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SUSTAINABLE BANKING

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Abstract

This paper reviews the literature on banks, climate change, and the global shift towards a low-carbon economy. It first examines the contribution of banks to climate change mitigation, with an emphasis on banks' roles in financing green innovation and the diffusion of low-carbon technologies. The paper then reviews whether banks have begun to recalibrate their credit supply in response to the transition and physical risks of global warming. Here, the focus is on empirical work analysing how sea level rise and the increased frequency and intensity of hurricanes, floods, droughts, and wildfires are impacting banks' balance sheets and operations. Last, the paper discusses several related topics: credit access and climate change adaptation; carbon arbitrage and greenwashing; and green financial regulation and credit guidelines. The paper concludes by sketching a few promising avenues for future research on sustainable banking.

JEL Classification: F30, F64, G21, O44, Q01, Q32, Q54

Keywords: Sustainable banking, Climate finance, Climate change, Global warming

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1. Introduction

Human economic activity and the associated emission of greenhouse gases is warming the planet faster than at any time during the past 2,000 years (IPCC, 2021). The day-to-day impact of this global warming is becoming increasingly clear: extreme temperatures, droughts, floods, and storms are starting to cause substantial human, ecological, and economic losses.

To mitigate global warming to between 1.5 and 2 degrees Celsius (compared to pre-industrial times) many countries aim to reduce their greenhouse gas emissions to 'net zero' by 2050 or sooner. Achieving these climate ambitions requires a fundamental transformation of the global economy. Countries will need to move from carbon-based energy generation to electricity from sustainable sources such as solar, wind, and hydro power. Energy will also need to be used more sparingly when firms produce goods and services, during the transportation of people and freight, and in residential and commercial real estate. And, even then, societies will still be required to adapt to the irreversible climate impacts stemming from the stock of carbon dioxide that has already accumulated in the atmosphere since the late 18th century.

Both climate change mitigation (reducing greenhouse gas emissions) and adaptation (increasing climate resilience) will require trillions of dollars, annually, over the next decades. Indeed, Article 2.1.c of the 2015 Paris Agreement (COP21) states that the global response to climate change depends on "*making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development*". Policymakers have emphasised that the financing underpinning the green transition will need to encompass more than just public funds. Private financial resources, including bank lending, will be essential, too, to decarbonise the global economy (Carney, 2021; Lagarde, 2021; Yellen, 2021).

The role of banks in the green transition has only recently gained academic traction, in particular, since the Paris Agreement.[1] The aim of this paper is to review this new literature on how banks influence, and are themselves influenced by, climate change and the low-carbon transition. I first discuss research on finance and green growth (Section 2.1) and the role banks play in green innovation and technological diffusion (Section 2.2). In Section 3.1, I then review empirical findings on how (some) banks respond to the transition risks of climate change by adjusting their lending to carbon-intensive industries. Section 3.2 moves on to the physical

[1] Diaz-Rainey, Robertson, and Wilson (2017) analyse 20,725 articles published in 21 finance journals between January 1998 and June 2015. Only 12 articles (0.06%) dealt in some way with climate finance.

risks of changing climate as I discuss how sea level rise, hurricanes, floods, droughts, and wildfires have begun to impact credit markets. Last, Section 4 reviews research on several related topics: climate change adaptation; carbon arbitrage and greenwashing; and financial regulation and guidelines to steer banks in a more sustainable direction. Section 5 concludes by sketching some promising avenues for future research on sustainable banking.

Two caveats are in order. First, I narrowly define sustainable banking by focusing on the role of banks in climate change and the low-carbon transition. Sustainable banking is sometimes understood more broadly as bank activities that generate positive social impacts, such as poverty reduction, equality of opportunity, or the financial inclusion of women and minorities. Sustainable banking can also refer to the long-term stability of banks themselves and their resilience to internal and external shocks. Both of these social and stability aspects of sustainable banking are the subject of burgeoning literatures that arguably deserve review papers of their own. I instead limit myself to the 'green' dimension of sustainable banking.[2]

A second caveat is that, as mentioned above, sustainable banking has only drawn the full interest of academic researchers quite recently. I therefore discuss not only published articles but also a selection of working papers.

2. The impact of banks on climate change

2.1 Finance and green growth

Before delving into the nexus between bank lending and climate change, it is useful to take a step back and ask how the financial system, more broadly defined, can influence the shift towards a low-carbon economy. An extensive literature, starting with King and Levine (1993), establishes that financial development contributes causally to long-term economic development.[3] Early contributions did not identify a separate role for the structure of the financial system, that is, the relative size of the banking system and the stock market (Beck and Levine, 2002; Levine, 2002). However, more recent evidence, based on longer time series, indicates that, in richer countries, market-based finance tends to outperform bank-based finance in terms of supporting economic growth (Demirgüç-Kunt, Feyen, and Levine, 2013; Gambacorta, Yang, and Tsatsaronis, 2014; Langfield and Pagano, 2016). As countries develop,

[2] Moreover, I focus on banks and do not discuss the role of other financial institutions in the green transition.

[3] See Levine (1997) for an early survey of this literature and Popov (2018) for a more recent one.

they benefit more from equity markets and their greater ability, relative to banks, to fund innovation and technological progress (Hsu, Tiang and Xu, 2014). Relatedly, while liquidity creation by banks stimulates economic growth on average, this is less the case in countries where (innovative) industries rely heavily on intangible assets (Beck, Döttling, Lambert and van Dijk, 2023). After a certain threshold, additional bank lending may even have a *negative* effect on output growth (Beck, Georgadis and Straub, 2014; Arcand, Berkes and Panizza, 2015), for instance, because an increasing proportion of all bank credit gets allocated to consumers rather than producers (Beck, Büyükkarabacak, Rioja and Valev, 2012).

As economies grow, this recent evidence on the changing role of banks and stock markets raises the question of whether some sources of finance may be better suited to funding green investments than others. If this were the case, then a country's financial structure could shape the carbon intensity of its development path. De Haas and Popov (2023) empirically address this question using a 48-country, 16-industry, 26-year panel data set. They show that industries that pollute more for technological reasons emit relatively less carbon dioxide where and when domestic stock markets expand faster than domestic banking sectors.

The main channel underpinning this result is that stock markets facilitate the development of cleaner technologies by polluting industries. The authors show that deeper stock markets are associated with an increase in green patenting in carbon-intensive industries. This suggests that, relative to banks, stock markets are better suited to fund innovative green technologies and to force firms' management to reduce carbon emissions. A growing body of evidence confirms that investors increasingly take climate risks and carbon emissions into account (Choi, Gao and Jiang, 2020; Krueger, Sautner and Starks, 2020; Azar, Duro, Kadach and Ormazabal. 2021; and Bolton and Kacperczyk, 2021).

2.2 Banks, climate-change mitigation, and green growth

Even if stock markets outperform banks in funding green technological innovation, and even if equity investors do a better job than bankers in requiring firms to cut carbon emissions, the reality is that, in many countries (including in the eurozone and most developing countries), financial systems remain heavily bank-based. A recent literature therefore investigates (i) why banks may be unwilling to finance the development of new green technologies, and (ii) whether banks at least finance the diffusion of such technologies once they have been developed.

2.2.1 Banks and the green technological frontier

The steep decline in carbon emissions needed to achieve net zero involves the development and subsequent diffusion of new low-carbon technologies. Much of this green innovation is radical rather than incremental in the sense that it will disrupt industries. Precisely for this reason, banks may be unwilling to finance such breakthrough innovations.[4] Minetti (2011) formalised this idea through a model of lenders who acquire information on firms' productive assets during long-term lending relationships. This proprietary information allows them to recover value if a borrower defaults and assets need to be repossessed and redeployed. The model demonstrates how such banks refuse to finance new technologies if this erodes the value of their inside information about the legacy technology. Using Italian firm-level data, Minetti (2011) shows that, in line with his model predictions, banks with informationally intensive lending relationships foster incremental technological progress but hinder the introduction of radically new technologies. That is, they are technologically conservative.

More recently, Degryse, Roukny, and Tielens (2022) build on this idea by developing a model to analyse the impact of a financier's legacy portfolio (dubbed 'asset overhang') on its willingness to fund a new technology that may undermine the value of its existing portfolio. The authors highlight the crucial role of financial market structure. Their model predicts the presence of financiers with limited or no exposure to the negative spillovers of a new disruptive technology will trigger liquidity supply by the *entire* financial system. Only when *all* financiers are exposed to the disruptions caused by a new technology will funding be rationed and technological change slow down.

Using Belgian micro data, the authors show that 'green' corporate innovators that may negatively impact 'brown' firms are indeed less likely to receive bank credit compared with innovators that do not threaten banks' legacy positions. In line with their model, such rationing is absent when at least some banks do not have an asset overhang. An interesting implication

[4] In addition, strict prudential regulation might further dissuade banks from lending to relatively risky projects, such as those involving new and green technologies. Ampudia, Beck and, Popov (2021) find that, after the introduction of the Single Supervisory Mechanism – which involved the centralisation and, arguably, the tightening of bank supervision for large banks in the eurozone – firms borrowing from such banks, especially firms in research and development-intensive and innovation-intensive sectors, reduced their intangible assets.

is then that establishing legacy-free lenders (such as new green banks) may stimulate green innovation because such entrant lenders can 'break the barrier' to technological innovation.[5]

2.2.2 Banks and the diffusion of green technologies

Even if banks are too technologically conservative to fund the *invention* of new low-carbon technologies (that is, unless legacy-free competitors compel them to do so) they may still finance the subsequent *diffusion* of such technologies. Indeed, Schumpeterian growth models predict that, especially in emerging markets, reducing corporate credit constraints can facilitate the absorption of foreign technologies (Aghion, Howitt and Mayer-Foulkes, 2005).

In line with this prediction, several papers find that access to bank credit helps firms adopt new products and technologies (for example, Gorodnichenko and Schnitzer, 2013). Taking a cross-country perspective, Comin and Nanda (2019) show that banking sector depth has historically been an important driver of the speed of commercialisation and diffusion of major new technologies, such as railways and telegraphy. At the national level, Bircan and De Haas (2020) show that, in Russia, deeper local credit markets help firms catch up to the technological frontier by expanding their product offer and adopting new production technologies. For Italy, Herrera and Minetti (2007), and Benfratello, Schiantarelli, and Sembenelli (2008) also find a positive impact of bank credit on technological adoption.

Does bank lending also facilitate the diffusion of *low-carbon* innovations? Here, the paper by Degryse, Roukny, and Tielens (2022) finds that, at least in Belgium, banks not only ration credit to green innovators but also to firms that merely diffuse green technologies (although this rationing effect is four times less than that for original innovators). Several other contributions paint a somewhat more optimistic picture of banks' roles in funding the diffusion of technologies that reduce carbon emissions or other pollution.

Three papers provide indirect evidence in this regard by showing that, when firms gain easier access to bank loans, their local toxic emissions tend to reduce. Levine, Lin, Wang, and Xi (2018) show how positive credit supply shocks in U.S. counties due to local shale-gas

[5] Green banks are often publicly funded and mandated to improve welfare by lending to socially desirable investments, such as new green technologies, to which private banks may initially underprovide credit (Hainz and Hakenes, 2012). Based on this mandate, public banks may be willing to move first while in the process triggering commercial banks to start funding green technologies as well.

discoveries help reduce local air pollution. Likewise, Xu and Kim (2022) find that financial constraints increase the toxic releases of public firms in the U.S. Their evidence suggests that firms trade off pollution abatement costs against potential legal liabilities: the impact of financial constraints on local toxic releases is stronger when regulatory enforcement is weaker. Using data on French manufacturers, Gentet-Raskopf (2022) shows that financial constraints especially discourage firms from investing in pollution *prevention* (which entails relatively high up-front costs) and less so from spending on (cheaper) measures to treat toxic emissions.

Andersen (2016) studies the pollution impact of country-level credit market reforms, namely the introduction of credit bureaus. These bureaus tend to reduce information asymmetries, boost interbank competition and increase bank lending (Pagano and Jappelli, 1993). The author observes pollution-monitoring sites in 37 countries and shows that, once a country establishes a credit bureau, the industrial emission of sulphur dioxide and lead tends to decline.

This triad of papers thus establishes that positive credit supply shocks can loosen firm-level credit constraints and eventually reduce local pollution. Importantly, these papers do *not* observe actual changes in firms' investment in pollution abatement due to better access to credit. Such changes are simply assumed to drive the negative correlation between access to credit and pollutant emissions.

Goetz (2019) moves this literature forward by providing a more complete picture of the causal chain from bank lending to firm investment and, ultimately, local pollution. He finds that U.S. firms that depend on long-term debt financing reduced their toxic emissions when their capital cost declined during the U.S. Maturity Extension Program (an unconventional monetary policy implemented in 2011–2012). The author also shows – using facility-level data on pollution prevention – that cheaper funding allows firms to invest more in capital-intensive measures to reduce emissions.

An important question is whether access to credit not only allows firms to emit fewer locally polluting toxins, but also to invest in low-carbon technology and machinery to reduce globally harmful greenhouse gases. Recent work has begun to address this issue. It bears pointing out that, if the main purpose of low-carbon technology is to reduce greenhouse gas emissions (that is, correcting an environmental externality), then such projects may be low priority for profit-maximising managers and credit availability will matter little. Instead, credit constraints may influence investment in low-carbon technologies if such investments also have a positive effect on firm profitability (that is, increased energy efficiency goes hand in hand with increased overall efficiency), if firm managers follow a broader objective set than just profit maximisation, and/or if managers make green investments in response to or in anticipation of climate regulation.

Two recent papers use Italian data to shed light on whether bank lending enables firms to invest in greener technologies. Accetturo, Barboni, Cascarano, Garcia-Appendini, and Tomasi (2022) use text algorithms to extract information on green investments from the financial statements of Italian small businesses. They combine this information with data from the Italian credit registry and find that a one standard deviation increase in a firm's credit supply raises the likelihood it undertakes a green investment by around two to three percentage points. While these authors provide rigorous evidence on the effect of credit availability on green investments, their text-based method does not distinguish between different types of green investments, nor do they investigate the ultimate effect of bank-funded green investments on carbon emissions.

Apicella and Fabiani (2023) also use Italian credit registry data, but exploit variation across firms in their exposure to surging carbon prices in the EU Emissions Trading System (EU-ETS). Following De Jonghe, Muliers, and Schepens (2020), they measure ETS exposure as the difference between a firm's total emissions and its quota of free permits. The authors find that firms more exposed to higher carbon prices ramp up their credit demand and expand their production. They do so without emitting more carbon, implying a lower emission intensity. Importantly, this channel is limited to firms making green investments (identified using the methodology by Accetturo et al., 2022). Apicella and Fabiani (2023) therefore show how, in the presence of meaningful carbon pricing, credit access can enable firms to invest in greener technology and reduce the carbon intensity of production.

Carbon pricing may, however, backfire when firms are credit constrained *and* able to shift carbon-intensive activities elsewhere. Ben-David, Jang, Kleimeier, and Viehs (2021) show that firms headquartered in countries with strict environmental policies perform their polluting activities abroad, in countries with weaker policies. In a similar vein, Bartram, Hou, and Kim (2022) study the introduction of California's Cap-and-Trade Program and show that financially constrained firms shift emissions and output from California to plants in other states.[6]

[6] Relatedly, Berg, Ma, and Streitz (2023) show how, after the Paris Agreement, large corporate emitters under investor pressure to reduce their carbon footprints did so mainly by divesting polluting assets to firms that were less closely scrutinised.

Moreover, such constrained firms increase their *overall* emissions by about 20 per cent in response to surging regulatory costs. Unconstrained firms do not evade climate regulation, as their access to external finance allows them to comply with local regulations. I return to the topic of carbon arbitrage in Section 4.2 when discussing such cross-border arbitrage by banks rather than firms.

Lastly, De Haas, Martin, Muûls, and Schweiger (2023) use survey data from Eastern Europe to analyse which types of green investments benefit from reduced credit constraints. The authors distinguish between machinery and vehicle upgrades, on the one hand, and measures to explicitly reduce emissions and increase energy efficiency – such as the on-site generation of green energy and measures to control air pollution – on the other. They show that credit constraints matter primarily for investments in greener technologies embedded in new vintages of (collateralisable) vehicles or machinery. For investments whose main goal is to abate greenhouse gas and other emissions or to reduce other forms of environmental pollution, credit constraints play a lesser role. For these green investments, what matters instead is the quality of the firm's green management.

In sum, a growing body of evidence – based on observational data and, in some cases, exploiting quasi-experimental settings – indicates that access to bank credit can help firms invest in cleaner production technologies that reduce toxic pollution and carbon emissions (provided regulatory oversight is effective and carbon pricing cannot easily be bypassed).

Future research could tighten identification within this area of study by using randomised controlled trials (RCTs), for instance, to assess how bank credit can effectively support the integration of energy efficiency measures and low-carbon technologies by firms. Recent work by Berkouwer and Dean (2022) has paved the way for such an approach in the context of the adoption of more energy-efficient technologies by *households*. Based on an RCT in Kenya, the authors find that credit constraints prevent households from adopting durable goods (charcoal cookstoves) that are more energy efficient *and* have significant private benefits.

3. The impact of climate change on banks

3.1 Transition risk

A distinction can be made between the physical risks of climate change (discussed in Section 3.2) and transition risks.[7] The latter reflect uncertainty about the speed and scope with which climate policies and regulations are introduced, low-carbon technological innovation proceeds, and public attitudes change. For example, the sudden introduction of a carbon tax can generate transition risk for banks heavily exposed to carbon-intensive industries. Likewise, disruptive green innovation can quickly shift the relative prices of carbon-intensive and low-carbon technologies, and hence the value of firms using such technologies.

A recent literature investigates whether banks have begun to take transition risk into account when pricing loans. This work builds on contributions showing that banks charge higher interest rates to firms that display little corporate social responsibility (Goss and Roberts, 2011) or that raise environmental concerns. Chava (2014) shows that firms responsible for hazardous waste or toxic pollutants experience more expensive external capital, both debt and equity. In a similar vein, firms that experience adverse environmental incidents, such as oil spills or the involvement in deforestation projects, see the cost of bank credit go up (Anginer, Hrazdil, Li, and Zhang, 2020). More recently, Chang, Fu, Li, Tam, and Wong (2023) find that U.S. firms with larger environmental liabilities (toxic waste) are less leveraged overall and have a lower proportion of bank debt in total debt. Similar evidence exists for bond pricing. Seltzer, Starks, and Zhu (2022) show that U.S. firms with a poor environmental profile have a lower credit rating and a higher bond spread, especially in states with stricter environmental regulation.

However, not all banks respond similarly to negative revelations about firms' environmental performance. Gao (2023) shows that it is mainly green banks (those lending more to firms with good environmental performance) that price in environmental risks (the author focuses specifically on risks associated with the Deepwater Horizon oil spill). In contrast, brown banks respond by issuing loans with shorter maturities and by demanding more collateral.

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[7] Litigation risk is a third type of climate risk that intersects with both physical and transition risks (NGFS, 2023). For example, litigation may arise about who is responsible for damage caused by extreme weather events attributed to climate change (physical risk) or when a bank fails to accurately disclose how a new carbon-pricing mechanism will affect its credit and securities portfolios (transition risk).

An important recent line of inquiry asks whether the Paris Agreement acted as an environmental 'wake-up call': a structural break in banks' willingness to lend to carbon-intensive firms. Various studies provide empirical evidence showing that banks have begun to price in at least part of the transition to a low-carbon global economy.[8] Delis, de Greiff, Iosifidi, and Ongena (2023) use data from the global syndicated loan market to address this question. The authors compare the pricing (all-in drawn spread) of syndicated loans to non-fossil fuel firms with fossil fuel firms while differentiating the latter according to their country-specific climate policy exposures. A key result is that, post-COP21, a one standard deviation increase in a fossil firm's climate policy exposure implies a pricing increase of around 16 basis points for a fossil firm with average carbon reserves compared with a non-fossil fuel firm. This uptick in loan pricing is slightly more pronounced for green banks, here defined as those that participate in the United Nations Environment Programme Finance Initiative (UNEP FI).[9]

The results of Delis et al. (2023) are confirmed for a broader set of industries by Ehlers, Packer, and de Greiff (2022). They also use data from the syndicated loan market and show that, after the Paris Agreement, not only are firms with fossil fuel reserves at risk of stranding, but also a wider group of carbon-intensive industries began to pay higher interest rates.[10] Importantly, they show that only carbon emissions directly caused by the firm (so-called scope 1 emissions) are priced, and not the overall carbon footprint including indirect emissions. Reghezza, Altunbas, Marques-Ibanez, d'Acri, and Spaggiari (2022) address the same issue using confidential data on eurozone banks' large loan exposures, matched with carbon emissions data. In line with papers using syndicated loan data, the authors find that European banks reallocated a smaller share of total credit to relatively polluting firms after the Paris Agreement.

Degryse, Goncharenko, Theunisz, and Vadas (2023) differentiate not only banks but also their borrowers according to their greenness. Like Delis et al. (2023), they define green banks as those participating in UNEP FI. On the firm side, they consider firms to be green if they

[8] In a similar vein, Ilhan, Sautner, and Vilkov (2021) compare high-emissions industries before and after the Paris Agreement and show that option markets are pricing in the uncertainty that surrounds future climates policies.

[9] Fatica, Panzica, and Rancan (2021) show that United Nations Environment Programme Finance Initiative signatory banks can issue green bonds at a premium because they can better signal their green lending credentials.

[10] Stranded assets include hydrocarbon resources that can no longer be burned, as well as fossil fuel infrastructure (such as pipelines) that end up as liabilities before the end of their anticipated economic lifetime (for example, McGlade and Ekins, 2015).

voluntarily report to the CDP,[11] formerly known as the Carbon Disclosure Project. Again, using syndicated loan data, the authors find that green firms borrow at lower rates, especially when the lender is also classified as green. This again only holds after the Paris Agreement. The authors interpret their result as indicating that, following this agreement, green banks – with superior ability to differentiate between 'brown' and 'green' borrowers – began to engage in third-degree price discrimination based on firms' greenness. Degryse et al. (2023)'s finding of 'green homophily' echoes the earlier results of Hauptmann (2018), who shows that firms with strong sustainability scores can borrow at lower spreads when their bank also boasts a strong sustainability performance. Relatedly, Houston and Shan (2022) show that banks are more likely to lend to borrowers with ESG profiles akin to their own. In contrast, the aforementioned study by Ehlers et al. (2022) does not find that green banks price carbon risk differently than other banks.

The increased 'post-Paris' pricing of transition risk in the global market for (large) syndicated loans may not necessarily generalise to other credit markets. Further research in other settings seems warranted. An interesting contribution in this regard is Ivanov, Kruttli, and Watagula (2023). The authors show that high-emissions firms most affected by the introduction of California's Cap-and-Trade emissions scheme faced higher interest rates, shorter loan maturities, and less access to term loans from banks. Moreover, the authors document more participation of shadow banks in lending syndicates to firms with higher transition risk.

Even with the pricing of bank loans becoming more sensitive to borrowers' (disclosed) carbon assets, Beyene, Delis, De Greiff, and Ongena (2021) show that many (large) banks continue to lend to fossil fuel firms at spreads that underprice the risk of stranded assets when compared with the pricing of bonds issued by similar firms. As a result of this pricing difference, firms more exposed to stringent climate policy (measured by their carbon reserves multiplied by the country's climate policy stringency) are gradually switching from bond to bank funding. The authors find no break in this bond-to-loan substitution or in bank pricing after the Paris Agreement. This could reflect that the firms in their data set are relatively financially unconstrained (as they have access to both the syndicated loan and the bond market).

[11] In this context, it is worth pointing out that any firm can disclose its activities through CDP regardless of whether it is a 'green' or 'brown' firm. Indeed, due to increased pressure from regulators as well as (some) investors, increasing numbers of carbon-intensive firms may report via CDP and similar disclosure frameworks. This means that, over time, CDP participation may have become a less useful proxy for whether a firm is green or not.

Firms themselves may also influence the price of bank credit by voluntarily disclosing information about their carbon intensity. Kleimeier and Viehs (2021) analyse the effect of firms providing non-financial information on their cost of credit. Using comprehensive CDP data on carbon emissions, they find that publicly listed firms that voluntarily disclose their carbon emissions are charged lower loan spreads than non-disclosing firms. Moreover, firms disclosing higher carbon emissions face a higher cost of credit than firms with low emissions.

Kacperczyk and Peydró (2022) also differentiate between brown and green banks, defining the latter as banks that signed up to the Science Based Targets Initiative (SBTi). SBTi signatories commit to a science-based path to reduce the carbon intensity of their assets.[12] The authors treat these signings as bank-level shocks that may affect the supply of credit to existing corporate clients. Among a global firm sample, they find that affected firms with high scope 1 emissions experience a significant decline in *total* credit after their bank commits to decarbonise. This implies that high-emission firms not only experience a negative credit supply shock from existing lenders, but also that they cannot substitute this decline one for one with credit from other sources. While affected firms deleverage and shrink their investments and asset bases, they also do not cut back emissions, at least not in the short term. What changes is that affected firms boost their ESG scores through better communication about environmental opportunities, suggesting they may engage in some greenwashing (see also Section 4.2.2).

The findings of Kacperczyk and Peydró (2022) are sobering and give pause. While adherence to environmental commitments may help to decarbonise banks' loan portfolios, there is little evidence of real change among affected firms. Their results are clearly at odds with environmentally conscious banks lending more to brown firms to finance low-carbon technology. Instead, banks simply reduce some of their lending to these polluters. For changes in bank lending to have an impact on the carbon intensity of firms, other conditions may also need to be met, such as the presence of carbon pricing (cf. Apicella and Fabiani, 2023) or better green management at firms (cf. De Haas, Muûls, Martin, and Schweiger, 2023).

The aforementioned papers on (green) banks' credit repricing and reallocation in the face of more salient transition risks are based on syndicated loan data and hence skewed towards larger firms. This begs the question of whether these findings apply to smaller firms as well. Recent evidence from France suggests this may not be the case. Mésonnier (2022) investigates whether

[12] Targets are considered science-based if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to 1.5°C above pre-industrial levels.

French banks reallocated credit from more to less carbon-intensive sectors over the period 2010–2017. He finds that banks with stronger self-reported climate commitments slow their credit supply to large – but not to small and medium-sized firms – in carbon-intensive industries.

A useful direction for future research, possibly involving lab-in-the-field experiments, is to prise open the black box of the green bank. That is, who exactly is responsible *within* banks for making green or brown lending decisions? An interesting contribution on this is that of Bu, Kelharju, Liao, and Ongena (2023) who explore data on loan applications and banker preferences from a Chinese bank. The authors find that loan officers provide more favourable recommendations for green firms when they adhere to strong green values themselves. However, a minority of environmentally sceptical bankers counteract this trend, including by trying to downgrade favourable recommendations by junior 'green' colleagues.

To recap, empirical banking research shows that since the Paris Agreement, banks – especially those with stronger green credentials – have started to somewhat reduce their credit supply to (and increase the pricing of) loans to carbon-intensive firms with higher transition risks. The climate impact of these adjustments may be limited because banks still appear to underprice transition risks relative to bond markets because non-bank lenders may partly replace bank lending to carbon-intensive firms and because, even when overall credit to carbon-intensive firms goes down, such firms do not necessarily cut emissions back by much.

3.2 *Physical risk*

Global warming increases the frequency and intensity of hurricanes, floods, droughts, and heatwaves (IPCC, 2021). Moreover, sea levels are slowly rising due to the thermal expansion of oceans and the melting of glaciers and ice sheets. These phenomena generate significant uncertainty ('physical risk') for banks. Think, for example, of mortgaged property in low-elevation coastal areas or agricultural loans in regions that are increasingly prone to flooding or prolonged droughts. Natural disasters amplified by climate change can also cause significant disruptions to non-agricultural production: firms exposed to extreme temperatures experience lower earnings (Addoum, Ng, and Ortiz-Bobea, 2023; Pankratz, Bauer, and Derwall, 2023). This section reviews the rapidly growing literature on how physical risks have begun to influence banks' balance sheets and lending activities.

3.2.1 General natural disasters

Several contributions analyse whether disaster exposure has a meaningful impact on overall bank risk and financial fragility. This literature tends to conclude that these impacts have so far been limited, at least in high-income countries. For the U.S., Noth and Schüwer (2023) show that weather-related natural disasters increase the riskiness of affected banks: non-performing loans and default probabilities go up, while banks' z-scores and asset returns go down. However, these effects are generally negligible and short-lived. Similarly, Blickle, Hamerling, and Morgan (2021) find that weather disasters have insignificant or only minor effects on bank performance in the U.S. One reason is that, as discussed below, disasters often increase loan demand and boost bank profits. This U.S. evidence lines up well with international results by Klomp (2014). Using data on more than 160 countries, he shows that, while natural disasters can reduce a bank's distance to default, such negative impacts are mostly concentrated in less developed countries with relatively weak financial regulation and supervision (see also Nie, Regelink, and Wang (2023) on this account).

A related strand of the literature analyses how the presence of different types of banks affects the impact of natural disasters on affected communities. Cortés (2014) defines natural disasters quite broadly by considering, for example, earthquakes, coastal damage, landslides, avalanches, hurricanes, and wildfires. The author analyses how U.S. counties struck by severe disasters fare depending on whether they are served mainly by local banks or by those belonging to a bank holding. She finds that, in areas served mainly by local banks, job creation and job retention among young and small firms are higher following a natural disaster. These counties also recover more quickly in terms of economic growth. Cortés and Strahan (2017) dig deeper into the role of geographically diversified (multi-market) banks in the U.S. They show that such banks reallocate capital out of unaffected counties towards disaster-affected counties where local credit demand rises (for example to finance reconstruction). For the most part, multi-market banks move money away from areas in which they do not operate branches, thus shielding their core markets. The ability of local bank branches to continue lending in the wake of a natural disaster not only depends on their access to an internal capital market, but also on their ability to attract additional local deposits. Dlugosz, Gam, Gopalan, and Skrastins (2022) document that bank branches that are authorised to set their own deposit rates increase these rates following a disaster to raise additional local funding for local mortgage lending.

A recent contribution by Meisenzahl (2023) investigates whether banks became not only more sensitive to transition risks after the Paris Agreement (as documented in Section 3.1) but also to physical risks. The author uses supervisory data on large U.S. banks, and finds that banks significantly reduced lending to counties more impacted by climate change – using flood and wildfire risk as proxies – around 2015. Banks mostly curtailed lending to riskier borrowers while *expanding* credit to low-risk borrowers in areas impacted by climate change.

Banks may not only adjust their lending to affected borrowers and areas, but also to similar as yet unaffected clients at risk. In line with this idea, Correa, He, Herpfer, and Lel (2022) analyse how natural disasters affect the (syndicated) loan pricing of U.S. corporate borrowers that are, given their geographical footprint, indirectly at risk of future extreme weather events. They find that, following natural disasters, banks start to charge higher spreads on loans to such exposed borrowers, although this pricing effect wears off over time. Related results are found by Ginglinger and Moreau (2023) for France. The authors document that again, in the wake of the Paris Agreement, French firms exposed to greater physical climate risks reduced their leverage due to both lower credit demand and supply.

3.2.2 Hurricanes and flooding

Warming oceans have fuelled the intensity of hurricanes over the past decades. Several papers assess the impact of hurricanes on bank lending, exploiting the fact that the precise timing and paths of hurricanes are unpredictable. Physical damage and economic impacts are often concentrated locally, with sharp delineations between affected and unaffected areas. Research shows that, at least in the U.S., hurricanes are followed by significant relative price declines for residential (Gibson and Mullins, 2020) and commercial real estate (Addoum, Eichholtz, Steiner, and Yönder, 2023) in flood zones. These price effects are persistent (Ortega and Taspinar, 2018) and therefore do not just reflect short-term adjustments due to immediate physical damage.

A related strand of literature assesses how banks adjust their lending in response to hurricanes. Chavaz (2016) exploits the variation in local hurricane exposure during the 2005 U.S. hurricane season to estimate the impact of bank-level diversification on lending during post-hurricane recoveries. Echoing the results of Cortés (2014), he finds that, compared to geographically diversified banks, local banks originate a higher share of new mortgage and small business loans in affected areas. These banks subsequently also sell more of these mortgages in the secondary market. This suggests that local banks, leveraging local knowledge and proprietary information, specialise in loan origination but then transfer these loans to (more diversified) financial institutions that can better absorb the risks of significant natural disasters.

Relatedly, Gallagher and Hartley (2017) study New Orleans neighbourhoods affected by 2015 Hurricane Katrina. They find that, in areas where more banks are local, total household mortgage debt declined less as local lenders were more likely to make new loans and to continue existing lending relationships. Billings, Gallagher, and Ricketts (2022) provide a more granular picture by focusing on the role of flood insurance following 2017 Hurricane Harvey. Mortgage lenders typically only require borrowers to purchase flood insurance if the property is situated within the 100-year floodplain. The authors find that, outside of this area, residents with low repayment ability face an increase in their debt delinquency share, whereas residents with high repayment ability see no negative credit consequences. In contrast, no significant effect of flooding on credit outcomes occurs within the floodplain, suggesting that flood insurance moderated the impact of flooding across the credit distribution.

Schüwer, Lambert, and Noth (2019) focus on Hurricane Katrina and two other hurricanes that struck the Gulf Coast of the U.S. in the same year. They find that affected counties with a relatively large share of independent banks (that are not part of a bank holding company) and relatively high average bank capital ratios show stronger post-hurricane income and employment growth. Independent banks in disaster areas increase their risk-based capital after hurricanes, possibly by ramping up loan sales and securitisation, thus allowing them to continue lending to local firms. Relatedly, Ouazad and Kahn (2022) show that, in the aftermath of natural disasters, lenders are more likely to approve mortgages they can securitise, thus offloading climate risk to other parties, including government-sponsored enterprises Fannie Mae and Freddie Mac.

Duqi, McGowan, Onali, and Torluccio (2021) take a different perspective and show that, in the aftermath of hurricanes, economic growth recovers faster in U.S. counties with less-competitive banking sectors. The effect of market power on local recoveries is most noticeable among profitable and well-capitalised banks. This suggests that these banks can deploy the retained earnings they accumulate during normal times to bolster the local economy following a disaster. They do so by increasing the supply of real estate credit, and especially by refinancing existing mortgages. Some local market power can thus allow banks to support struggling borrowers and avert unnecessary foreclosures.

Other contributions investigate the role of banks in the aftermath of large-scale flooding outside of the U.S. Koetter, Noth, and Rehbein (2020) find that German firms benefited when banks increased their lending to regions affected by heavy flooding in 2013. Rehbein and Ongena (2022) build on this work by comparing firms in *non*-flooded areas that are connected to disaster-exposed banks with those in the same regions that are unconnected to such banks. Using this design, the authors find that banks reduce lending in non-flooded areas in order to provide loans to flood-affected firms. This spatial reallocation of credit flows results in lower economic growth and employment in areas unaffected by the flooding itself. These spillovers are weaker for better-capitalised banks. These findings confirm those from the U.S., such as Chavaz (2016), and Cortés and Strahan (2017), by showing that banks reallocate funds towards disaster-affected areas while decreasing credit to non-affected areas.

Over the coming decades, much of the impact of climate change will be felt in emerging markets and developing countries rather than in high-income countries (Stern, 2007). More work is needed to explore how banks in poorer parts of the world respond to physical climate risks. It is not obvious that results derived from analysing bank behaviour in richer countries are transferable to developing countries. For example, the ability and willingness of Western banks to reallocate funding towards flooded areas may depend on these banks being well-capitalised, on de facto risk-sharing arrangements with the government in the form of crisis insurance and disaster aid, and on the presence of well-functioning private insurance markets.[13] In developing countries – with weaker banks, larger agricultural sectors, and fewer social safety nets – banks may not be willing or able to increase lending in the wake of a natural disaster and, instead, may even be tempted to move money out of disaster areas.

A first piece of evidence on this account comes from Abedifar, Kashizadeh, and Ongena (2022), who study the impact of large-scale flooding in Iran on local smallholder farms. The authors show that the presence of local bank branches helped to bridge the gap between the disaster occurring and governmental financial assistance being received. Local branches increased their recovery lending immediately after the flooding, and did so especially to farmers with stronger pre-existing relationships with their banks. These findings indicate that, especially in agrarian societies with weaker formal social safety nets, relationship banks may rise to the occasion in the immediate aftermath of catastrophic weather.

[13] See Garmaise and Moskowitz (2009) on how inefficient disaster insurance can distort bank lending.

To recap, recent work on banks' operational responses to natural disasters, flooding in particular, has uncovered two important patterns. First, local (relationship) lenders tend to be relatively stable funding sources in disaster-hit areas compared to geographically diversified banks, even though the latter often reallocate some funding towards affected areas.[14] Second, the stabilising influence of local banks may be especially strong for low-risk borrowers when these banks can offload part of the disaster-related credit risk through loan sales or securitisation and if they hold some local market power.

3.2.3 Sea level rise

Rising sea levels have started to affect vulnerable coasts across the world. While developing countries are likely to be impacted the most – not only low-lying small island states, but also populous countries such as Bangladesh, Vietnam, and Egypt – most finance research has centred on the repercussions for real estate pricing and credit markets in the U.S. This partly reflects the granularity of data needed to arrive at credible estimates of the impact of rising sea levels. Beach and coastal properties that are more exposed to sea level rise (with possible negative price effects) typically also have a higher amenity value (positive price effect). Disentangling the two is a key empirical challenge in this literature.

Giglio, Maggiori, Rao, Stroebel, and Weber (2021) focus on U.S. properties expected to be flooded if sea levels rise by at least six feet. Even within small geographic areas, differences in elevation create substantial variations across properties in terms of such flood risk. While properties in flood zones generally trade at a premium compared with otherwise similar properties (probably because of positive amenities such as beach access), this premium declines at times of heightened attention to climate risk, such as after hurricanes.

Bernstein, Gustafson, and Lewis (2019) also estimate the relationship between sea level rise and house prices. They find that coastal homes exposed to sea level rises sell for approximately 7 per cent less than equivalent houses situated equidistantly from the beach (with distance to the beach again being an important and positively valued amenity). Interestingly, the discount is mostly driven by properties unlikely to be inundated for at least half a century, suggesting that investors are already pricing in the longer-term physical consequences of sea level rise.

[14] This finding mirrors that of a related strand of the literature showing that relationship banks tend to be relatively stable lenders during financial crises. See, for example, Sette and Gobbi (2015); Bolton, Freixas, Gambacorta, and Mistrulli (2016); and Beck, Degryse, De Haas, and Van Horen (2018).

Murfin and Spiegel (2020) separate the impact of sea level rise from the hedonic value of property elevation by using the rate of land subsidence and rebound as a source of variation. In contrast to Bernstein, Gustafson, and Lewis (2019), their findings indicate more limited price effects. This could reflect that expectations about future climate change adaptation have changed or point to spatial differences in how much local populations believe that climate change is, in fact, real (Bakkensen and Barrage, 2022; Baldauf, Garlappi, and Yannelis, 2020).

Finally, Nguyen, Ongena, Qi, and Sila (2022) analyse the impact of sea level rise on U.S. mortgage markets. They show that the financing costs of houses that are exposed more to sea level rise experience higher interest rate spreads. In line with Bernstein, Gustafson, and Lewis (2019), these results indicate that, even though some of the physical risks may only materialise in the distant future, credit markets – at least those in high-income countries with relatively developed banking sectors – have already started to price them in.

3.2.4 Heatwaves, droughts, and wildfires

Evaporation intensifies and moisture is lost from soil and vegetation as global temperatures rise. Changing precipitation patterns also result in prolonged dry spells in some regions. This can intensify droughts and create conditions conducive to wildfires. Several recent papers analyse how bank lending is responding to these changing climatic conditions and how the availability of credit can help communities cope with prolonged droughts.

Similar to the studies on the pricing of the physical risks of flooding and sea level rise, evidence is emerging that the physical risks of droughts and wildfires are gradually being priced into housing values (Garnache and Guilfoos, 2019) and bank loans (Javadi and Al Masum, 2021). In terms of banks' lending responses, Islam and Singh (2023) show that larger, geographically diversified banks reduce small-farm lending more (relative to their undiversified counterparts) in response to abnormally hot temperatures in U.S. counties. In line with Cortés and Strahan (2017), the authors find that banks do not reduce credit flows indiscriminately but instead shield their core markets in which they operate branches.

Well-functioning credit markets can also shape society's long-term adaptation to droughts. Rajan and Ramcharan (2023) illustrate this by focusing on the protracted drought that plagued the U.S. in the 1950s. They show how bank lending, net immigration, and population growth declined sharply in drought-exposed areas where pre-existing credit markets were shallow (the authors use plausibly exogenous variation in the local supply of credit based on historical bankentry regulations). In contrast, agricultural investment and long-term productivity increased more in drought-exposed areas where access to credit was easier.

4. Sustainable banking: Selected topics

4.1 Banks and climate change adaptation

Compared with the thriving literature on banks and climate change mitigation, less attention has been paid to the role of banks in climate change adaptation: the ability of economies to remain functional in the face of global warming. The aforementioned paper by Rajan and Ramcharan (2023) on the 1950s drought in the U.S. suggests that well-functioning credit markets can help agricultural communities to become more climate resilient. Recent work in environmental economics provides some contemporary evidence along these lines, highlighting how accessible credit allows crop and livestock farmers adapt to a changing climate.

In the case of agriculture, adaptation includes transitioning to alternative crops, implementing soil conservation methods, adjusting planting schedules, and upgrading irrigation systems.[15] In the case of animal husbandry, credit can be applied to make farming more resilient by diversifying livestock feed, changing animal breeds, and moving animals to other sites (Silvestri, Bryan, Ringler, Herrero, and Okoba, 2012; and Da Mata and Resende, 2020)

As yet, little empirical research has been conducted on the relationship between credit availability and climate adaptation outside the context of agriculture in the developing world. An exception is Custódio, Ferreira, Garcia-Appendini, and Lam (2022), who show that the production of financially constrained firms in the U.S. is less resilient to changing temperatures because these firms cannot finance and implement climate adaptation measures.

4.2 Banks, carbon arbitrage, and greenwashing

Section 3.1 discussed how global banks have begun to price some of the transition risks related to climate change and to reallocate part of their syndicated lending from brown to green sectors.

[15] Bryan, Deressa, Ghetibouo, and Ringler (2009) and Deressa, Hassan, and Ringler (2011) provide such evidence for rural crop farmers in Ethiopia and South Africa, respectively.

At the same time, it bears reminding that the world's 60 largest banks provided about USD 5.5 trillion in fossil fuel financing in the seven years since the adoption of the Paris Agreement (OCI, 2023). This suggests that, in the aggregate, global banks' credit reallocation away from carbon-intensive industries has not been very significant. Two topics are worth discussing in this regard are banks' active engagement in carbon arbitrage, and their tendency to exaggerate their green credentials (greenwashing).

4.2.1 Carbon arbitrage

Despite climate change being a global challenge that transcends national borders, climate policies mostly remain a domestic affair.[16] Recent evidence suggests that cross-border arbitrage by banks may have undermined the effectiveness of such national carbon-pricing regimes. Laeven and Popov (2023) use syndicated loan data to study the cross-border reallocation of fossil fuel lending by internationally active banks in response to changes in the domestic cost of carbon. They find that the introduction of a carbon tax increases domestic banks' lending to fossil fuel companies (and other carbon-intensive sectors such as metallurgy and cement) abroad, especially in countries without a carbon tax. This effect is most pronounced for banks with large prior exposures to the hydrocarbon sector. The authors use host country *x* year dummies to show that their results are not driven by changes in the foreign demand for credit.

In a similar vein, Benincasa, Kabas, and Ongena (2021) find that banks increase cross-border lending in response to stricter climate policy stringency (as measured by the Climate Change Performance Index) in their home countries. In line with banks using cross-border lending to arbitrage climate regulation, this increase in cross-border lending occurs only if banks' home countries have a more stringent climate policy compared to that of their borrowers' countries. Compared with Laeven and Popov (2023), this paper controls more tightly for demand by including borrower *x* year fixed effects (under the standard assumption that loan demand is constant across lenders) or syndicated loan fixed effects. At the same time, the authors also show that the increase in higher lender shares due to stricter home regulation within syndicates is not offset by a reduction (at a higher aggregation level) by fewer loans to foreign CO_2-

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[16] Exceptions include the current ETS and its future Carbon Border Adjustment Mechanism, which will take full effect in 2026.

intensive firms. When they aggregate their loan-level data up to lender level, they find higher total cross-border flows as well.

Another way to move transition risk is by securitising loans to less-regulated entities. Banks indeed use corporate loan securitisation to shift climate transition risk to less-regulated shadow banking entities. This behaviour can undermine the effectiveness of bank climate strategies, especially when securitisation enables banks to offer lower-interest loans to carbon-intensive firms. When carbon risk is not fully priced, firms face fewer incentives to reduce their carbon footprint. Mueller, Nguyen, and Nguyen (2023) document that banks indeed appear to price transition risk less if they can securitise loans to high-carbon firms.

4.2.2 Greenwashing

Banks that face public or regulatory pressure to decarbonise their activities may exaggerate the extent to which they make meaningful changes to their asset portfolios. Giannetti, Jasova, Loumioti, and Mendicino (2023) provide evidence for such strategic behaviour, which is sometimes called greenwashing. The authors combine internationally harmonised data on lending by eurozone banks with measures of how much these banks stress environmental goals in their communication to investors and in their environmental sustainability profiles. Strikingly, banks that portray themselves more forcefully as being environmentally conscious, lend *more* to carbon-intensive industries. This holds especially true for lending to smaller firms (which is less easily observable to outsiders).[17] Importantly, the authors find no evidence that these carbon-intensive firms use this credit to invest in cleaner production methods.

In a related paper, Basu et al. (2022) show that banks with high environmental, social, and governance (ESG) ratings grant fewer mortgages in poor neighbourhoods relative to low-ESG banks. This can be interpreted as evidence of what the authors call 'social washing': banks using ESG rhetoric without increasing their exposure to disadvantaged communities. Importantly, the authors find no difference in mortgage default rates between high- and low-ESG banks. This suggests that their findings do not merely reflect differences between both types of banks in the quality of their screening.

[17] This echoes the results of Mésonnier (2022), who shows that French banks with strong self-reported climate commitments reduced credit to large but not to small and medium-sized firms in carbon-intensive industries.

One way to prevent banks from engaging in green- or social washing is to implement mandatory, standardised, and verifiable disclosure of the environmental and climate profile of banks' borrowers. Mésonnier and Nguyen (2021) investigate the impact of mandatory climate disclosure by financial institutions on their funding of carbon-intensive industries. They study what happened when France introduced a law in 2016 that requires insurers, pension funds, and asset management firms – but not banks – to report on both their climate-related exposure and climate change mitigation policies. The authors show that investors subject to the new disclosure requirements curtailed their financing of fossil energy companies relative to investors in the control group (which includes banks).

4.3 Green regulation, supervision, and guidelines

4.3.1 Green regulation and supervision

In addition to compelling banks to disclose the emission intensity of their borrowers more credibly, supervisors could also recalibrate capital requirements to punish brown lending and incentivise green lending. Suggestions have been submitted to adjust capital requirements by making the weighting factor for risk-weighted assets contingent on the carbon intensity of assets. This can either be achieved through a so-called 'green supporting factor' or a 'brown penalising factor'. The former lowers capital requirements to encourage lending to green sectors, while the latter requires banks to hold more capital for loans to brown sectors.

Although initial policy proposals, such as those by the European Commission, concentrated on green supporting factors, this approach could undermine financial stability by easing regulatory capital adequacy requirements too greatly (Dafermos and Nikolaidi, 2021). Lamperti, Bosetti, Roventini, Tavoni, and Treibich (2021) stress that, while green capital requirements can help reduce carbon emissions, the implications for overall financial stability are unclear. Others have therefore focused on a brown penalising factor for carbon-intensive assets. This would increase banks' capacity to absorb transition risks while, at the same time, discourage further investment in such assets (Boot and Schoenmaker, 2018). Yet, Oehmke and Opp (2022) show theoretically that imposing higher capital requirements on brown (high-emissions) firms may, at the margin, crowd out lending to green borrowers. While this course of action may still be optimal for a prudential regulator mainly concerned about climate-related credit risks, such a policy will not necessarily bring down carbon emissions. One reason is that carbon-intensive industries may attract funding from non-bank sources.[18] The authors therefore conclude that the direct pricing of carbon externalities through, for example, a carbon tax is a more effective way to reduce emissions. Yet, they underline that capital requirements can play a useful indirect role. By ensuring banks have adequate buffers to absorb the losses a carbon tax may entail (for instance, due to stranded assets), green capital requirements may make it more likely politicians will introduce such a tax in the first place.

In addition, concerns have been raised that differentiating between green supporting and brown penalising loans by industry may be too blunt since firms may engage in a variety of activities whose carbon intensity may differ. Moreover, a borrower may use a loan either for expanding polluting activities or for reducing the carbon intensity of that same activity, thus making it difficult to distinguish between green and brown loans in practice. Overall, it seems fair to say that no clear consensus has emerged on the desirability of either green supporting or brown penalising factors to redirect investment towards low-carbon sectors.

Some empirical insights on this matter have recently emerged from Brazil in a study by Miguel, Pedraza, and Ruiz-Ortega (2022). Brazil mandated banks to factor environmental risks into their capital assessments. This policy resembles a brown punitive element in the sense that it forces banks to allocate sufficient internal capital to cover the environmental exposure of their portfolios. The authors show that the policy prompted large banks to shift their lending away from exposed sectors. Yet, this credit reallocation only minimally impacted the carbon emissions of these sectors as smaller banks stepped in and expanded their lending. This resembles the substitution effects of which Oehmke and Opp (2022) warn.

4.3.2 Green credit guidelines

In addition to stricter environmental disclosures by banks and/or adjusting capital adequacy requirements, governments can also persuade banks more directly to shift their lending in a low-carbon direction. China has followed such an interventionist approach when it introduced its Green Credit Guidelines in 2012. These guidelines encouraged banks to develop green credit products and adopt more robust environmental and social risk management. The aim was to

[18] Some of the research discussed in previous sections shows that this risk is real. See, for example, Huang, Gao, and Jia (2023), Ivanov, Kruttli, and Watagula (2023), and Mueller, Nguyen, and Nguyen (2023).

redirect lending towards projects and businesses with positive climate and environmental impacts while discouraging funding for firms that could harm the environment.

Several papers investigate the medium-term impact of these credit guidelines. Fan, Peng, Wang, and Xu (2021) show that, once the guidelines were introduced, firms non-compliant with local environmental laws saw their access to credit curtailed. In response, large firms reduced their emission intensity by investing more in abatement facilities, while small firms scaled back production. Affected firms invested mainly in pollution prevention at the source instead of end-of-pipe treatments (Sun, Wang, Yin, and Zhang, 2019) and, in the case of highly polluting industries, in more green innovation (Hu, Wang, and Wang, 2021). Huang, Gao, and Jia (2023) conclude that the policy, on average, successfully steered more bank lending to cleaner industries (though not so much to cleaner firms *within* industries). The policy impact was weaker, however, whenever polluting firms could leverage political connections to evade the guidelines or when they could replace bank credit with loans from non-bank lenders.

4. Conclusions

This paper has reviewed the growing literature on climate change and the banking system. Cross-country evidence at the sector level suggests that deeper equity markets, rather than larger banking sectors, may speed up countries' transitions to low-carbon economies. One reason is that banks with legacy loans to carbon-intensive industries can be reluctant to fund green disruptive technologies that may undermine their current loan portfolios. The literature paints a more positive picture regarding banks' roles in financing the diffusion of new low-carbon technologies. Access to bank credit can help firms invest in more energy-efficient production methods and in pollution abatement.

The paper has also discussed how, in the wake of the 2015 Paris Agreement, global banks – especially those with stronger green credentials – have gradually started to adjust their credit supply to large carbon-intensive firms. So far, the impact of these adjustments appears limited. This is partly because banks tend to underprice transition risks relative to bond markets, because non-bank lenders can replace bank credit to carbon-intensive firms, and because such firms often do not cut back emissions much when they face tighter financial constraints.

Banks have also begun to respond to the physical risks of climate change. A growing literature on the impact of severe weather events and sea level rise shows that, while the costs of these events have been increasing, banks have so far managed the associated risks well. Moreover, local (relationship) lenders tend to be relatively stable funding sources in disaster-hit areas compared with geographically more diversified banks. This stabilising influence of local banks tends to be stronger for low-risk borrowers, when banks can offload disaster risk through loan sales or securitisation, and if banks hold some local market power.

There are several research directions in the field of sustainable banking that hold great promise. I will focus on five broad areas. First, most extant research on banking and climate change has focused on high-income countries. More insight is needed on the role of banks in financing climate mitigation and adaption in low- and middle-income countries, many of which will be hit relatively hard by climate change.

Second, much empirical banking research has focused on lending by large banks to large publicly listed firms – often in the form of syndicated loans. Developing a more complete picture of banks' roles in climate change is important for two main reasons. First, because small banks can step in when large banks reallocate credit away from carbon-intensive industries. Second, because smaller banks tend to lend to smaller firms, which often have different carbon-abatement needs than larger companies. Efforts to collect comprehensive data on bank-firm links and on carbon emissions across the firm-size distribution are therefore especially valuable (see, for example, Hoffner and Steffen, 2022).

Third, future research could use randomised controlled trials or other experimental methods to generate more accurate causal estimates of whether and how bank credit facilitates the implementation of energy-efficiency measures and low-carbon technologies at the firm level. Complementarities between credit access and the managerial capacity of firms are particularly worthwhile to explore. In addition, lab-in-the-field experiments can yield useful insights into green decision-making *within* banks. These methods can also help better quantify the magnitude of any causal effects. For example, it would be useful to know whether changes in the availability of bank credit have a quantitatively meaningful impact on corporate investment in less carbon-intensive production methods.

Fourth, many supervisory and regulatory authorities are looking for more robust evidence on the aggregate materiality of climate risks. Further work on climate stress-testing, using forward-looking climate scenarios while modelling interdependencies within the financial system, will be particularly worthwhile.[19] The practical impact of such work will also depend on progress with the introduction of mandatory and internationally harmonised disclosure of climate-related risks and carbon footprints by individual firms.

Fifth, and most fundamentally, there is scope for more theoretical and empirical work to delineate more precisely the roles of firms, banks, and financial regulators in the green transition. It could be argued that banks are merely passive service providers that respond to the realities on the ground. In this view, policymakers should focus on addressing frictions in the real economy by regulating emitting industries, introducing carbon pricing, and increasing firm-level transparency about carbon emissions. Such measures could, in principle, lead to the first-best allocation of capital. On the other hand, frictions within the financial system itself may keep firms from moving towards greener production methods. More research work is needed to identify these frictions more precisely. One relevant area is the distorting effect of banks' brown legacy positions (discussed in Section 2.2.1). Another relates to how information asymmetries vis-à-vis small firms (rather than those borrowing in the global syndicated loan market) may interfere with the reallocation of capital towards greener investments. In a similar vein, such financial frictions may prevent households from accessing bank credit for much-needed investments to make their homes more energy efficient.

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[19] See Battiston et al. (2017); Alogoskoufis et al. (2021); and Acharya et al. (2023) for a discussion of the main issues related to climate stress-testing.

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