020) to net out the sector×bank×time component η_{sbt} by computing the time-varying difference between (true) exposure-weighted and equally weighted (i.e., assigning to each firm the same share of the loan portfolio) firm shocks, each aggregated at the bank-sector level.

In formulas, the instrument is computed as:

$$GIV_{sby} = \sum_{f \in s}(w^s_{fby} * e_{fby}) - \frac{1}{N_{sby}} * \sum_{f \in s} e_{fby} \tag{7}$$

where N_{sby} is the number of firms active in sector s borrowing from a given bank b in year y.

In practice, we proceed with a two-step estimation, where the first stage is given by

$$\overline{e}_{sby} = \alpha_b + \alpha_{sy} + \rho GIV_{sby} + \zeta_{sby} \tag{8}$$

and compute:

$$\hat{u}_{sby} = \hat{\rho} GIV_{sby} \tag{9}$$

The second stage is given by

$$R_{sby} = \alpha_b + \alpha_{sy} + \beta_{GIV}\hat{u}_{sby} + \xi_{sby} \tag{10}$$

This procedure allows us to isolate the variation in the aggregate $\overline{e}_{sby}$ that originates from the granular borrowers' demand, washing away bank supply factors.

The IV approach requires the instrument $\hat{u}_{sby}$ to affect the bank-level returns on loans (the dependent variable) only via the aggregated shocks (endogenous variable). This requirement may not be satisfied if the loan shares used in the calculation of GIV_{sby} are correlated with the return on bank loans, which may happen if firms with larger shares of the portfolio are systematically granted lower rates. Two considerations speak in favor of this condition being satisfied. First, the e_{fby} are constructed to be as idiosyncratic as possible, being the residuals of a large model with many firm variables—both time-invariant and time-variant, observable and unobservable. Second, the observed loan shares and firm shocks are uncorrelated in the sample.

Note that in the aggregation of the shocks, we implicitly set to zero the emission shock for those firms for which emission data are not available. This would bias the estimator if there were an unobserved aggregated shock that correlates with each individual firm's shock (i.e., if the firms' individual shocks were not i.i.d.). We argue that this is unlikely: such an aggregate shock would hit individual firms by flowing through "aggregate" structures, such as the sector of activity, the year, and/or the firms' location. However, the effect of these characteristics is controlled for in the estimation of the individual shocks via the fixed effects, and, in addition, in the IV estimation. Given these considerations, firms' individual shocks can be considered i.i.d., and assigning a zero value to those observations for which emissions data are not available boils down to assigning them their expected (zero) mean.

Results, displayed in Table 7, indicate that a bank's exposure to large positive (negative) shocks causes larger (smaller), statistically significant, returns on its portfolio of loans. This means that banks that receive large negative (green) emission shocks on their portfolio also realize lower returns on that same portfolio.

The positive relationship between brown shocks and portfolio returns may capture banks' loan price increases after positive shocks (more emissions than expected) and loan price decreases after negative shocks (fewer emissions than expected), or one of the two. To discriminate whether this result is driven by a lower cost charged to greener-than-expected firms, or by a higher cost imposed on browner-than-expected companies (or both), we interact the aggregated idiosyncratic shock variable with the dummy "positive", which takes the value of one whenever the former is greater than or equal to zero. Estimates in Table 8 indicate that, even if there is no statistical difference in the impact between positive and negative shocks, the larger baseline coefficient (which, given the interaction, captures the effect of negative shocks) suggests that the results are driven by a "discount" on the cost of credit for firms with lower-than-expected emissions, rather than by an increase in the interest rate levied on those with higher-than-expected pollution.

Together with the results in the previous section, this indicates that intermediaries look favorably on firms displaying lower-emission production processes (i.e., firms that exhibit negative emission shocks). However, this positive attitude, which materializes in lower interest rates for firms with negative emission shocks, also leads to a decrease in the banks' return on the sector-level portfolio.

5.3 Do green granular shocks affect loan supply to other borrowers?

If the green granular shock leads to a reduction in banks' margins on short-term credit, being associated with a lower cost of credit to shocked firms, which also emerges at the sectorial portfolio level, intermediaries may want to recover the lost revenues by expanding their loan supply.[15] While banks have several levers to pull to increase profitability, we focus on their lending decisions, as these would eventually be the most consequential for borrowers.

In the same spirit of Galaasen et al. (2020), we begin by examining the impact on volumes through the estimation of the following Khwaja and Mian (2008) model of banks' lending

[15] At this stage, we are not investigating the possibility that profitability is recovered by expanding the extensive margin, increasing the cost of credit, or from other investments, e.g., in the financial portfolio. We leave these analyses for future research.

policies:

$$\Delta loan_{fby} = \alpha_{bs} + \alpha_{fy} + \beta \Delta \hat{u}_{bsy} + z_{fbsy}. \tag{11}$$

Here we regress year-on-year changes in the granular credit shock $\Delta \hat{u}_{bsy}$ on year-on-year changes in loan-level credit supply $\Delta loan_{fby}$, i.e. the normalized growth rate for loans to firm f by bank b between year y and $y+1$; in Equation 11 α_{bs} are bank×sector dummies and α_{fy} are firm×year dummies.

These two sets of indicator variables are meant to capture, respectively, bank-sector preferences that may determine sector-level loan evolution beyond the effect of the aggregate green shock, and firm demand. We estimate this regression for overall firm loans, and then separately for short-term and medium-to-long-term contracts.

Results, considering all firms, are displayed in Table 9. As can be seen, a green shock in year y is associated with an increase in medium-term loan supply, which impacts overall loan supply; we detect no effect on short-term credit supply.

To investigate this result further, we run the same regression on the subsample of non-granular borrowers, i.e. borrowers whose share of the sector-level portfolio falls below the 75th percentile of the shares' distribution in that year. Aggregate results appear to be driven by smaller borrowers (Table 10). This suggests that when faced with a green shock to one of their granular borrowers, which implies a reduction in loan margins, intermediaries try to lock this borrower in by offering lower rates, while simultaneously expanding supply to smaller borrowers.[16] The fact that the supply expansion is driven by lending to small borrowers is suggestive of the large bargaining power that banks have over them.

Understanding the mechanism. Results so far suggest that intermediaries respond to shocks to a firm's emissions by discounting a "green premium" on the cost of credit extended to granular firms that pollute less than expected. This green premium is significant enough to lower the return on assets in the banks' portfolios of loans to firms, particularly in

[16]For completeness, we have also checked the effect for other granular borrowers. Results, available upon request, indicate a statistically insignificant relationship.

sectors where firms have unexpectedly low emissions. To recover this lost profitability, the intermediary expands the volume of loans supplied to smaller, non-granular firms. To better understand the mechanisms behind this portfolio reallocation, we consider various sample splits to discriminate between a specialization and a reputation motive.

First, we examine whether the expansion in credit supply to non-granular borrowers is targeted at firms more generally active in the climate transition. If this were the case, the results would suggest that intermediaries are trying to build a reputation for being environmentally friendly.

Results in Table 11 show that the small borrowers targeted by this loan expansion are predominantly active in sectors characterized by a higher share of initiatives toward greenification or climate-friendly production processes, as indicated by the most recent wave of the Istat permanent census of enterprises.[17] In the table, the analysis above is replicated for the subset of non-granular firms active in sectors generally moving towards greener production. Specifically, these are sectors that score above the 75th percentile of the distribution of the sectorial number of firms that, in a given year, either report having taken actions to improve climate sustainability (panel a) or plan to take such actions (panel b). In both cases, these firms observed an expanded supply of credit, especially medium-to-long-term, once one of their lenders experienced a green shock (i.e., one of its granular borrowers produced fewer emissions than expected).

This first set of results suggests that banks are actively engaged in supporting the green transition and do not use lending to large green borrowers to subsidize loans to smaller, brown companies.

Next, we investigate whether the expansion in credit supply is directed toward firms active in the same sector as those firms that, for a given bank×year pair, exhibited the most negative surprise on emissions (i.e., the largest "green" shock) in the previous year. This test helps discriminate between the reputation and specialization mechanisms: if the

[17] https://www.istat.it/en/censuses/enterprises for more details.

expansion were driven by larger loans to same-sector firms, it would suggest that the bank is seeking to leverage the knowledge gained from the production processes of the shocked firm, which successfully resulted in lower emissions, to lend to similar companies. If, however, loan expansion is targeted at other sectors, this, in conjunction with the previous results that the effect is concentrated on green firms, would support the reputation effect, with the intermediary boosting its environmentally friendly portfolio.

Results in Table 12 indicate that the loan expansion is targeted at firms operating in sectors different from the one in which the firm, for a given bank×year pair, experienced the most negative surprise on emissions in the previous year, consistent with the reputation mechanism being at play.[18]

Taken together, the results suggest that intermediaries are overall supportive of the green transition. When existing borrowers prove to pollute less than expected, banks reward them by applying a green premium on the cost of their loans. To recover this lost profitability, intermediaries expand loan supply to smaller firms, active in green sectors, not specifically targeting specific sectors. This behavior is consistent with a reputation mechanism, which may stem from large borrowers transitioning to greener production processes and not wanting to be associated with "brown" banks.[19]

Our findings complement those of other papers documenting how green reputation motives drive banks' actions. Closest to our findings, Hrazdil et al. (2023) find that banks charge significantly higher spreads to borrowers with negative news coverage about their polluting activities. Notably, firms' fundamentals do not change following the news, suggesting that banks' reputation concerns are at play.

Giannetti et al. (2023) show that banks are willing to "gloss up" their environmental disclosures, even beyond what would be warranted by their actual actions, clearly motivated

[18] Unreported regressions for firms active in the same sector yield no significant results.

[19] While our empirical strategy accounts for this, we acknowledge that regulation may also be playing a role in supporting green lending. Among the various initiatives, the Non-Financial Reporting Directive (NFRD) issued in 2014, the Sustainable Finance Disclosure Regulation (SFDR), and the European Commission Guidelines on the disclosure of non-financial information (the "Guidelines") of 2019.

by the desire to build a green reputation.

6 Conclusion

In this paper, we have studied how a bank's lending policies respond when its large (granular) borrowers unexpectedly reduce their overall emissions, in the context of the green transition. First, we document that such borrowers are valuable to the bank, and that following the lower emissions shock, they are rewarded by being charged a lower price on their short-term loans. Second, we show that shocks to large borrowers are not idiosyncratic, in the sense that they negatively affect the return on the intermediary's portfolio of loans to firms in the same sector as the rewarded firm. Finally, we find that banks recover the margins lost by expanding supply to non-granular borrowers active in green sectors.

In terms of implications, the findings shed new light on the levers that regulators and policymakers can pull to accelerate the green transition toward more sustainable economies.

More generally, beyond the scope of this paper, the fact that the Italian banking sector appears to be characterized by a high degree of borrower granularity raises interesting questions regarding the transmission of various shocks to the real sector.

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Tables

Table 1: Descriptive statistics

Variable	Observations	Mean	Std.Dev.	Min	Max
		Emissions data			
Scope 1 emissions (ktCO2e)	407	2,515,940.15	13,103,867.9	0	119,510,000
Scope 2 emissions (ktCO2e)	407	141,824.14	341,557.66	0	2,300,688
Scope 3 emissions (ktCO2e)	407	5,845,281.25	31,937,730.1	567.29	390,655,043.4
Total emissions (ktCO2e)	407	2,657,772.23	13,265,118.8	220.22	120,164,000
		Balance sheet data			
Total assets (log)	407	11.75	2.7	4.13	17.74
Bond emission dummy	407	0.07	0.25	0	1
Profitability	407	0.09	0.12	-0.69	0.75
Cashflow	407	0.08	0.11	-0.65	0.72
Trade credits	407	0.23	0.16	0	0.81
Debt to assets	407	0.26	0.49	0	9.29
Investment to assets	407	0.04	0.07	0	0.76

This table displays the summary statistics for the main firm variables used in the analysis. Scope 1 emissions are direct Emissions; scope 2 emissions are energy indirect emissions; scope 3 emissions are other indirect emissions. Total emissions are computed as scope 1 + scope 2 emissions. Observations are at firm-year levels. Authors' elaboration on ISS and CADS databases (see Subsection 3.1 for more details).

Table 2: Green shocks autocorrelation

Dep. var.	emissions shock$_t$	
	(1)	(2)
emissions shock$_{t-1}$	0.158	0.187
	(0.112)	(0.142)
emissions shock$_{t+1}$		0.155
		(0.122)
constant	0.001	0.004
	(0.028)	(0.036)
Observations	285	191
R^2	0.026	0.045

This table displays the correlation of firms' emissions shocks with 1-period lag (column 1) and 1-period lag and 1-period lead of the same variable. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. Detailed results are available upon request.

Table 3: Green shocks and the cost of credit - Dynamic effects

Dep. var.	interest rate$_{\{.\}}$			
	$t-1$	t	$t+1$	$t+2$
	(1)	(2)	(3)	(4)
emissions shock$_t$	-0.009	0.078**	0.132***	0.027
	(0.049)	(0.039)	(0.040)	(0.054)
FE bank× year	yes	yes	yes	yes
FE sector× year	yes	yes	yes	yes
FE firm	yes	yes	yes	yes
Observations	940	1,145	852	573
R^2	0.549	0.653	0.670	0.718

This table displays the dynamic impact that a shock to firms' emissions shocks has on the (normalized) cost of short-term credit at various horizons. Column (1) considers the cost of credit in the year previous to the shock, column (2) looks at the year of the shock, and columns (3) and (4) at the effect one and two years after the shock materialises. Both the short-term interest rate and the shocks have been normalized by their standard deviation. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at the firm and year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. Detailed results are available upon request.

Table 4: Green shocks and firms' risk

Dep. var.	Z-score$_\mathrm{t}$		
	(1)	(2)	(3)
emissions shock$_\mathrm{t}$	0.017	-0.014	-0.060
	(0.099)	(0.175)	(0.147)
FE sector ×year	no	yes	yes
FE firm	no	no	yes
Observations	388	388	388
R^2	0.000	0.414	0.705

This table displays the impact that the firm level emissions shock have on firm's Altman Z-score from CADS database. The shock is computed as the residual in a regression where, besides on the variables used in table B.1, emissions are regressed on year times sector and firm fixed effects. Shocks have been normalized by their standard deviation. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at the firm and year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. Detailed results are available upon request.

Table 5: Green shocks and the cost of credit

Dep. var.	interest rate$_t$		
	(1)	(2)	(3)
emissions shock$_t$	0.040	0.100**	0.078**
	(0.106)	(0.046)	(0.038)
FE bank×year	yes	yes	yes
FE sector	yes	no	no
FE sector×year	no	yes	yes
FE firm	no	no	yes
Observations	1,145	1,145	1,145
R^2	0.529	0.593	0.653

This table displays the impact that the firm level emissions shock have on the cost of short-term credit charged to the firm. The shock is computed as the residual in a regression where, besides on the variables used in table B.1, emissions are regressed on year times sector and firm fixed effects. Both the short-term interest rate and the shocks have been normalized by their standard deviation (as for shocks, they have zero mean it is not necessary to subtract the mean value at the numerator).Sector represents two-digit NACE2 sector classification. Standard errors are clustered at the firm and year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. Detailed results are available upon request.

Table 6: Green shocks and the cost of credit - Granular borrowers

Dep. var. interest rate$_t$	(1)	(2)	(3)
emissions shock$_t$ $\times D95$	0.069*	0.096*	0.096*
	(0.041)	(0.054)	(0.051)
emissions shock$_t$ $\times D95^c$	0.014	0.068	0.048
	(0.030)	(0.056)	(0.049)
FE bank×year	yes	yes	yes
FE sector	yes	no	no
FE sector×year	no	yes	yes
FE firm	no	no	yes
Observations	1,056	1,056	1,056
R^2	0.543	0.612	0.670

This table displays the impact that the firm level emissions shock have on the cost of short-term credit charged to the firm. The shock is computed as the residual in a regression where, besides on the variables used in Table B.1, emissions are regressed on year times sector and firm fixed effects. Both the short-term interest rate and the shocks have been normalized by their standard deviation (as for shocks, they have zero mean it is not necessary to subtract the mean value at the numerator). $D95$ is a dummy equal to one if in year t the bank-firm relationship fb stands above the 95th percentile of the amount distribution (see 3). $D95^c$ is defined as $1 - D95$. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at the firm and year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Reported levels of statistical significance remain robust when using bootstrapped standard errors with 1,000 replications. Detailed results are available upon request.

Table 7: Impact of granular green shocks on sector-level loan portfolio

Dep. var.	interest rate_t					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
aggregated emissions shock_t	1.224***	1.3843***	1.399**	1.269**	1.211*	1.044*
	(0.457)	(0.552)	(0.638)	(0.652)	(0.675)	(0.607)
FE bank	yes	yes	no	no	no	no
FE year	yes	yes	no	no	no	no
FE bank×year	no	no	yes	yes	yes	yes
FE sector	yes	yes	yes	yes	no	no
FE sector×year	no	no	no	no	yes	yes
Observations	1,903	1,903	1,895	1,895	1,895	1,895
R^2	0.873	0.873	0.913	0.913	0.920	0.920
F-statistic weak instruments		11,059		9,051		8,476
Adj. R^2		0.864		0.883		0.891

This table displays the impact that firms' emissions shocks, aggregated at the bank-sectorial portfolio level have on that portfolio's return, measured as the aggregated cost of short-term loans. Results are displayed for the standard OLS model (ie without controlling for the possible effect that supply has on the shares used to aggregate the individual effects) and for the IV model, which uses the Gabaix and Koijen (2020) GIV methodology. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Asymmetric impact of granular green shocks on sector-level loan portfolio

Dep. var.	interest rate_t (1) OLS	(2) IV
aggregated emissions shock_t $\times$ positive	0.438	-0.102
	(1.070)	(1.055)
aggregated emissions shock_t $\times$ negative	2.461**	2.563**
	(1.037)	(1.010)
FE bank$\times$year	yes	yes
FE sector$\times$year	yes	yes
Observations	1,947	1,947
R^2	0.919	0.919
F-statistic weak instruments		2,389
Adj. R^2		0.891

This table displays the asymmetry of the impact that firms' emissions shocks, aggregated at the bank-sectorial portfolio level have on the cost of credit applied to the firm. The variable *positive* is a dummy equal to one whenever the aggregate emission shock is greater or equal than zero, zero elsewhere. Results are displayed for the standard OLS model (i.e. without controlling for the possible effect that supply has on the shares used to aggregate the individual effects) and for the IV model, which uses the Gabaix and Koijen (2020) GIV methodology. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 9: Spill over of the green shock to loan supply

Dep. var.	Δtotal credit_{t+1} (1)	Δshort-term credit_{t+1} (2)	Δm-l term credit_{t+1} (3)
Δaggregated emissions shock_t	-0.090***	0.021	-0.349**
	(0.019)	(0.018)	(0.050)
FE firm$\times$year	yes	yes	yes
FE bank$\times$sector	yes	yes	yes
Observations	360,228	360,228	360,228
R^2	0.440	0.438	0.386

This table displays the impact that firms' emissions shocks, aggregated at the bank sectorial portfolio level have on the supply of bank credit. Coefficients estimates are obtained via OSL with FEs. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector and firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 10: Spill over of the green shock to loan supply to non granular borrowers

Dep. var.	Δtotal credit$_{t+1}$ (1)	Δshort-term credit$_{t+1}$ (2)	Δm-l term credit$_{t+1}$ (3)
Δaggregated emissions shock$_t$	-0.123***	0.023	-0.458***
	(0.020)	(0.024)	(0.057)
FE firm×year	yes	yes	yes
FE bank×sector	no	no	yes
Observations	224,352	224,352	224,352
R^2	0.481	0.477	0.477

This table displays the impact that firms' emissions shocks, aggregated at the bank-sectorial portfolio level have on the supply of bank credit to non granular borrowers, defined as those borrowers who detain shares of loans lower than the 75p in the banks' sector level portfolio. Coefficients estimates are obtained via OSL with FEs. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector and firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 11: Spill over of the green shock to loan supply to non granular, green borrowers

Panel (a)

Dep. var.	Δtotal credit$_{t+1}$	Δshort-term credit$_{t+1}$	Δm-l term credit$_{t+1}$
	(1)	(2)	(3)
Δaggregated emissions shock$_t$	-0.892***	-0.080	-2.531***
	(0.178)	(0.1235)	(0.461)
FE firm×year	yes	yes	yes
FE bank×sector	yes	yes	yes
Observations	65,732	65,732	65,732
R^2	0.476	0.459	0.414

Panel (b)

Dep. var.	total credit$_{t+1}$	short-term credit$_{t+1}$	m-l term credit$_{t+1}$
	(1)	(2)	(3)
aggregated emissions shock$_t$	-0.868***	-0.120	-2.528*
	(0.172)	(0.117)	(0.453)
FE firm×year	yes	yes	yes
FE bank×sector	yes	yes	yes
Observations	69,842	69,842	69,842
R^2	0.471	0.466	0.417

This table displays the impact that firms' emissions shocks, aggregated at the bank sectorial portfolio level have on the supply of bank credit to non granular borrowers, defined as those borrowers who detain shares of loans lower than the 75th percentile of the banks' sector level portfolio loan shares' distribution and that are active in "green" sectors. Green sectors are defined as sectors that lie above the 75th percentile of the distribution of the sectorial number of firms that in a given year either report to have taken actions to improve climate sustainability (panel a) or that plan to take such actions (panel b). Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector and firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 12: Spill-over of the green shock to loan supply to non granular borrowers in non shocked sectors

Dep. var.	Δtotal credit$_{t+1}$ (1)	Δshort-term credit$_{t+1}$ (2)	Δm-l term credit$_{t+1}$ (3)
Δaggregated emissions shock$_t$	-0.159***	0.022	-0.562***
	(0.018)	(0.159)	(0.50)
FE firm×year	yes	yes	yes
FE bank×sector	yes	yes	yes
Observations	137,468	137,468	137,468
R^2	0.500	0.496	0.439

This table displays the impact that firms' emissions shocks, aggregated at the bank sectorial portfolio level have on the supply of bank credit to non granular borrowers, defined as those borrowers who detain shares of loans lower than the 75th percentile of the banks' sector level portfolio loan shares' distribution, that are active in sectors other than the sector in which operates the firm that, for a given bank-year, displays the largest negative shock. Sector represents two-digit NACE2 sector classification. Standard errors are clustered at bank-sector and firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Figures

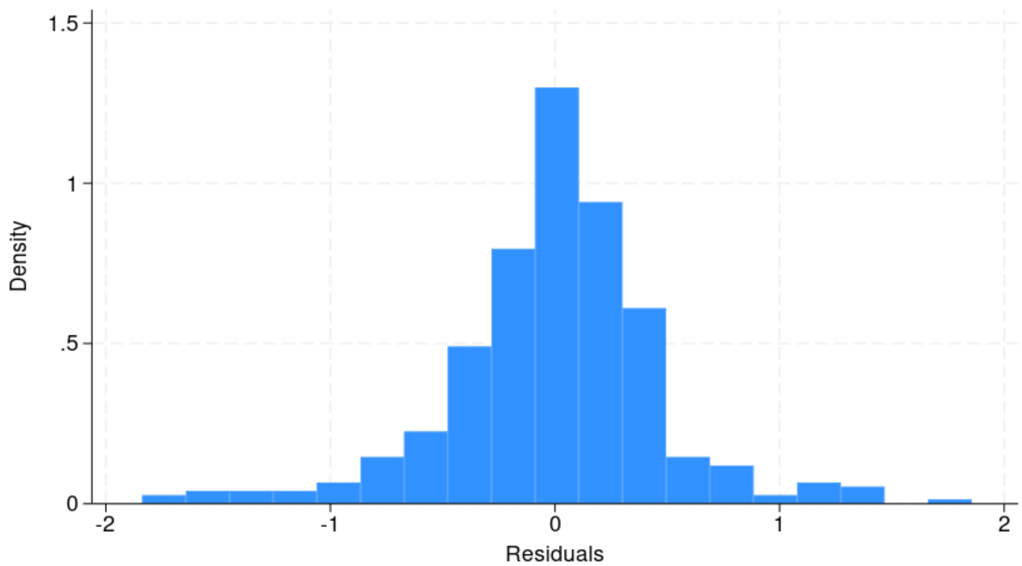

Figure 1: Firms' green shock

A Granular borrowers in the Italian credit market

In this appendix, we aim to assess the presence of granular borrowers in the Italian credit market for the period 2014–2019. To achieve this, we compute, for each borrower-bank-year triple, the share of utilized credit from borrower f by bank b in year t relative to the total credit granted to non-financial corporations by bank b in year t.

Figure A.1 presents the distribution of these bank loan shares, pooling data across all years and zooming in on the 99th percentile of the shares.

In the top 1 percent of borrowers, about one fifth of them (in the right tail) hold shares greater than 1 percent of the bank's corporate loan portfolio.

We then assess more formally whether the distribution of bank loan shares is thick-tailed. To approximate this distribution, we use a power law of the form: $P(Z > s) \sim Cs^{\zeta}$ where C and s are strictly positive. We find that this coefficient is equal to 0.35 for the entire distribution of loans. The Pareto exponent increases to 1.10 when estimated over the 95th percentile and to 1.62 when defined on the 99th percentile. These values compare well with those found in other studies. In particular, Galaasen et al. (2020) examines the Norwegian credit market over the period 2003–2015 and finds a Pareto exponent of 1.16 at the 99th percentile. Similarly, Baena et al. (2022) studies the French credit market and estimates a skewness parameter of 0.38.

Regarding the sample of firms for which we have emissions data, more than half of the firm-bank relationships related to these firms fall above the 95th percentile of the distribution, and more than one third are above the 99th percentile.

In this paper, we consider the relevance of borrowers' granularity by examining the importance of a borrower relative to the bank's portfolio of loans to other borrowers in the same sector. We focus on the sector-level portfolio as the benchmark for granularity because, for example, it is unlikely that an emissions shock to a large borrower in manufacturing would spill over to borrowers in services, given the transmission mechanisms discussed in Section 1. The regularities described above hold when we consider granularity at the sector level.

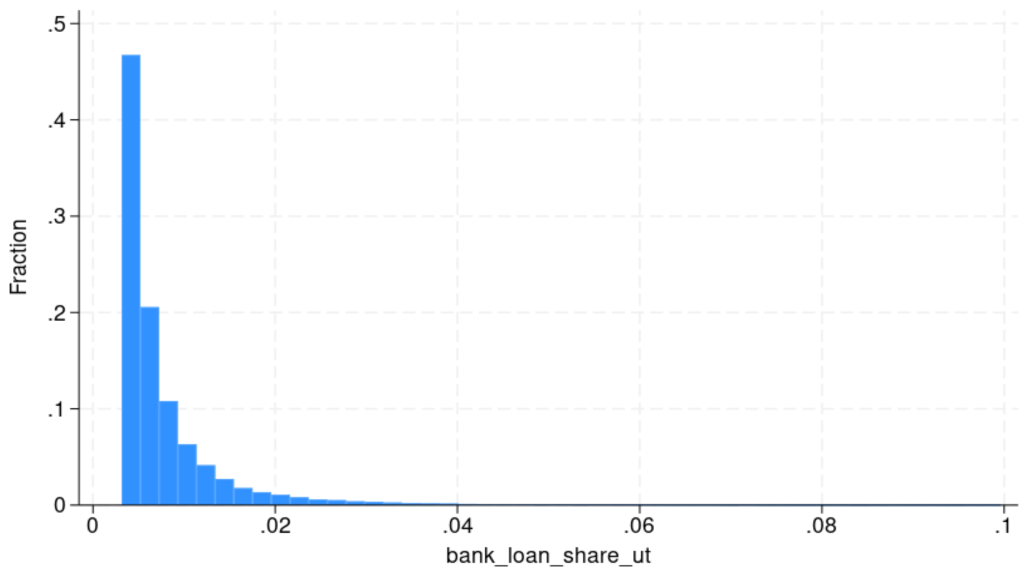

Figure A.1: The distribution of granular borrowers in Italy

B Validating the goodness of emission data

To investigate the validity of these data, we analyze them using a regression model to test whether they behave consistently with our priors regarding the effect of firm characteristics on emissions. More precisely, we estimate the following at the firm-year level:

$$Emission_{fy} = \beta FirmChar_{fy} + \alpha_f + \alpha_i + e_{fy} \tag{12}$$

where $Emission_{fy}$ represents the yearly level of emissions for firm f in year y, and $FirmChar_{fy}$ includes the following contemporaneous firm controls: log(assets), squared log(assets), profitability, cash flow, trade credit, leverage, investments, and a dummy indicating whether the firm is financing itself via the bond market. In addition, we include various combinations of firm, industry, and year dummies.

Results are displayed in Table B.1. We confirm that, in accordance with our priors, emissions are negatively correlated with a firm's presence in capital markets, as proxied by its use of bond issuance for financing. This is consistent with the findings in Haas and Popov (2023), which show that investors generally apply a green premium to companies mindful of their climate impact. Second, emissions are positively related to various proxies of economic activity, such as cash flow, leverage, and investment. Third, profitability emerges as negatively correlated with emissions. This is consistent with the notion that green goals are a kind of "luxury" good for companies, pursued only once basic survival objectives, such as profitability, are secured. Furthermore, investments in green technologies are highly capital-intensive (see Allcott and Greenstone (2012); Fowlie et al. (2018), or the more recent Accetturo et al. (2022)), which can erode profitability.

Table B.1: The determinants of firm's emissions

	scope 1 emissions		scope 2 emissions		scope 3 emissions		total emissions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(total assets)	-0.441	0.120	-1.203**	-0.904	-0.835	-0.282	-0.607	-0.240
	(0.495)	(0.607)	(0.557)	(0.659)	(0.578)	(0.626)	(0.486)	(0.613)
log(total assets)ˆ2	0.011	-0.008	0.045*	0.033	0.028	0.007	0.018	0.005
	(0.023)	(0.027)	(0.026)	(0.029)	(0.026)	(0.028)	(0.023)	(0.028)
bond emission: yes	-0.553**	-0.623*	-0.120	-0.032	-0.446	-0.469	-0.441	-0.463
	(0.272)	(0.367)	(0.427)	(0.588)	(0.296)	(0.340)	(0.292)	(0.336)
profitability	-2.509**	-1.764*	-1.563*	-0.904	-2.182**	-1.312	-1.929**	-1.334
	(0.956)	(0.898)	(0.804)	(1.047)	(0.844)	(0.990)	(0.823)	(0.955)
cashflow	2.864***	2.972**	2.094**	1.514	2.461**	2.030	2.336**	2.252*
	(1.051)	(1.241)	(0.983)	(1.182)	(1.034)	(1.310)	(0.991)	(1.278)
tradecredit	1.073	1.105	1.017	0.563	1.066	0.909	0.945	1.069
	(0.679)	(0.766)	(0.708)	(0.843)	(0.667)	(0.791)	(0.621)	(0.755)
debt to assets	1.234**	1.722***	2.194***	2.505***	1.462**	1.884***	1.505**	1.851***
	(0.565)	(0.571)	(0.635)	(0.622)	(0.594)	(0.558)	(0.575)	(0.535)
investment to assets	1.076*	0.712	1.926***	2.552***	1.398**	0.995*	1.457**	1.140**
	(0.554)	(0.645)	(0.505)	(0.845)	(0.552)	(0.522)	(0.561)	(0.513)
FE sector	yes	no	yes	no	yes	no	yes	no
FE year	yes	no	yes	no	yes	no	yes	no
FE sector×year	no	yes	no	yes	no	yes	no	yes
FE firm	yes	yes	yes	yes	yes	yes	yes	yes
Observations	392	364	389	357	393	365	393	365
R^2	0.969	0.977	0.918	0.935	0.961	0.969	0.966	0.974

This table displays the role of various firm characteristics in explaining firms' GHG emissions. Standard errors clustered at firm-level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

C Additional tables

Table C.1: Macro sectors of activity used in the analysis

Sectors of activity
01 AGR. SILV. AND FISHING
02 MINERAL EXTRACTION
03 FOOD INDUSTRIES
04 TEXTILES AND CLOTHING
05 WOOD AND FURNISHING
06 PAPER AND PRINTING
07 CHEMISTRY AND PHARMACEUTICAL
08 RUBBER AND PLASTIC MATERIALS
09 METALLURGY
10 ELECTRONIC PRODUCTS
11 MACHINERY
12 TRANSPORT MEANS
13 OTHER MANUFACTURING
14 LIGHT, GAS, ETC SUPPLY
15 CONSTRUCTION
16 TRADE
17 TRANSPORT AND STORAGE
18 ACCOMMODATION AND CATERING
19 INFORMATION AND COMMUNICATION
20 REAL ESTATE ACTIVITIES
21 PROFESSIONAL ACTIVITIES
22 RENTAL, TRAVEL, ETC.
23 OTHER ACTIVITIES TERTIARIES
24 NOT APPLICABLE
25 OTHER ACTIVITIES
21 PROFESSIONAL ACTIVITIES
22 RENTAL, TRAVEL, ETC.
23 OTHER ACTIVITIES TERTIARIES
24 NOT APPLICABLE
25 OTHER ACTIVITIES

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