# The Monitoring Costs of Green Lending*

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**Abstract**

Using pan-European credit register data, we analyze the sharp increase in public guaranteed lending (PGL) during the COVID-19 loan guarantee programs and show that banks leverage PGL to expand lending to low-emission firms. This behavior is driven by industries less affected by COVID-19, banks with "browner" portfolios, and younger firms. Notably, compared to high-emission firms, banks' internal risk assessments in PGL to low-emission firms are less frequently updated and exhibit weaker predictive power for future credit quality deterioration, indicating lax monitoring efforts. These findings highlight the additional information production costs associated with green lending and shed light on why banks may be slow to transition to greener portfolios.

**Keywords:** Green lending, public guaranteed loans, bank monitoring

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***"The misalignment with the EU climate transition pathway can lead to material financial, legal and reputational risks for banks. It is therefore crucial for banks to identify, measure and most importantly manage transition risks, just as they do for any other material risk.***

***[...] it is not for us supervisors to tell banks who they should or should not lend to. However, we will continue insisting that banks actively manage the risks as the economy decarbonises. And banks cannot do this without being able to accurately identify transition risks and how they evolve over time."***

(Frank Elderson, member of the ECB Executive Board and Vice-Chair of the Supervisory Board, "Failing to plan is planning to fail" why transition planning is essential for banks. 23 January 2024)

# 1 Introduction

The European banking sector has been under increasing pressure to transition to greener loan portfolios in alignment with the ambitious climate goals set forth by the Paris Agreement and the EU's climate agenda. The European Central Bank (ECB) joined the Network for Greening the Financial System (NGFS) in 2018, signaling its commitment to addressing climate risks, and began prioritizing these risks significantly by 2019. This focus became more institutionalized in 2020 with the introduction of supervisory expectations on managing climate-related risks. Existing studies indicate that banks have begun incorporating firm emission levels into their lending decisions—often influenced by their own profiles or transition risk considerations (Houston and Shan, 2022; Kacperczyk and Peydró, 2022; Altavilla et al., 2023; Martini et al., 2024; Ivanov et al., 2024). However, recent evidence suggests that banks' portfolio greening effort remains inadequate. For instance, the ECB's 2022 climate stress test revealed that banks' exposures to high-carbon sectors remained substantial, highlighting the slow pace of portfolio rebalancing.

On the one hand, banks may feel compelled to continue financing financially struggling high-carbon borrowers to prevent defaults and maintain asset quality (Giannetti et al., 2023). On the other hand, banks may need to incur additional information production costs when lending to green firms. Treating pollution generated from the production process is costly and requires substantial financial resources (Xu and Kim, 2022; Bartram et al., 2022), mean-

ing that managers in green firms may struggle to meet earnings targets and have to sacrifice shareholder value (Barber et al., 2021; Thomas et al., 2022). As a result, while low-emission firms are not inherently riskier, understanding the interplay between environmental and financial performance in such firms can be complicated. Lending to green firms can require banks to exert additional monitoring effort in producing information to assess risks beyond traditional default indicators. Given that monitoring is costly, banks are thus slow to transition to greener portfolios.

To examine whether this *monitoring cost* hypothesis is indeed at play, we leverage the large-scale and speedy nature of loan guarantee programs in European countries following the initial COVID-19 outbreak in 2020. In public guaranteed lending, banks are able to shift downside risk to the government and taxpayers. Unlike pre-COVID loan guarantee programs—which were limited in scale, targeted specific sectors, and required complex procedures—pandemic-related programs prioritized speed and accessibility. These programs covered up to 100% of loans, lacked sectoral restrictions, and significantly reduced banks' monitoring burdens as governments prioritized rapid disbursement over rigorous due diligence. This unique context enables us to observe whether banks become more willing to expand credit to low-emission firms when they can bypass the additional information production costs associated with green lending.

We use the ECB proprietary loan-level credit register database AnaCredit to identify European banks' lending activities to both public and private companies in 18 European countries. The coverage of the data became comprehensive in 2019. To assess firm-level emissions, we utilize data from Urgentem, which collaborated with the ECB for its economy-wide climate stress test and provided greenhouse gas (GHG) emission estimates for over 4 million firms. Given its use in the ECB stress test, we rely on Urgentem reported total GHG emissions relative to firm revenues as a proxy for banks' perception of borrowers' emission levels.

To mitigate potential concerns that the likelihood of receiving public guaranteed lending (PGL) is associated with omitted firm characteristics that also interact with emission levels to influence lending decisions, we use a firm×quarter fixed effect specification to compare

banks lending to the same firm within the same quarter, with and without PGL. Additionally, we include bank×quarter fixed effects to account for time-varying bank-specific factors, such as evolving preferences for green lending. Due to this empirical design, we require our sample firms to have multiple lenders in a given quarter and focus on lending growth of existing portfolio firms as in Khwaja and Mian (2008).

Our final sample consists of 119,397 firms borrowing from 74 banks during the period of 2019 Q2 to 2020 Q4. Our baseline analysis shows that while loan guarantees indeed lead to significant lending growth, this effect is stronger in low-emission firms than in high-emission firms. Specifically, an interquartile decrease in GHG emission level is associated with a 3% stronger effect of PGL on lending growth. In addition to our baseline continuous measure of firm emissions, we also adopt an alternative industry level classification of green and brown firms using data from Eurostat following Giannetti et al. (2023). Firms are classified into green or brown industries using the industry's GHG emissions relative to its annual value added within the corresponding country. This classification allows us to assess the broader impact of loan guarantees across different industry profiles. Our analysis reveals that PGL has no significant differential effect on lending growth for firms in brown industries. However, for firms in green industries, PGL is associated with a 19% stronger effect on lending growth, on average. We further find that lending through PGL is generally associated with lower interest rates, and this reduction in financing costs is even more pronounced for low-emission firms receiving guarantees. Finally, we find that these results are mainly pronounced for loan guarantees during the period following the COVID-19 outbreak (2020 Q2 to Q4). These findings provide evidence that banks leveraged the large-scale and urgent nature of the COVID-related loan guarantee programs to green their portfolios. This supports the hypothesis that banks may view green lending as requiring greater monitoring effort, which these guarantees helped mitigate.

One potential alternative explanation for our findings is that a firm's emission level might correlate with unobserved characteristics influencing how severely it was impacted by the pandemic. Altavilla et al. (2021) show that COVID-related loan guarantees were primarily directed toward low-risk firms in industries that were hit more by the COVID disruption.

Therefore, our results could be interpreted as reflecting a more aggressive credit expansion to firms with urgent liquidity needs rather than a deliberate effort to green portfolios. To address this concern, we conduct a cross-sectional analysis based on the extent to which the focal firm's industry was affected by COVID. Following the approach of Altavilla et al. (2021), we calculate sector value-added growth during the pandemic as a measure of industry-level disruption. Our analysis reveals that the strengthened effect of PGL on lending growth for low-emission firms is primarily concentrated in industries that were less affected by COVID. This evidence suggests that our findings are unlikely to be driven by pandemic-related confounding factors. Moreover, it indicates that banks did not prioritize greening their portfolios at the expense of addressing the primary objective of loan guarantee programs, which was to provide liquidity to firms in need.

We next explore banks' incentives to leverage loan guarantees for portfolio greening. Since 2018, the ECB has increased pressure on banks to decarbonize their loan portfolios. Consequently, banks with relatively browner portfolios are more motivated to utilize PGL as a tool to advance their greening efforts. Notably, banks with a greater concentration of high-emission borrowers often lack the expertise to assess the complex relationship between environmental and financial performance in green firms, making lending to such firms more costly due to higher information production requirements. To analyze this, we calculate the loan value weighted average GHG emissions across the loan portfolio of each sample bank in each quarter, and rank them at the country-quarter level. Banks in the top quartile of portfolio emissions are classified as having brown portfolios. Our findings reveal that the positive impact of PGL on lending growth to low-emission firms is significantly stronger for banks with browner portfolios in the preceding quarter.

Our result should also become more prominent when the firm has a higher level of opaqueness. Younger firms are usually considered more informationally opaque because of their limited operating history and lack of established relationships in the market (Diamond, 1991; Berger and Udell, 1995). As such, the difficulty of understanding the interplay between environmental and financial performance should be even more concerning when lending to younger firms. We find that the strengthened effect of PGL on lending growth for low-

emission firm is indeed mainly pronounced when such firms are younger. Even though these firms were already part of the banks' loan portfolios before the pandemic, the lack of operating history makes it particularly challenging to assess how their environmental performance can influence financial prospects. This evidence further reinforces the notion that our key findings are driven by information frictions.

Finally, we aim to provide more direct evidence on the concern over additional information production effort in green lending. To examine this, we utilize AnaCredit's data on banks' internal risk assessment of their borrowers. Banks estimate and update the probability of default (PD) for borrowers in their portfolios over time. Such internal assessments can be used to reflect banks' private information (Howes and Weitzner, 2023; Beyhaghi et al., 2024). We argue that significant PD updates should indicate banks' information production intensity. Our results first show that, banks are less likely to update PDs significantly one year forward if their lending to the borrower involves loan guarantees. This is not surprising given that banks have largely shifted downside risk to the public in these relationships and monitoring takes significant effort.[1] More importantly, we find that banks lending through PGL to low-emission firms are even less likely to have significant PD update in the near future than to high-emission firms. This evidence supports the notion that conventional green lending requires higher monitoring intensity.

High-quality risk assessments should effectively predict future credit quality deterioration. Following Altavilla et al. (2021), we use arrears to proxy for firm risk, and find that PDs normally do have significant predictive power for the percentage of debt overdue or with missing payment in the near future. However, such predictive power largely diminishes in lending involving loan guarantees. This weakening effect of PGL on PD's predictive power is again more pronounced in firms with lower level of GHG emissions. We interpret this as additional evidence that loan guarantees reduce banks' monitoring burden more in low-emission firms, suggesting that lending to such firms in the absence of guarantees typically requires more intensive information production efforts.

Our findings first contribute to the emerging literature on the role of financial insti-

[1]For example, Gustafson et al. (2021) show that bank monitoring activities range from private borrower meetings, physical site visits, third party appraisals, to demanding monthly or even daily financial updates.

tutions in sustainable finance, particularly banks in green lending. Existing studies have provided evidence that carbon emission risks are being priced in equity, bond, and even options markets by institutional investors (Krueger et al., 2020; Ilhan et al., 2021; Bolton and Kacperczyk, 2021, 2023; Hsu et al., 2023; Duan et al., 2023; Zhang, 2024). Banks have also begun to account for borrowers' environmental practices and transition risks when making lending decisions (Houston and Shan, 2022; Correa et al., 2023; Ivanov et al., 2024; Martini et al., 2024). Banks with stated commitments to decarbonization tend to disengage from their brown borrowers (Kacperczyk and Peydró, 2022). In addition to such exclusion-based lending practices, there is also evidence that banks expand credit to green firms by offering lower loan spreads (Altavilla et al., 2023; Shin, 2024) or through sustainability-linked contracts (Kim et al., 2022; Du et al., 2023). Despite these recent developments, recent evidence from the ECB has indicated that many European banks' portfolio greening efforts remain inadequate.[2] One explanation proposed by a recent study of Giannetti et al. (2023) is that banks may feel compelled to continue lending to financially struggling brown firms in their portfolios to prevent defaults and main asset quality. Our findings provide an additional perspective on why banks are slow to transition to greener portfolios, based on the additional information production efforts required to understand the interplay between environmental and financial performance. This is particularly important since banks cannot simply price in this uncertainty for loans to green firms, given that existing evidence suggests that banks often need to offer lower rates to such borrowers.

We also contribute to the literature on public loan guarantees by examining their diverse impacts. Using the removal of government guarantees for savings banks in Germany, Gropp et al. (2014) show that public guarantees may be associated with excessive bank risk-taking. Wilcox and Yasuda (2019) find similar results on bank risk-taking using a setting of Japanese government guarantees of loans to small businesses. Bachas et al. (2021) highlight that U.S. Small Business Administration (SBA) guarantees effectively expand credit supply rather

[2]See, for example, the ECB's good practices for climate-related risk management report, observations from the 2022 thematic review https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.thematicreviewcercompendiumgoodpractices112022~b474fb8ed0.en.pdf; or the ECB's Annual Report 2022, https://www.ecb.europa.eu/press/annual-reports-financial-statements/annual/html/ecb.ar2022~8ae51d163b.en.html

than merely subsidizing lenders. Carletti et al. (2023) theorize that loan guarantees can enhance monitoring incentives, except in poorly capitalized banks, by channeling guaranteed funds to depositors even when monitoring fails, aligning incentives with financial stability. Regarding COVID-19 loan guarantee programs, Altavilla et al. (2021) find that stronger banks substituted guaranteed loans for non-guaranteed credit to riskier, smaller firms in affected sectors, while Jiménez et al. (2022) observe banks providing more guarantees to firms accounting for larger portfolio shares. By showing how banks used COVID-related guarantees to green their portfolios, we underscore a positive externality of public guaranteed lending.

# 2 Institutional background

## 2.1 EU banks' role in transitioning to a low-carbon economy

On December 12, 2015, 195 nations signed the "Paris Agreement" at the UN Climate Change Conference (COP21). This legally binding international treaty, along with the UN 2030 Agenda for Sustainable Development[3] represents the most significant initiative aimed at transitioning from a high-carbon economy ("brown economy") to a low-carbon economy ("green economy")[4]. In November 2021, during the 26th Conference of the Parties (COP26), the guidelines for the Paris Agreement were approved and formally adopted.

The European Union (EU) has been at the forefront of the global effort to significantly decrease carbon emissions. In 2018, the European Commission (EC) announced its strategic mid-term goal to limit greenhouse gas emissions by at least 55% by 2030, with the long-term objective of creating a climate-neutral European economy by 2050[5]. This ambitious climate agenda has profound implications for various sectors, including the European banking sector.

[3]Available at: https://sustainabledevelopment.un.org/post2015/transformingourworld.

[4]The Paris Agreement, with its goal of limiting the increase in global average temperature to a maximum of 2°C above pre-industrial levels, marks a turning point in creating a truly low-carbon and climate-resilient global economy

[5]European Commission communication, November 2018 "A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy" Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773.

In alignment with the EU's climate goals, the European Central Bank (ECB)[6] took significant steps to address the financial sector's role in managing climate-related risks. In April 2018, the ECB joined the Network for Greening the Financial System (NGFS), a coalition of central banks and supervisors committed to addressing climate-related risks. In late 2019, the ECB began incorporating climate risk into its strategic reviews and speeches. In May 2020, the ECB published its first draft of the "Guide on climate-related and environmental risks: supervisory expectations relating to risk management and disclosure." This guide, finalized in November 2020 after a period of public consultation[7], outlines the ECB's expectations for how banks should manage and disclose climate-related and environmental risks, ensuring that the financial sector supports the EU's transition to a low-carbon economy.

In addition to describing for the first time the meaning of climate-related and environmental risks for European banks, the climate-related and environmental key performance indicators (KPIs) that EU banks are expected to integrate into their strategy,[8] the guide also requires banks to embed climate-related and environmental risks into their risk appetite framework (RAF), business strategy, governance structures, committees, organizational frameworks, reporting, and overall risk management framework, with full compliance expected by the end of 2024.

As a result, European banks have been under strong pressure from banking supervisors and regulators since 2018 to reduce their exposure to high-carbon ("brown") companies and increase their exposure to low-carbon ("green") companies, ultimately supporting the transition to a greener economy.

[6]Precisely, the Single Supervisory Mechanism (SSM) that is the banking supervisory arm of the ECB. See: https://www.bankingsupervision.europa.eu/about/thessm/html/index.en.html.

[7]Guide on climate-related and environmental risks. Available at:https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks~58213f6564.en.pdf.

[8]Page 18, "Guide on climate-related and environmental risks". Available at: https://www.bankingsupervision.europa.eu/legalframework/publiccons/html/climate-related_risks.en.html..

## 2.2 Public guaranteed lending in Europe

Even before the COVID-19 pandemic, loan guarantee programs in Europe were well-established tools for fostering economic growth, particularly by improving access to finance for small and medium-sized enterprises (SMEs). These programs were designed to address market failures in credit markets, where SMEs often faced challenges in securing loans due to insufficient collateral or perceived higher risk. For instance, the EU COSME (Competitiveness of Entreprises and SMEs) program, managed by the European Investment Fund (EIF), provided loan guarantees to improve access to finance for SMEs across the European Union, with a particular focus on high-growth potential firms. However, this program only covered up to 50% of default risk provided to SMEs by financial intermediaries. The InnovFin SME guarantee program targeted firms in sectors such as technology and life sciences, guaranteeing for loans up to €7.5 million. Various national level programs in France, Germany, and Italy also exist primarily to support SMEs.

Loan guarantee programs during the COVID-19 pandemic in Europe differed significantly from pre-pandemic programs in terms of scale, focus, design, and objectives. While pre-COVID programs mainly targeted SMEs, COVID–related program coverage extended beyond SMEs to include larger corporations. Pre-COVID loan guarantees typically covered 50%-80% of the loan amount to ensure shared risk between public entities and private lenders. During COVID-19, governments often covered 80%-100% of the loan amount to encourage rapid credit disbursement and reduce the reluctance of financial institutions to lend during heightened uncertainty, with default risk significantly shifted to the public sector. COVID-19 programs were also designed to be simple and quick to deploy, reflecting the urgency of the crisis. Eligibility criteria were relaxed and there was no sector restriction. Finally, pre-COVID programs encouraged high-quality risk assessment by financial institutions to prevent moral hazard and ensure the effective use of public funds. For programs during the pandemic, monitoring efforts were relaxed as governments prioritized rapid disbursement over rigorous due diligence. Lenders faced less incentive to conduct thorough credit assessments, as much of the risk was borne by public entities. We list the criteria of loan guarantee programs in different EU countries during COVID-19 in Appendix Table **??**.

# 3 Sample construction and empirical design

## 3.1 Data

We construct a comprehensive and unique dataset that matches (i) the ECB proprietary loan-level credit register *AnaCredit*[9], (ii) firm-level GHG emissions data from Urgentem, and (iii) firm-level characteristics from Orbis BVD. AnaCredit provides granular loan-level or credit instrument information. It is a proprietary and confidential database of the ECB that presents individual transaction-level data together with in-depth information, among others, about the lender, the borrower, the precise provider of the collateral (or guarantees/protection), as well as specific information about the nature of the collateral or guarantees provided in each case.[10] We use at the instrument level, the individual annualised interest rate of the credit instrument and the outstanding nominal amount[11], inception date, and the probability of the debtor's default taking part in the instrument as assigned by the creditor.

The debtor companies are identified at the RIAD level, the ECB's Register of Institutions and Affiliates Database (RIAD). This infrastructure provides information on the financial composition and control structure of financial and non-financial legal entities.[12] From this layer, we obtain key corporate-level variables such as the country location of the legal entity, the territorial unit (*NUTS codes level 3*), the postal code, enterprise size[13], as well

[9]The European Central Bank (ECB) initiated in 2011 the "AnaCredit" project to create a harmonized database of detailed information on individual loans. Data collection began in September 2018 and covers all loans exceeding 25,000 granted to legal entities in the Euro area. The database excludes data on households and does not consider self-employed individuals as legal entities, thereby excluding them as well. The 25,000 threshold is calculated based on the consolidated position of the debtor at each bank. Consequently, different instruments between a bank and the same borrower, which individually fall below the threshold, are included in the database if their combined total meets or exceeds the threshold.

[10]The database takes into consideration the different collateral instruments existing for each transaction, as well as in turn, the multiple collateral providers for each of these guarantees. The data has been collected since September 2018 on a monthly level data, covering a reporting set of financial institutions of around 3400 Euro area banks. There are 3400 financial institutions at the consolidated level and 5800 at the subsidiary level, and approximately 120 million credit instruments for 7 million debtors across all Euro area countries. The database includes details for all loans above 25,000 euros granted in the Euro area to a legal entity.

[11]The outstanding nominal amount refers to the portion already drawn under the instrument. (AnaCredit Reporting Manual - Part 1, p. 49, available here)

[12]Monetary and Financial Institutions, Investment Funds, Financial Vehicle Corporations and Insurance Corporations.

[13]Company size classification from 1 to 4 (Large, Medium, Small and Micro) enterprise as following the

as its institutional NACE sector.[14] One of the important features that we exploit is the comprehensive information on the collateral, guarantee or protection securing each of the instruments at hand, as well as on the institution behind this collateral. Through this, we can disentangle the guarantee tranches and the loans provided by the government agency underwriters in the policy context.

We obtain firm-level annual data on greenhouse gas emissions (measured in tonnes of GHG emissions) from Urgentem (Gambacorta et al., 2023; Giannetti et al., 2023; Papoutsi et al., 2021). The Urgentem Carbon Dataset provides the complete range of Scope 1, 2 and 3 emissions disclosed at a consolidated level by approximately 6,000 global companies. Importantly, Urgentem worked with the ECB for its economy-wide climate stress test and provided emission estimates for more than 4 million public and private companies in 2018 (Alogoskoufis et al., 2021). Through the ECB, we are able to obtain such estimates for 2018, which is immediately prior to the start of our sample period (2019), for a wide range of European firms. In our analysis, we use the total GHG emissions (the sum of scope 1,2 and 3) to calculate the relative GHG emissions following the procedure in Bolton and Kacperczyk (2021), which measures a company's carbon intensity, expressed as tonnes of GHG equivalent divided by the company's revenues in EUR millions.

## 3.2 Empirical framework

To test our hypothesis, we need to examine first if banks indeed increase lending to firms through PGLs and more importantly, whether this relationship differs based on the firms' emission level. Our credit register data allows us to track banks' credit commitment to firms dynamically. We adopt an approach similar to that in Khwaja and Mian (2008) and Irani and Meisenzahl (2017) by constructing a firm-bank-quarter panel. For each firm in a given quarter, we test how each of its lenders' credit exposure changes from the previous quarter. By comparing different banks' lending behavior to the same firm in the same quarter, we are able to isolate credit demand side characteristics that can affect lending decisions such as

Annex to Recommendation 2003/361/EC.

[14] Statistical Classification of Economic Activities in the European Community (NACE Rev.2).

default risk. Furthermore, we include bank×quarter fixed effects to control for bank-specific characteristics that can determine lending intensity such as bank liquidity.

Our baseline regression follows the equation below:

$$LendingGrowth_{i,b,t} = \beta_1 PGL_{i,b,t} + \beta_2 PGL_{i,b,t} \times GHG\ emission_i + \lambda_{i,t} + \gamma_{b,t} + \epsilon_{i,b,t}, \quad (1)$$

where $LendingGrowth$ is the difference in log loan size from quarter t-1 to quarter t, between bank $b$ and firm $i$. $PGL$ is an indicator that equals one if bank $b$'s used any level of public guaranteed lending in its credit exposure to firm $i$ in quarter $t$. $GHG\ emission$ measures the firm's emission of greenhouse gas expressed as tonnes of GHG emissions per million EUR of revenues. $\lambda_{i,t}$ is firm×quarter fixed effect controlling for time-invariant and time-varying credit demand side characteristics. The standalone $GHG\ emission$ term is absorbed by the high-dimensional fixed effect specification since we are comparing different banks' credit exposures to the same firm in the same quarter. $\gamma_{b,t}$ is bank×year fixed effect controlling for bank-specific characteristics. Standard errors are double clustered at the firm and bank level.

By examining banks lending to a firm through PGL to those lending to the same firm in the same quarter without PGL, our approach allows us to absorb potential unobserved borrower-specific variables that can be correlated with firm emission level while also affecting the probability of getting PGL. While we expect the use of PGL to be associated with positive lending growth, i.e. a positive $\beta_1$, the interaction term between PGL and GHG emission should indicate whether the effect of PGL differs across firms with different emission levels. If $\beta_2$ is negative, it means that PGL expands lending more to firms with lower emission levels than those with more emissions. The limitation of this analysis is that it focuses on firm-bank pairs with existing active lending. In later analysis, we retrieve data on dates on which a firm-bank pair started its relation and examine whether the same effects exist for new lending relationship formation.

### 3.3 Sample and descriptive statistics

As we need data on lagged firm-bank lending and AnaCredit started comprehensive coverage in 2019 Q1, our final sample covers quarterly data from 2019 Q2 to 2020 Q4. Due to our empirical specification, we keep only firm-quarter observations that have multiple lenders and non-missing lending growth. The final sample includes 1,025,509 firm-bank-quarter observations with 74 banks and 119,397 firms. Summary statistic in Table 1 show that 34% of our observations involve public guaranteed lending. In 21% of the sample observations, over half of the bank's lending to the firm is guaranteed by the government. On average, around 20% of bank lending to an average firm in the sample is guaranteed. Figure 1 shows that the majority of lending relationships involving PGL started to occur following the COVID-19 outbreak in Q1 2020. From 2019 Q2 to 2020 Q1, the percentage of bank-firm pairs with PGL is consistently around 10%, while it increases to over 60% over the last three quarters of 2020. Within guaranteed loans, the average portion being guaranteed also increases significantly from around 50% to to 65%.

The GHG emission variable measures the sum of Scope 1, 2, and 3 GHG emissions relative to firm's revenue, as obtained from Urgentem. The average GHG emission in our sample is 764.5 tonnes per million dollars of revenue, with a median of 564.8. To identify "green" and "brown" firms, we also adopt an alternative approach from Giannetti et al. (2023), which is based on GHG emissions at the NACE-2 industry-country-year level from Eurostat. Industries that rank in the upper (bottom) quintile for GHG emissions relative to the industry's value added in a given year are classified as brown (green).[15] We end up with 619,460 observations with 66 banks and 70,726 firms using this approach. Using this alternative sample with alternative green and brown classifications, we show that around 7% of the firm-bank-quarter observations involve firms from brown industries while the number is 8% for green industries. Figure 2 demonstrates that while firms in green industries were more likely to receive PGL following the COVID-19 outbreak, the probability of having PGL also increased substantially for firms in brown industries-from approximately 10% before COVID

[15]Certain NACE-2 industries are missing in Eurostat's reporting of GHG emissions, hence we have a smaller sample using this alternative classification.

to over 50% by 2020 Q4. We observe a similar pattern for the average percentage of lending guaranteed. Although the average guaranteed portion was consistently higher for green firms during the COVID-19 loan guarantee program, it also rose significantly for brown firms, from around 50% pre-COVID to 60% in Q4 2020. This evidence highlights substantial variation in PGL coverage for both green and brown firms following the COVID-19 outbreak. Such variation supports the use of our firm×quarter fixed effects specification, enabling meaningful comparisons between banks lending with and without PGLs to the same firm at the same time, within both green and brown firms.

In Table 1, we also include summary statistics for an internal risk assessment sample that we use for later analysis of banks' information production activities. This sample focuses on firm-bank lending during the period following the initial COVID-19 outbreak in our sample (2020 Q2 - Q4). The PD variable is banks' internal assessment of a borrower's default probability in a given quarter. The average default probability based on bank internal risk assessment is 2.6%. Around 40% of the firm-bank-quarter observations in this sample experience a significant update in PD (increase or decrease by at least one percentage point) one year forward, indicating that banks often update their internal risk assessment. Slightly over half of the observations in this sample have PGL, which corresponds to the increase in PGL following COVID outbreak. The average level of GHG emission remains similar to the baseline sample. Finally, we obtain data on one year forward arrears for the observations in this sample. The average percentage of debt overdue or with missing payment is 0.09%, with slightly over 8% of the sample observations having some level of arrears one year forward. In addition, we also create an indicator, significant arrears, that takes the value of one if the one year forward value of arrears as a percentage of the bank's total credit exposure to the firm in the given quarter is over 1%. In our sample, 2.1% of the observations have significant arrears after one year.

# 4 Loan guarantee, firm emissions, and lending growth

## 4.1 Baseline results

Our baseline analysis focuses on lending growth. Figure 3 illustrates an overall positive lending growth of approximately 5% during the three quarters following the COVID-19 outbreak. Figure 4 highlights that this positive lending growth was primarily driven by publicly guaranteed lending. Using the green and brown firm classifications, data visualization further suggests that loan guarantees have positively impacted lending growth for both green and brown firms during this period, with a stronger effect observed for green firms.

Table 2 presents the baseline regression results on lending growth, estimated using Equation 1. Column (1) reveals that banks lending through PGLs indeed exhibit an additional quarterly lending growth of 14% for the average firm in the sample, compared to other banks lending to the same firm within the same quarter. Column (2) shows a significant negative coefficient for the interaction term between PGL and GHG emission, indicating that the impact of PGL on lending growth diminishes as a firm's GHG emission level increases. When comparing firms across the interquartile range in the sample's emission distribution (9.373 - 3.006 = 6.367), the effect of PGL is 3% stronger for low-emission firms than for high-emission firms (((-0.0007 × -6.367)/0.145)=3%), translating into an additional 0.5% growth in lending. Next, we examine cases where public guarantees cover more than 50% of the bank's total lending to a firm. Column (3) reveals a similar pattern: while higher PGL coverage significantly boosts a bank's lending to a firm, the effect is more pronounced for low-emission firms. Finally, in column (4), we replace the PGL indicator with the level of PGL involved in the firm-bank lending relationship. The result suggests that as the level of PGL increases, its impact on lending growth intensifies, though the effect remains stronger for firms with lower GHG emission levels. Overall, these findings support our prediction that banks can leverage PGL to green their portfolios. By using PGLs, banks can bypass additional information production costs related to evaluating the interaction between their borrowers' environmental and financial performance, while transferring the potential associated risk to European governments and taxpayers.

We extend our analysis by using the industry level classifications of green and brown firms. Table 3 presents the results of using this alternative approach. Using brown and green indicators allows us to capture potential non-linear relationships between emission level and the impact of PGL on lending growth. Column (1) shows that PGL does not appear to have any differential effect on lending growth for firms in brown industries, compared to the average firm in the sample. The interaction term between PGL and the brown industry indicator is both economically and statistically insignificant, with a coefficient near zero. The economic magnitude of the PGL coefficient remains consistent with the baseline results, suggesting that the overall PGL effect on lending growth is comparable across the two samples. In contrast, column (2) reveals that the impact of PGL on lending growth is significantly stronger for firms in green industries. The interaction term between PGL and the green industry indicator has a coefficient of 0.0271, significant at the 1% level. This translates to a 19% increase in the PGL effect (0.0271/0.139), equivalent to an additional 2.7% growth in lending for green firms. Column (3) includes both interaction terms simultaneously, yielding consistent results. We use the alternative measures of PGL in columns (4) and (5) as in Table 2, i.e. PGL $>$ 50% that captures significant loan guarantee and % PGL which gauges the intensive margin of loan guarantee. Both results support that banks leverage PGL to increase lending to existing green firms in their portfolios.

## 4.2 Interest rate

Beyond credit supply decisions, banks may also factor in the risks associated with uncertainty about the interplay between a borrower's environmental and financial performance when pricing loans. Altavilla et al. (2023) provide evidence that banks account for climate transition risk by charging higher interest rates to firms with higher carbon emissions, even after controlling for credit default risk. Similarly, banks may adjust loan pricing for green firms if they lack sufficient understanding of how commitments to environmental performance might impact financial prospects. In the context of state loan guarantees, we can assess whether banks are more inclined to lend to low-emission firms when they can offload associated risks as in our baseline analysis. However, it is equally important to determine

whether such increased lending comes at a cost—specifically, risk premiums reflected in higher interest rates. This section explores whether loan guarantees have varying effects on firms based on their emission levels.

We begin by calculating the loan value-weighted average interest rate across all loan instruments within a firm-bank pair in a given quarter. We then analyze how interest rates change in the presence of loan guarantees. Column (3) of Table **??** shows a significant and negative coefficient of -0.283 for the standalone PGL variable, indicating that firm-bank relationships involving government loan guarantees are associated with substantially lower interest rates—approximately 33% lower than the sample mean of 291 basis points. Additionally, the interaction term between PGL and GHG emissions shows a significant positive coefficient of 0.0026, suggesting that the impact of loan guarantees on loan pricing is stronger for low-emission firms. Specifically, an interquartile decrease in GHG emissions strengthens the PGL effect on loan pricing by 6% ((-6.367 $\times$ 0.0026)/-0.283).

Column (4) presents a similar pattern, revealing that the PGL effect on loan pricing is 14% stronger for firms in green industries (-0.0359/-0.257). These findings indicate that loan guarantees make banks more comfortable with the potential risks stemming from limited scrutiny of how green firms' environmental efforts interact with their financial prospects. This supports the notion that a more complex informational environment poses risks that banks consider when lending to low-emission firms.

Interestingly, column (4) also shows that the effect of loan guarantees on loan pricing is about 24% weaker for firms with higher emission levels (0.0614/0.257). This is likely due to the highly visible nature of publicly guaranteed loans and European governments' strong commitments to decarbonization. To avoid the appearance of supporting high-emission businesses with public funds, banks may adopt more cautious pricing strategies for PGLs to these firms.

## 4.3 COVID-19 loan guarantee programs

As previously described, publicly guaranteed lending increased substantially in Europe following European countries' loan guarantee programs in response to the COVID-19 out-

break. Altavilla et al. (2021) show that recipients of such loan guarantees tend to be firms that were not ex-ante risky but from sectors that experienced harder hits from COVID-19. Loan guarantees in Europe before COVID-19 were well-established and primarily tools for addressing financing gaps and fostering economic growth, with a strong emphasis on SMEs and innovation. The pandemic, however, greatly expanded their scale and scope to meet the urgent liquidity needs of a broader range of businesses.

The urgent, large-scale shift in COVID-related loan guarantee programs, compared to the pre-existing programs' stable and long-standing framework, allows us to observe how banks responded to new opportunities without the usual institutional inertia. The scale of COVID-19 loan guarantees often covered up to 100% of the loan value, whereas pre-COVID loan guarantee programs generally had lower coverage and were more targeted. For example, the EU COSME loan guarantee facility program only covered up to 50% of default risk for loans provided to SMEs by financial intermediaries. The InnovFin SME guarantee program targeted innovative firms in sectors such as technology and life sciences, providing guarantees for loans up to €7.5 million. The focus on speed of the COVID-related programs also allowed banks to extend such lending promptly, bypassing the detailed information production typically required in regular guarantee programs. Overall, in the pandemic's aftermath, banks had a rare opportunity to quickly restructure their portfolios, potentially increasing their green or sustainable investments without significant risk.

We analyze the effect of loan guarantees on lending before and after the COVID-19 outbreak, and how it differentiates across firms with different emission levels. We define a post-COVID outbreak period in our sample as the three quarters following the initial COVID outbreak in the first quarter of 2020, i.e. 2020 Q2 to Q4. Column (1) of Table 5 shows that while loan guarantees did have a positive effect on lending growth before the COVID outbreak, this effect became substantially more significant following the outbreak. The coefficient for the interaction term between PGL and GHG emission is not statistically significant, suggesting that the effect of pre-COVID loan guarantees does not differ for firms with different emission levels. The three-way interaction term of PGL, GHG emission, and the post COVID outbreak indicator has a significant and negative coefficient of -0.0007. This

indicates that our key result is mainly pronounced during the period following the COVID-19 outbreak. In columns (2) and (3), we observe similar patterns for new lending relationship formation and loan interest rates. Overall, the evidence from Table 5 supports that banks leveraged the large-scale and urgent nature of the COVID-related loan guarantee programs to green their portfolios.

## 4.4 Industries less affected by COVID

An alternative explanation for our results is that a firm's emission level may be correlated with characteristics that influenced how severely it was impacted by the COVID-19 disruption. For instance, firms in service industries, which tend to have lower emissions due to less reliance on heavy machinery or global supply chains, may have been harder hit by the pandemic due to movement restrictions. As COVID-19 loan guarantee programs were designed to address the urgent liquidity needs of such firms, this could explain the stronger observed effect of PGL on lending growth.

To address this concern, we assess whether our key result is driven by firms in industries more or less affected by COVID-19. To evaluate how hard an industry was hit by COVID, we follow Altavilla et al. (2021) and calculate the sector value added growth during year 2020. We merge this measure to our sample based on the sector to which each sample firm belongs. We then rank our sample into quartiles and define firms in the top quartile as being in industries less affected by COVID-19. The average value added growth for industries less affected by COVID in our sample is -1.25%, compared to -12.7% for the rest of the sample. If our results were driven by COVID-19-related confounding factors, we would expect a stronger effect for firms in industries more severely hit by the pandemic.[16]

Column (1) of Table 6 presents the result of this cross-sectional test. The interaction term between PGL and GHG emission has a coefficient of -0.0003 that is not statistically significant with a t statistic of -1.127. The three-way interaction of PGL, GHG emission, and the indicator for less COVID-affected industry has a coefficient of -0.002 that is significant

[16]Since we need to gauge the COVID industry effect for the analysis and given that our main result is driven by COVID-related loan guarantee programs, our sample for this cross-sectional test covers 2020 Q2 - Q4. For consistency, all the following cross-sectional tests are conducted for this period.

at the 1% level. The economic magnitude of the effect is also much larger than that of our baseline result. This result indicates that our key result is mainly pronounced for firms in industries that were less hit by the pandemic. Therefore, our results are unlikely to be driven by COVID-19-related confounding factors correlated with GHG emission levels. Moreover, this evidence also suggests that banks indeed first prioritized the main purpose of the COVID-related loan guarantee programs by focusing on liquidity provision in industries severely hit by the pandemic, while only leveraging the opportunity to green their portfolios in those less affected.

## 4.5 Bank portfolio emission level

Banks with higher exposure to high-emission borrowers are likely more incentivized to green their portfolios, especially given the EU's strong emphasis on transitioning to a low-carbon economy. The key obstacle for such banks with "browner" portfolios can be the lack of experience in understanding what lending to "green" firms entails. The complicated nature of understanding the interplay between environmental and financial performance in low-emission firms is likely to be even more exacerbated for these banks. The large-scale COVID-19 loan guarantee programs provide an opportunity for these banks to overcome this friction. By allowing them to shift potential credit risk to the public, these programs reduce the information production costs typically associated with lending to low-emission firms. Therefore, we expect banks with browner portfolios to leverage loan guarantees more aggressively to green their portfolios.

For each bank, we calculate the loan value weighted average GHG emission level across all its portfolio borrowers in a quarter. Next, we rank banks into quartiles based on this value weighted average portfolio level emission measure for each sample quarter and each country in which they have lending activities. For each firm-bank-quarter observation during the COVID period sample, if the bank's portfolio emission level is ranked in the top quartile for the previous quarter, then the indicator, Brown portfolio, takes the value of one, and zero otherwise. Column (2) of Table 6 presents the result of this cross-sectional test. In this case, the two-way interaction term of PGL and GHG emission has a coefficient of -0.0005 that is

significant at the 5% level, while the three-way interaction of PGL, GHG emission, and Brown portfolio has a coefficient of -0.0017 that is significant at the 1% level. This result suggests that while all banks tend to use loan guarantees to expand credit to low-emission firms, those with brown portfolios do so to a significantly greater extent. This evidence strengthens the argument that the observed patterns are driven by portfolio greening motives and highlights the role of information expertise as a critical barrier to transitioning to low-carbon lending. It underscores how public interventions, such as COVID-related loan guarantees, can facilitate this transition by mitigating the costs and risks associated with acquiring green lending expertise.

## 4.6 Firm opaqueness

Given the extensive coverage of European firms in our dataset, the majority of the sample consists of private firms. In banking literature, firm age is often employed as a proxy for gauging the level of informational opacity in private firms. Younger firms are usually more informationally opaque because they have not yet established reputations in the market (Diamond, 1991). Their shorter operating history and lack of established relationships make them inherently more opaque (Berger and Udell, 1995). Therefore, the difficulty of understanding the interplay between environmental and financial performance should be even more concerning when lending to younger firms. To test this, we create an indicator, Young firm, that takes the value of one if the firm's age is ranked in the bottom quartile of the sample distribution, and zero otherwise. The average firm age in our sample is 22 years and the median is 19 years. For observations flagged as young firms, the mean and median firm age are both 7 years.

Column (3) of Table 6 presents the result of this cross-sectional test. Our main result is mainly pronounced in younger firms - banks leverage COVID-19 loan guarantee programs to expand credit supply to young low-emission firms. Notably, even though these firms were already part of the banks' loan portfolios before the pandemic, the lack of operating history makes it particularly challenging to assess how their environmental performance can influence financial prospects. This evidence further reinforces the notion that our key findings

are driven by information frictions.

# 5 Information production intensity and quality

## 5.1 Internal risk assessment

The AnaCredit credit register database provides detailed data on banks' internal risk assessments of their borrowers. For each portfolio firm and each month, it records the probability of default (PD) assigned by the bank to the firm. This measure serves as a reflection of the bank's information production efforts, derived from ongoing borrower monitoring activities. Similar internal risk assessment data have been utilized in recent studies using the U.S. Federal Reserve Y14-Q database to evaluate the value and quality of banks' private information—an aspect that was previously challenging to quantify (Howes and Weitzner, 2023; Beyhaghi et al., 2024). This data provides us an opportunity to assess the information production effort banks exert when expanding lending to low-emission firms through COVID-19 loan guarantee programs.

We first aggregate the PD measure to the firm-bank-quarter level by averaging across months for each quarter, then match this measure to our sample. We again focus on the period following the COVID-19 outbreak, i.e. 2020 Q2 to Q4, since the interaction effect of PGL and firm emission level is driven by loan guarantee programs during this period. As described in our summary statistics in Table 1, the average PD in our sample is 2.65%, with a median of 1.29%. Banks' risk assessments are dynamic. There exists significant variation in PD updates over time. Examining the difference between one-year forward PD and current PD, the average difference in our sample is 2.17%. PD increases after one year for 48% of the sample and decreases for 38% of the observations. We define an absolute change in PD of over one percentage point as a significant change in PD. Slightly over 40% of the sample observations have a significant change in PD after one year. The average PD for firms receiving PGL is lower (2.19%) than that for those without PGL (3.09%), consistent with evidence from prior studies that public guaranteed loans were predominantly allocated to firms that were not ex-ante risky but in need of temporary liquidity (Altavilla et al., 2021).

To gauge the intensity of banks' information production effort, we examine the likelihood of a significant PD update one year forward. Table 7 presents the results of this test. We exclude observations that end up in default status one year forward (PD=100%). Column (1) shows that when banks have public guaranteed loans with a firm, they are 7.5% less likely to significantly update its PD in the near future (-0.03/0.402). This is not surprising given that banks' downside risk has been largely shifted to the public with loan guarantees, reducing banks' incentives to engage in costly monitoring. Gustafson et al. (2021) provide evidence that bank monitoring activities often range from having private borrower meetings, physical site visits, hiring third-party appraisals, to demanding monthly or even daily financial updates. Column (2) show that the interaction between PGL and GHG emission has a significant coefficient of 0.0006, indicating that low-emission firms receiving PGL are less likely to get a PD update compared to high-emission firms with PGL. Specifically, an interquartile decrease in emission levels weakens the PGL effect on one-year-forward PD updates by over 10% ((5.878 $\times$ 0.0006)/-0.034). We also examine whether the current PD level influences the interplay between PGL and GHG emissions in affecting the likelihood of PD updates. The three-way interaction of PGL, GHG emissions, and current PD has an insignificant coefficient of -0.0001, with a t-statistic of -1.483. Conversely, the interaction term between PGL and GHG emissions remains significant, with a coefficient of 0.0008. This suggests that the relationship between emissions and the PGL effect on future PD changes is not driven by the current PD level.

The findings from this analysis reinforce the idea that loan guarantees alleviate the information production burden for lending to low-emission firms. Banks' reduced monitoring efforts for low-emission firms under guaranteed lending, compared to high-emission firms, reflect the typically higher monitoring intensity required in conventional green lending.

## 5.2 Predictive power of risk assessment

After examining the intensity of banks' information production effort when loan guarantees are involved, in this section we turn to analyze the quality of the information they produce. The primary purpose of the PD is to gauge the probability of default. There-

fore, high-quality risk assessment should have strong predictive power of future defaults. Conversely, if banks have shifted some of the default risk to the public, their incentives to conduct high-quality assessment of the borrower's future credit quality should diminish. After all, monitoring is costly, especially when banks have to assess the borrower's environmental performance in addition to the usual financial performance. To test this, we use the percentage of debt in arrears as a measure of firm risk, following Altavilla et al. (2021). If a bank fulfills its monitoring responsibility, the PD assigned to a borrower by the bank should predict future arrears within the firm-bank pair.

Table 8 presents the results of this analysis. Column (1) shows a positive and significant coefficient of 0.0061 for PD, indicating that on average the PD indeed can predict future credit quality deterioration. An interquartile increase in the PD is associated with a 16% increase in arrears one year forward (((2.38-0.44) $\times$ 0.0061)/0.091). Over 8% of the sample observations have at least some arrears one year forward. We also create an indicator, Significant arrears indicator, that takes the value of one if the one year forward arrears is more than 1% of total credit exposure between the firm-bank pair, and zero otherwise. In our sample, 2.1% of the observations have significant arrears one year forward. PD indeed predicts future significant arrears. An interquartile increase in PD is associated with a 14% higher likelihood of having significant arrears in one year (((2.38-0.44) $\times$ 0.0015)/0.091).

Columns (2) and (4) examine the predictive power of PD when loan guarantees are involved. The interaction term between PD and PGL has a significant and negative coefficient in both cases. The predictive power of PD on future arrears is 47% weaker when the bank is lending to the firm through PGL (-0.0034/0.0072). Similarly, PD's ability to predict the probability of future significant arrears diminishes by 35% when loan guarantees are involved in the firm-bank relationship. These results suggest that banks have less incentive to monitor borrowers rigorously when default risk is shifted to the public. Furthermore, the standalone PGL variable is significantly negative, consistent with evidence that COVID-related loan guarantees were mostly allocated to less risky firms.

In columns (3) and (6), we analyze the diminishing effect of PGL on PD predictive power across firms with varying emission levels. The three-way interaction term of PD, PGL, and

GHG emission has a significant and positive coefficient in both cases. PGL weakens the predictive power of PD more in low-emission firms than in high-emission firms. An interquartile decrease in GHG emission is associated with a 29% stronger PGL diminishing effect on PD predictive power on future arrears ((-(8.884-3.006) $\times$ 0.0003)/-0.0058), and 53% stronger on PD predictive power on having significant future arrears ((-(8.884-3.006) $\times$ 0.0001)/-0.0011). Overall, our findings reveal that banks' internal risk assessments are of significantly lower quality when lending through loan guarantees to low-emission firms compared to high-emission firms, reflecting reduced monitoring efforts. These results suggest that lending to low-emission firms in the absence of guarantees typically requires more intensive information production efforts from banks.

# 6 Conclusion

To address the COVID-19 pandemic, European governments implemented large-scale loan guarantee programs to incentivize banks to provide liquidity to the economy. Unlike previous programs, these COVID-era guarantees imposed no sectoral restrictions, covered up to 100% of lending, and eased lenders' monitoring requirements. Our analysis reveals that European banks capitalized on this opportunity by increasing lending to low-emission firms in their portfolios. This behavior is driven by firms in less COVID affected industries, hence, unlikely to be biased by confounding factors from the pandemic. The result is also stronger for banks with initially browner portfolios and younger firms. Furthermore, banks reduce their monitoring effort more significantly in guaranteed lending to low-emission firms than to high-emission firms. This supports the idea that green lending typically requires greater information production, which may partly explain the slow pace of decarbonization in bank portfolios.

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# Figures

Figure 1: **Trend of public guaranteed lending**

This figure plots the percentage of firm-bank relationships in our sample involving loan guarantees, and the percentage of lending guaranteed in an average firm-bank relationship from 2019 Q2 to 2020 Q4.

Figure 2: **Public guaranteed lending to green and brown firms**

This figure plots the percentage of firm-bank relationships involving loan guarantees, and the percentage of lending guaranteed in an average firm-bank relationship from 2019 Q2 to 2020 Q4, for green and brown firms respectively.

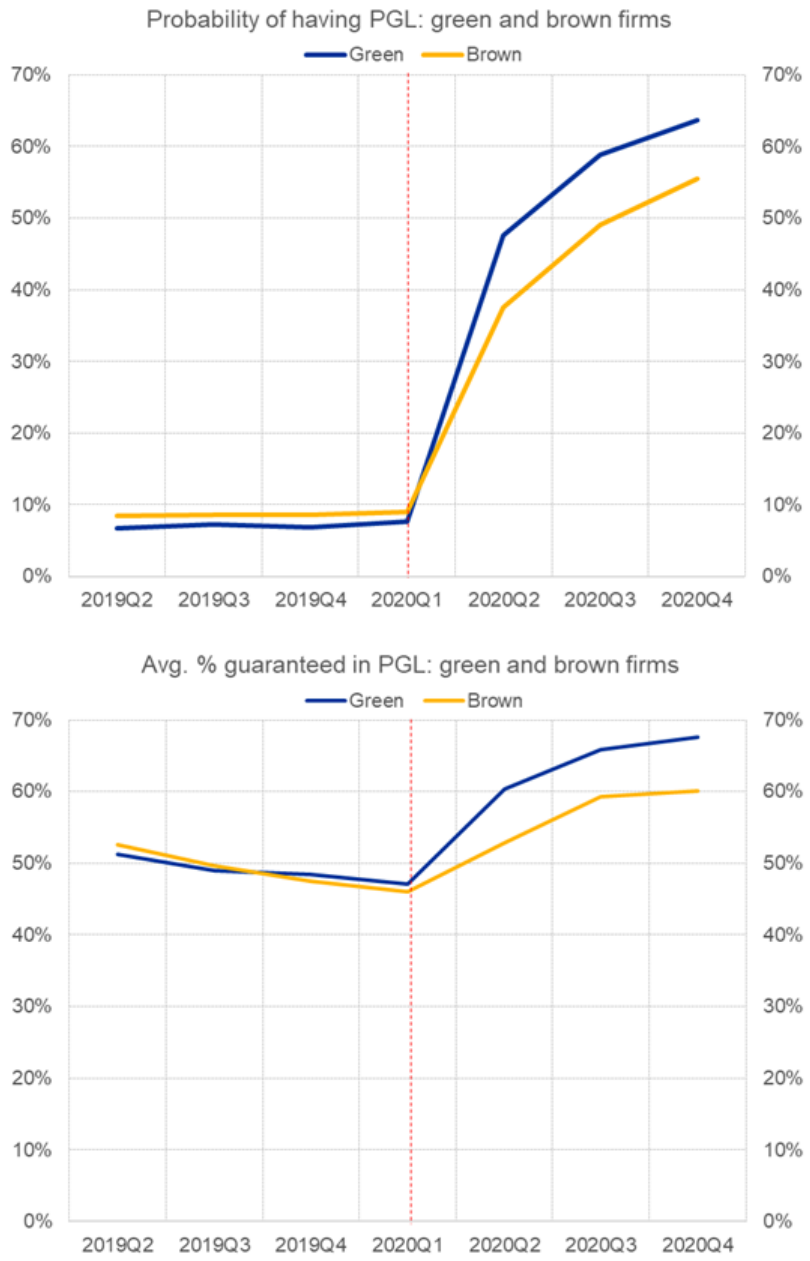


Figure 3: **Trend of lending growth**

This figure plots the quarterly lending growth for the average firm-bank pair from 2019 Q2 to 2020 Q4.

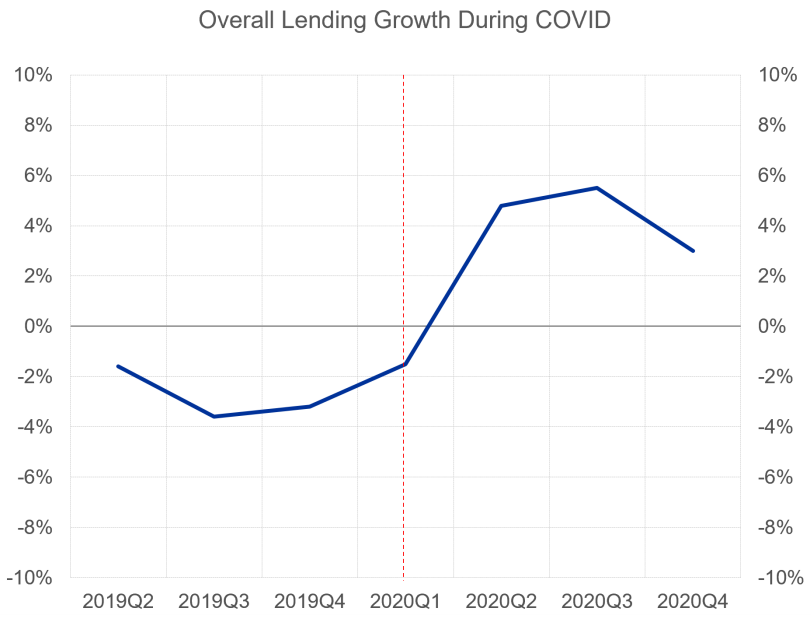
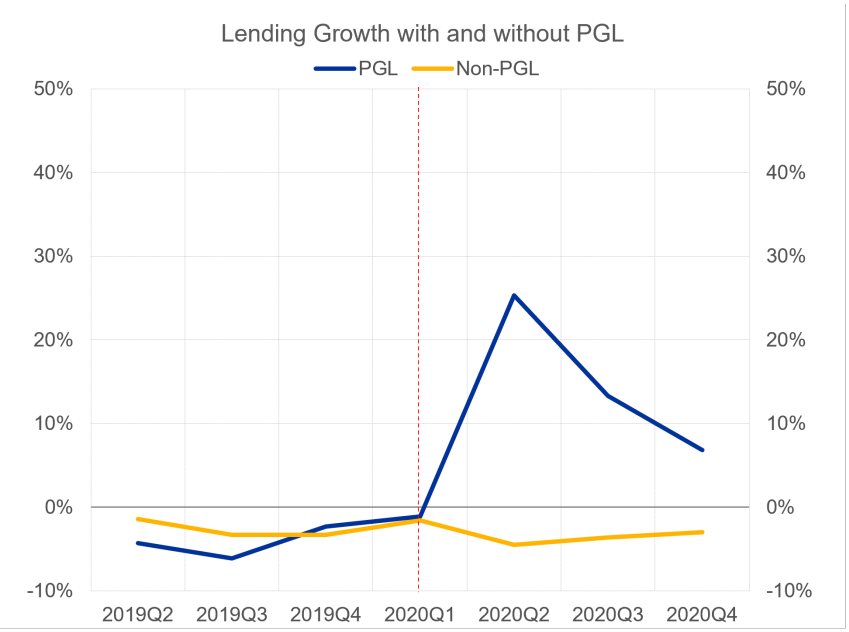
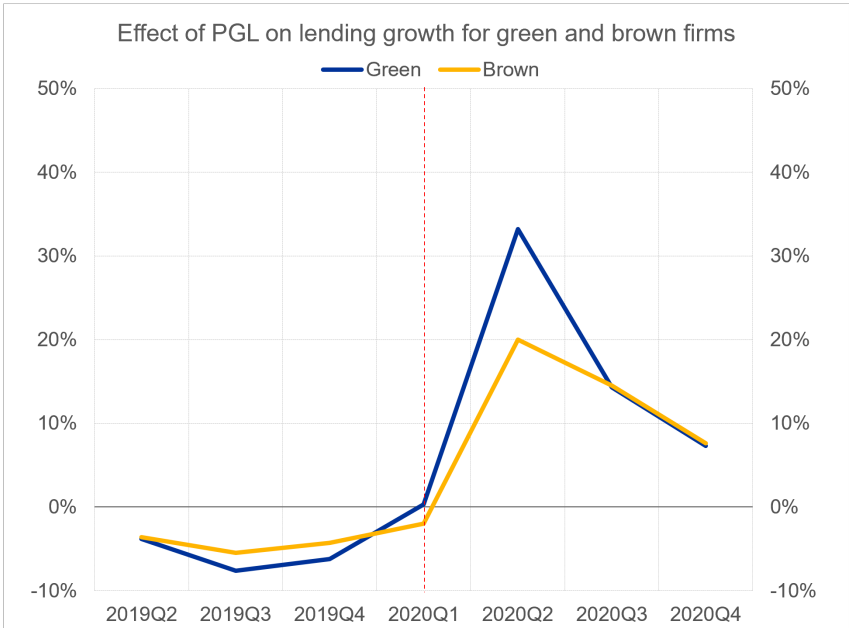


Figure 4: **Lending growth with and without public guaranteed lending**

This figure plots the quarterly lending growth for the average firm-bank pair with and without public guaranteed lending, from 2019 Q2 to 2020 Q4, then for green and brown firms respectively.



# Tables

Table 1: **Summary Statistics**

This table provides summary statistics of the main variables used in our analyses. The unit of observation is at the firm-bank-quarter level. The sample period for lending growth sample is from 2019 Q1 to 2020 Q4. The sample period for internal risk assessment sample is from 2020 Q2 to Q4. Reported statistics include the number of observations ($N$), the mean, the standard deviation ($SD$), the 5th percentile, the 25th percentile, the median, the 75th percentile, and the 95th percentile. Detailed variable definitions are in Appendix A.

| Variables | N | Mean | SD | 5th perc. | 25th perc. | Median | 75th perc. | 95th perc. |
|---|---|---|---|---|---|---|---|---|
| ***Lending growth sample*** | | | | | | | | |
| Lending growth | 1,025,509 | 0.011 | 0.367 | -0.485 | -0.092 | -0.014 | 0.062 | 0.630 |
| PGL | 1,025,509 | 0.340 | 0.474 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 |
| PGL > 50% | 1,025,509 | 0.206 | 0.404 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| % PGL | 1,025,509 | 0.197 | 0.323 | 0.000 | 0.000 | 0.000 | 0.345 | 0.899 |
| GHG emission | 1,025,509 | 7.645 | 8.011 | 2.792 | 3.006 | 5.648 | 9.373 | 13.863 |
| Brown industry | 619,460 | 0.066 | 0.249 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| Green industry | 619,460 | 0.081 | 0.272 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| Interest rate (%) | 1,201,143 | 2.908 | 2.317 | 0.623 | 1.507 | 2.257 | 3.587 | 7.400 |
| Post (COVID outbreak) | 1,025,509 | 0.564 | 0.496 | 0.000 | 0.000 | 1.000 | 1.000 | 1.000 |
| ***Internal risk assessment sample*** | | | | | | | | |
| PD (%) | 465,545 | 2.649 | 4.287 | 0.060 | 0.440 | 1.290 | 2.820 | 10.433 |
| Significant PD change 1 year forward | 456,510 | 0.402 | 0.490 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 |
| PGL | 465,545 | 0.511 | 0.500 | 0.000 | 0.000 | 1.000 | 1.000 | 1.000 |
| GHG emission | 465,545 | 7.609 | 8.024 | 2.792 | 3.006 | 5.648 | 8.884 | 13.863 |
| Arrears (%) | 465,545 | 0.091 | 0.623 | 0.000 | 0.000 | 0.000 | 0.000 | 0.043 |
| Significant arrears indicator | 465,545 | 0.021 | 0.143 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Table 2: **Effect of loan guarantee on lending growth across firms with different emission levels**

This table reports the effect of public guaranteed lending on lending growth across firms with different emission levels. The sample period is 2019 Q2 – 2020 Q4. The unit of observation is at the firm-bank-quarter level. The dependent variable lending growth, which is natural log difference of the total credit exposure of the bank to the firm from the previous quarter to the current quarter. *PGL* is an indicator that equals one if any of the bank's lending to the firm in the given quarter is state guaranteed. *PGL > 50%* is an indicator that equals one if over 50% of the bank's lending to the firm in the given quarter is state guaranteed. *% PGL* is indicates the percentage of the bank's lending to the firm in the given quarter that is state guaranteed. *GHG emission* is the total of scope 1, 2, 3 emissions estimated by Urgentem for the ECB in 2018, scaled by firm revenue. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Lending growth | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| PGL | 0.140*** | 0.145*** | | |
| | (21.14) | (21.92) | | |
| PGL × GHG emission | | -0.0007*** | | |
| | | (-3.811) | | |
| PGL > 50% | | | 0.104*** | |
| | | | (14.12) | |
| PGL > 50% × GHG emission | | | -0.0008*** | |
| | | | (-3.511) | |
| % PGL | | | | 0.173*** |
| | | | | (18.57) |
| % PGL × GHG emission | | | | -0.0011*** |
| | | | | (-3.451) |
| N | 1,025,505 | 1,025,505 | 1,025,505 | 1,025,505 |
| Firm-Quarter FE | Yes | Yes | Yes | Yes |
| Bank-Quarter FE | Yes | Yes | Yes | Yes |
| R-squared | 0.487 | 0.487 | 0.481 | 0.483 |

Table 3: **Industry level classification of brown and green borrowers**

This table reports the effect of public guaranteed lending on lending growth across firms from brown and green industries, using industry level emissions scaled by the industry's value added in the country in a given year. The sample period is 2019 Q2 – 2020 Q4. The unit of observation is at the firm-bank-quarter level. The dependent variable lending growth, which is natural log difference of the total credit exposure of the bank to the firm from the previous quarter to the current quarter. *PGL* is an indicator that equals one if any of the bank's lending to the firm in the given quarter is state guaranteed. *PGL > 50%* is an indicator that equals one if over 50% of the bank's lending to the firm in the given quarter is state guaranteed. *% PGL* is indicates the percentage of the bank's lending to the firm in the given quarter that is state guaranteed. *Brown industry* is an indicator that equals one if the emissions relative to industry value added for the NACE-2 industry the firm belongs to is ranked in the upper quintile in the country in a given year. *Green industry* is an indicator that equals one if the emissions relative to industry value added for the NACE-2 industry the firm belongs to is ranked in the bottom quintile in the country in a given year. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Lending growth | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| PGL | 0.141*** | 0.139*** | 0.138*** | | |
| | (18.10) | (18.36) | (18.06) | | |
| PGL × Brown industry | 0.0000 | | 0.0021 | | |
| | (0.009) | | (0.288) | | |
| PGL × Green industry | | 0.0271*** | 0.0272*** | | |
| | | (3.223) | (3.253) | | |
| PGL > 50% | | | | 0.097*** | |
| | | | | (14.03) | |
| PGL > 50% × Brown industry | | | | -0.0109 | |
| | | | | (-1.419) | |
| PGL > 50% × Green industry | | | | 0.0180* | |
| | | | | (1.729) | |
| % PGL | | | | | 0.162*** |
| | | | | | (17.76) |
| % PGL × Brown industry | | | | | 0.0034 |
| | | | | | (0.299) |
| % PGL × Green industry | | | | | 0.0234* |
| | | | | | (1.897) |
| N | 619,444 | 619,444 | 619,444 | 619,444 | 619,444 |
| Firm-Quarter FE | Yes | Yes | Yes | Yes | Yes |
| Bank-Quarter FE | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.483 | 0.483 | 0.483 | 0.477 | 0.479 |

Table 4: **Effect of loan guarantee on loan financing costs across firms with different emission levels**

This table reports the effect of public guaranteed lending on loan interest rate, across firms with different emission level as in Table 2 and from brown and green industries, using industry level emissions scaled by the industry's value added in the country in a given year as in Table 3. The sample period is 2019 Q2 – 2020 Q4. The unit of observation is at the firm-bank-quarter level. *Ln(interest rate)* is the natural log of loan value weighted average interest rate across all loans the bank has outstanding with the firm in the given quarter. Sample for this regression includes observations in which the firm-bank pair did not have active credit outstanding in the previous quarter. It is therefore slightly larger than the baseline sample. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Ln(interest rate) | |
|---|---|---|
| | (1) | (2) |
| PGL | -0.283*** | -0.257*** |
| | (-10.57) | (-12.74) |
| PGL × GHG emission | 0.0026*** | |
| | (3.668) | |
| PGL × Brown industry | | 0.0614*** |
| | | (3.691) |
| PGL × Green industry | | -0.0359* |
| | | (-1.662) |
| N | 1,201,140 | 719,688 |
| Firm-Quarter FE | Yes | Yes |
| Bank-Quarter FE | Yes | Yes |
| R-squared | 0.736 | 0.742 |

Table 5: **COVID-19 loan guarantee program**

This table reports the effect of public guaranteed lending on lending growth and interest rate, across firms with different emission level with a focus on the period following the COVID-19 outbreak. The sample period is 2019 Q2 – 2020 Q4. While public guaranteed lending existed prior to COVID-19, loan guarantee programs launched by European countries following the outbreak substantially increased the percentage of lending activities involving state guarantee. *Post COVID outbreak* is an indicator that equals one if the observation is in the period from 2020 Q2 through 2020 Q4, following the COVID-19 outbreak in 2020 Q1. The sample for columns (2) regression includes observations in which the firm-bank pair did not have active credit outstanding in the previous quarter. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Lending growth | Ln(interest rate) |
|---|---|---|
| | (1) | (2) |
| PGL | 0.011** | -0.102*** |
| | (2.137) | (-3.224) |
| **PGL × Post COVID outbreak** | **0.180*** ** | **-0.235*** ** |
| | **(20.82)** | **(-5.812)** |
| PGL × GHG emission | 0.0002 | 0.0010 |
| | (0.866) | (1.205) |
| **PGL × GHG emission × Post COVID outbreak** | **-0.0007** ** | **0.0016* ** |
| | **(-2.283)** | **(1.904)** |
| N | 1,025,505 | 1,201,140 |
| Firm-Quarter FE | Yes | Yes |
| Bank-Quarter FE | Yes | Yes |
| R-squared | 0.490 | 0.737 |

Table 6: **Bank portfolio, COVID effect, and firm opaqueness**

This table reports the effect of public guaranteed lending on lending growth across firms with different emission level, based on different cross sections. *Less COVID affected industry* is an indicator that equals one if the firm's sector's value added growth during COVID outbreak period (from 2019 to 2020, only annual data on value added is available) is ranked in the top quartile of the sample. *Brown portfolio* is an indicator that equals one if the loan value weighted average GHG emissions of the bank's lending portfolio in the previous quarter is ranked in the top quartile of the country. *Young firm* is an indicator that equals one if the firm's age is ranked in the bottom quartile of the sample. Youn firms are considered opaque due to limited operation history, lack of established relationships, and lower transparency. Other two-way interaction terms not directly related to the effect of loan guarantee as a function of firm emission level are omitted for brevity. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Lending growth | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| PGL | 0.190*** | 0.188*** | 0.190*** |
| | (23.79) | (24.08) | (23.69) |
| PGL × GHG emission | -0.0003 | -0.0005** | -0.0003 |
| | (-1.127) | (-2.009) | (-1.140) |
| PGL × GHG emission × Less COVID affected industry | -0.0020*** | | |
| | (-3.834) | | |
| PGL × GHG emission × Brown portfolio | | -0.0017** | |
| | | (-2.083) | |
| PGL × GHG emission × Young firm | | | -0.0010* |
| | | | (-1.896) |
| N | 578,288 | 578,288 | 578,288 |
| Other two-way interaction terms | Yes | Yes | Yes |
| Firm-Quarter FE | Yes | Yes | Yes |
| Bank-Quarter FE | Yes | Yes | Yes |
| R-squared | 0.500 | 0.501 | 0.500 |

Table 7: **Bank internal risk assessment**

This table reports the effect of loan guarantees on likelihood of future updates on bank internal risk assessment. The sample period is 2020 Q2 to Q4. The dependent variable is signficant PD change 1 year forward, an indicator that equals one if the absolute difference between the PD the bank assigns to the firm in one year and now is more than 1 percentage point, and zero otherwise. *PD* is the quarterly probability of default estimated by the bank for the borrowing firm. *PGL* is an indicator that equals one if the firm-bank lending relationship involves public guaranteed lending. *GHG emission* is the total of scope 1, 2, 3 emissions estimated by Urgentem for the ECB in 2018, scaled by firm revenue. Fixed effects are included and indicated at the base of columns. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Significant PD change 1 year forward | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| **PGL** | **-0.030*** ** | **-0.034*** ** | **-0.030*** ** |
| | **(-6.253)** | **(-6.539)** | **(-6.059)** |
| **PGL × GHG emission** | | **0.0006*** | **0.0008*** ** |
| | | **(1.847)** | **(2.698)** |
| **PGL × GHG emission × PD** | | | **-0.0001** |
| | | | **(-1.483)** |
| PGL × PD | | | 0.0035*** |
| | | | (2.913) |
| PD × GHG emission | | | 0.0002*** |
| | | | (3.484) |
| PD | | | 0.0265*** |
| | | | (18.52) |
| N | 456,510 | 456,510 | 456,510 |
| Firm-Quarter FE | Yes | Yes | Yes |
| Bank-Quarter FE | Yes | Yes | Yes |
| R-squared | 0.557 | 0.557 | 0.581 |

Table 8: **PD predictive power of future credit deterioration**

This table reports the predictive power of banks' internal risk assessment on future credit quality. The sample period is 2020 Q2 to Q4. The dependent variable is one year forward arrears, which indicate the percentage of debt between the firm-bank pair that is overdue or with missing payment. The second dependent variable, significant arrears indicator, is an indicator that equals one if the one year forward arrears is more than 1% of the bank's total exposure to the firm, and zero otherwise. *PD* is the quarterly probability of default estimated by the bank for the borrowing firm. *PGL* is an indicator that equals one if the firm-bank lending relationship involves public guaranteed lending. *GHG emission* is the total of scope 1, 2, 3 emissions estimated by Urgentem for the ECB in 2018, scaled by firm revenue. Fixed effects are included and indicated at the base of columns. Standard errors are double clustered by bank and firm. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

| | Arrears (%) | | | Significant arrears indicator | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **PD** | **0.0061*** ** | **0.0072*** ** | **0.0072*** ** | **0.0015*** ** | **0.0017*** ** | **0.0017*** ** |
| | **(5.721)** | **(4.908)** | **(4.952)** | **(5.364)** | **(5.079)** | **(5.227)** |
| **PD × PGL** | | **-0.0034** ** | **-0.0058*** ** | | **-0.0006* ** | **-0.0011*** ** |
| | | **(-2.366)** | **(-3.613)** | | **(-1.752)** | **(-3.139)** |
| **PD × PGL × GHG emission** | | | **0.0003*** ** | | | **0.0001*** ** |
| | | | **(3.144)** | | | **(3.117)** |
| PD × GHG emission | | | -0.0000 | | | -0.0000 |
| | | | (-0.042) | | | (-0.250) |
| PGL × GHG emission | | | 0.0002 | | | -0.0000 |
| | | | (0.478) | | | (-0.132) |
| PGL | | -0.0350*** | -0.0372*** | | -0.0085*** | -0.0085*** |
| | | (-6.186) | (-5.210) | | (-5.826) | (-5.256) |
| N | 465,541 | 465,541 | 465,541 | 465,541 | 465,541 | 465,541 |
| Firm-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Bank-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes |
| R-squared | 0.605 | 0.606 | 0.606 | 0.575 | 0.575 | 0.575 |

# Appendix A Variable Definitions

- **Lending growth**: The difference in the natural log of credit exposure the bank has in the firm from the previous quarter to the current quarter.
- **PGL**: An indicator that equals one if the bank lends to the firm through public loan guarantees in the quarter, and zero otherwise.
- **PGL > 50%**: An indicator that equals one if over 50% of the bank's lending to the firm in the quarter is state guaranteed, and zero otherwise.
- **% PGL**: The portion of the bank's lending to the firm in the quarter that is state guaranteed.
- **GHG emission**: The sum of Scope 1, 2, and 3 greenhouse gas emissions relative to the firm's revenue (tonnes per million dollars), as provided by Urgentem in 2018.
- **Brown industry**: An indicator that equals one if the firm's NACE-2 industry's greenhouse gas emissions relative to the industry's value added is ranked in the top quintile in the country from the previous year, and zero otherwise.
- **Green industry**: An indicator that equals one if the firm's NACE-2 industry's greenhouse gas emissions relative to the industry's value added is ranked in the bottom quintile in the country from the previous year, and zero otherwise.
- **Interest rate (%)**: Loan value weighted average interest rate across all loan instruments
- **PD (%)**: The bank's private assessment of the firm's probability of default in the quarter.
- **Significant PD change 1 year forward**: An indicator that equals one if the PD changes by more than one percentage point 1 year forward, and zero otherwise.
- **Arrears (%)**: The percentage of the bank's total credit exposure to the firm that is in arrears 1 year forward.
- **Significant arrears indicator**: An indicator that equals one if the 1 year forward arrears is over 1% of the bank's total credit exposure to the firm, and zero otherwise.
- **Less COVID affected industry**: An indicator that equals one if the firm's sector's value added growth from 2019 to 2020 is ranked in the top sample quartile, and zero otherwise.
- **Brown portfolio**: An indicator that equals one if the bank's loan value weighted average emission level is ranked in the top quartile in the firm's country in the previous quarter, and zero otherwise.
- **Young firm**: An indicator that equals one if the firm's age is ranked in the bottom quartile of the sample distribution, and zero otherwise.