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The credit role of monetary policy in the green transition

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Acknowledgments

First of all, I would like to express my gratitude and appreciation to my supervisor, prof. Andrea Polo, for his precious support and advice throughout my thesis writing along with his dedication on lectures, a source of inspiration making me keen about the economic literature developments.

My thankfulness goes to LUISS University faculty for giving me the opportunity to attend such a challenging and stimulating program, an unforgettable experience.

I am deeply grateful to my beloved mum and dad for their constant and never ending love and support, believing in me especially during not so easy moments of this personal and academic path.

I am very thankful to Ludovica and Alberto for their unconditional friendship.

I would like to thank the community of San Roberto for always being a reference point during these years in Rome, especially to the wisdom guidance of don Antonio. I will never forget the given opportunity of following an ACR group made by wonderful children, always remembering me the beauty of a life spent with joy, kindness, bravery and curiosity, even when passing through difficulties.

Contents

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Abstract

Recent extreme weather events have led to a more urgent response of our economies to climate change challenge. In this spirit, we investigate the contribution provided by the credit channel of monetary policy, by analyzing whether firm-level carbon emissions may differentiate the reactivity of bank credit to monetary policy shocks. Using Euro area firm-bank level data, we find that credit levels of firms with lower sum of Scope 1 and Scope 2 emissions are actually characterized by a more negative reaction to monetary policy tightening. We show that these results can be understood through the lens of the financial frictions channel of monetary policy, particularly explained by the difference in default risk exposure of firms, which influences their credit sensibility to shocks. Then, we find more evidence on firm heterogeneity role to predict the impact of monetary policy surprises on credit, while less evidence on bank's characteristics explanation.

Keywords: green transition, carbon emissions, monetary policy, bank lending, climate finance.

Introduction

Our recent times have been marked by a global and urgent call to action in the face of climate change issue. On the one side, we register a more established scientific consensus around the human-driven causes of global warming, as emphasized by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report in 2021 expecting a global warming scenario of 1.5° C and 2° C will be exceed during the 21st century unless a deep decrease in CO_2 and other greenhouse gas emissions[1]. On the other, we find a more widespread awareness regarding the related environmental, social and economic costs[2] becoming far too high. From this perspective, a gradual "green transition" concept has emerged, well declined in a wide array of approaches encompassed by the *"Green philosophy and its applications"* in Nordhaus (2010), requiring a strong involvement of many economic players, such as the financial sector[3]. In particular, the role of the banking sector is pivotal in allocating resources to non-financial companies (NFC's) as well as its capability to charge costs to non-compliant companies and its coordination power[4].

So far, many empirical contributions have investigated the question whether banks account for climate risk in their lending policies, finding a positive evidence with this respect in the Euro area, as reported by Altavilla et al. (2024). Remaining in the same geographical area, it seems relevant to include in our analysis the role played by the well-established underlying mechanism of the credit channel of mon-

[1] For further information, see: `https://www.ipcc.ch/report/ar6/wg1/`.

[2] To this extent, we report a quote from the speech held by President von der Leyen at the EU Green Week 2021 conference: *"So the fight against pollution is also a fight for fairness and equality."*.

[3] See Bolton et al. (2021).

[4] See Kacperczyk and Peydrò (2024).

etary policy in improving the ongoing process of the green transition.

This paper evaluates the role of firm level emissions in the transmission of monetary policy to loans granted to companies by the European banking sector. Our objective is to assess how firm differences in carbon footprints may influence the bank credit responsiveness to unexpected monetary policy shocks. Given the above outlined context, we would assume that a milder credit level sensibility can be experienced by less pollutant firms (i.e. green firms). To empirically investigate this hypothesis, we employ a firm-bank level panel collected from Orbis and BankFocus databases on Euro area firms and banks, over the 2015-2022 period. This matched dataset is then merged first with firm-level data on emissions downloaded from Refinitiv and finally with monetary policy shocks following the ECB policy announcements, occurred in the same time window as reported in the EA-MPD Database. Endowed with these data, we proceed by providing a "green" definition for firms whenever the median emission level computed as the sum of Scope 1 and Scope 2 emissions is lower than the median emission level of the entire firm sample. Hence, we estimate our baseline model in which the dependent variable is given by the (natural logarithm of) bank credit and the main explanatory variable is the interaction term between the monetary policy shock variable and the indicator variable *Green* representing the previously defined firm's emission profile.

Our study essentially contributes to two strands of research: the one relating to the monetary policy shocks effects on financial frictions affecting companies and the blooming literature on financial world's contribution to the green challenge.

Our main hypothesis investigates the opportunity for green firms to experience a less negative response of their granted credit levels after a monetary policy surprise. In our analysis we include a wide set of fixed effects (e.g. firm and industry-country-time fixed effects) to control for unobserved demand factors isolating supply-side effects, as in Khwaja and Mian (2008). However, our findings show a different result: bank credit of green firms tends to react more in a negative direction when affected by a positive monetary policy shock, hence a monetary policy tightening.

These results shed a light on the contemporaneous action of the financial frictions channel of monetary policy. Indeed, our green firm sample is characterized by a lower default risk profile and size, both negatively contributing to shape the credit response to shocks. This statement is consistent with the conducted heterogeneity analysis at firm level. Finally, a bank heterogeneity analysis suggests a milder credit sensitivity towards contractionary monetary policy when we demand for a more stringent capital requirements of the bank lenders associated with green firms.

Finally, our findings have been subjected to some robustness checks. Specifically, our main specification results are re-estimated first using different definitions of the monetary policy shock variable, considering the OIS rate at different maturities, and then changing the definition of green firms by comparing to the lower quartile of the total emissions level distribution, rather than the median of the total emissions level of the sample. Finally, we present the results of our main specification when considering a restricted time window to the latest five years of analysis, those characterized by more turbulent external challenges. The significance of our results persists when using the median green definition and enhanced when we adopt a different version of firm greenness.

Until now, our study has ascertained consistent differences between low and high carbon emissions firms (i.e. green and brown firms, respectively) in terms of some important financial measures, those determining differences in credit response to monetary policy shocks. This outcome confirms the combined duo made by the implicit financial frictions channel influencing the more general credit channel of monetary policy, both showing a potential in shaping firm's sustainable choices.

Chapter 1

Literature Review

Our analysis will contribute to two significant strands of research. It aims at bringing together the literature relating to the impact of monetary policy shocks on financial frictions faced by companies and the flourishing studies on the support to the green transition provided by the financial world.

Firstly, by investigating the impact of monetary policy and its influence on the real course of the economy, historically there has been a consensus on the real output movements driven by monetary policy at least in the short run, as from the empirical early findings of Friedman and Shwartz (1963). Nevertheless, the extent to which monetary policy exerts its influence has been controversial, resulting in the so called "black box" of monetary policy transmission. A significant contribution in overcoming the difficulty in quantifying the effects of the cost of capital variable in a frictionless market setting is provided by Bernanke and Gertler (1995). Their evidence moves from the credit channel theory, according to which changes in the *external finance premium*[1] amplifies the direct effects of monetary policy. In particular, the authors discuss two important components explaining the credit transmission mechanisms: *the balance sheet channel* and *the bank lending channel*[2]. However, the role played by the latter linkage appears to be controversial. The model proposed

[1] "Difference in cost between the funds raised externally (by issuing debt or equity) and funds generated internally (by retaining earnings)".

[2] While the first "stresses the potential impact of changes in monetary policy on borrowers' balance sheets and income statements", the latter has its focus on "the possible effect of monetary policy actions on the supply of loans by depository institutions".

by Bernanke and Blinder's (1988) suggests how an open market sales operation conducted by the Fed would determine a limit to the supply of bank loans to an extent that is "over and above" the IS-LM effect. The limitation of this model lies in the constrained capability of replacement of "lost" deposits with other types of funds present in the U.S. prior to the 1980. Nevertheless, as stated by Kashyap and Stein (1994), *"it is sufficient that banks do not face a perfectly elastic demand for their open-market liabilities"* in a way that the Fed operation would raise the banks' cost of funds, bringing to an inward shift of the supply of loans and an increase in the external finance premium. Finally, looking at the behavior of the interest rate terms and spreads consistent with the bank lending channel as predicted by Bernanke and Blinder, as well as with the balance sheet channel since *"a tightening of monetary policy leads to a worsening of both borrowers' and banks' balance sheets"*, Bernanke and Gertler reach the conclusion that is more appropriate referring to the existence of a *credit channel* in general than a sharp division between the two mechanisms.
However, these contributions are based on identifications using micro data by starting from theory and testing the cross-sectional predictions[3] . An alternative *difference-in-difference* effect approach is followed by Kashyap and Stein (2000) and Gertler and Gilchrist (1994). The first analyze different responses relating to the monetary policy on lending, by studying quarterly observations on U.S. insured commercial banks from 1976 to 1993. Their findings show a stronger impact for banks having a less liquid balance sheet and so a lower ratio of securities to assets, a pattern particularly followed by small banks (those in the bottom of the 95 percentile of the distribution).
Gertler and Gilchrist (1994) analyze financial transmission of monetary policy shocks by looking at small versus large manufacturing firms. They find how small firms suffer from a more pronounced sectoral decline following a period of contractionary monetary policy, playing a crucial role in the fall of the inventory demand, probably

[3]According to Kashyap and Stein (2000), this micro identification is not able to provide the whole picture describing the total effect of a monetary policy shock on the real economy and Ciccarelli, Maddaloni and Peydrò (2015) agree with this view by stating that this "micro approach cannot fully identify the credit channel".

due to a more constrained access to financial resources.

The effectiveness of the overall credit channel is also witnessed by Ciccarelli, Maddaloni and Peydrò (2015). By examining the Bank Lending Survey (BLS) for the Euro area and the Senior Loan Officer Survey (SLOS) for the U.S. quarterly information on the lending standard applied by banks to the pool of borrowers, they find how a 25 basis point tightening in monetary policy brings about a restraining in the lending conditions concerning both the borrowers' balance sheet and the bank lending of about 2 to 4 percentage points.

Moving to the European framework, in the attempt to overcome doubts casting from the results in the years before the financial crisis in the 2007-2010 relating to the strength of the bank lending channel, Gambacorta and Marques-Ibanez (2014) show how other factors, such as market funding patterns or changes in the business models of banks, have modified the traditional monetary transmission mechanism prior to the crisis in Europe and in the U.S.. Moreover, their findings highlight a stronger restriction in the loan supply during the crisis period by banks having weaker core capital position, *"greater dependence on market funding and on non-interest sources of income"*. The authors' perspective sustains the Basel III focus on banks' core capital and on funding liquidity risk.

Another interesting analytical focus under which the monetary transmission mechanism is examined is proposed by Ottonello and Winberry (2020). They study how financial frictions and firm heterogeneity influence the investment channel of monetary policy. Indeed, by using a heterogeneous firm New Keynesian model with default risk, the authors find that monetary policy shocks have a more severe impact on firms with low default risk, reaching the conclusion that the overall effect of monetary policy depends on the distribution of default risk. Furthermore, the contribution of Jeenas (2019) highlights a difference in responses to high frequency monetary policy shocks by non-financial firms conditional on their financial situation. In particular, higher leverage and lower liquid asset holdings are the most predictive explanatory variables relative to a "lower fixed capital, inventory and sales growth" during the period of tightening monetary policy shock. In the same spirit, Anderson and Cesa Bianchi (2024) reach the conclusion that firms having high leverage register a deeper impact of contractionary monetary policy, bringing to an increase in credit spreads mainly due to a component that is beyond the firm's expected default risk, implying that a significant role is played by financial intermediaries in the transmission mechanism.

The second strand of research to which we want to contribute concerns the relationship between lending and green transition, taking in account climate related risks[4] and the importance of how climate change can be studied through the lens of financial economics[5]. By analyzing the syndicated loan market, Kacperczyk and Peydrò (2021) study the relationship between firm-level carbon emissions and bank lending. Their findings show that banks involved in climate-related commitments decrease their lending to firms with higher carbon footprint, the latter increasing their liquid assets and reducing total debt, leverage, size, and real investment.
A turning point for the banking sector's lending decisions as a determinant of the green transition is represented by the Paris Agreement in 2015. Indeed, Degryse et al. (2023) analyze whether the pricing of bank credit is affected by the environmental consciousness of firms and banks. Using an international sample of syndicated loans, they find a more significant discount offered by "green consortia"[6] to green firms in comparison to brown ones of about 50-59 bps in the post-Agreement period. To assess the effectiveness of the Paris Agreement, Reghezza et al. (2021) match loan-level data to firm-level greenhouse gas emissions, aiming at investigating whether climate-oriented policies have an impact on lending decisions towards polluting firms, reaching the conclusion of what an extent the implications of policies significantly influence the banks' behavior in the implementation of climate change measures[7]. Looking at the credit markets in terms of pricing climate risk, papers re-

[4]Following Carney (2015), the literature distinguishes between three types of climate-related risks. Transition risks, which are financial risks stemming from the process of "adjustment towards a lower-carbon economy". Physical risks derive from the today impact of climate and weather-related events on insurance liabilities and financial assets value. Liability risks could arise tomorrow from costly litigation from parties having suffered from damages or losses from climate change events against those they believe responsible.

[5]Giglio et al. (2021).

[6]Consortia made by all green lenders.

[7]The authors present differences in the European banks' credit reallocation behavior, reporting

fer only to the syndicated loan market, with the exception of the analysis conducted on a panel data for the whole Euro area credit market by Altavilla et al. (2024). Indeed, a broader view of the phenomenon[8] allows the authors to state that banks' pricing loan decisions are taken on the basis of firms' current carbon emissions influence and today commitments to reduce their future carbon footprints. A similar conclusion is reached by de Greiff, Delis and Ongena (2018), finding that after 2015 climate policy risk is priced especially for firms with more fossil fuel reserves and that "green banks" marginally increase their loan rates to fossil fuel firms. Ehlers, Packer and de Greiff (2022) agree in identifying after the Paris Agreement in 2015 a substantial "carbon premium", finding that only directly produced carbon emissions (Scope 1) are priced and not the overall carbon footprint. An opposite view is presented by Bolton and Kacperczyk (2020). By exploring how the carbon premium varies across the world and by estimating the stock return premium on carbon emissions at the firm-level in a cross section, they claim that stock returns are affected by direct and indirect emissions through the supply chain channel.

Besides the watershed Paris Agreement, other initiatives aim to particularly encourage financial institutions to commit themselves to environmentally sustainable financial policies, such as the recent Net Zero Bank Alliance[9].The impact of these initiatives has been controversial. Exploiting a cross-sectional variation of banks' commitment, through the Science Based Target Initiative (SBTi)[10], to a reduction in carbon emissions in their asset portfolios, representing a shock to firms with whom they had a credit relationship, Kacperczyk and Peydrò (2021) find that effectively this commitment has been reflected in a lending reduction to higher emissions firms.

a decrease of 3 percentage points in loan share for more polluting corporations with respect to less polluting ones after the announcement of the Agreement. In contrast, the 2017 President Trump's decision for the USA to withdraw from the Paris commitment has brought to a decrease of 2.4 percentage points in loan share for U.S. polluting firms by European banks.

[8]More appropriate in the European context, since syndicated loans cover only 10 percentage points of the entire credit market.

[9]It represents the climate accelerator of UN Environment Program Finance Initiative's Principles for Responsible Banking (PRB) and the sector-specific alliance for banks under the Glasgow Financial Alliance for Net Zero (GFANZ). For more info: `https://www.unepfi.org/net-zero-banking/`.

[10]More than 6,000 companies around the world are working with this initiative, among which 100 are financial institutions. For further information see: `https://sciencebasedtargets.org/`.

An aligned view regarding banks with climate concerns is shared by Degryse et al. (2023), de Greiff, Delis and Ongena (2018) with respect to offer better pricing conditions to green firms. Moreover, analyzing the impact of banks voluntary joining the NZBA on their lending behavior and on the climate attitudes of their borrowing firms, Sastry, Marques-Ibanez and Verner (2023) state that the banks' commitment leads to a credit reduction in sectors targeted as high priority for decarbonization. However, they register neither a difference in lending or loan pricing behavior between climate-aligned or not banks nor a more climate target activity by firm borrowers after their lenders set a climate target. A controversial view is also sustained by Ehlers, Packer and de Greiff (2022), showing that "green" banks do not seem to price carbon risk differently from other banks.

Chapter 2

Institutional background and hypothesis development

2.1 An urgent call to action

The threat of extreme weather events shows us the urgency of the climate change challenge, particularly felt on the European continent[1]. During our sample period, i.e. 2015-2022, various calls-to-action have been launched worldwide sharing as main focus mitigation as well as adaptation objectives, even involving the so called climate finance[2] in this vital support, as reminded at a global level by the United Nations Climate Change (UNCC). This concern has led to a growing recognition of the role played by financial institutions in steering financial flows towards more sustainable and low-carbon investments. Having a particular focus on monetary policy, the period between 2015 and 2022 experiences a more pronounced awareness of central banks in promoting climate-related initiatives through financial regulations and sustainability goals, as well as through the indirect impact of monetary policy shocks on the interest rates charged to firms with different polluting levels.

The Paris Agreement in 2015 represents a landmark event in the early stages of

[1] According to the European Environment Agency (EEA), Europe is the fastest warming continent in the world, see `https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation`.

[2] A definition of climate finance is provided by Hong, Karolyi,and Scheinkman (2020).

consciousness of the climate change problem. It globally binds 196 countries at the UN Climate Change Conference (COP21) to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels"[3]. In particular, all the member states of the European Union (EU) have signed, ratified and been strongly committed to the implementation of the Agreement, pushing themselves even beyond by launching the European Green Deal Strategy which aims at transforming the EU economy to become climate-neutral by 2050. In line with the European Green Deal objectives, a vital help in directing investments towards sustainable projects is determined by the EU Taxonomy for Sustainable activities [4].
Alongside these initiatives, financial players start to comprise the implications of climate-related risks on the maintenance of financial stability, both in their transition and physical declination. To this extent, in May 2018, the sustainable finance topic begins to be incorporated in the Financial Stability Review of the European Central Bank[5], following the Commission's proposal to include sustainability in the financial decision making process contained in an Action Plan on financing sustainable growth[6]. In this occasion, the ECB claims the more effectiveness of direct policy tools such as taxes or subsidiaries compared to prudential regulation in attracting financial resources towards green assets. In the same years, despite the absence of an explicit environmental target in the Eurosystem's Asset Purchase Programme (APP), the ECB has purchased green bonds[7] under both the Corporate Sector Purchase Programme (CSPP) and the Public Sector Purchase Programme (PSPP), contributing to the establishment of a well-diversified portfolio.
In 2020, the COVID-19 pandemic has deeply shocked the entire world, a sudden

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[3] `https://unfccc.int/process-and-meetings/the-paris-agreement`

[4] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088.

[5] `https://www.ecb.europa.eu/pub/pdf/fsr/ecb.fsr201805.en.pdf`.

[6] See: Communication from the Commission – Action Plan: Financing Sustainable Growth (2018) `https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN`.

[7] They refer to debt securities whose proceeds are employed to finance investment projects with a positive environmental impact, as defined in De Santis, Hettler, Roos, Tamburrini (2018).

health crisis turned into a global economic crisis which has not made forgotten the urgency of the climate change mitigation in the European agenda. Indeed, it has been considered within the green transition critical investment area of the *Next Generation EU* for a greener, more digital, and resilient European future. Having as centrepiece the Recovery and Resilience Facility (RRF), at least 30% of the RRF Regulation funds allocation[8] and the EU's multiannual budget (2021-2028) are earmarked to tackle climate change, supporting green projects. Moreover, the Commission has put in place the European Green Deal Investment Plan (EGDI), including the Just Transition Mechanism which ensures "a fair and just transition to a green economy"[9], under the intent to mobilize massive investments over the 2021-2027 period to sustain citizens living in the most addressed regions by transition.

In March 2021 the European Commission has introduced the main provisions (Level 1) of the Sustainable Finance Disclosure Regulation (SDFR)[10], which require financial market participants and advisors to inform investors about the sustainability risks potentially affecting the value of return of their investments ('outside-in' effect) as well as the description of the principal adverse impact of such choices on the environment and society ('inside-out' effect). The SDFR represents a key driver of the green finance development in Europe, particularly for institutional investors. As a last shaken event towards green transition we can point out the rise in energy prices, followed by the Russia's invasion of Ukraine in February 2022, event that has accelerated the European energy transition[11]. Indeed, one-quarter of the energy consumption in Europe comes from natural gas, much of that (45%) was imported from Russia before the war outbreak, bringing Europe to look for new sources of energy. In response to this prompted energy reckoning, the European Commission has mobilized close to €300 billion to fund and launch the REPowerEU Plan. The

[8]€648 billion of overall investment, at 2022 prices, divided in €291 billion in loans and €357 billion in grants. Available at `https://next-generation-eu.europa.eu/index_en`.

[9]`https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal_en`.

[10]Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector.

[11]See: `https://www.eib.org/en/essays/europe-energy-transition-renewable`.

objectives of this plan aim at saving energy, diversifying energy supply and producing clean energy. Specifically, the last goal implies a booster in European green transition by promoting investments in renewable energy[12].

2.2 The European banking sector and monetary policy

Between 2015 and 2022 the global financial system has faced challenges on different fronts. In the years after the Great Financial Crisis, the European banking sector has been heavily influenced by an environment characterized by low interest rates (LIR) and a contrast between more challenging market and external conditions and a "tepid" economic recovery, mining the bank's profitability prospects. In particular, the greater amount of non-performing loans in a number of countries has represented a constraint for the banks' lending capacity and profitability (European Central Bank (2016a)). However, The ECB's decision to cut its deposit facility rate (DFR) to negative territory, hence conducting a negative interest rates policy (NIRP), was part of monetary stimulus package to defend from deflationary risks during a period in which policy rates had reached zero. Indeed, Demiralp et al. (2021) finds in the period 2010-2017 an expansionary effect of the NIRP through an increase in the lending activity of those highly-exposed banks intending to mitigate the negative effects of NIRP on their profitability.

Alongside the NIRP, the recovery of bank lending to Euro area households and non-financial corporations (NFCs) has been supported by the ECB's new series of targeted longer-term refinancing operations (TLTRO-II)[13] as of March 2016 (Eu-

[12]For the first time in 2022 there has been registered more electricity production from renewables than gas and more than double the amount of solar energy produced since 2019. For further details, see: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en.

[13]The TLTROs are targeted operations consisting of offering banks long-term funding at favorable conditions depending on the banks' amount of loans issued to NFC and households to incentivize bank lending to real economy. The first series of TLTROs started in June 2014. For further information, see: https://www.ecb.europa.eu/mopo/implement/omo/tltro/html/index.en.html.

ropean Central Bank (2016b)). Moreover, to further support the transmission of low policy rates to bank lending[14] the ECB has introduced a two-tier system to remunerate excess reserves. In addition to these measures, various targeted macroprudential policy instruments are adopted to improve the financial resilience in the banking sector and real estate markets by introducing tools such as capital buffer requirements or lending controls for banks. However, we have to admit that the study on the impact of higher capital requirements on banks' balance sheets and the relative transmission to the real economy conducted by Gropp et al. (2019) highlights a reduction in bank lending to corporate and retail customers[15].

At the onset of the COVID-19 pandemic, the banking sector is characterized by a substantial increase in lending to NFCs and by a stable behavior of lending rates, resulting in a situation in which the credit supply overtakes the credit demand (European Central Bank (2020b)). Indeed, the credit risk has risen, especially for small and medium-sized enterprises (SMEs) which are more exposed to tightening credit conditions. However, in 2021 a number of vulnerabilities have been intensified such as risks deriving from the pandemic that have not entirely ceased, the rising energy prices constituting a new pressure to the global supply chain recovery from inflation and a questioned resilience of the banking sector to climate-related hazards represented by the more intense natural catastrophes in Europe (European Central Bank (2021b)). As a result, the ECB's banks lending survey shows a declining demand for guaranteed loans among large and SMEs. In this occasion the ECB's new monetary policy strategy counts over a strengthen in prudential measures in terms of macroprudential capital buffers, supervisory policies and regulatory framework for financial institutions.

At the start of 2022, the banking sector resilience is challenged by the outbreak of the Russia-Ukraine war, lowering the post-pandemic recovery together with the period of elevated inflation materialized in large rises in commodity and energy prices.

[14] The NIRP also entails costs for banks proportional both to the time in which negative interest rates are in place and the banks' amount of excess liquidity (European Central Bank (2019b)).

[15] The study employs an ideal quasi-natural experiment given by the European Banking Authority (EBA) Capital Exercise in 2011.

All these latter factors have contributed also to worsen the solvency risk of those firms whose balance sheets were already weaken by the pandemic (European Central Bank (2022b)). Moreover, the ECB's bank lending survey shows how loan demand has risen for short-term maturities, as firms need to cover the increase in production costs. However, rising interest rates brings to an increase in the short-term profitability of Euro area banks, the latter being more active in the interest rate swaps market hedging interest rate risk. Finally, a contribution to tightening financing conditions for corporation loans is provided by the normalization[16] of monetary policy. This measure brings to a sharp increase in credit interest rates, having as a direct impact the enhancement of the process of shifting from bank loans to market-based funding started after the financial crisis.

2.3 Hypothesis development

The presented challenges inspire the reasonable question whether the credit behavior might have been influenced by the more pronounced sensibility towards the sustainable matters, even considering the ever present shocks coming from the monetary policy side. It moves from the thought that the credit channel of monetary policy could contribute to the green transition through its impact on firm's investment strategies. Therefore, the focus of our analysis will be on testing whether monetary policy affects the credit levels of firms having different sustainability attitudes in terms of carbon footprints. Our hypothesis sustains how the credit channel of monetary policy and the more widespread sustainability consciousness can constitute a decisive factor combination towards a more favorable lending dynamics towards the less pollutant firms. Our view can be encouraged by recent public policy initiatives to foster green transition, such as the carbon neutrality by 2050 promised by the European Green Deal, as a factor for an higher riskiness assessment from banks to those more polluting firms.

[16] *"Normalization occurs when the central bank adjusts its policy parameters as medium-term inflation approaches its price stability objective, so as to achieve this objective durably,(...)shifting from a stance that aims to raise the inflation path (...) to one that aims to cement the inflation path at the target"*.(Panetta, 2022).

Chapter 3

Data and Empirical Methodology

3.1 Data description

Our empirical study begins with the retrieval of data from four different sources. In particular, firm-level data are collected from *Orbis*, bank-level variables from *Moody's Analytics Bank Focus*, monetary policy shocks from the *Euro area Monetary Policy Event-Study Database* (EA-MPD) and firm-level data on emissions from *Refinitiv*.

3.1.1 Firm-bank data

Orbis[1] is a global and comprehensive financial database for listed and unlisted companies provided by Moody's Analytics company Bureau van Dijk, covering information on more than 550 million companies all over the world. Our choice leads to select all listed companies for which a known yearly value of our research variables is available over the time period 2015-2022. We chose only quoted companies because they are the only ones that usually disclose data on emissions. We downloaded data on the 20 countries that are members of the Euro area[2] to obtain a heterogeneous setting that includes countries belonging to both Northern Europe and Southern Eu-

[1] `https://www.bvdinfo.com/enus/our-products/data/international/orbis.`

[2] Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, Spain.

rope. A key information provided by this database is the name of the main lenders to a firm, then exploited to perform a fuzzy matching operation[3] with the dataset on banks information. Our downloaded dataset includes a total of 6,893 firms.
Bank-level data are retrieved from Moody's Analytics *Bank Focus*[4], looking for financial statement variables of interest concerning only the Euro area banks to have a more appropriate view of the effects of the monetary policy driven by the ECB. Our selected dataset includes a total of 5,554 saving, commercial and cooperative banks, from which we performed a cleaning procedure to get their unconsolidated balance sheet information then matched to lenders' names in the firms' dataset.
Firm-level data on emissions are collected from the *Refinitiv* database, together with the LEI[5] code to merge with the firms information. In particular, we compute the median emission value in thousands of tonnes over revenues in million US dollars in order to remove the bias otherwise determined by large firms polluting more in light of the scale of their business.
Firms', banks', and emissions' datasets were not balanced, hence we drop observations for which most were missing, resulting after the fuzzy matching procedure in a strongly balanced panel dataset and 3,023 perfect firm-bank matches found. Moreover, it also contains 62 NACE2 core code[6], which allows us to exploit industry classification to conduct an industry-level analysis. Summary statistics are presented in Table B.2. However, this panel presents the main limitation inherited by *Orbis* which does not provide single firm-bank loan exposure. As a consequence, we formulate the approximate assumption according to which we divide the total firm's debt (given by the sum of long-term debt and short-term debt) into a number of equal fractions based on the number of lenders associated with each firm. For the sake of completeness, another binding constraint is determined by the lack of data

[3]For further details on this procedure, see Appendix A

[4]It combines contents from Bureau van Dijk and Moody's Investor Service with expertise provided by Moody's Analytics, `https://www.moodys.com/web/en/us/site-assets/Moodys-Analytics-BankFocus-Brochure.pdf`

[5]The Legal Entity Identifier is a 20-digit alphanumeric code based on the ISO 17442 standard which uniquely identifies legal entities taking part in financial transactions and other official exchanges

[6]The "Nomenclature des Activités Économiques dans la Communauté Européenne" represents a standard system to classify economic activities in the European Union.

on emissions for the whole original set, leading us to further restrict observations to reach a balanced panel. Despite of these limitations, we are able to carry out our desired analysis on the impact of monetary policy shocks on the credit levels of firms with different sustainability attitudes.

3.1.2 Monetary policy shocks

The monetary policy shock variable is collected from the *Euro area Monetary Policy Event-Study Database* (EA-MPD) developed by Altavilla et al.(2019)[7], containing high-frequency monetary policy surprises calculated as intraday asset price changes following the ECB policy announcement for a broad class of assets with different maturities, among which are covered the Overnight Index Swap (OIS) with 1, 3, 6 month and 1 to 10, 15, and 20 year maturities[8]. Data are available from 1999 until November 2023. Specifically, the authors report changes in the median prices/yields from the pre-event (15 minutes before) to the post-event (15 minutes after) for each communication window released by the Gouverning Council of the ECB, in the sprit of the event-study literature on monetary policy effects on asset prices[9]. In particular, OIS is an over-the-counter derivative, having the EONIA (Euro Overnight Index Average) as floating reference rate in the Eurozone[10]. The latter represents the average overnight reference rate for unsecured transactions between Euro area banks. The EONIA counts several factors of influence, among which the most significant is represented by the European Central Bank's policy rates[11] as an extension of their impact on the interbank lending cost. This close relationship leads to the consideration of the change in the median price of the OIS rate for each monetary event

[7]Available at `https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx`

[8]Asset price changes are measured for the Press Release Window, the Press Conference Window, both combined in the Monetary Event Window.

[9]For the US it starts with Cook and Hahn(1988) then flourished with Kuttner(2001), while for the Euro area we need to recall the contributions of Brand et al.(2010).

[10]Lloyd (2021).

[11]The Governing Council of the ECB sets the following key interest rates for the Euro area: the rate on deposit facility, the interest rate on the main refinancing operations and the rate on the marginal lending facility (European Central Bank, *Key ECB interest rates*, available at `https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html`

window as a good measure of monetary policy shocks.
For our purposes, we select the intraday price changes of the 1-year OIS rate because it represents a sufficiently long maturity to cover price fluctuations as responses to monetary policy announcements of standard and non-standard measures (Altavilla et al. (2019)). We proceed via constructing the monetary policy shock variable by time aggregating the high-frequency shocks to get the annual frequency to be subsequently matched with the annual observations of our firm-bank level dataset. The annual monetary policy shock variable for the year t, MP_t, is then obtained by summing all 1-year OIS rate variations registered in the EA-MPD Database arising within each year comprised in between 2015 and 2022[12]. This time aggregation methodology of simply summing all the shocks occurred in the considered time window is based on the assumption that shocks are orthogonal to the economic variables analyzed in the same time period along with their serial uncorrelation with other expansionary or contractionary shocks, as in Wong (2019). Hence, an increase in the OIS rate is associated with a positive value of our MP_t, implying a contractionary monetary policy shock. Summary statistics are reported in Table B.1 of the Appendix.

3.1.3 Greenhouse Gas Emissions and "Green" Firms

Anthropogenic climate change is deeply interconnected with Greenhouse Gas (GHG) emissions. Actually, we need to admit the spontaneity presence of a greenhouse effect in the Earth's atmosphere, where it guarantees life regulation by trapping heat and warming our planet's surface. However, human activities have amplified this natural process, increasing the emission of one of the greenhouse gases, carbon dioxide (CO_2), mainly produced by the combustion of fossil fuels. Analyzing the firm's carbon contribution and according to the GHG Protocol[13] we are able to classify

[12]The dataset reports 8 price shocks for each year of our time window, following the fact that the Governing Council of the ECB meetings are typically held every six weeks.

[13]The Greenhouse Gas Protocol is the result of the partnership between World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). It provides detailed accounting and reporting standards for GHG emissions, globally reaching public and private entities. For further information: `https://ghgprotocol.org/`

emissions in three categories: Scope 1 are emissions directly produced by sources owned or controlled by the company (e.g. emissions produced by on-site fossil fuels combustion); Scope 2 concerns those emissions arising from the consumption of purchased electricity, steam, heating and cooling (e.g. emissions produced by a power plant generating energy); Scope 3 comprises all the other indirect emissions generated in the value chain of the company not included in the previous categories (e.g. emissions derived from transporting raw materials to a manufacturing plant).

Our analysis involves the data collection of Scope 1 and Scope 2 emissions of CO_2 generated by our firm sample from *Refinitiv*. We construct the current emission variable for firm f at time t, called *Emissions*, by summing the two types of CO_2 emissions then scaled by revenues. The latter is used to build our indicator variable $Green_{f,t}$ by comparing the median *Emissions* level as of 2015 to 2022 with the median *Emissions* for all firms in the same period. We state a "green" firm whenever its median emission level is below the median one of the entire firm sample. As a result, we get 62 "green" firms and the remaining 57 are considered as "brown".

3.2 Empirical Methodology

By exploiting both cross-sectional and time series differences in credit exposure of companies that show different CO_2 footprints, our objective is to analyze how loans to green firms are affected by monetary policy shocks. In particular, we are interested not only in the overall picture but also in a setting taking into account the heterogeneity provided by differences in banks' responses due to their size and capital structure. Furthermore, the heterogeneity evaluation will involve the firm side by looking at their default risk level and size.

3.2.1 Firm-bank level specification

In our baseline specification, we run a panel fixed effects regression model to investigate how a shock in monetary policy affects the willingness of banks to grant loans to firms with different environmental impacts. Exploiting the final matched dataset, we choose as a dependent variable the (natural logarithm) of total credit held by our firm sample. Hence, we estimate the following firm-bank level equation:

$$\begin{aligned} Ln(BankCredit)_{b,f,t+1} =& \alpha + \beta \cdot MP_t \cdot Green_{f,t} + \gamma \cdot Bank_{b,t} + \delta \cdot Bank_{b,t} \cdot MP_t \cdot Green_{f,t} \\ &+ \mu \cdot Firm_{f,t} + \theta_f + NACE_{f,t} + \psi_{ict} + \epsilon_{f,t} \end{aligned}$$

The variable MP_t represents our high frequency monetary policy shock then interacted with the indicator variable $Green_{f,t}$ to assess the impact of monetary policy depending on the green or brown firm classification on the credit level through the β coefficient.

We use banks' and firms' characteristics as variables to control whether such a number of factors may affect the credit behavior. In particular, the former, $Bank_{b,t}$, covers the natural logarithm of *Total Assets*, which is considered as a proxy for the bank size, the banks' *Return on Average Assets* ($ROAA$), measuring the banks' profitability, and the *Equity Ratio*. They are taken standalone and then interacted with the variable combination of $MP_t \cdot Green_{f,t}$ to better capture the differential impact of the credit channel of monetary policy. Moving to the vector of firm controls, $Firm_{f,t}$, we include the natural logarithm of firms' *Total Assets*, which is used as a proxy for the firm f size, of the firms' *Total Liabilities*, given by the sum of *current* and *non-current liabilities*, *Revenues* and *ROE*.

Finally, we control for firm fixed effects, θ_f, to capture permanent differences across firms, and for industry fixed effects, $NACE_{f,t}$, to investigate an unobserved time invariant heterogeneity at industry-level. Moreover, we consider firm cluster-year fixed effects (ψ_{ict}) following the identifying assumption of our model that firms belonging to the same cluster face similar shocks. Firms clusters includes firm's country c and industry i (NACE Rev 2). Standard errors are clustered at the firm-industry level.

3.2.2 Heterogeneity Analysis

After investigating the immediate response of firms' credit levels to monetary policy surprises, we want to enrich our analysis to include a heterogeneous perspective. In this regard, we estimate variants of the baseline of the empirical specification:

$$
\begin{aligned}
Ln(BankCredit)_{b,f,t+1} =& \alpha + \beta_0 \cdot MP_t \cdot Green_{f,t} + \beta_1 \cdot Leverage_{f,t} \cdot MP_t \cdot Green_{f,t} \\
&+ \beta_2 \cdot Size_{f,t} \cdot MP_t \cdot Green_{f,t} + \gamma \cdot Bank_{b,t} + \delta \cdot Bank_{b,t} \\
&\cdot MP_t \cdot Green_{f,t} + \mu \cdot Firm_{f,t} + \theta_f + NACE_{f,t} + \psi_{ict} + \epsilon_{f,t}
\end{aligned}
$$

Our extended regression shows coefficients concerning important financial features of the considered firm sample. Following Ottonello and Winberry (2020), we introduce a measure of firm's default risk, that is the debt-to-equity ratio as a metric of firms' financial *Leverage*. Indeed, by relating the values of equity and liabilities to form an estimate of the probability of default for each firm, this latter variable verifies how a company is able to finance its operations and growth whether through debt (liabilities) or its own funds (equity). Moreover, we include firm's *Size* in the set of main explanatory variables to investigate how firms with different levels of total assets experience a change in their credit exposure due to monetary policy shocks and their carbon footprint. The estimated coefficients will reflect whether the intensity of monetary policy shocks is different in relation to different financial frictions exposure faced by our "green" or "brown" firms.

A similar heterogeneity setting is constructed for the bank's side, enriching the baseline model by introducing a triple interaction between $MP_t \cdot Green_{f,t}$ and bank balance sheet variables *Tier1Ratio*, which is a crucial index of bank's financial strength and regulatory compliance, and *Deposits*, which represents the amount of bank customer deposits scaled by total assets. The resulting specification is:

$$
\begin{aligned}
Ln(BankCredit)_{b,f,t+1} =& \alpha + \beta_0 \cdot MP_t \cdot Green_{f,t} + \beta_1 \cdot Tier1Ratio_{f,t} \cdot MP_t \cdot Green_{f,t} \\
&+ \beta_2 \cdot Deposits_{f,t} \cdot MP_t \cdot Green_{f,t} + \gamma \cdot Bank_{b,t} + \delta \cdot Bank_{b,t} \\
&\cdot MP_t \cdot Green_{f,t} + \mu \cdot Firm_{f,t} + \theta_f + NACE_{f,t} + \psi_{ict} + \epsilon_{f,t}
\end{aligned}
$$

The coefficients of this regression will display the role played by the characteristics of banks in assessing the credit level of our firms belonging to the two different sustainable clusters subsequently to monetary policy surprises.

Chapter 4

Results

This section is organized as follows: Section 4.1 reports the results of the baseline model; Section 4.2 analyzes possible heterogeneous effects for firms and banks; finally, Section 4.3 provides some robustness checks.

4.1 The Baseline model

Table 4.1 reports the estimated coefficients of interest of the baseline specification.

We show the results of the baseline model for different types of firm clusters. Column (1) includes firm, country and industry fixed effects to consider possible unobserved heterogeneity at firm-industry level, but not time effects as these would absorb changes in the monetary policy path. Column (2) refers to the same fixed effects, but we augment the model by including firms and bank controls. Columns (3), (4) and (5) account for time fixed effects, however resulting in a less demanding control for unobserved heterogeneity since we drop completely firm fixed effects and partly industry fixed effects (they are only present in column (4)), but it allows to check the validity of our results considering the location where firms are placed. Finally, column (6) encompasses firm and industry-country-time fixed effects to verify whether the credit level has increased with respect to those firms part of the same industry and country. Bank and firm controls are separately considered in columns (3) and (5) respectively, while they are jointly included in columns (2) and (6). All specifications in columns (3), (4), (5) and (6) of Table 4.1 report a negative coefficient estimate reflecting the monetary policy shock impact on the credit granted to green firms, always statistically significant even when reaching the saturation in terms of controls and fixed effects. Instead, an analysis of the coefficient estimates for the monetary policy shock variable considered standalone in columns (1) and (2) leads to the consideration that adding the full set of controls brings to a change in the coefficient sign, together with a statistical significance lost.

Ln(Bank Credit)	(1)	(2)	(3)	(4)	(5)	(6)
MP_t	0.00469**	-0.00160*				
	(0.002)	(0.001)				
$Green \times MP_t$			-0.138**	-0.0243***	-0.0189***	-0.00301**
			(0.059)	(0.008)	(0.007)	(0.011)
Time FE	No	No	Yes	Yes	Yes	No
Firm FE	Yes	Yes	No	No	No	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	No
Industry FE	Yes	Yes	No	Yes	No	No
Industry-country-time FE	No	No	No	No	No	Yes
Bank controls	No	Yes	Yes	No	No	Yes
Firm controls	No	Yes	No	No	Yes	Yes
Observations	2137	2137	2137	2137	2137	1844
R-squared	0.927	0.959	0.294	0.726	0.799	0.996

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.1: Baseline Model

The table reports the estimates of the model at firm-bank level. MP_t represents the monetary policy shock variable. *Green* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the sample median emission levels. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the $Green \times MP_t$ variable. Standard errors are clustered at firm-industry level.

Overall, the green estimates vary when we consider differently bank and firm controls. In particular, their joint inclusion and the additional industry-country fixed effects imply a reduction in the negative impact on bank credit. However, bank and firm controls are of particular importance. On the one hand, by controlling for the bank *Total Assets* as a measure of their size, *ROAA* and *Equity Ratio* we are implicitly looking at the bank business model. On the other, the relevance of the firm controls lies on the nature of our dependent variable which is the natural logarithm of the total bank credit granted to our sample firms, part of the firm balance sheet, allowing us to include both balance sheet and income statement as firm variables, such as *Total Assets* (as a measure of the firms' size), *Total Liabilities*, *Revenues* and *ROE*.

Comparing the coefficients in columns (1) and (2) referring to the impact of the monetary policy surprises on credit with the estimates in the remaining columns relating to the additional consideration of the green firm type combined with monetary policy shocks, we can infer a more pronounced decline in the credit level. In particular, by comparing columns (1) and (4), which are the most similar in terms of controls and fixed effects, both statistically relevant even though their lack of completeness, we can infer a more pronounced decline in the credit level when we control for green firms as a reaction to a contractionary monetary policy (positive shock) of -2.4% relative to the small positive variation of 0.47% when we do not account for green characteristic. An interesting phenomenon is observable looking at columns (2) and (6) which are the most complete in terms of controls even though the absence of statistical significance in column (2). In this case, the negative impact on bank credit is registered even when we do not account for the green interaction, diminishing the gap between the two coefficients, however resulting in a slightly more negative outcome for the green which diverges from the column (2) coefficient of -14.1 basis points. Overall, based on our estimates, Table 4.1 provides evidence that a positive monetary policy surprise, hence a monetary policy tightening, has a more restrictive impact on green firms compared to brown ones. In order to rationalize our results, next paragraph investigates a possible underlying explanation of the observed phenomenon represented by the financial frictions channel of monetary policy.

Financial frictions channel of monetary policy. In order to assess the economic significance of our results, a possible reason behind the different effect of monetary policy on credit lies on the financial frictions channel of monetary policy. As Bernanke and Gertler (1989) suggest in their investigation of the influence of changes in borrower solvency capacity on business cycle, the financial frictions channel follows the idea that monetary policy differentiates its effects on credit levels with respect to collateral capacity. In particular, they sustain the view according to which a restrictive monetary policy brings banks to restrict granted credit relatively more to collateral-poor firms than to collateral-rich ones, accounting also for the firm's lower ratio of tangible assets to future cash flows. To this extent, the findings of Iovino et al. (2021) show that CO_2-intensive firms benefit more from the tax advantage of debt and by having an higher fraction of tangible assets they are able to offer more collateral relatively to low carbon emissions firms. Alongside these considerations and following Ottonello and Winberry (2020) pointing low *leverage ratio* and high *"distance-to-default"* as proxies for a low default risk, we would like to assess whether the different effect of monetary policy depends on differences in firm's leverage levels. Hence, we analyze differences in firm variables as reported in Table B.3, making the distinction between "brown" and "green" firm clusters. In addition, the table reports the results of the two-sample *t-test* performed in order to determine whether there is a significant difference between the mean value of each variable of the two firm groups. The observed differences are all different from zero and statistically significant, except for the ROE variable, showing a strong evidence against the null hypothesis according to which there is no significant difference between the green and brown firm mean variables. In particular, we can see that "green" firms are characterized by a significantly lower volume of *Total Assets*, implying a smaller firm size, by a slightly lower level of *Total Liabilities* and *Debt-to-Equity ratio*, implying a lower leverage ratio, and finally, by a substantially lower level of bank credit compared to the "brown" type. Our results confirm the claim that firms subject to low default risk, such as those belonging to the "green" cluster featured by a low debt-to-equity ratio- are more responsive to monetary policy surprises, as in Ottonello and Winberry (2020). Moreover, another possible reason to sustain the economic relevance of our results lies on the firm size characteristic of our sample. Indeed, the substantial difference between the two groups with this respect brings us to confirm the findings of Ehrmann (2000), who claims that large firms are those less affected by a restricted access to credit during a monetary policy tightening due to their *"overall higher level of colleteralizable assets and the lower collateral requirements on their loans* by analyzing the German manufacturing firms. Hence, results in Table 4.1 showing that low carbon emissions firms experience a more negative impact on their credit level due to a positive monetary policy shock event, i.e. a monetary policy tightening, can be explained through the lens of the financial frictions channel.

4.2 Heterogeneity Analysis

Our findings suggest that accounting for the categorization of firms based on their emissions may change the effects of monetary policy surprises on bank credit levels, resulting in a decrease of the latter after a positive shock. The following step in our analysis is to assess whether this outcome is homogeneous across firms and banks. Firstly, we investigate the firms' dimension. To this purpose, we include as interaction term the firm's *Leverage*, computed as the ratio between total liabilities and shareholder's equity, and the firm's *Size*, computed as (the natural logarithm) of firm total assets. Given the previous discussion, we expect an improvement of the credit level after adding the two firm's characteristics, since both factors are positively related to a softer impact of shocks in monetary policy. An interesting result reported in Table 4.2 suggests that the firm leverage characteristic improves the credit level as a response to positive monetary policy shocks steering to a more positive direction for the "green" firm cluster. This claim turns to be statistically significant in the triple interaction both when we consider or not our firm and bank controls in columns (2) and (1), respectively. Moving to the second firm feature, the comparison leads us to very similar conclusions as before. Indeed, large firms are those experiencing an increase in their credit levels, demonstrated by the positive coefficients of the double interaction with and without controls in columns (2) and (1). However, when we account for the greenness characteristic of firms in the triple interaction, the positive and significant coefficient in column (1) turns into slightly negative (not significantly different from zero) in column (2) loosing its statistical significance. Hence, we can confirm the presence of a firm level heterogeneity, in particular when we analyze the leverage feature that reveals a better responsiveness of "green" firms to positive monetary policy shocks.

Ln(Bank Credit)	(1)	(2)
$FirmLeverage \times MP_t$	0.00153***	-0.00159
	(0.001)	(0.001)
$FirmLeverage \times Green \times MP_t$	-0.00103*	0.00192*
	(0.001)	(0.001)
$FirmSize \times MP_t$	0.00316**	0.000324
	(0.001)	(0.001)
$FirmSize \times Green \times MP_t$	0.000601*	-0.00150
	(0.00033)	(0.001)
Time FE	Yes	Yes
Firm FE	Yes	Yes
Firm Controls	No	Yes
Bank Controls	No	Yes
Observations	2137	2137
R-squared	0.940	0.962

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.2: Firm Heterogeneity

The table reports the estimates for analyzing heterogeneity among firms. MP_t represents the monetary policy shock variable. *Green* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the sample median emission levels. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the $Green \times MP_t$ variable. In the double and triple interactions, $FirmLeverage$ is equal to the debt-to-equity ratio as a measure of the firm' leverage. $FirmSize$ is equal to the natural logarithm of firm total assets, considered as a measure of firm's size. Standard errors are clustered at firm-industry level.

Secondly, we study the bank heterogeneity to understand which bank characteristics facilitate an improvement of credit level following a monetary policy surprise. To this extent, in the interaction with the MP_t variable and then in the triple interaction with the *Green* dummy variable we include the $Tier1Ratio$, i.e. the ratio between core Tier 1 capital[1] and risk-weighted assets (RWA), and the *Deposits* variable, computed as the ratio of customer deposits to total assets (deposits-to-assets ratio). Both measures are indices of banks' strength, in particular they are used to assess financial and funding and liquidity stability, respectively.

Ln(Bank Credit)	(1)	(2)
$Tier1ratio \times MP_t$	-0.000103	-0.000136*
	(0.0001)	(0.000071)
$Tier1ratio \times Green \times MP_t$	-0.000135	-0.0000930
	(0.00012)	(0.00014)
$Deposits \times MP_t$	-0.00510	-0.00378*
	(0.004)	(0.002)
$Deposits \times Green \times MP_t$	0.00770	0.00215
	(0.006)	(0.005)
Time FE	Yes	Yes
Firm FE	Yes	Yes
Firm Controls	No	Yes
Bank Controls	No	Yes
Observations	2137	2137
R-squared	0.939	0.962

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.3: Bank Heterogeneity

The table reports the estimates for analyzing heterogeneity among banks. MP_t represents the monetary policy shock variable. *Green* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the sample median emission levels. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the $Green \times MP_t$ variable. In the double and triple interactions, $Tier1ratio$ is equal to the percentage level of Tier1 Capital over bank's total risk-weighted assets. *Deposits* is equal to the deposits-to-asset ratio.

[1]The core Tier 1 capital or CET1 includes bank's common shares (or the equivalent for non-joint stock companies) and retained earnings, as enounced by the Basel Committee on Banking Supervision (Basel III) proposal to build a regulatory capital instrument capable of *"absorbing losses at least in "gone concerns" situations"*(`https://www.ecb.europa.eu/pub/pdf/fsr/art/ecb.fsrart201012_02.en.pdf`).

As Table 4.3 reports, all the coefficient estimates related to the Tier 1 ratio are negative, even though not so different from zero and statistically significant only when we do not account for the greenness of firms and we include firm and bank controls in column (2). However, we can comment that a one percentage point increase in Tier 1 ratio brings to a general decrease in the credit level of -0.0136%, a less pronounced effect when we consider the environmental aspect. The latter consideration suggests that positive effects on bank lending towards green firms in a monetary policy shock environment can come from better capitalized banks, those well prepared by the European regulatory system to deal with a time period affected by different crises, as seen before. Moving to the second bank characteristic, columns (1) and (2) suggest the presence of a bank heterogeneity in terms of *deposit-to-assets ratio*, even though we have to admit the statistical inconsistency of this claim. Indeed, only in the triple interaction the coefficients are positive, implying that a mild increase in the credit level of "green" firms in a monetary policy shock setting can be due to more reliable banks in terms of liquidity. This positive effect changes sign when we do not account for the greenness factor, however acquiring statistical significance when we exploit firm and bank controls in column (2).

4.3 Robustness checks

In this section we are going to present some tests of robustness of our baseline specification.

As a first check, we consider different maturities of the OIS rate which has been used to construct our monetary policy shock variable. Indeed, the EA-MPD Database provides data on OIS rate with 1 week, 1,3,6 month, 1 to 10, 15 and 20 year maturities. For our robustness check purpose, we consider the 3-month OIS rate, the 6-month OIS rate and the 2-year OIS rate in order to control whether our estimates remain unchanged even when we consider monetary policy shocks accounting for the effects of short-term and long-term interest rates, as monetary policy events may influence short-term and long-term yields in a different manner. To this extent, we construct three different monetary policy shock variables by summing all the OIS rate variations at different maturities, reported in the EA-MPD Database and occurred in the year, considering the time period from 2015 to 2022. Then, we interact them with our variable of interest and we run the baseline specification. Table 4.4 reports the new coefficient estimates when considering the *Green* variable as main independent variable.

Ln(Bank Credit)	(1)	(2)	(3)	(4)
$Green \times OIS3M$	-0.00360**			
	(0.011)			
$Green \times OIS6M$		-0.00425**		
		(0.013)		
$Green \times OIS2Y$			-0.00330*	
			(0.010)	
$Green \times OIS1Y$				-0.00301**
				(0.011)
Firm FE	Yes	Yes	Yes	Yes
Industry-country-time FE	Yes	Yes	Yes	Yes
Bank controls	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes
Observations	1844	1844	1844	1844
R-squared	0.996	0.996	0.996	0.996

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.4: Robustness check

The table reports the estimates of the baseline model for different monetary policy shock variables. *Green* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the sample median emission levels. $Green \times OIS3M$ is the interacted variable with the 3-month OIS rate, $Green \times OIS6M$ is the interacted variable with the 6-month OIS rate, $Green \times OIS2Y$ is the interacted variable with the 2-year OIS rate, $Green \times OIS1Y$ is the baseline interacted variable constructed using the 1-year OIS rate. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the previously defined interacted variables. Standard errors are clustered at firm-industry level.

The coefficients are always negative, showing an evident closeness to the one of the baseline regression reported in column (4) of Table 4.4 when we evaluate different interest rate maturities to build our monetary policy shock variable. In particular, all the regressors are statistically significant at 0.05 level, except for the interaction with the 2-year OIS rate at 0.10.

Secondly, coming back the original definition of monetary policy shock variable (MP_t) constructed by summing the changes involving the OIS rate with 1-year maturity, we re-estimate part of our main specification (the one including our variable of interest), but now considering a more demanding definition of green firms. Indeed, Table 4.5 restricts the realm of the greenness label only to the portion of firms whose *Median Level Emission* is below the *Emission Threshold Q*, which is the lower quartile of our sample *Median Level Emission* during the 2015-2022 period. The coefficients persist in being negative and significant in columns (1) and (2). However, when we include the whole set of controls in column(3) of Table 4.5, they are still negative, showing a decrease in the negative impact on credit levels but loosing in significance.

Ln(Bank Credit)	(1)	(2)	(3)
$GreenQ \times MP_t$	-0.172**	-0.0269***	-0.0108
	(0.067)	(0.010)	(0.007)
Time FE	Yes	Yes	No
Firm FE	No	No	Yes
Country FE	Yes	Yes	No
Industry-country-time FE	No	No	Yes
Bank controls	Yes	No	Yes
Firm controls	No	Yes	Yes
Observations	2137	2137	1844
R-squared	0.315	0.802	0.996

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.5: Robustness check

The table reports the estimates of the model at firm-bank level. MP_t represents the monetary policy shock variable. *GreenQ* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the lower quartile of the sample median emission levels. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the $GreenQ \times MP_t$ variable. Standard errors are clustered at firm-industry level.

Finally, we estimate the baseline model only considering the latter part of our sample period, from 2018 to 2022, in order to test whether our estimates are still relevant and coherent in such recent turbulent time window, as seen in Chapter 2. To this extent, we evaluate both the two previous alternative versions of green firms. Estimates are reported in Table 4.6. All the coefficients are negative, showing a milder decline in credit when we use the *Green* definition in a comparison between the two most complete columns (3) and (6) in terms of fixed effects and controls.

Ln(Bank Credit)	(1)	(2)	(3)	(4)	(5)	(6)
$Green \times MP_t$	-0.0954*	-0.0160**	-0.00961**			
	(0.049)	(0.006)	(0.005)			
$GreenQ \times MP_t$				-0.134**	-0.0243**	-0.0128***
				(0.058)	(0.010)	(0.004)
Time FE	Yes	Yes	No	Yes	Yes	No
Firm FE	No	No	Yes	No	No	Yes
Country FE	Yes	Yes	No	Yes	Yes	No
Industry-country-time FE	No	No	Yes	No	No	Yes
Bank controls	Yes	No	Yes	Yes	No	Yes
Firm controls	No	Yes	Yes	No	Yes	Yes
Observations	1336	1336	1156	1336	1336	1156
R-squared	0.325	0.792	0.998	0.351	0.796	0.998

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.6: Robustness check

The table reports the estimates of the model at firm-bank level. Double interactions are defined by the following terms. MP_t represents the monetary policy shock variable. *Green* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the sample median emission levels. *GreenQ* is an indicator variable equal 1 if firm's median emissions from 2015 to 2022 are below the lower quartile of the sample median emission levels. Bank and firm controls are those specified in Section A.2. Bank controls are included as standalone and interacted with the previously defined double interactions. Standard errors are clustered at firm-industry level.

The above table shows a confirmed and increased significance level in the *Green* and *GreenQ* cases, respectively. This aspect suggests that, even though we are focusing on a shorter period, the sustainability consciousness in the financial world has spread more widely.

Conclusion

Investigating how the financial world can provide its contribution to the climate issue, we address the key question relating the well-established credit channel influence of monetary policy on bank credit granted to firms to the green transition. To this purpose, we employ matched firm-bank level data and identify monetary policy shocks occurred over the 2015-2022 period and affecting the 20 Member States forming the Euro area in a panel regression where the dependent variable is represented by the (natural logarithm of) bank credit level, using several sets of fixed effects and controls at firm and bank level.

We find robust evidence that green firms tend to suffer more for a contraction in their credit levels when they are affected by a positive monetary policy shock event, hence a monetary policy tightening. This outcome can be explained through a heterogeneous analysis of firms' response, finding that green firms are characterized by a lower profile of default risk and size. In particular, we show that when we increment the financial leverage of green firms by one percentage point, hence enhancing their default risk, we register a significantly softer response to policy shocks by 0.192%, in line with Ottonello and Winberry (2020) claim. Indeed, a 1% increase in the firm leverage improves the bank credit by about 20 basis points. This evidence highlights the influence of the financial frictions channel of monetary policy. Assessing which bank characteristics improve the green firms responsiveness to monetary policy shocks, we find that better capitalized banks are those supporting green firms credit thanks to a even negative but very close to zero coefficients representing the effect of a 1% increase in Tier 1 ratio bank capital requirement. Finally, our robustness check section sends a positive signal by highlighting how in the last time window of our analysis evidences are even more significant, suggesting a more widespread climate awareness in this field. In any case, we recognize that we are analyzing a very first stage period of a so widely felt climate sensibility, hoping that more and more policies can be implemented in this direction, even through their indirect effects as this is the case of the bank lending channel affected by monetary policy changes and influencing firm's future path of sustainable investment decisions.

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Appendix

A Data

Our empirical analysis relies on four data sources. We collected firm level data for listed companies from Bureau Van Dijk's *Orbis*, while data on bank's unconsolidated balance sheet from *Moody's BankFocus*. High-frequency monetary policy shocks are downloaded from the *EA-MPD Database*, while data on firm's emissions from *Refintiv*. We selected firms and banks belonging to the twenty countries part of the Euro area.

A.1 Fuzzy matching

It is possible to match the firm and bank datasets thanks to the provision of firm's main lenders from *Orbis*. However, the latter only provides the lenders' name with no other identification codes that could have been used to perform an exact matching with *Moody's BankFocus* information. Hence, we are required to use the fuzzy matching technique on bank's names to obtain the desired matched firm-bank dataset. To this extent, we clean bank's names in both datasets leaving them in lowercase type and without any non-alphabetic characters. Then, we are able to match the datasets using the function *reclink*[2], which performs a probabilistic matching by generating a score based on the similarity of the matched strings (in our case the bank's names present in both datasets). Figure A.1 presents the dis-

[2]Michael Blasnik, 2007. "RECLINK: Stata module to probabilistically match records," Statistical Software Components S456876, Boston College Department of Economics, revised 18 Jan 2010. `https://ideas.repec.org/c/boc/bocode/s456876.html`.

tribution of the matching score. An higher degree of similarity between the banks' names is associated with a higher score computed for each raw of the final bank-firm dataset. Moreover, we set threshold of tolerance of 0.9, below which we decide to drop observations. In our case, the *reclink* function finds 23,371 matched observations, among which 3,023 are perfect matches, out of 24,800 total observations.

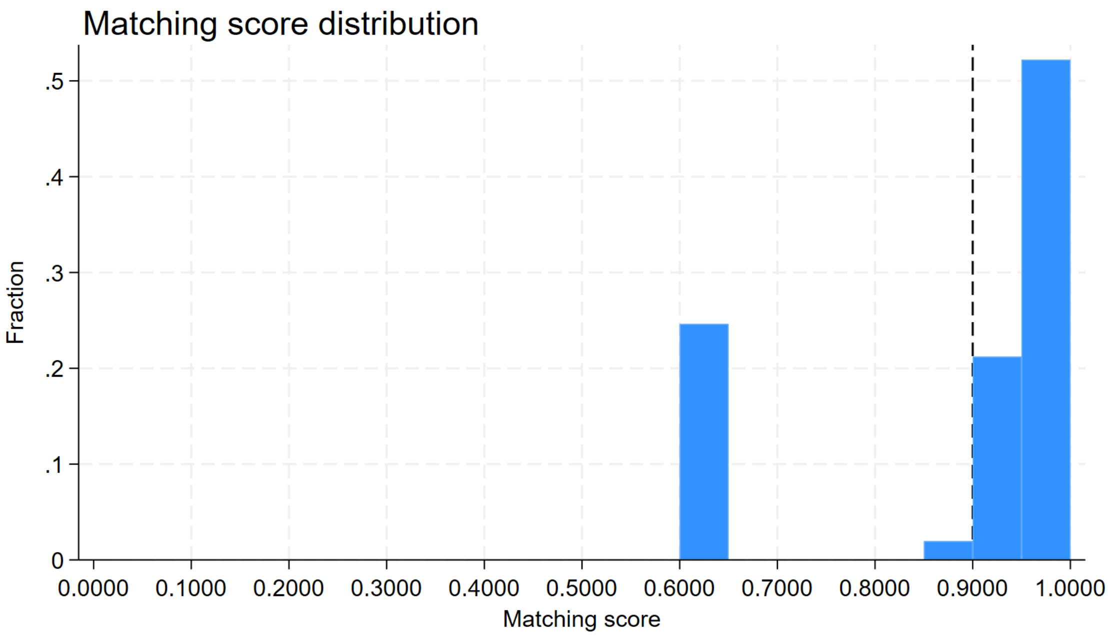

Figure A.1: Matching performance

The figure represents the distribution of the matching score generated by the function *reclink* in the fuzzy matching procedure. The dashed line is the set threshold below which we drop observations.

A.2 Variable definition

Variables	Definition and source
Main variables	
Ln(Bank credit)	Natural logarithm of total loans received by the firm (Source: Orbis)
MP	Monetary policy shock, computed as sum of 1-year OIS rate changes occurred in a year (Source: EA-MPD Dataset)
Emissions	Ratio of total emissions, computed as the sum of Scope 1 and Scope 2 emissions) to firm's revenues (Source: Refinitiv and Orbis)
Green	Indicator variable that equals 1 if the median firm level of emissions from 2015 to 2022 is lower than the median of total emissions produced by all firms from 2015 to 2022, and 0 otherwise
GreenQ	Indicator variable that equals 1 if the median firm level of emissions from 2015 to 2022 is below the lower quartile of the distribution of total emissions produced by all firms from 2015 to 2022, and 0 otherwise
Firm controls	
Ln(Total Assets)	Natural logarithm of firm total assets (Source: Orbis)
Ln(Liabilities)	Natural logarithm of the ratio between total liabilities (computed as sum of current and non-current liabilities) and total assets, i.e. debt-to-asset ratio (Source: Orbis)
Ln(Revenues)	Natural logarithm of the ratio between total revenues and total assets, i.e. turnover ratio (Source: Orbis)
ROE	Firm's Return On Equity (Source: Orbis)
Leverage	Ratio between firm's total liabilities and equity, i.e. debt-to equity ratio (Source: Orbis)
Bank controls	
Ln(Total Assets)	Natural logarithm of bank total assets (Source: BankFocus)
ROAA	Bank's Return On Average Assets (Source: BankFocus)
Equity ratio	Ratio of bank's equity to total assets, i.e. equity-to-assets ratio (Source: BankFocus)
Tier1Ratio	Bank's Tier1 Capital Ratio (Source: BankFocus)
Deposits	Ratio of bank's total customer deposits to total assets, i.e. deposits-to-assets ratio (Source: BankFocus)
Industry classification codes	
NACE	2-digit NACE2 core industry classification (Source: Orbis)

Table A.1: Definitions

B Additional tables

	N	Mean	StD Dev	min	max	p5	p50	p95
OIS_1M	64.00	0.57	2.00	-4.77	10.57	-0.80	0.00	4.14
OIS_3M	64.00	0.80	2.79	-4.19	14.67	-1.28	0.00	6.61
OIS_6M	64.00	0.71	2.81	-5.68	11.22	-2.48	0.00	8.12
OIS_1Y	64.00	0.84	3.99	-14.92	15.60	-2.94	-0.07	9.00
OIS_2Y	64.00	0.70	4.71	-19.50	18.45	-3.70	-0.22	8.86
OIS_3Y	64.00	0.48	4.55	-17.80	17.00	-4.40	-0.20	8.90
OIS_4Y	64.00	0.34	4.58	-19.15	17.25	-4.10	-0.35	9.05
OIS_5Y	64.00	0.22	4.61	-18.95	17.70	-4.30	-0.42	7.60

Table B.1: Summary statistics of monetary policy shock variables

The table reports the summary statistics of monetary policy shocks for the period 2015-2022. These shocks are computed by summing up the changes in OIS rate with different maturities, occurred within the year.

	N	Mean	StD Dev	p5	p50	p95
Total Assets	2164.00	2.96e+07	5.07e+07	1.43e+06	1.10e+07	1.35e+08
Revenues	2164.00	0.71	0.45	0.13	0.64	1.45
Bank credit	2164.00	2.74e+06	5.41e+06	35366.44	624669.12	1.48e+07
Total liabilities	2164.00	0.62	0.15	0.38	0.63	0.89
Equity-to-assets ratio	2164.00	0.38	0.15	0.11	0.37	0.62
Debt-to-equity ratio	2164.00	2.55	3.56	0.62	1.68	7.82
ROE	2164.00	9.10	24.33	-13.54	10.78	26.22
Emissions	2164.00	9.77e+06	3.84e+07	30263.19	581650.44	4.30e+07

Table B.2: Summary statistics of total firms level variables

The table reports the summary statistics of total firms level variables for the period 2015-2022.

	Brown		Green		Difference	
	Mean	StD Dev	Mean	StD Dev		
Total Assets	5.05e+07	6.40e+07	8.75e+06	1.25e+07	41770437.7***	(21.11)
Revenues	0.61	0.38	0.81	0.50	-0.192***	(-10.12)
Bank Credit	4.71e+06	6.64e+06	794403.03	2.66e+06	3911151.7***	(18.03)
Total Liabilities	0.66	0.13	0.58	0.17	0.0735***	(11.40)
Debt-to-Equity	2.87	3.53	2.23	3.56	0.637***	(4.18)
ROE	8.04	27.81	9.98	20.55	-1.941	(-1.85)
Emissions	1.95e+07	5.30e+07	236308.86	286538.07	19248769.6***	(11.98)
N	1076		1088		2164	

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

Table B.3: Summary statistics of "green" and "brown" firms and t-test results

The table reports the summary statistics of firm level variables making a distinction between "green" and "brown" firms according to the Table A.1 definition for the period 2015-2022. The labeled column "Difference" reports the results of the two-sample t-test with respect to the mean difference of the firm-level variables of the two groups.

	N	Mean	StD Dev	p5	p50	p95
Total Assets	2164.00	5.11e+07	2.14e+08	303480.25	7.16e+06	1.86e+08
ROAA	2164.00	0.42	1.24	-0.33	0.35	1.68
Equity ratio	2164.00	0.09	0.06	0.04	0.07	0.18
Tier1 Ratio	2164.00	18.76	12.43	9.43	15.10	43.28
Grossloans	2164.00	2.97e+07	1.04e+08	85117.49	3.75e+06	1.34e+08
Deposits	2164.00	0.53	0.26	0.02	0.57	0.87

Table B.4: Summary statistics of bank level variables

The table reports the summary statistics of bank level variables for the period 2015-2022.