Sustainability, Energy Finance and the Role of Central Banks: A Review of Current Insights and Future Research Directions

Monika Marcinkowska, Janusz Brzeszczyński, Ailie Charteris,

Jerzy Gajdka, Lidia Obojska and Jan Jakub Szczygielski

Sustainability, Energy Finance and the Role of Central Banks: A Review of Current Insights and Future Research Directions

ABSTRACT

The importance of energy finance in sustainable development and, in particular, within the sustainable finance strand has visibly increased in recent years. In this review article, we focus on the role of central banks in this area. We draw on official documents from regulatory and supervisory institutions, central banks, think-tanks, non-governmental organisations and academic publications. First, we discuss the definitions of energy finance, Environmental, Social and Governance (ESG) risks and their transmission channels. Then we describe the mandates of central banks to act in this field. Finally, we discuss key aspects of ESG monetary and macroprudential policies as well as central banks' communication in this regard. We conclude by proposing topics for further research in this area.

JEL codes: E50, E52, E58, E59, O23, Q56

1. Introduction

In 2015 the United Nations (UN) adopted the '2030 Agenda for Sustainable Development' to promote the transition of world economies towards more sustainable and inclusive economic models.[1] It was signed by 193 countries and broadly covers 17 Sustainable Development Goals (SDGs) and 169 more specific targets. The SDGs constitute a call for action by UN member states in a global partnership.

Simultaneously, sustainable finance emerged as a field, which provides mechanisms and instruments that help in facilitating the achievement of the SDG goals. The United Nations Environment Programme (UNEP) defines the concepts of sustainable finance, climate finance and green finance.[2] Sustainable finance incorporates Environmental, Social and Governance (ESG) factors, encompassing all financial activities that contribute to sustainable development. Climate finance is a subset within the environmental finance realm mainly concentrating on funds being allocated to address both the adaptation and mitigation of climate change as a global phenomenon, whereas green finance encompasses a broader spectrum including various environmental concerns such as biodiversity protection.

Sustainable finance is broadly considered to consist of a set of different financial regulations, norms, rules and products designed to achieve specific environmental and social objectives. The endorsement of the 2015 Paris Climate Agreement has further propelled the concept of sustainable finance advocating for financial practices aligned with reducing greenhouse gas emissions and the development of climate-resilient systems. Sustainable finance is integral to initiatives like the European Green Deal and various other international agreements. Notably, its importance has increased even more since the outbreak of the COVID-19 pandemic.

Related to sustainable finance is the newly emerging field of energy finance, which is focused on financial solutions for renewable energy, efficient energy projects and financing investments in new technologies in the energy market.

[1] We would like to thank the participants of the 2nd Conference on International Finance, Sustainable and Climate Finance and Growth (CINSC) in Ljubljana, Slovenia, on 18-20 June 2023 for helpful comments on earlier version of the manuscript. We are also grateful to the anonymous Reviewer for suggestions about improving this paper.
[2] More information about the UNEP programme is available at: https://www.unep.org.

Growing pressure to achieve the SDGs, as well as rapidly rising energy prices (which between 2022 and 2023 were largely driven by geopolitical risk), make energy transformation an increasingly urgent goal (Szczygielski et al., 2024). As part of the sustainable finance trend, new solutions are being discussed and implemented to motivate private and public organisations to undertake activities designed to achieve these aims. Among these solutions, the actions of central banks occupy an important place. Numerous studies confirm the importance of energy prices and energy transformation not only in the case of environmental and social factors (see, for example, Puttachai et al., 2022), but also concerning various economic aspects - including those that are (depending on the legislation) the domain of central banks, such as price stability (and, therefore, monetary policy) and financial system stability (and, therefore, macroprudential policy) (see, for example, Safarzyńska and van der Bergh, 2017; Volz, 2017; Vermeulen et al., 2018; Vermeulen et al., 2021; Schnabel, 2022). The significant increase in the importance of these issues recently, along with the awareness of the need to take urgent action (and, hence, the desire to find appropriate tools) to address these problems, are key motivators for this study.

The purpose of this study is to offer a comprehensive review of the mandates and roles of central banks in the area of sustainable energy finance. The specific objectives are as follows:

1. Discuss and clarify the links between the energy market and sustainable development and thus describe energy finance in the context of ESG risks;
2. Present ESG risk drivers and explain the transmission channels of these risks to the economy (including inflation) and to the financial system (including its stability);
3. Identify arguments in the debate on central banks' mandates for sustainable development and present practices in selected jurisdictions;
4. Highlight instruments that are used, or can be used, by central banks in their monetary and macroprudential policies aimed at addressing ESG issues;
5. Demonstrate that central banks' communication concerning sustainable development is an important tool for advocating for action on climate change; and
6. Identify research gaps regarding the role of central banks in energy finance and sustainability.

We discuss existing literature on sustainable finance with a particular emphasis on energy finance and examine the role of monetary policy, macroprudential policy and central banks in promoting the achievement of sustainable finance and energy finance goals. We

begin with a discussion of the energy market and energy finance in relation to ESG risks. We focus on environmental (i.e., climate-related) risks linked to fossil fuels, but also highlight environmental risks connected with non-fossil fuel energy sources. In addition, we discuss a less frequently emphasised aspect, i.e., social risks stemming from both conventional energy sources as well as the transition towards renewable energy sources (including orderly transition and rapid changes induced by emergencies, such as wars). We also describe interdependencies between different environmental and social risks, indicating how they can escalate.

Moreover, we analyse ESG risk drivers as well as the channels through which these risks are transmitted to financial institutions and markets (banks, insurance companies, firms and asset markets) as well as macroeconomic and social factors, namely price stability, economic growth, financial stability and social wellbeing (including full employment and living conditions). Next, we link ESG to the mandates of central banks to show how sustainability fits into the overarching objectives of these institutions and what their potential or, in some cases, actual role is in this area.

We further explore in detail two key areas of central bank activity, i.e., monetary policy and macroprudential policy, and present the instruments and tools (protective and proactive measures) that these institutions can use to serve not only the conventional goals of these policies but also the objectives of sustainable finance and energy finance. Within these areas, we discuss intermediate targets and ultimate objectives. We focus especially on monetary policy, as it is the most important area of activity for all central banks and, at the same time, the integration of sustainability aspects into monetary policy is becoming increasingly common worldwide. In particular, we explore various aspects of the debate on integrating sustainability into central banks' monetary policy and analyse monetary policy tools and operations focusing on interest rates, credit operations, collateral and asset purchases to show how these instruments are adjusted to incorporate sustainability objectives. In doing so, we illustrate how the inclusion of the SDGs impacts the effectiveness of these actions in terms of the primary (economic) objectives of central banks. The consideration of sustainability issues in macroprudential policy is much less advanced and common (in addition, not every central bank has macroprudential policy issues in its mandate). Regarding macroprudential policy, we focus on climate stress tests and capital requirements (analysing all three Basel capital accord pillars) and other supervisory requirements. We also point out the need to synchronise decisions in various areas of state financial policy (including fiscal, monetary and micro- and macroprudential policies).

Thereafter, we describe the issues related to central banks' communication with the market considering aspects of sustainable finance with a particular focus on energy finance. We concentrate on central banks' disclosures (on overall governance, strategy and risk management) regarding sustainability and present other means of communication (publications, speeches, education etc.).

We conclude by outlining the gaps in the existing literature and indicating directions for future research.

The discussion presented is based on various sources, including policy documents and speeches from officials at institutions such as central banks. These publications, and other forms of communication, reflect the nature of the field under review. Notably, much of the discussion about sustainable finance and energy finance, especially in the context of monetary policy, macroprudential policy and the role of central banks, occurs outside of purely scientific literature. We believe that integrating academic literature with practice-related sources, such as policy documents from central banks, represents a novel and significant contribution of our work.

This paper is a narrative review study and it can be classified, more specifically, within the state-of-the-art review sub-category of narrative reviews.[3] Generally, narrative reviews (also known as unsystematic narrative reviews) provide a narrative synthesis of evidence on a particular topic, whereas the methods for selection of the reviewed articles and other cited sources typically do not follow the rigorous protocols of systematic reviews. State-of-the-art reviews, in turn, usually deal with more current matters (as opposed to other, more retrospective, reviews) and discuss areas for further research or propose specific new research directions. In other words, state-of-the-art reviews aim to offer a description of the understanding of a particular field, highlight how it was developed and discuss where it should (or could) evolve in the future (see Czarniawska, 2004; Sukhera, 2022).

The remainder of the paper is organised as follows. Section 2 describes energy finance in the context of climate change and the transition to a low-carbon economy. Section 3 defines ESG risks, discussing ESG risk drivers and their transmission channels to the financial system. Section 4 describes sustainability in the mandates of central banks. Sections 5 and 6 discuss ESG within monetary and macroprudential policies, respectively. Section 7 deals with central

[3] Other popular types of review studies include systematic reviews, mapping reviews, scoping reviews, rapid reviews, meta-analyses, umbrella reviews and integrative reviews. However, they tend to focus on particular methods of selecting the analysed sources and more mechanical synthesis of the available evidence but less so on the narrative aspect thereof. In our case, the review which we conducted is more narrative in nature and it provides the state-of-the-art descriptions with indications of future research directions.

banks' communication regarding sustainability. Section 8 proposes directions for future research and Section 9 concludes.

2. The energy market and energy finance

Energy finance is a field of research which focuses on studying relationships between energy markets and financial markets. It deals with the management of financial resources, investment decisions and risk analysis related to energy projects and companies. Zhang (2018) emphasises the inherently interdisciplinary nature of energy finance and argues that it explores the linkages between energy markets and financial markets, but also necessitates a perspective that views energy products and markets through a financial lens.

Zhang (2018) identifies six key themes as the main research areas in energy finance: (i) energy and financial markets; (ii) pricing mechanisms (e.g., how energy prices are formed); (iii) energy corporate finance (e.g., understanding the financing and investment choices made by energy companies); (iv) green finance and investment; (v) energy derivatives markets (regarded as a primary factor contributing to the financialisation of the energy market); and (vi) energy risk management (e.g., as energy commodities exhibit financial attributes, their risks and the corresponding risk management strategies are crucial from economic as well as policy-making perspectives). Existing literature dealing with energy markets and, in particular, energy finance is to a large extent devoted to the energy transition to a low-carbon economy (carbon neutrality) or the green transformation in general.[4,5]

[4] In related research, Dees et al. (2023) examines the impact of the green transition on consumer prices and energy prices. They focused on four distinct scenarios, each representative of transition-related shocks. The initial set of scenarios concentrates on supply condition deterioration, potentially resulting in stagflation. The subsequent category centres on shocks with adverse effects on demand, leading to deflation. The third category conceptualises the transition as a sequence of positive demand shocks, potentially induced by sustainable public investments funded through a carbon tax, thereby fostering positive impacts on both growth and inflation. The final category posits an improvement in supply, facilitated by increased private capital spending without displacing other investments, leading to augmented output without causing inflationary effects. The findings of Dees et al. (2023) demonstrate that a disorderly transition, precipitated by a sudden increase of carbon prices or an insufficient shift toward green technologies, may have inflationary implications in the medium term. In contrast, a transition that is implemented earlier and more gradually is associated with reduced risks to inflation. The analysed scenarios illustrate the significance of private and public investment, as well as support for poorer households, in mitigating the macroeconomic costs associated with the transition.

[5] In the context of the low-carbon transition, Miller et al. (2023) also stresses the role of several 'critical' raw materials, such as rare earth elements or minerals. Through their empirical investigation, they quantitatively assess the material demand requirements associated with 'Transition-Critical Materials' within the framework of two Central Bankers and Supervisors Network for Greening the Financial System (NGFS) Climate Scenarios: 'net zero by 2050' and 'delayed transition'. The findings of Miller et al. (2023) reveal the potential presence of significant discrepancies between supply (considering such factors as current reserves, technological utilisation etc.) and demand. This disjunction would be further exacerbated in the event of a delayed transition as opposed to immediate realisation. Miller et al. (2023) contextualise these outcomes within various conceivable

Van Steenis (2019) presents a report on the future of finance and proposes a smooth transition to a low-carbon economy. In light of the imperative to address climate change and align with the Paris Agreement aims, a requisite reduction of 45% in carbon emissions by 2030, coupled with a concomitant annual investment in infrastructure of $6.9 trillion until 2030, is required, as indicated by the Organisation for Economic Co-Operation and Development (OECD) (2017). The OECD (2017) highlights the necessity of enhanced disclosures of climate-related risks to guide investments toward initiatives aimed at diminishing global reliance on fossil fuels and promoting investments in energy efficiency.

Sgaravatti et al. (2023) propose an industrial strategy response for the European Union (EU) to accelerate low-cost low-carbon electricity and reduce clean technology prices worldwide. They suggest that the EU should deploy large-scale renewables and build the electric grid interconnectedness and storage. Moreover, the EU could facilitate imports of energy-intensive products.

In support of the transition towards a low-carbon economy, Monasterolo et al. (2022) formulate a theory of change delineating the role of initiatives within the green financial sector in climate mitigation and identify criteria for applicability and conditions conducive to maximising impact. They emphasise the contributions of policymakers and financial institutions in promoting green finance. Monasterolo et al. (2022) analyse the inherent opportunities and challenges in carrying out initiatives within the green financial sector, with specific attention to the nuances present in emerging and developing economies. The analysis centres on three key issues: green monetary policies, green macroprudential policies and green public co-funding. Every green financial sector initiative undergoes a thorough examination of transmission channels to understand how it may affect the accessibility as well as the cost of capital for both high- and low-carbon goods. Simultaneously, the effect on output, investments and greenhouse gas emissions, considering the particular nature of the respective green initiative, is examined. Monasterolo et al. (2022) recommend that emerging and developing markets undertake initiatives to attract private capital to enable a transformation towards a low-carbon economy. Nevertheless, prevailing policies and market practices often incentivise emissions-intensive investments, production and consumption. Consequently, the study supports the introduction of incentivised energy transition solutions and novel policies, such as well-designed carbon pricing, emissions trading schemes and appropriate financial measures.

transmission channels, explaining how these material supply-demand mismatches could impact financial and price stability.

The maintenance of low financing costs is identified as critical to the expeditious and cost-effective realisation of this transition, as underscored by the OECD (2021a). These recommended policies have the potential to enhance the competitiveness of renewable-based solutions vis-à-vis fossil fuels, thereby stimulating investments in low-carbon activities, as suggested by the International Energy Agency (2021).

As Monasterolo et al. (2022) also state, the transition to low-carbon energy requires recommendations to policymakers, including the need to create a favourable regulatory and policy environment. Common definitions and standards should be established to promote transparency and disclosure of environmental risks and provide financial incentives to encourage green investment and innovation in the energy sector.

The pioneer Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) is the first set of German laws created to encourage the generation of renewable electricity (EEG, 2016). The EEG established a feed-in tariff system, which is set at rates higher than the market price for electricity, providing an incentive for investments in renewable energy projects. It helps to ensure a stable revenue stream for renewable energy producers and encourages the development of renewable energy infrastructure. The EEG includes regulations for grid expansion, stability and the integration of renewable energy sources into the existing energy infrastructure.

Mazzucato and Semieniuk (2017) demonstrate how successful innovation policies, citing the information technology and pharmaceutical sectors in the United States (U.S.) as examples, support the energy transition. Their investigation analyses the strategic implications associated with the public financing of innovation within the context of renewable energy. The study examines the potential of public funding to influence and cultivate markets, examining this phenomenon through three distinct dimensions: (i) within the context of financial support from public sources spanning the entirety of the innovation chain; (ii) when policies guided by a 'mission-oriented' approach give rise to novel technological and industrial landscapes; and (iii) in situations where a public actor assumes the role of an entrepreneurial and lead investor, demonstrating a willingness and capacity to undertake significant risks irrespective of the prevailing business cycle.

Jargalsaikhan et al. (2022) present a report on the responses of U.S. firms to the energy transition. Many firms adopted renewable energy sources to achieve carbon neutrality. Certain enterprises augmented their reliance on renewable energy sources by incorporating renewable natural gas in transportation and making investments in fuel cell and biomass technologies for energy generation. Emphasis is placed on improving greenhouse gas emissions, with specific

attention directed towards the energy efficiency of various aspects such as equipment, supply chains, transportation and overall business operations. Companies also highlight persistent apprehension about the scarcity of reliable ESG measurement data, which impedes informed decision-making within the real estate and finance sectors.

Energy finance is a field that faces many challenges which arise from climate change and related ESG risks. However, it also actively responds to these through different innovations, such as launching new financial instruments (e.g., green bonds). In particular, ESG-related derivatives constitute increasingly important financial tools that, by supporting the ecosystem of various market institutions, are used to advance the accomplishment of ESG goals and are poised to become pivotal instruments in global sustainability and various ESG-related initiatives. They also enable access to substantial amounts of capital necessary for the shift to cleaner energy technologies and the attainment of the net-zero emission objectives (Baker, 2022).

In summary, energy finance is a critical component of ESG. In the following section, we discuss ESG risks and evaluate their impact on the financial system, including the effects of the energy transition.

3. Sustainability, ESG risks and their transmission channels to the financial system

ESG risks refer to environmental, social and governance issues that may impact the reputation, financial performance or even solvency of a firm or financial institution (European Banking Authority (EBA), 2021). EU (2022) regulations provide a narrow definition of the ESG risk of a financial institution, defining it as "the risk of losses arising from any negative financial impact on the institution stemming from the current or prospective impacts of environmental, social or governance (ESG) factors on the institution's counterparties or invested assets."[6] These risks are distinct from traditional financial risks facing financial institutions as they have a negative focus. Coleton et al. (2020) highlight that although ESG risks constitute a new source of risk, they feed into traditional financial risks. Environmental and social risks rank among the top ten risks over the short (defined as two years) and long term (ten years) for governments and businesses (World Economic Forum (WEF), 2023).

[6] Thus, only the risk connected with the indirect impact of a financial firm is included (and not the direct one).

Understanding and addressing these risks is crucial for financial institutions to develop effective mitigation strategies.

Environmental risks can be categorised into two types[7]: physical risks and transition risks.[8] Physical risks arise from the physical effects of environmental degradation and climate change and may be *acute* (defined as short but severe impact events such as storms or wildfires) or *chronic* (referring to gradual changes with a sustained impact such as rising sea temperatures and variable rainfall patterns). Transition risks, on the other hand, stem from societal shifts toward a low-carbon economy, influenced by policy, technological changes and investor sentiment (Basel Committee on Banking Supervision (BCBS), 2021a; EBA, 2021; Kalfaoglou, 2021). This is the predominant focus of energy finance, as highlighted in Section 2.

Environmental risk is characterised by significant uncertainty, i.e., 'unknown unknowns', unlike traditional risks which are measurable 'known unknowns' (Battiston et al., 2021; BCBS, 2021a;). For example, Volz et al. (2020) and Battiston et al. (2021) highlight that the speeds at which climate-related changes are occurring is unclear and that these risks exhibit non-linearities (tipping points) and their impact is geographically heterogeneous. However, Bolton et al. (2020) argue that there is a high level of certainty that these impacts will materialise. Bolton et al. (2020) classify climate change as a green swan, a systemic risk involving complex, unpredictable environmental, economic, geopolitical and social dynamics that could trigger the next financial crisis. Green swans share similarities with black swans, such as fat-tailed distributions, extreme values and a lack of predictive power from past data, but differ in their complexity and potential for existential threats.

While environmental risks receive significant attention in the literature and policy discussions, social and governance risks are often overlooked (Holt, 2019; Saul, 2022). Social risks stem from relationships between a company and external and internal stakeholders (S&P Global, 2020; Kalfaoglou, 2021). This includes corporate citizenship, human rights, health and safety and customer-orientated issues. The EBA (2021) argues that environmental risks drive social risks, leading to increased migration, humanitarian crises and labour market challenges during the transition to greener industries (although this transition can create opportunities for other industries) (see also Alexforbes, 2023). The OECD (2020) acknowledges that policy changes, such as minimum wages and evolving market perceptions, often triggered by social

[7] Climate change risk dominates discussions of environmental risk in the literature and practice with many studies (such as Monasterolo et al., 2018; Dunz et al., 2021) and policy documents (for example BCBS, 2021a; Kalfaoglou, 2021) focusing exclusively on climate change.
[8] Carney (2015) adds a third type of risk, i.e., liability risk.

media, also contribute to social risk. Governance encompasses corporate governance codes and corporate behaviour in complying with relevant laws and regulations. The OECD (2020) identifies risks arising from non-compliance with codes, which damage a firm's reputation and financial performance. The poor management of environmental and social risks can exacerbate governance challenges (see also EBA, 2021; Kalfaoglou, 2021). The opposite is also true – poor governance can also contribute to worsening environmental and social risks. For example, Batten et al. (2016) state that banks' continued funding of high-carbon projects (attributable to poor governance) can contribute to increased climate change (environmental risk) (see also Harvey, 2023).[9] Accordingly, ESG risks exhibit a cascading effect with a positive feedback loop.[10] Jamali et al. (2008) and Gillan et al. (2021), among others, also highlight the strong and intricate relationship between ESG factors.

ESG risks dominate global long-term risk rankings (WEF, 2023). They affect households, companies, institutions and governments. As they directly and, to an even greater extent, indirectly affect financial institutions and systems, ESG risks are currently the subject of analysis and action by regulators and supervisors. Consequently, it is necessary to understand these risks and their transmission to the real economy as well as financial markets and institutions and, thereafter, to develop tools for the management of these risks at micro, mezzo and macro levels. This is necessary to plan towards sustainable development, including counteracting climate change and adapting to it.

ESG risks are transmitted to the financial system through microeconomic and macroeconomic channels (International Monetary Fund (IMF), 2019; BCBS, 2021a; Kalfaoglou, 2021). Microeconomic channels encompass both the direct effects of ESG risks on financial institutions' counterparties and the indirect effects on their financial assets. Macroeconomic channels are the causal links through which ESG risk drivers impact macroeconomic factors such as employment, output and price stability which, in turn, influence the financial system (the Central Banks and Supervisors Network for Greening the Financial System (NGFS)-INSPIRE, 2021). Through these transmission channels, the financial risks faced by financial institutions are exacerbated. Financial risks comprise credit risk (the borrower's ability to service their debt), market risk (fluctuations in the value of the institution's financial assets), liquidity risk (the bank's ability to fulfil its responsibilities to

[9] This kind of cascading effects with feedback loops are common in ecological systems (see for example Hočevar and Kuparinen, 2021).
[10] Cascading effects are often used in ecology and disaster risk management (Pescaroli and Alexander, 2015) and with respect to information cascades in financial markets (Doherty, 2018).

depositors and counterparties) and operational risk (failure from internal processes or external events) (BCBS, 2021a; NGFS-INSPIRE, 2021).

Monasterolo (2020) points out that the literature mainly focuses on environmental risk, particularly physical and transition climate change risk when studying transmission channels and their impact on financial risks. The discussion that follows therefore also adopts this focus.

The microeconomic climate risk transmission channel incorporates households, firms and governments which, in turn, impact financial institutions, although banks and insurance companies are also directly impacted. According to Fuerst and Warren-Myers (2021), physical climate risk impairs household wealth through the loss in value of real estate due to flooding and rising sea levels although the magnitude and persistence of effects vary (see also Ortega and Taspinar, 2018; BCBS, 2021a; Curtis, 2022). Banks, consequently, face losses in the event of default due to the decline in the collateral value of mortgage loans. Zhou et al. (2023) demonstrates that weather-related disaster damage also elevates the probability of default on mortgages and other loans by households, thus contributing to bank credit risk.

Physical climate risk poses a substantial threat to firms due to uninsured losses or potential liabilities. Barrot and Sauvagnat (2016) and BCBS (2021a) show that firms experience a drop in sales growth following a major natural disaster that impacts their suppliers. Giuzio et al. (2019) and Bremus et al. (2020) further argue that such losses trigger defaults on loan repayments and lead to financial instability when financial intermediaries lack sufficient buffers. Correa et al. (2022) and Huang et al. (2022) confirm that corporations face higher borrowing costs due to natural disasters and climate risk in general. For example, Pacific Gas and Electric, referred to as the 'first climate change bankruptcy', was driven into bankruptcy due to $30million in potential liabilities linked to the company's powerlines being associated with the California wildfires (Gray and Bakke, 2019).

Battiston et al. (2021) also highlight that insurance companies face increased liabilities arising from environmental damage to households and firms. Moreover, Batten et al. (2016) and Flavelle (2019) reveal that insurance costs rise in response to increased liabilities and there is reduced coverage for certain assets which represent vulnerabilities in the financial system.

Physical risk to firms and households can impact banks' liquidity as they seek to withdraw funds or draw on credit lines for recovery or precautionary reasons. Cortés (2014) highlights that banks are typically directed by regulators to lend following natural disasters to support recovery. Brei et al. (2019) and Koetter et al. (2020) find that banks increase their lending and experience increased deposit withdrawals following natural disasters. In contrast, Cortés and Strachan (2017) and Schüwer et al. (2019) find that banks reduced loans to affected

communities while Allen et al. (2022) document decreases in both bank deposits and lending after natural disasters. The BCBS (2021a) reports that where liquidity demands on banks become onerous, central banks may need to intervene to maintain financial stability as seen in Japan following the earthquake in March 2011. D'Orazio (2021) illustrates that climate-induced liquidity risks may induce catastrophic funding and market liquidity shortages.

The BCBS (2021a) points out that governments are also impacted by physical risks owing to lower tax revenues as a result of lower household income and reduced firm output and higher spending aimed at minimising the negative consequences of climate events and the implementation of adaptation measures. This can lead to higher government borrowing costs and reduced access to debt markets which heightens credit risk for banks exposed to government and governmental institutions (see also Beirne et al., 2021; Boehm, 2022; Cevik and Jalles, 2022; Mallucci, 2022). Volz et al. (2020) confirm the substantial risk that climate change poses to sovereign risk.

In addition to the indirect effects, banks also directly experience challenges in assessing the value and risk of properties in climate-affected areas and re-evaluating climate-affected assets can reduce bank profitability (market risk) (Batten et al., 2016; IMF, 2019; Battiston et al., 2021). Physical risk can also result in operational losses for banks through damage to telecommunications infrastructure and bank facilities or electricity supply failures (BCBS, 2021a). However, Fritz-Morgenthal et al. (2018) highlight that disasters have only contributed a relatively small proportion to total losses due to operational risks faced by banks since the Global Financial Crisis (GFC) of 2008.

Transition risk drivers are new policies, technological change and shifts in preferences due to the transition to a low-carbon economy. This risk is transmitted through households, firms and governments to financial markets and institutions (Bremus et al., 2020; Brunetti et al., 2021; Semieniuk et al., 2021). According to Monasterolo (2020), transition risks pose an equally existential threat to the possibility of systemic risk and financial instability as physical risk (see also IMF, 2019; Dafermos, Kriwoluzky et al., 2021). According to Semieniuk et al. (2021), new regulations that seek to reduce carbon emissions either through taxes or cap-and-trade schemes are a major risk driver for firms. Similarly, Dunz et al. (2021) demonstrate how the introduction of a carbon tax raises production costs for carbon-intensive firms leading to higher costs which are passed on to consumers through increased prices. This reduces demand and profitability, hampering the ability of firms to service loans, impacting banks' capital adequacy ratios and increasing borrowing costs. Aiello and Angelico (2023) calibrate credit risks for Italian banks stemming from the introduction of a carbon tax and find that firm default

rates increase although they remain below historical peaks. However, the effects vary across sectors, with agricultural and services most affected. Monasterolo et al. (2018) find that the climate transition risks of the international energy portfolios of two Chinese banks pose a significant market risk which could result in substantial losses and financial distress. Semieniuk et al. (2021) further argue that technological changes and buyers' preferences can also drive demand and prices which impacts firm profitability and risk (see also BCBS, 2021a).

Capasso et al. (2020) show that European firms' distance-to-default, which is a market-based measure of corporate default risk, increases as climate change exposure increases which impacts the risk profile of loans and bonds issued by corporations. Similarly, Ilhan et al. (2021) find that the cost of option protection against downside extreme risks is higher for carbon-intensive firms. Exposure to climate risks also reduces firms' leverage which is partially attributable to banks and bondholders charging higher interest rates when lending to these firms (Ginglinger and Moreau, 2019).

Transitioning to lower carbon economies may result in stranded assets; committed investments not able to generate an economic return prior to their estimated end of life due to changes in the market situation or in regulations[11] such as fossil fuel assets and the assets of carbon-intensive industries like the aviation sector (e.g., France's ban on short-haul flights; Frangoul, 2023). This causes the value of these firms to fall and impacts financial institutions exposed to these firms. Monasterolo and De Angelis (2020) and Brunetti et al. (2021) reveal that the risks of stranded assets are not fully reflected in current asset prices, amplifying their effects on financial institutions.

Several studies examine the extent to which climate change risk is reflected in bank practices to reduce credit and market risk. Birindelli et al. (2022) demonstrate that banks with a higher commitment to climate change have lower credit risk when banks have a medium to high level of attention to these issues. They attribute this to these banks better assessing the creditworthiness of their borrowers and opting for environmentally friendly and less risky clients. Delis et al. (2024) observe that only after the 2015 Paris Agreement and the call from the Financial Stability Board (FSB) for standard measures and disclosures of climate risk information, has climate policy risk been priced by banks, with loan rates offered to fossil fuel firms exceeding those offered to non-fossil fuel firms. Kleimeier and Viehs (2018) document that firms who voluntarily disclose carbon emission levels pay significantly lower costs on

[11] Carattini and Sen (2019) argue that the introduction of carbon taxes - the most cost-effective policy supporting decarbonisation - can result in asset overpricing (in particular, the creation of stranded assets).

bank loans than non-disclosers (see also Jung et al., 2018). However, at an absolute level, firms with higher carbon emissions incur higher borrowing costs, providing evidence of the existence of an environmental risk premium.

Battiston et al. (2016) argue that financial institutions' connectedness through contracts, shared assets and opacity of exposures can amplify the impact of climate shocks (physical and transition) on the financial system. According to Campiglio et al. (2018) this poses challenges for central banks and regulators. Overall, climate risk can impact the credit, market, liquidity and operational risk of banks through microeconomic channels, becoming a notable source of financial instability at the individual institution, national and global levels as pointed out by Carney (2015), Battiston et al. (2021) and Brunetti et al. (2021).

ESG risk drivers are also transmitted through macroeconomic channels affecting output and inflation which, in turn, influence the financial system. Physical environmental events directly impact the real economy, affecting both the supply (damage to capital stock) and demand side (lower consumption). In the short run, this leads to economic contraction. Albuquerque and Rajhi (2019) confirm that natural disasters result in a substantial decline in economic growth in low and middle-income countries although the effects appear to be temporary. Volz et al. (2020) hypothesise that the effect of natural disasters on small countries with a low tax base will be monumental. Schnabel (2020), Schnabel (2021b) and Schnabel (2021c) emphasise that an increased occurrence of physical risk can lead to fluctuations in output in the short term, which in turn may exacerbate longer-term volatility of different macroeconomic variables. Carleton and Hsiang (2016) and Hsiang et al. (2017) reveal how rising temperatures are adversely impacting mortality, agricultural yields, labour supply and productivity which leads to lower output. Volz et al. (2020) acknowledge that financial risks faced by banks are also likely to harm macroeconomic output (see also NGFS-INSPIRE, 2021). However, according to Fratzscher et al. (2020), replacing destroyed capital with productive investments and technology, along with expenditure from insurance payments, can enhance long-term growth.

Bremus et al. (2020) demonstrate that transition climate risks create uncertainty, hindering investment growth. The shift to renewable energy may also cause environmental hazards (such as deforestation, ecosystem collapse and water shortages) impacting economic output (Arrobas et al., 2017; Hickel, 2019; Parrique et al., 2019). Jackson (2009) argues that striving for economic growth without environmental harm is unrealistic. Relatedly, the move towards a low-carbon economy focuses on investments to reduce carbon-intensive processes but without necessarily focusing on improving productivity and output, stalling efficiency and

productivity. However, the effect of transition climate risk will vary across economies. Americo et al. (2023) suggest that most countries should benefit from cheaper, cleaner and locally sourced energy while major fossil fuel producers, like those in the Middle East and North Africa, will face challenges due to declining demand for existing energy sources. Countries that produce key metals and minerals for the clean energy transition will experience substantial benefits from exporting these.

Bloom and Finke (2024) illustrate that increased social risk leads to economic contraction. Insufficient investment in public health hinders labour productivity, education and investment, thus decreasing output. Dollar and Gatti (1999) and Ruiters and Charteris (2020) find that lower gender equality in employment harms economic growth. Škare and Hasić (2016) show that weaker levels of corporate governance contribute to decreased output, as such firms are more volatile, provide less consistent profits to shareholders and decrease investor confidence. Morck et al. (2005) and Fisman and Svensson (2007) find that governance risks, such as economic entrenchment and bribery, negatively impact growth. Importantly, macroeconomic deterioration because of environmental or social risks and the attendant consequences of these events will lead to increasing financial risks for banks, such as impaired borrowers' creditworthiness (NGFS-INSPIRE, 2021).

Environmental risks, both physical and transition, also impact price stability. Schnabel (2022) identifies three inflation shocks, termed 'climateflation', 'fossilflation' and 'greenflation', arising from climate change. Climateflation emerges from the escalating frequency of natural disasters and severe weather events globally, which can lead to production interruptions and shortages (see also Batten et al., 2020; Fratzscher et al., 2020; Dafermos, Kriwoluzky et al., 2021). According to Parker (2018), the inflation effect is more pronounced in developing than in developed countries. Of particular concern is the possibility of a significant surge in food prices (Schnabel, 2022). For instance, recent exceptional droughts in various regions have resulted in heightened food prices, imposing a substantial burden on individuals struggling to fulfil their basic needs. Chen and Villoria (2019), Bremus et al. (2020) and Dafermos, Kriwoluzky et al. (2021) confirm rapid spikes in food inflation due to climate shocks but, according to Parker (2018), the effects may reverse over time. However, Bremus et al. (2020) and Dafermos, Kriwoluzky et al. (2021) argue that industrial production slowdowns due to acute physical environmental risk may lead to a reduction in consumer prices, due to higher insurance costs faced by consumers and lower credit provision by banks. It is difficult to predict which forces will dominate *ex ante*.

Fossilflation stems from the persistent dependence on fossil energy sources (with petroleum products and natural gas still accounting for as much as 85% of total energy consumption in the Euro area as of 2019) (Schnabel, 2022). Efforts to combat climate change contribute to elevating the cost of fossil fuels, and despite recent volatility, the price of carbon remains notably higher in the EU. Institutional investors reducing their exposure to fossil fuel energy producers and embargoes on Russian oil imports further contribute to increased funding costs and impact global crude oil production, sustaining fossilflation. Government climate policies could contribute to inflation through emission-intensive goods' price increases (Bremus et al., 2020). Moreover, greenflation is activated by companies adapting their production processes to mitigate carbon emissions. The shift toward green technologies demands substantial quantities of metals and minerals like copper, lithium and cobalt, especially during the transition period. With growing demand for these resources and limited supply in the short and medium term, the prices of crucial commodities have witnessed significant increases in recent months. For instance, lithium's price has jumped by more than 1000% since January 2020.

Furthermore, Boyd et al. (2021) maintain that inflation poses the risk of reducing the profitability of banks' assets and loans as interest earned may be insufficient to match rising costs. Banks may also face increased credit risk if borrowers struggle to make loan payments amid higher living costs. Rising interest rates in response to higher inflation may also result in losses for banks if a significant portion of their assets are variable-rate.

Dafermos, Kriwoluzky et al. (2021) warn that climate change risk will severely impact central banks' ability to control inflation. Schnabel (2021a) suggests that the effects of climate change may hinder the effectiveness of the transmission of central banks' monetary policy tools to the financing conditions encountered by households and businesses, thereby affecting consumption and investment. Additionally, climate change could limit the efficacy of conventional monetary policy by reducing the equilibrium real rate of interest. Factors such as impaired labour productivity and increased morbidity and mortality rates due to higher temperatures play a role in influencing this rate. This reduction may result in a reallocation of productive resources to support adaptation measures and weaken the incentives for investment (Schnabel 2020; Schnabel 2021b; Schnabel 2021c).

ESG risks have implications for social well-being, affecting employment, living conditions and food security. Environmental risk can lead to job losses, limited alternative work opportunities and challenges in finding jobs. Whelan and Fink (2016) and Albert (2022) reveal that climate change also severely impacts living conditions and poses threats to food security.

According to Naffa and Dudás (2020), neglecting social risks can perpetuate gender inequality, poverty, illiteracy and other social issues. High ESG performance is closely linked to better social outcomes.

What follows from the discussion is that ESG risks, especially climate change risks, are transmitted through various channels and that they pose significant threats to households, firms, financial institutions and the macroeconomy, leading to financial instability, reduced output and increased inflation. Authorities must address these risks to mitigate their harmful effects on society. This motivates for the consideration of the validity and possibility (or necessity) of including these activities in the policies and mandates of central banks to address sustainability and ESG risk.

4. Sustainability in the mandates of central banks

The previous section discusses the influence of ESG risks on the economy and the financial system, among others. It concludes that regulators, supervisors and central banks should consider these risks when taking action. In this section, we focus on analysing the mandates of central banks in relation to sustainability, given the different tasks assigned to these institutions in various jurisdictions.

According to Oyegunle and Weber (2015), prior to the call by Mark Carney, the Bank of England (BOE)'s governor, for the financial sector to assess financial risks associated with stranded assets in the oil and coal industry, sustainability was not a central consideration in corporate decision making. Banks and other financial institutions lacked a comprehensive sustainability strategy and were hesitant to incorporate environmental and social (E&S) risk factors into their operations and client relationships. The 2008 GFC highlighted the significance of sustainability for the financial sector, as banks failed to address societal issues such as the excessive indebtedness of homeowners. Similarly, post the GFC, Volz (2017) reports an evolving dialogue about central banks' role in financial stability. Though stable inflation rates were traditionally seen as key to societal prosperity, this notion faced growing criticism for neglecting general financial stability. Furthermore, the evolving debate reflects the importance of considering environmental and sustainability factors in central banks' strategies, as these could be integral to achieving price stability and financial security. One aspect of sustainability, climate change, has begun featuring prominently in discussions.

Volz (2017) argues that environmental damage and climate change can directly impact financial stability and price stability through food and energy prices, potentially having a systematic impact affecting sovereign risk. Companies may encounter climate or environment-related liability risks, which could pose a significant challenge to the insurance sector (see also Section 3). Central banks have the capacity to mitigate systematic risks by identifying vulnerabilities, thanks to their comprehensive view of the interconnected financial system. In developing nations, the rationale for delegating environmental sustainability mandates to central banks and regulators is amplified due to their relative sophistication and influence as public institutions. Central banks can bridge gaps arising from public institutions' failure to enforce environmental regulations. Furthermore, central banks often take on a developmental role, despite denials, positioning them to act as advocates for sustainable development by backing targeted sectors through the direction of lending and investments. Finally, Volz (2017) proposes that central banks could act to address credit market failures that arise when markets provide credit for socially undesirable activities. As long as carbon pricing markets remain ineffective and environmental policies are either unenforced or poorly implemented, central banks may have the justification to employ their powers to influence credit generation and allocation.

Diggle and Bartholomew (2021) propose a more fundamental justification for central bank involvement in an increasingly important aspect of sustainability, namely that of climate change, that goes beyond price and financial stability. They argue that the imminent and potentially existential threat of climate risks necessitates the use of all public policy tools to achieve government climate goals. Consequently, central banks should ensure their actions are not counterproductive to these objectives. Also, central banks have some potentially effective tools at their disposal that can be used to fight climate change. This includes green quantitative easing (QE) favouring bonds or the exclusion of ‘brown’ bonds in asset purchase programmes, stress tests that consider climate-related risks, haircuts for collateral operations that consider climate scores and differential capital requirements tied to banks’ lending activities based on ESG criteria. The implementation of green monetary policy may breach the principle of bank neutrality, resulting in brown industries facing systematically higher capital costs, while bolstering green industries through reduced capital costs. However, Diggle and Bartholomew (2021) argue that in societies that entrust central banks with mandates to support climate objectives, deliberate deviations from neutrality could be justified to facilitate the green transition, given the profound welfare implications at stake.

Muñoz et al. (2022) examine whether central banks should integrate considerations of climate change into their mandates. They assert that central banks can extend their attention beyond conventional norms, incorporating supplementary mandates and environmental principles to address climate change. Financial regulations and supervisory powers can also aid in managing climate-related financial risks. Incorporating climate change in central banks' mandates can proactively prevent crises and reduce uncertainty for economic agents. Muñoz et al. (2022) assert that central banks are well-suited for this task due to their experience with time inconsistency issues and their ability to assess distortionary effects versus climate risks. In emerging scenarios, central banks can extrapolate their core functions to effectively tackle climate change.

Nevertheless, there exist views arguing that central banks should not be involved in tackling sustainability issues. Cullen (2023) asserts that there is no empirical proof to suggest that reducing capital requirements for environmentally friendly loans will be an effective strategy to tackle climate risks. Another point to consider is that green investments, while more appealing from a public policy perspective compared to non-green investments, do not necessarily have a higher creditworthiness than non-green assets. Cullen (2023) argues that asking banks to favour green investments could be equated to asking them to disregard risk management. Green QE is also likely to be ineffective given the expected shift towards higher interest rates and monetary tightening. The power of QE to stimulate green projects by making borrowing for such initiatives cheaper may be significantly diminished.[12] Macroprudential reform of capital regulation is often linked with the integration of climate risks into stress-testing frameworks of central banks, as these tests primarily serve to predict potential capital deficiencies among financial institutions.[13] However, conducting stress tests for climate risks is fraught with difficulties due to the unpredictability of future climate impacts, substantial data gaps and the extended duration of these risks. Standard stress test timeframes do not correspond to the lengthy period over which climate risks usually unfold. Moreover, when stress tests consider sudden climate transition risks, the effect on bank capital appears to be insignificant.

Former Deutsche Bundesbank President Jens Weidmann (2019) argues that the responsibility to shape the economy in response to climate change policies lies with governments and parliaments rather than central banks. Weidmann (2019) goes onto caution that monetary policy explicitly focused on environmental objectives may pose the risk of

[12] See Section 5 for further information.
[13] See Section 6 for further information.

burdening the central bank excessively and, over time, could erode its independence. Weidmann (2019) advocates for a decisive and effective climate policy but insists that it should be executed by entities possessing the democratic legitimacy necessary for such purposes.

Federal Reserve Chairman, Jerome Powell, expressed a similar viewpoint. Powell (2023) asserts that without explicit congressional legislation, it would be inappropriate to use monetary policy tools to promote a greener economy or achieve other climate-based goals. The Fed Chairman clearly stated: "we are not, and will not be, a climate policymaker" (Powell, 2023, p. 3) .

Landau and Brunnemeier (2020), discussing the difficulties associated with linking climate change to the monetary policies of central banks, refer to the disparity in the time horizon. Conventional wisdom suggests that monetary policy had a limited impact on long-term growth, with effects typically manifesting over a one and a half- to two and a half-year horizon. In contrast, climate change unfolds over several decades, making it a long-term concern. Another point of contention arises from the relationship between central banks and policymakers. In democratic societies, decisions regarding resource allocation and income redistribution are typically made by elected bodies. Policies addressing climate change fall within this category. However, independent central banks operate as non-elected entities with a well-defined mandate to stabilise the economy. Adjusting monetary instruments to influence resource allocation and credit direction may be perceived as exceeding this mandate.

Diggle and Bartholomew (2021), while supportive of green monetary policy (see above), acknowledge the notion of central bank neutrality as a factor against central bank intervention on climate issues. They argue that in the absence of significant market failures, the allocation of resources should be performed by the private sector. Furthermore, in democratic societies, elected governments and not technocrats should address microeconomic allocation issues. Finally, if a central bank involves itself in certain allocative issues, it might invite government pressure to intervene more in the economy, potentially leading to the politicisation of the central bank and undermining confidence in price stability. Such situations can discourage central bank involvement in climate-related issues, as it would inherently mean manipulating the cost of capital for specific sectors (green and brown), amounting to microeconomic credit allocation and breaches of neutrality.

Despite reservations about central bank involvement in sustainability issues, Oyegunle and Weber (2015) note that the implementation of sustainable financial sector regulations is an area that is rapidly evolving with developing and emerging countries being more proactive in integrating sustainability into financial regulations. Initiatives that stakeholders, including

central banks, are undertaking to link sustainability with the financial system comprise integrating environmental considerations into financial decision making and correcting for environment-related market failures, supporting policy frameworks and standards for the promotion of green financial products, promoting the flow of sustainability-related information through the financial system and integrating environmental factors into risk management practice. Measures also include investments and lending to priority sectors that promote inclusion and support development and establishing codes of conduct for environmental issues (Dikau and Ryan-Collins, 2017).

Dikau and Volz (2021) analyse 135 central bank mandates and found that 70 of them have either direct or indirect provisions for promoting sustainability or sustainable economic growth. Among them, 15 countries and one monetary union have mandates explicitly geared towards the promotion of sustainable growth or economic development. Sustainability mandates are more commonly included in the broader, often explicitly promotional, mandates of central banks in developing economies. Only a minor portion (12%) of the examined central banks possess clear mandates for sustainability and 40% (equivalent to 54 banks) have mandates that support government policy objectives, which may include sustainability goals. Almost half (48%) of central banks do not have any mandate, either direct or indirect, that requires their involvement in climate change-related issues. Dikau and Volz (2021) also find that despite not having explicit sustainability mandates, 33 of the central banks have been actively addressing climate-related changes and other ESG risks.

Durrani et al. (2020) survey 18 central banks in the Asia-Pacific region and find a growing recognition among these institutions of the need to tackle climate-related risks in financial markets. Most banks perceive a vital role for themselves in advancing sustainable finance, which involves developing regulatory frameworks, encouraging the creation of green financial products and including climate-related factors in their monetary and financial policy mandates. Most Asia-Pacific central banks are in the early stages of addressing climate and environmental risks or have not yet started. However, Durrani et al. (2020) find that six regional banks are leading in managing these risks. One central bank was drafting a sustainable finance framework to guide the integration of ESG and Environmental and Social Risk Management (SRM) principles and to encourage funding towards green industries. Three central banks implement guidelines or regulations on sustainable lending and ESRM and seven banks have set up task forces to focus on and mainstream green finance. Augoyard et al. (2021) report that the 2021 Asia-Pacific Central Bank Sustainability Survey reveals a growing interest in climate change and environmental risks, with several central banks developing or implementing

sustainable finance measures or planning to do so. At present, most activities are related to their own governance and strategy and micro-prudential supervision. Impediments to the implementation of sustainable finance measures stem from a perceived lack of expertise and data availability constraints. Most institutions link climate and environmental goals with their mandates concerning price stability, as well as micro- and macroprudential supervision. The number of institutions associating environmental objectives with economic growth and development mandates was slightly lower than those not linking this objective to this mandate. For several other mandates, such as currency stability, portfolio management and consumer protection, relatively fewer institutions took environmental and climate issues into account (the smallest proportion concerned currency stability). However, it is worth noting that almost all surveyed institutions already use some type of sustainable financing measures in their own management and strategy (at the same time, this area of intervention had the largest number of measures used). Durrani et al. (2020) note that many measures in this category are typically adopted in the initial stages of tackling climate and environmental objectives, potentially indicating a growing interest in the years to follow.

Fender et al. (2020) discuss the 2019 Bank of International Settlements (BIS) survey on reserve management and sustainability involving 102 central banks. They propose explicit and implicit integration of sustainability in reserve management. Explicit integration entails specifying sustainability as a policy for holding reserves, which no central bank has done yet, although some aim for it. Implicit integration involves recognising the impact of sustainability on policy objectives. While most central banks currently do not factor in sustainability when pursuing policy objectives, over half believe that it could be integrated as an objective in reserve management. Central banks perceive investing in instruments issued for sustainable purposes, using ESG criteria as metrics for investment decisions, integrating climate risk in investment beliefs and environmental risk management as tools for implementing sustainability. Fender et al. (2020) conclude that as central banks are taking on a more active role in developing green finance, integrating sustainability into policy frameworks, particularly for foreign exchange reserves, has received less attention. Perceived benefits include reputation, setting an example and fostering long-term sustainable growth.

The role of sustainability in central bank mandates is particularly evident for environmental issues and climate change. Central banks have implemented measures within their jurisdictions to address the economic and financial ramifications of climate change, as well as to promote sustainable finance in the financial sector. The NGFS, which was initially founded in December 2017 by eight central banks and supervisors, quickly expanded to include

121 central banks (Delgado, 2023). Its aim is to align with the Paris Agreement goals, intensify the financial sector's engagement in managing risk and to mobilise capital for environmentally sustainable initiatives, specifically green and low-carbon investments (Elsenhuber and Skenderasi, 2020). The NGFS (2019) encourages central banks and supervisors to undertake measures such as incorporating climate-related risks into financial stability monitoring and microsupervision, including sustainability considerations in their portfolio management, filling in missing data and fostering awareness and knowledge exchange (Breitenfellner et al., 2019). Importantly, after extensive debate, the NGFS (2019) reached the consensus that climate-related risks, due to their interconnectedness with financial risks, come under the purview of central banks.

D'Orazio and Popoyan (2022) argue that while central banks in G20 countries often prioritise price stability and economic welfare in their mandates, the explicit inclusion of sustainability as a mission statement remains uncommon. Unlike advanced economies, emerging economies such as China and Brazil have central banks with more expansive mandates. This provides them with increased flexibility in interpreting their objectives, which includes employing climate-related financial instruments to direct credit towards environmentally sustainable sectors, aligning with their broader sustainable development goals for the economy. D'Orazio and Popoyan (2022) state that in jurisdictions where implicit financial stability mandates are lacking, sustainable economic growth and development objectives are often employed as a compensatory measure. Within the context of sustainability, central banks are adopting green monetary policies, which manifest in different ways. These include adjusting asset purchase programs to exclude high-carbon assets from their portfolios, tying refinancing costs to the amount of household and corporate loans aimed at environmental investments and modifying the criteria for collateral eligibility (see Section 5).

Eames and Barmes (2022) present a green scorecard ranking central banks on research and advocacy (related to environmental risks and climate change), monetary policy (green lending, green asset purchase programmes, collateral), financial regulation (capital requirements, limits on dirty lending, transition plans) and leading by example (alignment with the Paris agreement and citizen and civil society engagement). While almost all central banks considered score well on research and advocacy, only France, Italy, Germany, the EU and the United Kingdom score satisfactorily on financial policy and only France performs well in the leading by example category. France, Italy and then Germany are leaders on the green central banking scorecard.

Central banks have taken varying approaches to incorporating climate risks into their mandates and practices. The European Central Bank (ECB) has demonstrated increased commitment by considering climate change as a mission-critical issue and placing emphasis on its implications for its primary monetary policy objectives. In July 2021, the ECB Governing Council implemented a roadmap to embed climate change considerations within its policy framework, with the goal of integrating environmental sustainability into its monetary policy. This action plan shifts the focus from market neutrality to market efficiency, enabling a comprehensive integration of climate change risks and societal costs (ECB, 2020; 2021; D'Orazio and Popoyan, 2022). The ECB has also made a commitment to adjusting its corporate bond portfolio in alignment with the objectives set forth by the Paris Agreement, striving for a temperature increase of no more than 1.5 degrees Celsius. This involves evaluating the climate performance of corporate bond issuers on criteria such as reduced greenhouse gas emissions, carbon reduction targets and enhanced climate-related disclosures (ECB, 2022a). In July 2022, the ECB made the decision to incorporate climate factors when determining assets eligible for collateral in liquidity provisions. Additionally, the establishment of guidelines mandating the disclosure of information regarding private sector assets has been implemented as an extra prerequisite for the acceptance of collateral assets (Delgado, 2023).

In 2021, the UK Chancellor, Rishi Sunak, announced that the BoE will receive a green mandate that will include environmental sustainability and net-zero compatibility. Accordingly, in pursuing price stability, the BoE will consider both the climate and environmental objectives of the U.K., as well as the broader transformation of the country's financial system aimed at achieving a state of net-zero emissions. The BoE has taken several steps aimed at giving effect to this mandate. Notably, it announced a climate stress test and has committed to accounting for climate impact when choosing which assets to purchase in its QE programme (Hodgson et al., 2021). The BoE has also worked with the Treasury to make the recommendation of the Taskforce on Climate-related Financial Disclosures (TCFD) mandatory, aiming to improve the reporting of climate-related risks (Krebel, 2021). In 2022 as part of what is regarded as the most stringent climate stress test for banks to evaluate the UK's resilience in the face of climate change and transition to a carbon-neutral economy, the BOE warned that banks and insurers who neglect the management of climate risks as a top-priority concern could potentially experience a reduction of 10% to 15% in their annual profits, along with increased capital demands (Jones and Bruce, 2022). In 2019, the Banco de España (Spain) initiated the integration of sustainable and responsible principles into its portfolio, aligning with the second principle of NGFS. This principle highlights the importance of incorporating

climate-related risks into the monitoring and supervision of financial stability. Subsequently, in March 2023, the bank commenced the disclosure of climate-related aspects within its own portfolios. It is envisaged that the Banco de España will honour the commitment made in February 2021 by the Eurosystem central banks and the ECB to apply sustainability and responsible investment principles to non-monetary euro-denominated portfolios (Delgado, 2023).

In December 2022, the EBA released a roadmap outlining its goals and timeline for addressing sustainable finance and ESG risks. In the coming three years, the EBA intends to incorporate ESG risk considerations into the banking framework, supporting the EU's shift towards a more sustainable economy. This roadmap is in line with legislative measures that have endowed the EBA with new responsibilities in the field of sustainable finance and ESG risks. These responsibilities encompass a range of areas including market discipline, supervision, prudential regulations and other aspects pertinent to sustainable finance and ESG risk evaluation. The roadmap builds on a previous action plan from 2019 and ensures the continuation of actions while adapting to market and regulatory changes. The EBA will focus on transparency, disclosures, risk management integration, climate stress tests, prudential regulations, green standards and addressing emerging risks such as greenwashing (EBA, 2022).

In December 2022, the U.S. Federal Reserve Bank (the Fed) unveiled a proposal mandating financial institutions with assets exceeding $100 billion to integrate climate-related risks into their strategic planning, as per the Principles for Climate-Related Financial Risk Management for Large Financial Institutions. This initiative compels banks to incorporate climate-related financial risks in their audits and broader risk management strategies, including the addition of climate-related scenarios in stress testing. Banks also need to evaluate the inclusion of climate-related risks in their liquidity reserves. The proposal, addressing both physical and transition risks linked to climate change (see Section 3), encompasses six fundamental areas of climate-related financial risk management, such as risk management, strategic planning and governance, among others. This follows on from the Fed's November 2020 Financial Stability Report which acknowledged that climate change adds to economic uncertainty and risk and can impact financial stability. Since then, Jerome Powell (current chair of the Fed as of the time of writing) asserted that addressing climate risks aligns with the Fed's prescribed mandate, stating that the Fed will take supervisory and regulatory actions to mitigate climate risks if they threaten U.S. financial stability. Relatedly, the Fed announced its intention to join the NGFS as an observer towards the end of 2020 (Board of Governors of the Federal Reserve System, 2020; 2022; Higgs et al., 2022; Prentice, 2022).

The Reserve Bank of India requires commercial banks to dedicate a certain percentage of their loans to designated ‘priority sectors’ (such as the renewable energy industry etc.). The Bangladesh Bank implemented a minimum credit requirement for financial institutions, mandating them to devote a portion of their lending to green sectors (currently 5%). It also offers other commercial banks refinancing lines with favourable terms for their green products (Campiglio et al., 2018).

In 2014, the Banco Central do Brasil (BCB) passed Resolution No. 4327 mandating authorised financial institutions to develop and implement a social and environmental responsibility policy. The objective is to foster an integrated approach that considers economic, social and environmental aspects within financial institutions, supporting sustainable development in Brazil (Stuber, 2014). China implemented a green credit policy in 2006, restricting loans to polluting industries and linking interest rates to environmental performance. In 2012, the policy expanded to cover multiple bank categories, emphasising sustainable lending practices. Additionally, the Green Credit Guidelines Statistical System, introduced in 2014, compels Chinese banks to report loan balances in 12 green sectors aligned with international sustainability standards (Oyegunle and Weber, 2015; Xie et al., 2022). The People's Bank of China (PBC) also now accepts green bonds, loans and securities with a rating of AA or higher as valid collateral for its medium-term lending facility. The PBC has also incorporated green loans into its standing lending facility (Peng and Xiong, 2022).

The Nigerian Sustainable Banking Principles (NSBP) were approved and made compulsory in September 2012. The NSBP comprises nine principles covering areas such as E&S risk management, human rights, financial inclusion and reporting. The Central Bank of Nigeria (CBN) mandates the adoption and implementation of these principles by financial institutions, providing incentives for compliance and requires banks to report on their social, environmental and economic impact (CBN, 2012; Nwagwu, 2020).

The literature in this section shows that central banks are increasingly aware of the need to incorporate sustainability into their mandates, especially following the GFC of 2008, though integration is not uniform. Central banks in emerging and developing markets appear to be leading the charge, this being potentially attributed to their less defined mandates and greater developmental role. While sustainability has multiple facets, the focus appears to be on environmental considerations and climate-related risks, which are perceived to pose a threat to financial stability. As suggested in Section 3, ESG risk affects both the economy (macroeconomic aspects, including inflation) and financial markets and institutions (including the stability of the financial sector). It is, therefore, necessary to consider what actions central

banks can take and what tools they can use to address ESG risk as part of their two key policies: monetary policy and macroprudential policy. We discuss these issues next in the subsequent sections.

5. Sustainability within monetary policy

In the previous section, we analysed the mandates of central banks in relation to sustainability issues focusing on the various responsibilities entrusted to these institutions. Among these responsibilities, maintaining price stability is one of the most prevalent and crucial ones. Achieving this objective is a primary aim of the monetary policy implemented by central banks. In this section, we explore in greater depth the connection between sustainability and monetary policy.

Monetary policy encompasses strategic decisions undertaken by central banks to influence the cost and availability of money within an economy (ECB, 2021). Interest rates, set typically by monetary policy councils of central banks, are a key element of these decisions and have a ripple effect on the rates charged by commercial banks. These policy choices shape both consumer spending and firm investments.

As an example of central banks' policy objectives, the ECB primarily focuses on maintaining price stability through its monetary policy with a target of 2% inflation rate over the medium term. This aligns with broader EU economic policies aimed at full employment and economic growth. While interest rates are pivotal, central banks also utilise a range of other instruments to implement monetary policy, as for example open market operations, required reserve system or standing facilities. It should also be noted that, following the GFC, central banks began employing unconventional monetary policy tools, with QE being the most prominent one. Under QE, central banks purchase securities from the open market to increase the money supply and stimulate lending and investment. This process injects new money into the economy and lowers interest rates by driving up the prices of fixed-income securities. Additionally, it results in the expansion of the central bank's balance sheet.

According to the traditional approach, when conducting monetary policy, central banks should be guided by the principle of market neutrality, which refers to the idea that when implementing monetary policy, they should not influence the allocation of resources between different sectors or enterprises. This rule ensures that central banks do not favour certain industries or companies, maintaining a level playing field in the market.

The urgent need to promote sustainability has prompted central banks to incorporate ESG considerations into their monetary policies. This involves broadening the scope of policy beyond the traditional objectives of price stability and economic growth and expanding their toolkit (ECB, 2021). Existing literature primarily explores the challenges presented by climate change and the necessity of transitioning to a green economy.

In Section 4 we discussed various issues and disparities regarding the engagement of central banks in addressing climate change. However, there exist distinct approaches of central bank officials to incorporate monetary policy into activities related to climate change.

Schnabel (2022) argues that monetary policy should not disregard the consequences of the green transition, especially if they pose a threat to achieving the goal of the primary mandate of maintaining price stability by the ECB. While acknowledging that fiscal policy should lead the charge in advancing the green agenda, Schnabel (2022) distinguishes three measures that the ECB can and will implement to bolster the green transition. First, the ECB will meticulously discern the nuances between climateflation, fossilflation and greenflation (see also Section 3) and tailor its actions accordingly. Both climateflation and fossilflation exhibit characteristics of adverse supply shocks and terms of trade shocks, necessitating a finely calibrated policy response. In contrast, greenflation, though currently subtle in its effects, is likely to arise from a robust and enduring positive demand shock or an upswing in investment. This scenario reinstates the ‘divine coincidence’ of monetary policy, highlighting the capacity of central banks to simultaneously stabilise inflation and output variables. Second, the ECB is committed to further greening its monetary policy framework, striving to align its set of instruments with the Paris objectives as much and as swiftly as possible. This involves selecting instruments that, among equally effective options, also contribute to the achievement of the EU's environmental objectives. Third, the ECB needs to intensify its endeavours to encourage green practices in financial markets. Through the influence on collateral rules, the ECB can establish standards that govern interactions among all financial market participants. For example, the Eurosystem may set restrictions on high-emission assets that counterparties can utilise as collateral, thereby influencing the overall collateral pool held by Eurosystem counterparts over time.

Building on Schnabel's (2022) framework on inflation, Schreiber (2022) puts forward recommendations concerning three crucial tools of the ECB to facilitate a clean energy transition and contribute to the broader goals of the EU. These measures involve modifying asset purchases and collateral policies to exclude fossil fuel developers, introducing dual rates jointly with a green lending facility to support certain construction projects and partnering with

the European Investment Bank and/or European Commission (EC) to promote a fair energy transition.

The President of the Deutsche Bundesbank, Joachim Nagel, underscores that maintaining price stability is vital for effective climate policy (see Nagel, 2023). He emphasised the necessity for significant investments in technological innovations and renewable energies as part of the green transition. Additionally, Nagel (2023) highlights the crucial role of central banks in promoting a shared understanding of how climate change influences various economic aspects, including inflation, interest rates and asset prices.

Honohan (2019), the former Governor of the Bank of Ireland, explores whether central banks can actively utilise their monetary tools to address climate change and contends that while it is essential not to stray from the core objectives of monetary policy, central bank mandates justify increased attention to broader issues such as climate change, especially when policy decisions have significant potential impacts. Navigating thoughtfully in this direction can strengthen central bank independence and contribute to improving the effectiveness of public policy in these realms.

Although some important central bank officials, such as former Bundesbank President Weidman (2019) and the Fed Chairmen Powell (2023), do not share the view that monetary policy tools should be used to support the greener economy (see Section 4), this issue is a matter of interest both in terms of theoretical and practical aspects related to the conduct of this policy by central banks.

Several authors discuss a set of actions or tools which can be used for integrating monetary policy and climate change issues. For example, Boneva et al. (2021) examine both direct and indirect linkages between climate change and the monetary policies of central banks, exploring a variety of policy options for central banks enabling them to deal with the climate change challenges, including more specific challenges for central banks with inflation-targeting mandates. They categorize potential central bank actions to address that issue into three groups: reacting to climate change, raising awareness of climate change and proactively mitigating climate change. The first category, reacting to climate change (also called passive or defensive actions), involves several key measures. These include protecting central banks' balance sheets by reducing the weight of brown and other assets at risk of becoming stranded. Additionally, it encompasses assessing the impact of climate change on the economy, financial markets and the monetary transmission mechanism. Incorporating climate change into the analytical toolkit is another crucial aspect, as is developing a monetary policy strategy that is resilient to climate change. This means central banks may need to review their monetary policy

frameworks to determine how they can adapt to climate-related risks and shocks in a world where the impact of climate change will continue to increase over time. According to Boneva et al. (2021), these actions are generally seen as supporting central banks' price stability mandate and therefore do not raise concerns about legitimacy. The second category of actions, which involves raising awareness of climate change, encompasses several initiatives. These include joining the NGFS, publicly communicating about climate change and the urgent need to green the financial system, promoting the disclosure of climate-related risks and supporting policymakers' initiatives to finance sustainable growth. The measures in this category do not necessitate trade-offs with central banks' primary mandates related to price stability. The third category of actions involves proactively mitigating climate change and includes several measures related to monetary policy. These measures consist of greening outright asset purchase programs (QE), central bank financing and/or lending quotas and the collateral framework for monetary policy operations. Measures in this category are considered controversial and subject to various trade-offs, depending on central banks' legal mandates and operational frameworks.

However, Boneva et al. (2022) recommend that central banks looking to integrate climate change considerations into their monetary policy framework should carefully consider the potential unintended environmental impacts of their policies. If various configurations of monetary policy instruments can achieve price stability equally well, an environmentally conscious central bank might prefer the option that best aligns with the government's environmental goals, or at the very least, the one that does not undermine those objectives. For instance, during an expansionary phase of the monetary policy cycle, a central bank with an existing asset purchase program might choose to prioritize purchases from less-polluting issuers, as long as this selection does not alter the intended level of monetary accommodation.

Kotecki (2023) further explores potential routes through which climate change can impact monetary policy and the operations of central banks and assesses various choices that central banks have at their disposal to allow them to contribute to the endeavours to combat climate change. Some of these choices are closely related to monetary policy. These include measures such as: differentiating interest rates to highlight climate-related loans granted by central bank counterparties; varying interest rates to reflect the quality of the pledged collateral with a preference for low-carbon assets; making access to certain credit instruments conditional on the contractor's disclosure of information about the project's carbon intensity; making reserve requirements dependent not only on banks' liabilities but also on their assets, so that, for example, it would be possible to give preference to institutions involved in financing the

climate and energy transformation; targeting the acquisition of assets with a preference for assets and issuers with better climate and environmental performance or exclusion of certain issuers or assets if they do not meet climate-related criteria.

The report by the NGFS (2021a) deals with the implications of climate-related risks on the economic outlook, the financial system and the execution of monetary policy. It underscores that the timing and severity of these implications hinge on the efficacy of transition policies. The report puts forth a series of stylised options for adapting monetary policy operational frameworks to consider climate-related risks. These options encompass actions related to credit operations, such as adjusting pricing based on counterparties' climate-related lending and collateral composition and modifying the counterparties' eligibility. Regarding collateral, adjustments include altering haircuts, implementing negative and positive screening and aligning collateral pools with climate-related objectives. The report primarily concentrates on potential measures related to the asset side of a central bank's balance sheet, specifically addressing liquidity-providing instruments. However, it acknowledges the relevance of liquidity-absorbing instruments, such as reserve requirements, term deposits and the issuance of central bank bills, without delving into detailed discussions.

Some studies explore the connections between climate change and central banks' monetary policy from a macroeconomic standpoint, which sometimes concerns modelling of macroeconomic phenomena and the analytical frameworks used within this policy. For example, Batten (2018) and Batten et al. (2020) examine the channels through which climate change and mitigation policies may influence a central bank's ability to achieve its monetary policy and financial stability objectives. This underscores the relevance of two types of risks: physical risks arising from weather-related disasters and transition risks resulting from abrupt shifts in carbon emission policies. They also propose various approaches to model macroeconomic effects resulting from these issues, emphasizing the importance of regular monitoring and quantification of emerging climate change risks on the economy. Based on these approaches Batten et al. (2020) develop implications for the analytical framework of monetary policy authorities, discussing specific models that central banks should consider. They argue that disaggregated quantitative analysis may provide more useful insights for monetary policymakers than, for example, the use of Integrated Assessment Models (IAMs), which are commonly employed to project the future impact of climate change on GDP. They also highlight that transition risks related to announced climate policies can be integrated into macroeconomic forecasting models, whereas those associated with unannounced future policies and technological changes are more challenging to incorporate. The primary transition

risks include changes in climate policy, which fall under broader fiscal policy variables, and energy supply risks, which can be modeled as technology shocks in a dynamic stochastic general equilibrium (DSGE) model. However, since conventional DSGE models may not be well-suited to analyse the complex systemwide transition to a low-carbon economy, they suggest an alternative approach: agent-based modelling (ABM). Nonetheless, ABMs often include arbitrary behavioural rules and their transmission mechanisms can be difficult to identify, requiring caution when drawing monetary policy conclusions from these models.

Mongelli et al. (2024) investigate the impact of climate change on the natural rate of interest, which is a crucial benchmark guiding monetary policy decisions and an important macroeconomic variable, that allows the economy to operate at its potential while maintaining inflation at the target level. Their study explores various models to simulate the effects of climate change on the natural interest rate. The findings suggest a dampening effect of climate change on the natural interest rate. Mongelli et al. (2024) highlight the long-term challenge for monetary policy, as the declining natural interest rate constrains its policy space, albeit within the context of considerable uncertainty about the outcomes.

Chen et al. (2021) considering some macroeconomic issues investigate the interplay between monetary and climate policy using an extended Environmental Dynamic Stochastic General Equilibrium (E-DSGE) model. Their findings indicate that the formulation of monetary policy should account for existing climate policies, as these policies can influence price levels and inflation. Additionally, they discovered that reaction coefficients in traditional monetary policy rules can be better adjusted to increase welfare when climate policy is provided, which offers a way to optimise the combination of policies. They also noted that central banks face risks when proactively addressing climate issues through ‘narrow’ monetary policy tools like interest rates.

The next group of studies analyses the connections between global warming, climate change and monetary policy, addressing this issue in relation to specific countries or geographical regions. For example, Drudi et al. (2021) explore the impact of climate change on the conduct of monetary policy in the euro area. As part of their considerations, they suggest several potential measures the ECB could consider within its monetary policy implementation framework. They emphasize four main areas: climate-related disclosures, risk assessment, the corporate sector purchase programme (CSPP) and the collateral framework.

Regarding climate-related disclosures, the authors propose that the Eurosystem could enhance its role and risk management practices by implementing its own disclosures and introducing disclosure requirements for private assets. These disclosures could serve as a new

eligibility criterion or as a basis for differentiated treatment of collateral and asset purchases. Specifically, the Eurosystem could begin by disclosing climate-related information for its CSPP and euro-denominated non-monetary policy portfolios (NMPPs).

For risk assessment, Drudi et al. (2021) suggest that the ECB should enhance its capabilities to evaluate climate-related financial risks. This could be achieved through climate stress testing of the Eurosystem's balance sheet and incorporating climate-related risks into credit ratings and assessments (further details on these actions are provided in Section 6).

As for the ECB's CSPP programme, Drudi et al. (2021) argue that it has significant potential to promote green finance by signaling and directly channeling financial flows. While the Eurosystem has already started integrating climate considerations into its due diligence process for CSPP issuers, they recommend further adjustments. These adjustments would involve revising the framework for allocating corporate bond purchases to include climate change criteria, aligning with the ECB's mandate. In making these changes, the Eurosystem should consider the impact on financial risks, feasibility and operational implementation. One possible approach is a 'tilting' strategy, which would prioritise issuers that align, at a minimum, with EU legislation implementing the Paris Agreement, as measured by climate-related metrics or commitments to climate goals.

Regarding the collateral framework, Drudi et al. (2021) suggest that the Eurosystem should consider integrating relevant climate-related risks into the methodologies used for calibrating its risk control framework and valuing assets provided as collateral in Eurosystem credit operations. The authors note that the Eurosystem has already begun accepting certain sustainability-linked instruments as collateral and for asset purchases, demonstrating a commitment to financial innovation in environmental sustainability. Specifically, as of January 2021, the Eurosystem started accepting sustainability-linked bonds as collateral and included them in its asset purchase programmes.

Rudebusch (2019) highlights the increasing influence of climate change and the related environmental shifts on the U.S. economy. These effects, along with their associated risks, are crucial factors for the Fed to consider as it seeks to fulfil its stability mandate with respect to key macroeconomic and financial variables. However, while the effects and risks of climate change are relevant considerations for the Fed, the institution is not positioned to actively use monetary policy to facilitate a transition to a low-carbon economy. The Fed's statutory mandate focuses on price stability and full employment, without directly including environmental sustainability or climate change mitigation. Additionally, the Fed's primary tool, the short-term interest rate policy, is not suited for promoting low-carbon industries. And although some have

suggested that central banks could leverage their balance sheets to support the transition to a low-carbon economy by purchasing low-carbon corporate bonds, this approach, often referred to as green QE, is an option for certain central banks, however, it is not feasible for the Fed, which is legally restricted to purchasing only government or government agency debt.

Some researchers in their discussions on addressing climate change consider the connection between monetary policy and fiscal policy. For example, Ohtaki (2023) investigates the interplay between monetary policy and climate change and develops an overlapping generations model that incorporates the environment and money. According to the results of this study if policymakers can choose tax instruments in addition to money growth rates, a range of optimal combinations of these factors can implement an optimal allocation as a stationary monetary equilibrium allocation. According to Ohtaki (2023), these research findings indicate the need for coordination between monetary and fiscal authorities to effectively address climate challenges.

Hansen (2021) claims that while fiscal policy is generally regarded as the most effective government tool for combating the negative effects of greenhouse gas emissions and global warming, monetary policy can play a supportive role by promoting sound strategies for assessing the long-term impacts of climate change uncertainty. However, monetary policy is not a strong substitute for prudent fiscal policy. Central banks that overestimate their ability to contribute risk both encroaching on the political arena and creating false expectations among the public about the best ways to address climate change.

Another set of studies focuses on selected unconventional monetary policy instruments that take climate change issues into account, with particular emphasis on the issue of QE. Abiry et al. (2022) explore the impact of central banks' monetary policy on addressing global warming by employing green QE, i.e., a strategy that entails reallocating a monetary authority's privately held bonds towards those held by the green sector of the economy. Abiry et al. (2022) demonstrate that the implementation of green QE results in the partial crowding out of private capital in the green sector, with only a modest temperature decrease of 0.04 degrees Celsius by 2100. They also find that the effects of the moderate global carbon tax on climate change mitigation are substantially larger - by a relative effectiveness factor of about 4.3 - than what is achieved through green QE. In fact, green QE has a larger effect if used in isolation than in combination with a carbon tax. Anyhow they also find that pursuing a green QE policy on top of the introduction of the carbon tax leads to an additional climate change mitigation.

Ferrari and Nispi Landi (2024) investigate the effectiveness of a green QE policy, which involves adjusting the central bank's balance sheet to favour green bonds. They use a DSGE

framework combined with an environmental model to explore both the transmission mechanism of a temporary green QE and the short-term effects of a permanent green QE. The study explores two types of green QE: one that does not alter the size of the central bank's balance sheet and another that increases the balance sheet size. In this context, various scenarios are simulated to examine the positive and normative aspects of a temporary green QE. The results are presented using several macroeconomic and environmental indicators, providing insights into the broader economic and environmental impacts of these policies. In conclusion, Ferrari and Nispi Landi (2024) assert that for green QE to be effective, green and brown bonds must be imperfect substitutes. Under the assumption of imperfect substitutability, their findings indicate that while green QE can reduce the flow of harmful emissions, the impact is quantitatively small. Thus, green QE does not appear to be a particularly potent tool for addressing climate change.

In another paper, Ferrari and Nispi Landi (2023) continue their examination of the effectiveness of green QE This time, they employ a DSGE model to assess the effectiveness of central bank green-asset purchases along the transition to a carbon-free economy, facilitated by an emission tax. They refer to the European Union's goal of achieving climate neutrality by 2050. Their simulations indicate that green QE can curb emissions by shifting demand from the brown sector to the green sector. However, they also demonstrate that its impact on the overall stock of euro-area and global pollution (i.e., the net cumulative sum of emissions) is small. Additionally, it was shown that green QE is particularly effective in reducing emissions during the early stages of the transition, with its effectiveness diminishing over time as the carbon tax becomes more influential. The results of Ferrari and Nispi Landi (2023) complement the findings of Ferrari and Nispi Landi (2024) and Abiry et al. (2022). Collectively, these studies suggest that green QE offers only limited environmental benefits, making it a relatively weak tool for addressing the climate challenge. However, green QE becomes more valuable if the government fails to implement or delays the introduction of an appropriate carbon tax.

The issue of the carbon tax, considered in the studies by Abiry et al. (2022) and Ferrari and Nispi Landi (2023), is related to the broader problem of decarbonization, which is the subject of research by Schoenmaker (2021) with a focus on monetary policy aspects. According to this research although there is an increasing focus on decarbonising monetary policy, central banks hesitate to compromise market neutrality. However, there is evidence suggesting a market inclination towards carbon-intensive companies. Schoenmaker (2021) outlines an approach to adapt the asset and collateral framework of the ECB, with the aim of giving preference to low-carbon assets. By employing a moderately tilted strategy, carbon

emissions in the ECB's corporate and bank bond portfolio could be diminished by more than 50%. It is proposed that it is possible to attain a low carbon allocation without overly disrupting the transmission mechanism of monetary policy.

Van Eyck (2024) puts forward recommendations concerning other unconventional monetary policy tools useful for taking into account the issue of sustainability in monetary policy, such as dual interest rates. This proposal aligns with French President Macron's suggestion during his COP28 speech, where he advocated for implementing favorable interest rates on loans for green projects, as opposed to 'dirty' projects. Van Eyck (2024) highlights that since 2020, scholars and civil society have been urging the ECB to incentivize private banks to increase lending for green investments. However, the ECB maintains that in the current economic context, boosting lending volume would conflict with its goal of fighting inflation. Despite this, van Eyck (2024) argues that the green transition necessitates significant investment increases and dual rates are crucial to bridging the net-zero transition investment gap.

Costa (2024) notes that dual interest rates are not a novel concept. After the financial crisis, the ECB offered lower interest rates to banks through the Targeted Longer-Term Refinancing operations (TLTRO) and the Bank of Japan implemented a green lending programme providing zero interest to lenders supporting renewable energy projects. However, in the EU and UK, this tool has not been specifically used for green purposes.

Referring to the fact that since 2021 the macroeconomic landscape in major economies has shifted dramatically, in particular due to high levels of inflation jumping up in short time period, Aguila and Wullweber (2024) observes that, to date, there has been very little focus on systematically analysing and assessing the challenges associated with green central banking in an inflationary environment. They explore various approaches to green monetary policy under these conditions, focusing on asset purchase programmes, direct credit allocations, policies for lending and financial regulations. Regarding asset purchase policies, central banks could purchase bonds to finance green investments or impose a ban if bonds were linked to carbon-intensive industries (unless they have been designed to support green projects). Lending policies include measures to distinguish between central banks interest rates to lower the cost of green borrowing or make the dirty borrowing more expensive, thereby incentivizing green loans while discouraging loans for polluting activities. They also encompass a green collateral framework for secured lending by, for example, banning dirty securities as collateral and accepting green assets for this purpose.

As far as credit allocation is concerned, it typically requires active coordination between the central bank and other institutions and it relies on the way the direct credit allocation is structured. The specific tools that central banks can use in this field include quantitative restrictions on lending, banning investment in particular industries or requirements for banks regarding setting different interest rates for green and dirty lending. In the area of financial monetary policy regulations, the central bank could exploit the reserve ratio requirement for banks and increase it for lending in case of carbon-intensive activities or reduce it in case of green investments. Aguila and Wullweber (2024) point out that higher interest rates slow down the green transformation by increasing the cost of sustainable investments which, in turn, is harmful for achieving price stability. However, they also argue that monetary policy can support a greener economy without compromising price stability through providing cheaper funding for green projects while at the same time restricting funding, due to higher interest rates, for those which are harmful for the environment. Aguila and Wullweber (2024) conclude that the current macroeconomic environment necessitates a 'greener and cheaper' monetary policy strategy to tackle the environmental and climate crisis while also conquer inflation.

To summarise this part of the discussion, it is important to note that the literature reviewed so far highlights the absence of a consistent approach to central banks' involvement in climate-related activities. Anyhow, so far in our discussion the focus has primarily been on considerations and recommendations, rather than on concrete evidence of actions taken by central banks. However, there is also a body of research that concentrates on the actual activities of central banks in this area, which will be the focus of the further discussion presented in this section.

The first set of actions related to incorporating sustainability issues into monetary policy involves asset purchase programs.

Eliet-Doillet and Maino (2022) highlight recent actions taken by central banks with a focus on the BoE and ECB. The purchase programme CSPP is a prominent tool in the ECB's green agenda, aiming to reduce firms' cost of capital and stimulate investment. The ECB plans to integrate climate criteria into its corporate bond purchasing scheme, with ongoing discussions on practical and legal requirements. The BoE's initiative involves greening the Corporate Bond Purchase Scheme (CBPS). Notably, the use of green bonds to finance climate-friendly projects positively impacts environmental performance and garners favourable responses from investors.

However, Dafermos et al. (2020) uncovered that the portfolio of the BoE was skewed towards the most carbon-intensive sectors, including fossil fuels and utilities, making up

around 57% of the value of bonds in the BoE list. Despite this, these sectors only contribute 19% to the GVA. Building on this, Dafermos et al. (2020) conclude that the BoE, while a pioneer in announcing detailed rules for greening its portfolio, adheres to market neutrality, limiting penalties for carbon-intensive activities. The BoE's approach, though nominally greener, may have relatively negligible effects on the climate perspective of the CBPS portfolio, as indicated by the Weighted Average Carbon Intensity, showing only a modest 7% change.

Similarly, Matikainen et al. (2017) examine asset purchase programmes of the ECB and BoE and discover that emission-intensive sectors, such as manufacturing and utilities, represent a disproportionate share of estimated purchases compared to their contribution to Gross Value Added (GVA) and the European bond market. This disproportionality raises concerns that high-carbon sectors may benefit more from reduced financing costs, contributing to the potential mispricing of assets in sectors at risk of becoming stranded assets. The inadvertent reinforcement of the status quo by central banks through market-aligned asset purchase programmes may perpetuate a 'green investment gap,' impeding low-carbon investments from reaching the socially optimal scenario for climate goals. Kroll and Kühne (2024) discuss the idea of 'climate bailout' tool – allowing central banks to buy potentially stranded assets from fossil fuel industries on the condition that the proceeds of the transaction are used to invest in renewable energy.

Eliet-Doillet and Maino (2022) highlight, that the focus on green bonds introduces uncertainty regarding whether the ECB will depart from market neutrality—a policy wherein central banks purchase bonds in proportion to the outstanding amount, a practice that is often criticised. In support of this perspective, Papoutsi et al. (2021) argue that market neutrality does not straightforwardly follow from the formulas employed by policymakers; rather, it hinges on the impact of central bank purchases on firms' cost of capital and the proportion of capital funded by bonds. Their study, utilising different microdata, also unveils that the ECB's corporate bond portfolio exhibits a bias towards the sectors with high emissions.

Aloui et al. (2023) point out that in July 2021 the ECB introduced new environmental criteria for the inclusion of private assets in its programme. They investigate how shocks related to green bonds impact the stock market both before and after the COVID-19 pandemic. Their analysis reveals a non-linear relationship between green bonds and green equities. The results suggest that the ECB's implementation of green QE can guide investors toward green investments in the stock market during non-crisis periods. However,–Aloui et al. (2023)

emphasise that the effective transmission of green QE shocks to the stock market is dependent on economic conditions and may not be very impactful during the crisis periods.

Senni et al. (2023) explore the climate impact of central bank refinancing operations, with a particular focus on the ECB's green TLTRO programmes. Their findings reveal that over the TLTRO III reference period (March 2020-March 2021), more than 80% of total cumulated loans were directed towards polluting companies, constituting 8% of the overall Euro Area 2019 emissions. Senni et al. (2023) investigate the potential effectiveness of a green credit easing scheme and suggest that central bank policies could redirect loans to less-polluting firms, but they also emphasise the need to carefully consider financial stability implications.

Apart from asset purchase and TLTRO programs, another set of actions possibly incorporating sustainability issues into monetary policy involves collateral management.

Dafermos et al. (2021) discuss the issue of collateral framework of the Eurosystem. They claim that in contemporary financial markets, where collateral plays a crucial role, the central banks' handling of collateral - specifically, the conditions under which they accept bonds or loans from banks - conveys a powerful message to private financial markets. The existing structure of the collateral framework not only runs counter to the specified goals of the Paris Agreement and the EU's Green Deal but also actively sustains failures in the financial market and reinforces carbon lock-in. Despite contributing less than 24% to EU employment and 29% to GVA, companies with high carbon intensity are responsible for issuing 59% of the corporate bonds accepted by the ECB as collateral. This framework implicitly provides incentives for fossil fuel companies, as some significant players in the fossil fuel industry rely on bonds subsidised by the ECB's collateral framework for more than half of their total financing. As a result, so far it cannot be said that the monetary policy of central banks plays a significant role in solving problems related to sustainable development.

Eliet-Doillet and Maino (2022) argue that, in addition to unconventional monetary policy tools, the collateral framework plays a pivotal role as it constitutes the basis for the implementation of the ECB's conventional monetary policy. The ECB employs collateralised lending to offer liquidity and the framework delineates regulations governing how central banks inject funds into the banking system. Critique is directed at the ECB framework because, similarly to extensive corporate bond acquisitions, the eligibility criteria frequently lean towards favouring high-emission companies, which happen to be the primary issuers of bonds meeting the specified criteria.

However, Aguila and Wullweber (2024) argue that in some cases current practices demonstrate the ability of central banks to adjust eligibility requirements, enabling them to

exclude environmentally harmful securities and include green assets as collateral. The ECB, Bank of Japan and the People's Bank of China are already incorporating various green bonds as acceptable collateral in their credit facilities. A less ambitious alternative would involve central banks imposing margin requirements on non-green assets.

The proposal to introduce dual central bank interest rates in order to provide cheaper financing to less polluting firms and projects, discussed, among others, in Europe.is already introduced into practice. For example, the Bangladesh Bank has initiated several green refinancing schemes with lower interest rates for green loans (Dikau and Ryan-Collins, 2017; Aguila and Wullweber, 2024).

Another monetary policy tool that central banks can use to encourage sustainable lending and discourage financing of carbon-intensive activities is the reserve requirement. Although this approach is rarely used in practice as a green monetary policy tool, there are instances of its application. For example, Lebanon's Banque du Liban has reduced reserve requirements for loans that finance environmentally friendly projects. An additional option related to adjusting reserve requirements includes application of different interest rates on reserves. For instance, the People's Bank of China rewards banks characterized by excellent green financing performance and pays them a higher interest rate on required reserves. Similarly, banks borrowing from the Bank of Japan's green lending facility can benefit from higher-paying rate on reserves (Barmes and Livingstone, 2021; Aguila and Wullweber, 2024).

A set of monetary policy activities that central banks undertake to promote green sectors involves also direct credit allocation policies (see also Section 4). For instance, the central bank in China applied 'soft pressure' on reallocation of credit from carbon-intensive borrowers to other investors involved more in green projects. Banco do Brasil has imposed lending restrictions in case of some of Amazon's environmentally sensitive areas. The Bangladesh Bank mandates quantitative minimums on green lending, requiring financial institutions to allocate 5% of their portfolios to green sectors and the Reserve Bank of India requires commercial banks to lend a specific proportion of their loanable funds to priority sectors, including renewable energy (Dikau and Ryan-Collins, 2017; Dikau and Voltz, 2021; Campiglio et al., 2018; Aguila and Wullweber, 2024).

The overview of central banks' actions in incorporating sustainability into monetary policy, as presented above, appears to be extensive and diverse. However, some researchers point out that a detailed analysis of the scale and outcomes of these actions leads to the conclusion that their scope is still insufficient. For example, Boneva et al. (2022) state that current initiatives by central banks predominantly concentrate on integrating climate-related

considerations into prudential supervision, while progress in embracing climate change factors in monetary policy appears to be trailing behind. As a result, so far it cannot be said that the monetary policy of central banks plays a significant role in solving problems related to sustainable development.

This claim is partially supported by Tufail et al. (2024), who examine the impact of monetary policies in the US, EU and China on global green investment. Their findings indicate that significant changes in the monetary policies of these major economies are necessary to advance global green investment and facilitate an ecological transition.

Concluding the considerations on taking into account issues related to sustainability in the monetary policy of central banks, it can be noted that, despite differences in views on this issue, a number of proposals in this area have been presented in the literature. They encompass various activities within the monetary policy framework, the most important of which appear to be:

- Asset purchase programs implemented by central banks as a part of QE with a preference for assets and issuers that exhibit strong climate and environmental performance;
- Lending policies that differentiate interest rates and collateral regulations to favour low-carbon assets;
- Reserve requirements that consider not only banks' liabilities but also their assets, prioritising institutions involved in financing climate and energy transformations;
- Direct credit allocation that prioritizes access to specific credit instruments for low-carbon projects, imposes quantitative restrictions on lending to carbon-intensive firms, or sets minimum thresholds for green lending.

However, although a significant portion of these proposals has been implemented and is utilized to varying degrees within the monetary policies conducted by central banks, the scale of this implementation seems too small to claim that monetary policy exerts a sufficiently significant impact on sustainable development. Moreover, some of the applied measures, such as asset purchase programs, are not always executed in a manner that aligns with the declarations regarding the preference for green assets and issuers.

Despite this, given the central banks' declarations and approaches, significant progress in this area is anticipated in the near future, with such steps likely to be more evident from central banks like the ECB than the Fed.

In summary, monetary policy primarily addresses macroeconomic issues, which are associated with various types of macroeconomic risks. Closely related to it is another set of

central bank activities, including those conducted under macroprudential policy. The integration of sustainability macroprudential policy is discussed next in Section 6.

6. Sustainability within macroprudential policy

As discussed in Section 3, climate-related risks – and more broadly environmental and social risks – affect financial institutions (mostly indirectly). As a result, there is a call for the integration of these risks into the regulatory and supervisory frameworks of financial institutions. The NGFS (2019) propose a comprehensive framework to incorporate climate-related factors into prudential supervision. This framework involves several key elements: increasing awareness and bolstering capabilities within firms, evaluating risks associated with the climate, establishing supervisory standards, mandating transparency to encourage market accountability and minimising risks by utilising financial resources such as pillar 1 or 2 capital requirements. There is wide-ranging debate about the possible prudential tools (both at the micro and macro levels[14]) to address the ESG risk in financial institutions and at the same time reach sustainability goals in broader terms.

Some studies are devoted to the microprudential measures that can be used to address climate-related financial risk (see, for example, NGFS, 2020b; Diluiso et al., 2021; Dunz et al., 2021; Smoleńska and van't Klooster, 2022). Special attention is devoted to capital requirements for banks, including the green supporting factor (reduction in risk weights for green exposures) or the brown penalising factor (increase in risk weights for brown exposures). Studies however find that both of these tools are ineffective (at this stage of climate change) given unintended consequences or they have limited scope (see Dunz, Naqvi and Monasterolo, 2021; Chamberlin and Evain, 2021). The overall conclusion is that other tools are needed, such as macroprudential tools (Baranović et al., 2021; Chaves et al., 2021; Alessi et al., 2022). Additionally, as there is a concern regarding inadequate application (or calibration) of macroprudential tools that could be overly restrictive for some individual banks adequately managing ESG risks, Dikau et al. (2024) point to the potential of prudential transition plans for better targeting of macroprudential instruments to individual entities.

[14] It should be noted that some supervisory instruments can be used for both micro-prudential and macro-prudential policies.

The macroprudential approach is justified by the fact that depending on the risk factors and their specificity, the risk can be systemic - causing threats to financial stability[15] (Nieto, 2018; NGFS, 2019; Rudebusch, 2019; Bolton et al., 2020; FSB, 2020a; Philipponnat, 2020; Steele, 2020; Alogoskoufis et al., 2021; Grünewald, 2021; Svartzman et al. 2021) (see also Section 3). One argument is that the global economy is heading for a disorderly transition (drastic and imminent changes to meet net-zero targets), which will exacerbate transition risks in the long term[16] (Miller and Dikau, 2022). Dennis (2023) highlights that climate change externalities have macro implications for insurance companies and widespread climate damage resulting from global shocks which may require a macroprudential approach.

Grünewald (2021; 2023) examines two facets of systemic risk concerning climate risks; the temporal dimension, addressing the evolution of aggregate risk in the financial system and the cross-sectional dimension, addressing risk allocation within the financial system at a specific moment. The former is affected by the radical uncertainty associated with climate risk, its course and consequences, making it difficult to analyse and address using traditional backward-looking tools (Bolton et al., 2020). The latter causes risk to be transferred between sectors and multiplied by adding the effects of second-round effects and successive round-effects, requiring consistent actions to counteract this risk in different sectors.[17] In addition, some climate change policies can also generate systemic risks. This applies to both direct incentives towards the low-carbon transition and the financial incentives for decarbonisation. For example, in the first case, Safarzyńska and van der Bergh (2017) demonstrate that energy policies could heighten the probability of cascading bank failures.[18] In the latter case, asset overpricing may occur (in particular, the creation of stranded assets) (see Section 3). Appropriate macroprudential tools need to therefore be applied in advance to limit the negative systemic impact of such policies.

As in many jurisdictions, the responsibility for systemic risk (macroprudential policy) lies on central banks (Calvo et al., 2018). This responsibility should also be addressed when

[15] Lamperti et al. (2019) conducted scenario analysis based on which they concluded that climate change is likely to elevate the occurrence of banking crises by 26% to 248%.
[16] This situation is commonly known as a 'climate Minsky moment.' This term was first used by Mark Carney (2016) to depict a situation where a swift transition toward a low-carbon economy could significantly harm financial stability. This occurs due to the rapid reassessment of climate risks, leading to swift adjustments in asset prices and potential negative feedback loops impacting growth—an idea also discussed by Sarah Breeden (2019).
[17] For example, Roncoroni et al. (2021) analysed the climate risk and financial stability within the network of financial institutions, such as investment funds and banks.
[18] An explanation to that is given by Nasim and Downing (2023) who show that banks face substantial vulnerability to energy price shocks due to the interconnectedness between the energy sector and financial markets. Lehmann (2022) also points out complex interlinkages between the banking sector and the markets on which energy and commodity contracts are traded.

discussing the role of central banks in the context of sustainable development. Dikau and Volz (2021) argue that integrating climate-related risks into macro-financial policy frameworks is warranted as these risks directly align with the traditional responsibilities of central banks. In the FSB (2020b) survey, almost three-quarters of respondents affirmed their consideration of climate-related risks in monitoring financial stability (much more in relation to physical risks than transition risks).

Several studies (such as Schoenmaker et al., 2016; Dikau and Ryan-Collins, 2017; Volz, 2017; Dikau and Volz, 2019; D'Orazio and Popoyan, 2019b; Steele, 2020; Le Quang and Scialom, 2022; Grünewald 2023) discuss different macroprudential policy tools that can be used to address climate change risks. Some of these are discussed below.

After analysing the consequences of low-carbon transition, the European Systemic Risk Board (ESRB) (2016) suggests several macroprudential policy implications. Short-term suggestions include emphasising improved information gathering and disclosure, along with integrating regular stress tests into climate-related prudential risks. For the medium term, potential measures might involve systemic capital buffers, regulations mandating loss absorbency (such as promoting the issuance of carbon risk bonds), targeted capital surcharges tied to the carbon intensity of specific exposures and imposing large exposure limits to assets considered highly susceptible to a sudden shift towards a low-carbon economy.

Johnston (2022) proposes an adapted macroprudential framework addressing systemic risks posed by climate change. As the key challenge is to link the financial asset and loan composition to climate targets, Johnston (2022) proposes steps to establishing such a link.

The ECB/ ESRB (2022) highlights that addressing climate change stands as a significant collective challenge necessitating robust international cooperation and comprehensive policy endeavours across all domains. The report also reviews the ongoing policy initiatives by national or international regulatory or supervisory bodies, targeted at banks, insurance companies, asset managers or the financial system as a whole and reveals that green macroprudential regulation initiatives so far only cover banks. The report stresses that few countries are using capital requirements regarding the sustainability aspect of macroprudential regulation, however, in the case of many institutions (such as the FSB, EBA, ESRB, ECB, EC and BCBS) there is an ongoing discussion concerning the topic. The ECB/ESRB (2022) report places climate-related macroprudential policy into the broader context arguing that it has the potential to supplement a microprudential approach and will hinge on a wider array of public policies designed to mitigate and adapt to climate change. One of the issues indicating the relevance of the macroprudential approach to climate risks are

systemic aspects. This approach could aid in managing risks that extend across different sectors and limit the potential for arbitrage. The report by the ECB/ESRB (2022) discusses measures used within micro- and macroprudential approach to climate risk as follows:

a) Concerning classic systemic externalities: (i) systemic capital-based measures (systemic bank buffers); (ii) sectoral requirements (risk weights or minimum Loss Given Default (LGD) ratio, a sectoral systemic risk buffer, sectoral leverage ratio); (iii) borrower-based measures (e.g., loan-to-value/ debt service-to-income/ debt-to-income/maturity limits); and (iv) addressing the insurance protection gap.
b) Specific climate risk features (both micro- and macroprudential tools): (i) climate stress testing; (ii) the strengthening of market standards; (iii) disclosure requirements; (iv) common minimum requirements (e.g., concentration thresholds and concentration charges); and (v) transition plans.
c) Microprudential tools addressing idiosyncratic risks: (i) individual capital-based (e.g., green supporting factor or brown penalty factor) and liquidity measures; (ii) supervisory scrutiny; and (iii) risk management procedures.

The study analyses these tools concluding that none of the current instruments are immediately applicable to tackle climate risks. Hence, there is a need to adapt these instruments and craft new tools to address climate-related challenges. The systemic risk buffer and concentration thresholds are emphasised as effective tools for managing the systemic dimensions of climate risks in the banking sector and with a more neutral rationale; concentration charge and sectoral requirements – risk weights or minimum LGD.

The follow-on report compiled by ECB/ESRB (2023) explains in detail the systemic nature of climate risk and outlines potential macroeconomic policy tools to address these systemic aspects of climate risk, claiming that a common macroprudential framework for the EU is possible. It points out that macroprudential policy can aim to make the system less vulnerable to climate-related risks or to increase its loss-absorbing capacity, while the tools used should have a system-wide perspective (in particular, considering not only the banking sector but also the insurance sector), preventing the migration of risk. In doing so, it is essential that macroprudential policies complement microprudential policies in this area. The ECB/ESRB (2023) report also identifies the following as the most important macroprudential tools that can be used to address climate risk; capital surcharges (in particular the climate buffer/systemic risk buffer), concentration limits/thresholds, borrower-based measures and some measures concerning non-banks.

Monnin (2021) discusses in detail why and how systemic risk buffers for climate risk should be implemented. It is also important to note that while some measures can capture climate-related risks, they do not contribute to environmental goals (e.g., reducing emissions). For example, Oehmke and Opp (2023) point out that while capital requirements can effectively manage financial risks, implementing them may not inherently decrease emissions. For instance, imposing higher capital requirements on carbon-intensive loans might displace clean lending opportunities.

Bartsch et al. (2024), based on stress tests performed on granular data, analysed potential bank losses caused by transition risk and suggested a methodological framework that could be used for the calibration of climate-related macroprudential capital buffers.

The OECD (2021b) presents examples of macroprudential policy tools supporting the green transition, as well as examples of climate change stress tests and actions taken by central banks (and financial regulators) regarding climate change. D'Orazio and Popoyan (2019b), based on a large database constructed by the authors (D'Orazio and Popoyan 2019a), analyse different macroprudential tools. They present the advantages and disadvantages of the main instruments, compare them with alternative proposals and propose complementary actions. D'Orazio and Popoyan (2019b) note that some of the currently used or proposed instruments are prone to destabilising effects in the financial sector. Among them, they point to liquidity norms (both the liquidity coverage ratio and net stable funding ratio) and green supporting factor. They conclude with a suggestion for a collection of other alternative strategies to adapt existing banking prudential measures to also serve as climate strategies namely; (i) setting minimum credit thresholds (floors) or maximum credit caps (ceilings); (ii) introducing a sector-specific leverage requirement targeting exposure to a specific green sector; (iii) enforcing liquidity regulations aimed at moderating short-term practices in financial intermediation; (iv) implementing a countercyclical (or negative) capital buffer aligned with the carbon-intensive credit cycle aimed at ensuring financial stability and alleviating excessive growth in brown credit; and (v) imposing limits on large exposures to reduce banks' involvement with industries associated with brown sectors. Chenet et al. (2021) suggest a comprehensive climate-related precautionary financial framework that integrates all aspects of financial policy, including macroprudential and monetary interventions. This approach involves utilising capital adequacy requirements, credit controls aligned with climate risks (such as prohibiting the most polluting forms of lending, such as for thermal coal projects, or imposing a cap on credit to firms surpassing a designated carbon threshold) and employing credit guidance tools to steer or discourage credit flows towards particular sectors.

Baranović et al. (2021) argue that currently used macroprudential tools might already offer a means to curtail the accumulation of systemic climate risks and bolster banks' abilities to withstand their occurrence. This is primarily due to their adaptable nature in addressing diverse risks across various stages of financial intermediation. They stress, however, that these measures require adaptations. For example, capital-based macroprudential measures would require careful calibration, while limitations on banks' portfolios pose operational and legal obstacles. Ford et al. (2022) propose several changes to the banking prudential framework, including macroprudential tools. Their proposal involves applying variable capital risk weights to all fossil fuel-related assets, mirroring the global overshoot from a secure carbon budget within a 1.5 degrees Celsius scenario.[19] They argue that this approach would dynamically link prudential policy to the net-zero carbon transition.

Coelho and Restoy (2023) highlight an additional aspect of prudential requirements, sectoral buffers (or similar measures aimed at carbon-intensive counterparts such as concentration limits or surcharges), which might not encompass all exposure to carbon-intensive industries and counterparts. They suggest implementing prudential tools (additional capital requirements for dirty exposures, concentration limits or a concentration surcharge) not at the firm-level, but rather at the project level. They argue that this narrowly defined scope will not only increase the resilience of the financial system (as the broadly defined one), but also aid in alleviating transition risks rather than exacerbating them (as opposed to the broadly defined one). Such an approach, however, would require supervisors to have credit registers.[20] Also, Miller and Dikau (2022) propose a 'transition-aligned large exposures framework' - a 'soft limit' of 25% of eligible capital for aggregate large exposures to transition-sensitive sectors.

Currently, most jurisdictions concentrate on stress testing and disclosure requirements in addressing climate change-related risks, emphasising the importance of analysing this risk. The BCBS (2021b) discusses the methodological issues of measuring and assessing climate-related financial risk and points out the main differences between macroeconomic and climate scenario analysis. The NGFS (2020b) has published a series of guidelines and guidance on conducting physical and transition climate and environmental risk assessments. In addition, it developed climate scenarios that can be used by central banks, supervisors and individual

[19] This would mean that the risk weighting would vary over time depending on the trajectory of fossil fuel usage.
[20] Campiglio et al. (2018) highlight several challenges (for researchers and central banks) to investigating climate-related financial risks, including the availability of sufficiently detailed data and the difficulty in identifying which assets are exposed to climate-related risks. Also, Nieto (2018) points to the necessity to use granular credit risk data in stress-testing.

institutions (see also NGFS, 2022b). The Association for Financial Markets in Europe (AFME) (2023) sums up the scope, methodology, assessment approach and scenarios used by central banks in their climate risk stress tests. The ECB (2022b) lists favourable practices observed in the banks considered, based on the results of its climate stress test.

While stress testing can aid in the understanding as well as handling of climate-related financial risks (both micro- and macroprudential), its potential to address climate change and ensure financial stability remains untapped to a large degree. Simultaneously, it underscores that while stress testing is crucial for grasping the impact of climate change on financial stability, it is not a cure-all solution. Reinders et al. (2023) examine the existing methods for stress testing climate risk, encompassing various climate shocks (abrupt and gradual transitions, extreme scenarios like hot house conditions[21], climate-related disasters, green swan events and Minsky-type shocks[22]), along with diverse modelling techniques (traditional macro-financial models, micro-financial approaches, non-structural methods and disaster risk approaches). They assert that these methods exhibit several limitations that could result in substantial underestimation of potential losses within the financial sector. Reinders et al. (2023) suggest that the tests' scope is overly restrictive encompassing only specific assets, the climate shocks are too small (more green swans and Minsky-type scenarios should be included and feedback loops are not modelled (within the financial system, but also from the financial system to the economy and from the economy to climate risk).

While most publications concentrate on the banking sector, several studies consider insurance companies. Böffel and Schürger (2023) argue that the way sustainability issues are integrated into banking and insurance regulatory frameworks (approaches, techniques and instruments) fundamentally varies in terms of supervisory attention. This is due to the different risks faced by banks and insurance companies and the different roles of banks and insurance firms in combating climate change. The BoE (2023) suggests that insurance regulations do not explicitly mandate capital for macroprudential aims. Instead, it argues that macroprudential risk is implicitly incorporated, to a certain degree, within the Solvency II valuation framework.

[21] 'Hot house world' or 'hot house earth' conditions are understood as global warming: the substantial increase of global average temperature from the pre-industrial times. For example, NGFS includes the 'hot house world' scenario for stress tests, assuming that critical temperature thresholds are exceeded, which would lead to irreversible impacts (e.g., sea-level rise). The most recent NGFS methodology refers to the levels +2,4-2,9°C of end of century warming (NGFS 2023). (Some scientists suggest that the hot house climate might stabilise at the level of 4–5°C higher than pre-industrial average temperatures, leading to see levels 10-60 meters higher than currently – see for example Steffen et al., 2018).

[22] Reinders et al. (2023) define a 'Minsky-type' shock as a "sudden repricing of financial assets based on climate-related factors due to changing sentiments and/or better data availability."

The macroprudential supervision targeted at climate risks of the insurance sector concentrates currently on data collection and climate scenario analysis (International Association of Insurance Supervisors, 2023). The BoE included climate risks in its stress tests of the insurance sector in 2019 (BoE, 2019a; 2019b) and in 2021 ran its exploratory scenario exercise on climate risk, engaging both banks and insurers (BoE, 2022). The European Insurance and Occupational Pensions Authority (2022) has set the methodological principles for incorporating climate change risks in its stress test framework for insurance companies. Philipponnat (2020) propose an adaptation in the insurance prudential framework similar to the banking one – by applying capital charges to specific exposures connected with fossil fuel assets.

Demekas and Grippa (2021) discuss the challenges associated with different regulatory and prudential approaches and conclude that financial regulators cannot achieve the goal of a low-carbon economy by themselves – a combination of tolls from different areas and policies is necessary. For example, Campiglio (2016) shows that macroprudential policies can be implemented in addition to carbon taxes.[23] Altaghlibi et al. (2022) also stress that green central bank policy should be complementary and not substitutionary for fiscal and regulatory policies. Carney (2015), the governor of the BoE and chairman of the FSB at that time, argues that the choice of the policy response is the responsibility of governments and not of central banks. In contrast, Bolton et al. (2020) point out the potential role of central banks in co-ordinating efforts to combat climate change. As indicated in Section 4, the debate on central banks' mandate to address sustainability remains open. Svartzman et al. (2021) agree that enhanced coordination among fiscal, monetary and prudential policies is necessary. They also emphasise the necessity for heightened international cooperation among monetary and financial authorities concerning environmental concerns. The authors suggest that central banks should help in coordinating these policies. Krogstrup and Oman (2019) offer an overview of how macroeconomic and financial policy tools can address climate change. They emphasise the importance of fiscal tools while acknowledging the potential need to supplement these with financial (both micro- and macroprudential) and monetary policy measures. Additionally, Chenet et al. (2021) advocate for the complete integration of climate-related financial risks into various financial policy domains, encompassing prudential, macroprudential and monetary frameworks.

[23] Campiglio (2016) also explains that they would be more effective in developing economies than in developed ones. This is firstly because of the higher dependence of these economies on loans and secondly, because central banks in these economies tend to have a higher level of control over credit dynamics through using a wider range of monetary policy instruments.

Similarly, Campiglio et al. (2018) highlight that the responsibility for transitioning to a low-carbon economy primarily lies with governments. They underscore the need for a comprehensive array of policies, some of which might necessitate collaboration between central banks and financial regulators. Examples of such collaboration and the effects of different sets of policies are provided by Lamperti et al. (2021) and Annicchiarico et al. (2022).

Carattini et al. (2023) argue that macroprudential policies possess the capability to diminish the risk of a recession after the implementation of a significant climate policy. However, they assert that solely relying on macroprudential policy (without the inclusion of a carbon tax) lacks effectiveness in mitigating the pollution externality (this conclusion is similar to that noted in Section 5 that monetary policy needs fiscal policy tools implemented at the same time, to be effective). Masciandaro and Russo (2022) highlight that for central banks to accomplish climate-related objectives without compromising their monetary and macroprudential aims, it is imperative that these institutions possess sufficient independence and robust monitoring capabilities. Benmir and Roman (2020) use a stochastic general equilibrium model with financial frictions to analyse both green and dirty production sectors, evaluating the effectiveness of various fiscal, monetary and macroprudential policies. Their research shows that employing sectoral macroprudential weights on loans beneficial to the green sector elevates green capital and output. This action diminishes the impact of sub-optimal carbon policies on welfare. Moreover, they highlight the role of macroprudential policy in incentivising central banks to become involved in extensive green QE. Their broader implication is that QE regulations could serve as a short-term countercyclical tool, whereas sectoral macroprudential policy could assume a more integral role, facilitating a seamless transition toward achieving net-zero goals. Also, Annicchiarico et al. (2022) show that macroprudential tools designed to stabilise the economy can reduce uncertainty inherent in climate policy tools including carbon tax and cape-and-trade systems and align their performances. Monasterolo et al. (2022) develop a ‘theory of change’ concerning the role of green financial sector initiatives in achieving climate change mitigation and transition. The analysis covers green prudential policies (green supporting factor, dirty penalizing factor, green portfolio rewards), green monetary policies (green collateral framework, green quantitative easing) and green public co-funding (soft loans and credit guarantees). This theory includes not only ESG goals (GHG emissions reduction, social cohesion), but also maintaining economic competitiveness and financial stability. Monasterolo et al. (2022) stress the necessity of the policy complementarity.

In an EC (2022) survey, most respondents[24] expressed the opinion that specific macroprudential tools are not required to tackle systemic risks arising from ESG (including climate) risks or stressed that more data and analytical systems are required. This approach is also reflected in the communication of central banks. Admittedly, Arseneau et al.'s (2022) analysis indicates that a very small proportion (a mere 6%) of central banks' speeches on climate change refer to macroprudential policy issues. It should be stressed, however, that the discussion on macroprudential policies that take climate risks into account is relatively recent.[25] D'Orazio and Popoyan (2019b) observe that many low-income countries are implementing prudential instruments to address climate change risks, while high-income countries tend to postpone decisions and actions, concentrating on discussions and analysis. Dikau and Ryan-Collins (2017) show that in emerging and developing countries central banks have started to assume an important role in mitigating the risks presented by climate change and they explain that those markets are more exposed to the immediate difficulties posed by climate change recognise the need to rapidly transform their economies. Le Quang and Scialom (2022) comment on the inclination to delay action until a clearer comprehension of climate risks emerges, referring to the 'bias to inaction' inherent in macroprudential policy. They conclude that the consequence of this inaction in the short term will likely result in climate-related disasters. Grünewald (2021) argues that another motive for inaction is the cost-benefit perception; costs incurred by market participants due to macroprudential measures are evident and immediate, whereas their advantages are uncertain and only manifest in the long run.

Battiston et al. (2017) apply a network-based climate stress test methodology to large banks in the Euro area under green and brown scenarios cautioning that a delayed and sudden[26] policy framework might trigger adverse systemic consequences. They advocate for an early and consistent policy framework. Vermeulen et al. (2018) present the results of an energy transition risk stress test for the Netherlands' financial system and conclude that while individual financial institutions can mitigate portfolio risks through energy transition considerations, policymakers can avert unnecessary losses by implementing timely and effective climate policies. Vermeulen et al. (2021) introduce a stress test framework to assess financial stability risks linked to the energy transition, highlighting significant potential financial losses from credit and market risks. They highlight the importance of avoiding a

[24] Respondents represented a broad spectrum of stakeholders including fiscal authorities, central banks and macroprudential authorities, financial regulators, banks, academics and other experts.
[25] See Section 7.
[26] Battiston et al. (2017) refer to the situation that if no appropriate action is taken now to reduce emissions, at some point in time more radical and urgent interventions will be needed (see Weyzig et al., 2014; ESRB, 2016).

transition that is both 'too late and too sudden'[27]. Similarly, Alogoskoufis et al. (2021) discuss the results of the ECB climate stress test and underline the benefits of acting early.

In conclusion, existing studies find evidence of the systemic aspect of climate risk, validating its incorporation into macroprudential policy. At the same time, it is emphasised that macroprudential tools cannot be exclusive, i.e., a coherent financial policy framework - combining fiscal, monetary, micro and macroprudential decisions - is required. To limit undesirable effects, solutions to support green finance are urgently needed.

7. Central banks' communication on sustainability

Regardless of the decision to include (or not include) sustainable development and ESG risks into the monetary and macroprudential policies by individual central banks, these institutions still play an important role in advocating for those issues. In fact, many central banks around the world, in their pursuit of sustainable finance and energy finance goals, have started to develop communication policies with markets and with the wider public regarding these matters. Moreover, disclosures and other forms of communication can help central banks 'lead by example' and advocate for climate action.

As we discussed in Sections 5 and 6, the key areas of action for central banks in the context of climate risk (and ESG risk more broadly) relate to monetary and macroprudential policy. In addition, however, communication (both in the form of formal disclosures and other outreach activities, including, for example, communiqués, public consultations and speeches given by representatives of central banks) is pointed out as an important activity in helping to achieve central banks' goals. This is primarily linked to the objective of central banks promoting the idea of sustainability and sustainable financial market practices (which is an example of the implementation of 'soft power' as described by Volz (2017)) and setting an example for market participants ('leading by example' as advocated by Eames and Barmes, 2022). The OECD finds that information specifically addressing environmental concerns (explaining how policies work and who can benefit from them) can substantially increase support for climate policies (Dechezleprêtre et al., 2022). Below we provide some examples of such actions by central banks.

In April 2016, the FSB established the industry-led TCFD to help identify the information on climate-related risks and opportunities needed by investors, lenders and

[27] The wording refers to European Systemic Risk Board (2016).

insurance underwriters. The 32-member TCFD comprised large banks, insurance companies, asset managers, pension funds, large non-financial companies, accounting and consulting firms and credit rating agencies. The goal of the 18-month consultations, which included industry interviews and meetings with business and financial leaders, was to help companies better communicate climate-related issues. As a result, in 2017, the TFCD developed a report containing climate-related financial disclosures aimed at companies, providing guidelines for different groups of stakeholders (TCFD, 2017). This report demands transparency from organisations on their governance structures, strategies and risk (especially climate-related risk) management practices. It also requires that organisations make financial disclosures in accordance with their national disclosure requirements. One of the key recommended disclosures focuses on the resilience of an organisation's strategy in adapting to changes associated with the transition to a low-carbon economy. Kyriakopoulou et al. (2022) demonstrate how these recommendations can be applied by central banks. They suggest that central banks should monitor their own practices and the broader financial sector in applying the TCFD disclosures. Additionally, they should promote coordination and convergence both internally and internationally by implementing the TCFD recommendations.

The NGFS (2021b) report delineates a comprehensive guide for central banks, which serves as a supplementary resource to prevailing standards and regulations pertaining to climate-related disclosures. The guide is structured into three chapters, each addressing distinct aspects of central banks' engagement with climate-related concerns. Within governance (Chapter One), central banks are asked to present their approach towards climate-related risks and opportunities. This encompasses asset management, disclosure of climate-related governance structures around monetary policy, financial stability as well as internal operations. The NGFS (2021b) report also advocates for the disclosure of explicit strategies employed by central banks in the identification, assessment and articulation of climate-related risks. Furthermore, it emphasises the communication of adaptive measures undertaken in various areas and functions to address climate-related risks and capitalise on associated opportunities. In this context, central banks are urged to articulate material risks, specifying the temporal horizon considered most pertinent for the management of such risks. The second chapter, focused on risk management, encourages central banks to transparently communicate their climate-related risk management practices. This includes the integration of climate-related risk management with broader, non-climate-related risk management frameworks. Such disclosures are necessary for a comprehensive understanding of central banks' endeavours in managing risks associated with climate considerations. The third chapter of the NGFS (2021b) guide also

recommends the transparent disclosure of central banks' utilisation data, including the delineation of data sources, their assimilation into risk analysis frameworks and taking into consideration limitations intrinsic to the data. Overall, the guide is focused on the integration of climate-related risks into the broader spectrum of financial risks.

During the Lufthansa Cargo Sustainability Conference in 2022, executive board member of the Deutsche Bundesbank, Sabine Mauderer, supported the aviation industry's transition towards achieving net-zero emissions. Mauderer (2022) further emphasised the pivotal role of central banks in addressing climate change and fostering sustainable finance, highlighting the need for central banks to protect their balance sheets from the risks associated with climate-related factors. In alignment with this objective, the Eurosystem has resolved to integrate climate change considerations into its monetary policy. This initiative involves a comprehensive assessment of the climate performance exhibited by bond issuers together with an increase in assets issued by entities demonstrating superior climate performance.

In 2021, the BCB (2021) proposed a new regulation developed in the form of public consultations (which is a form of bi-directional communication) to promote the allocation of resources towards the development of a more sustainable, dynamic and modern economy where potential physical risks from climate change and transition risks arising from the gradual shift to a low-carbon economy are taken into account by the financial sector. This regulation was among the first of its kind in the world promoted by central banks. It aims to ensure that organisations take proactive measures to identify and manage risks related to social, environmental and climate impacts and businesses integrate sustainability and risk management practices into their operations. The new regulation establishes that institutions must monitor their reputation, as well as the concentration of risks in economic sectors or geographic regions. Financial institutions are required to prepare and disclose their social, environmental and climate responsibility policy focusing on their positive contribution to social, environmental and climate issues.

In April 2021, the World Wildlife Fund (WWF) launched the Sustainable Financial Regulations and Central Bank Activities (SUSREG) framework, a novel initiative designed to assist central banks and financial regulators in formulating a more environmentally sustainable financial system (Augoyard, 2021). The SUSREG framework offers pragmatic guidance for the integration of environmental and social considerations within monetary policy, financial regulations as well as supervisory expectations. The framework's development was founded on the practices of central banks, recommendations from the NGFS and research conducted at

leading universities and by non-governmental organisations focused on central banking and supervisory practices.

The above initiatives recognise the intrinsic interconnectedness of climate-related and environmental risks with prudential risk categories for financial institutions, namely credit, market, underwriting, operational and liquidity risks. This acknowledgement aligns with assertions previously made by the BIS, the ECB and the NGFS. Importantly, the framework emphasises that a comprehensive understanding of the transmission mechanisms of climate and environmental risks to price stability is crucial for quantifying the potential impacts. In this context, central banks are identified as playing the main role in facilitating this understanding and mitigating associated risks.

Finally, the communication style and methods of central banks have also been the subject of research. For example, Arseneau et al. (2022) analyse central banks' communications relying on the use of natural language processing techniques. They focus on macroprudential tools within the framework of comprehending the financial stability implications associated with climate change. Arseneau et al. (2022) consider the set of all central bank speeches available from the BIS from January 1997 to December 2021, covering a total of 17,405 speeches delivered by representatives from 108 different central banks (37 from advanced economies and 71 from emerging market economies). Of these, only 427 deal with climate-related topics; 48 speeches touch on climate risk management, 26 on green taxonomy and 30 on the low-carbon-economy. The authors note an increase in the intensity of central banks' communications with the public regarding climate change, particularly intensifying in more recent years.

Neszveda and Siket (2023) analyse the influence of environmentally orientated speeches delivered by the ECB from 2010 to 2020 on the stock returns of portfolios characterised by varying levels of emission reductions. Neszveda and Siket (2023) define green speeches as communications underlining environmentally friendly aspects or containing at least one term related to green initiatives. They use the ECB green sentiment index to examine whether the ECB's green speeches cause a significant divergence in stock returns based on a company's emissions reduction performance. Their findings indicate that the green tone of the ECB positively (negatively) affects the most (least) eco-friendly firms based on their emissions scores. This results in a notable decrease in returns for portfolios associated with higher emissions compared to greener portfolios, suggesting that companies failing to reduce their emissions are subjected to financial losses after green speeches. They conclude that central

banks should communicate about green topics because it significantly influences financial decisions.

In conclusion, the dialogue between central banks and the market and between non-governmental organisations and central banks (e.g., NGFS, WWF) is mainly focused on environmental and climate issues. In this context, central banks play a key role in mitigating associated ESG and financial risks. Central bank regulations and speeches aim to ensure that companies and organisations take suitable measures to identify and manage such risks. However, there is limited literature that analyses whether disclosures and other forms of central bank communication influence environmentally friendly actions and how they impact financial markets.

8. Future research directions

The review conducted in this study shows, firstly, that analytical and research activity by central banks, regulators, supervisors, think tanks and non-governmental organisations is significantly ahead of academic research in many areas and, secondly, that there are still many fields that require further (often urgent) in-depth research. In this section, we identify key directions and examples of issues for further research.

As it was discussed in Section 2, within the field of energy finance, much of the existing research has focused on financial markets and instruments, while energy corporate finance remains a somewhat overlooked area. Therefore, this field constitutes a gap in the literature and an interesting research direction. For example, even though energy derivatives have existed for a relatively long time, this market is constantly developing and innovating, so it offers many opportunities to conduct research using new instruments and new, unique, data. In particular, investment strategies which combine other financial instruments and energy commodities with energy derivatives may be explored more intensively in future research.

From a broader perspective, although institutional and retail investors have been showing a growing interest in sustainable finance, it is often unclear what qualifies as green and what does not for these investor groups (Mauderer, 2022). Investors must be convinced that their funds really contribute to transformation. Therefore, a clear definition of sustainable activities is more than necessary (especially given the differences in taxonomies worldwide). On the other hand, Kyriakopoulou et al. (2022), point out that definitions, data and methodologies for assessing climate-related issues are constantly evolving. This means that efforts to develop climate-related disclosures should follow progressive work done in parallel

with further work on definitions, data and methodologies and a flexible framework could suit the distinct operational models and different mandates of central banks. Therefore, a golden mean should be developed with regard to this issue.

In Section 3, we covered ESG risks, their interaction and their transmission channels to the financial system. While there is a substantial body of knowledge in this area, additional research is crucial to further unpacking ESG risk transmission channels. We group this research into four categories although there is an overlap: (i) interaction of ESG risks; (ii) social and governance risks; (iii) climate change risks; and (iv) macroeconomic transmission channels. First, further exploration of the interconnected nature of ESG risks is needed to understand how these risks interact and amplify each other and, in turn, how this influences an institution, its counterparties and invested assets. For example, the EBA (2021) highlights that natural disasters and environmental degradation contribute to the displacement of millions of people and social and political unrest. Second, while significant progress has been made in the mapping of ESG risks to banks' financial risks, this is limited to climate change risks, with very little known about how social and governance risks impact banks and their counterparties. Such knowledge is critical for banks in developing risk mitigation strategies. Kalfaoglou (2021) highlights that these social and governance risks need to be incorporated into banks' corporate governance structures and risk management frameworks alongside environmental risks. Third, further research is needed on various aspects of climate change risk and the spillovers to banks. The effects of climate risks on bank credit and market risk have been examined, examples of studies that do this are those of Aiello and Angelico (2023) and Monasterolo et al. (2018). However, this research is limited to scenarios and greater consideration of more complex relationships and factors such as market competition is required. The impact of ESG risks on banks' operational and liquidity risks is also needed. Lang et al. (2023) is one of the few studies focused on bank liquidity, with the BCBS (2021b) confirming that publicly available information on climate-related operational risks is scarce. Relatedly, how banks have adapted their lending practices to minimise the effects of ESG risk on their credit and market risk (such as Birindelli et al., 2022) needs greater consideration. New research should also investigate how physical and transition climate risks directly impact banks, i.e., understanding the specific challenges which banks face in assessing and managing climate-affected assets, evaluating the potential for stranded assets and navigating the changing regulatory landscape as this can inform risk management strategies. Daumas (2024) highlights the role of the NGFS in this regard but also the need for alternative approaches. Relatedly, examining the effects of physical climate risks on households' real estate values and their ability to repay loans can offer further

insights into banks' credit risk; knowing how climate disasters impact on household borrowing patterns and banks' liquidity can provide a clearer picture for financial institutions. Existing research, such as Bremus et al. (2020), Correa et al. (2022) and Huang et al. (2022) focuses on corporates rather than households. Finally, at the macroeconomic level, further research on the impacts of ESG risks on economic growth and price stability, building on the work of Bremus et al. (2020) and Dafermos et al. (2021) among others, is critical to enhance understanding of their broader implications for financial systems and economies.

In Section 4, we discussed the sustainability mandates of central banks. The literature overwhelmingly suggests that sustainability mandates and the integration of sustainability into banking regulations are relatively nascent with most sustainability-related mandates developed by central banks focusing on environmental and climate change considerations. A research direction is the analysis of the reasons why sustainability mandates have focused so extensively on climate-related (and other environmental) risks and less so on other aspects of sustainability such as sustainable and equitable development. It may be that the adoption of other mandates, such as those focusing on sustainable and equitable development, has spillover effects that can assist in the adoption of environmental and climate-related mandates.

The charge in adopting sustainability mandates is led by central banks in developing and emerging countries. Oyegunle and Weber (2015) and Volz (2017) suggest that this can be attributed to their relative sophistication in their respective jurisdictions, influence, developmental role and mandates that are not always strictly defined. Central banks in developed countries (notably the G20 countries) tend to prioritise price stability (see D'Orazio and Popoyan, 2022). The latter grouping is highly influential within an economic context and disruptions caused by climate-related factors in these countries have the potential to result in severe spillovers. Given the recency and the growing importance of the topic and asymmetric adoption, future research is needed on the development of a comprehensive scoring system that can be used to measure the adoption of central bank sustainability mandates. The scope of scorecards can extend beyond the G20 nations mentioned by Eames and Barmes (2022), which calls for a development of a broader taxonomy of sustainable finance. This also motivates for research into what systematic conditions and features in the banking and financial favour the adoption of sustainability mandates by central banks.

A question raised in Section 4 relates to the effectiveness of policies in promoting sustainability mandates. For example, Cullen (2023) argues that there is no empirical proof to suggest that reducing capital requirements for environmentally friendly loans will be an effective strategy to tackle climate risks. Contrastingly, Diggle and Bartholomew (2021) and

Muñoz et al. (2022) suggest that central banks are well-positioned to integrate climate change considerations into their mandates. Volz (2017) argues that central banks should address credit market failures to discourage the provision of credit for socially undesirable initiatives. An area for further research that follows from this relates to which tools are most effective and in what situations. Research should evaluate which policy measures, for example, will promote investment in environmentally friendly projects and which measures will discourage participation in socially undesirable projects. It may be that different policy measures are required to achieve these although this is seemingly a single objective.

There is also the question of central bank neutrality. Diggle and Bartholomew (2021) propose that the implementation of green monetary policy may breach central bank neutrality and argue that in the absence of a significant market failure, resource allocation should be performed by the private sector. However, given that there may be welfare implications of not acting to prevent climate change, deviations from neutrality can be justified. An area of future research could be about the consequences of breaking central bank neutrality and whether the benefits outweigh the costs. There are likely to be unintended consequences, which can be mitigated by scenario analysis and further research. In essence, this is a question of action *versus* inaction, which is an important new research issue in this field.

Another possible question relates to the creditworthiness and risk around green versus brown investments. For example, what are the differences in risk around such projects and what risk management practices should be implemented, if central banks are to promote green over non-green investments using monetary policy? Sustainability and climate-related mandates also call for a deeper analysis of the transmission channels through which they have the potential to impact the financial sector and further research into financial sector vulnerabilities to climate-related risks. Overall, those research questions call for the development of new quantitative modelling tools.

Discussions presented in Section 5 show that progress in integrating climate change and other ESG factors into monetary policy appears to be lagging. Consequently, it is imperative to conduct more research on how monetary policy should be adjusted in light of the green transition and climate change. A key issue in this research is the theoretical framework for combining these factors, considering the disparity in time horizons between climate change (long term) and monetary policy (relatively short term), as highlighted by Landau and Brunnemeier (2020). This research should be complemented by investigations aimed at better understanding the impact that ‘greening’ monetary policy could have on national and global carbon emissions.

Another research field worth exploring is how climate change and the green transition affect different monetary policy frameworks, including objectives and targets, monetary policy transmission channels and instruments. Several issues related to instruments are particularly important. Given the distinct nature of energy-related inflation (climateflation, fossilflation and greenflation), more research is needed on each specific aspect and the instruments that central banks could use to address them efficiently. Although the phenomenon of climateflation has garnered increasing attention in empirical studies, the implications of fossilflation and greenflation are less understood and require more in-depth analysis (Aguila and Wullweber 2024).

Considering that monetary policy in the context of climate change requires the application of several unconventional instruments (e.g., green QE, including green asset purchase programmes, green bonds, or dual interest rates), it is worthwhile to conduct research on various aspects of these tools. An example of such research is examining the effects of applying dual interest rates in the context of the current climate crisis. Advocates of dual interest rates contend that central bank utilization of this tool allows for a relaxation of bank lending conditions without heightening the risk appetite that a conventional rate cut might trigger, particularly when contemplated following an extended period of low or negative interest rates. However, opponents claim that this approach would be inconsistent with efforts to combat inflation. Therefore, new research is needed to evaluate the advantages and disadvantages of dual interest rates. Additionally, there is a need for a better understanding of how climate change impacts the natural rate of interest. The sensitivity of green investments to changes in interest rates and credit supply also demands closer theoretical and empirical examination. Another interesting area of research involves examining how climate change and the green transition should interact simultaneously with fiscal, monetary and structural policies to address the challenges triggered by those phenomena. New research in these areas will be important for designing better monetary policies and for reacting more effectively to the environmental and climate change challenges.

As Section 6 shows, further research is also needed on macroprudential policies to ensure a comprehensive approach within the context of climate change. Many supervisory and scientific analyses indicate the scale of ESG risks to which financial institutions (mainly banks and insurance companies) are, or will be, exposed in the future. Certain management and supervisory decisions are made on this basis. The main tool for assessing the scale of ESG risks is stress testing. As highlighted by Reinders et al. (2023) current stress tests underestimate these risks. The consequence may be that the prudential instruments applied to financial institutions

are inadequately calibrated and therefore do not cover all ESG risk in supervision. As a result, the financial sector may take excessive risks and not take the necessary action to reduce them. Further research is, therefore, needed to improve stress tests (including refinement of the scenarios themselves, sets of channels and asset classes included as well as feedback effects). In addition, analyses currently focus on climate risk and - to a lesser extent - other environmental risks. There is a need to improve analyses of the entire spectrum of ESG risks.

Currently, regulators and supervisors are analysing various options for micro- and macroprudential instruments that may be applied to financial institutions in relation to ESG risks. Although some researchers have already examined the potential limitations and consequences of using these tools, this is still an area requiring deeper exploration. Its effect should be the indication of optimal tools (and the combinations in which they can or should be used), along with their calibration, accounting for specific conditions. In particular, the issue of the scope of application of micro- and macroprudential instruments and the connections between them requires resolution. In this respect, prudential transition plans also require further research.

With regard to communication with central banks, which we covered in Section 7, many studies highlight the interconnectedness of green policy tools (see, for example, Benmir and Roman, 2020; Carattini et al., 2023). Given the current state of knowledge and the ongoing debate about sustainable prudential instruments, more research is needed in the field of the effectiveness of those instruments and the optimal choice of fiscal, monetary, micro- and macroprudential tools in achieving both stability and sustainability goals, while limiting the negative spillovers. Additionally, the possible unintended adverse consequences (short and long-term) of sustainable central bank policies and tools should be investigated. Buch (2022) highlights that statistics play a crucial role in central banks' policy decisions. However, better measurement and better statistics do not necessarily have to serve as a substitute for correct policies, but rather they should complement such policies to support properly informed decision-making processes. Good management of risks requires correct measurements and high-quality data; hence, innovations regarding different measurement techniques or data accuracy must be developed.[28] Although the NGFS (2022a) presents a report on bridging data gaps, these concerns remain valid.

[28] The 2021 survey conducted by the Irving Fisher Committee on Central Bank Statistics showed that statistics on sustainable finance attract increasingly more attention of central banks, however the recommendations for central banks were to "intensify the identification of sustainable finance data needs to pursue their policy objectives", "cooperate with traditional and new stakeholders to close data gaps, especially at the micro level" and "lead by example by improving the usage of the new data being collected" (Schmieder et al., 2021).

Finally, it would be also interesting to investigate whether disclosures and other forms of central banks' communication with markets play the desired role of advocating for climate action.

9. Conclusions

The importance of environmental, social and governance risks has been recognised in recent academic literature and in reports published by various institutions. The delineation of the interaction between environmental, social and governance risks is a small but substantive contribution of our paper. We put forward the idea of a *cascading effect with a positive feedback effect* meaning that environmental risks affect social risks and environmental and social risks affect governance, but governance risks also negatively impact environmental risks (hence the feedback loop).

ESG risks affect businesses, households and, thus, also financial systems and economies. Our paper describes both the drivers and transmission channels of these risks and demonstrates that they impact price stability, financial stability and economic growth, i.e., the key areas with which the objectives normally set for central banks are associated and therefore there are indeed grounds for those institutions to have such a mandate.

In this article we focus on the role that central banks can play in managing and mitigating ESG risks. We find that there is no clear view of whether indeed these institutions have a mandate to integrate ESG issues into their policies. There are countries where central banks recognise this mandate as well as those that do not.

On this basis, our paper describes the green aspects of central banks' monetary and macroprudential policies more broadly. The most important conclusion of this study is the conundrum that the tools of all financial policies (monetary, micro- and macroprudential and fiscal) and green policies are linked. Importantly, some instruments are effective (i.e., they achieve the objectives assigned to them within a given policy framework), but at the same time, they may cause negative effects in the area of other policies (e.g., they are effective in reducing financial institutions' exposure to ESG risks but may negatively affect climate objectives; they achieve climate objectives but reignite risks to financial system stability). This leads to the obvious recommendation that the coordination of these policies, including the selection of the appropriate instruments, should be ensured. However, who should coordinate these policies remains an open question (although many studies point to a leading role for government).

We also highlight the role of central banks' communication in relation to sustainability issues, especially the energy transition. Both formal disclosures (publication of specific information and data in official reports) and other forms of communication (including speeches and presentations by central bank authorities) are not only intended to provide information about central banks' actions in this area (and their effects) but, above all, their function is to raise awareness among financial market participants and to set examples (or even role models) of specific attitudes and actions.

As our study shows, the issue of ESG risks and their impact on both climate change and the transition towards net-zero is relatively new. In the mid-2010s, it was first financial market supervisors and regulators who identified the importance of these issues for the financial system, particularly in terms of risk. Many existing publications (including those in the form of recommendations and guidelines) have originated from financial safety net institutions as well as through transnational initiatives (both top-down and bottom-up from financial institutions, think tanks, consumer and environmental organisations etc.). Climate risks have become so important and urgent that in a short period of time, many regulatory actions have been implemented (targeting both the financial and the real sector) and financial institutions themselves have acted on their own initiatives. Unsurprisingly, academic work in this area has somewhat lagged. Although there are many publications on climate change itself or on the impact of human activities (including economic activities) on climate change, there is much less academic research available on ESG risks in financial institutions, including their impact on financial stability. Consequently, there is little academic work published yet analysing the issues of central bank mandates and instruments, which were discussed in this article in relation to energy finance. There are, therefore, many existing research gaps. The examples of various research directions identified in the section above can contribute to filling these gaps and can help in the development of an effective central bank policy framework linking financial objectives (price stability, financial stability and economic development) with climate objectives.

REFERENCES

Abiry R., Ferdinandusse, M., Ludwig, A., Nerlich, C., 2022. Climate change mitigation: How effective is green quantitative easing? European Central Bank. Working Paper Series No. 2701. Available at: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2701~72d8bfaa67.en.pdf (accessed 30 May 2023)

Aiello, M.A., Angelico, C., 2023. Climate change and credit risk: The effect of carbon tax on Italian banks' business loan default rates. Journal of Policy Modeling, 45(1), 187-201. https://doi.org/10.1016/j.jpolmod.2022.11.007.

Aguila, N., Wullweber, J., 2024. Greener and cheaper: Green monetary policy in the era of inflation and high interest rates. Eurasian Economic Review, 14, 39-60. https://doi.org/10.1007/s40822-024-00266-y.

Albert, M.J., 2022. Beyond continuationism: Climate change, economic growth, and the future of world (dis) order. Cambridge Review of International Affairs. 35(6), 868-887. https://doi.org/10.1080/09557571.2020.1825334.

Albuquerque, P.H., Rajhi, W., 2019. Banking stability, natural disasters, and state fragility: Panel VAR evidence from developing countries. Research in International Business and Finance, 50, 430-443. https://doi.org/10.1016/j.ribaf.2019.06.001 .

Alessi, L., Di Girolamo, F., Petracco-Giudici, M., Pagano, A., 2022. Accounting for climate transition risk in banks' capital requirements. European Commission – Joint Research Centre (JRC). JRC Working Papers in Economics and Finance No. 2022/8. Available at: https://joint-research-centre.ec.europa.eu/document/download/daf0ee3e-9b09-4d8e-84d0-2dfb501bd4fa_en?filename=JRC129221.pdf (accessed 20 May 2023)

Alexforbes, 2023. S to the power E: The relationship between environmental and social factors in ESG. Daily Maverick. 19 May. Available at: https://www.dailymaverick.co.za/article/2023-05-19-s-to-the-power-e-the-relationship-between-environmental-and-social-factors-in-esg/ (accessed 22 May 2023)

Allen, K.D., Whitledge, M.D., Winters, D.B., 2022. Community bank liquidity: Natural disasters as a natural experiment. Journal of Financial Stability, 60, 101002. https://doi.org/10.1016/j.jfs.2022.101002.

Alogoskoufis, S., Dunz, N., Emambakhsh, T., Hennig, T., Kaijser, M., Kouratzoglou, C., Muñoz, M.A., Parisi, L., Salleo C., 2021. ECB economy-wide climate stress test. European Central Bank. Occasional Paper Series No. 281, September. Available at: https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op281~05a7735b1c.en.pdf (accessed 15 March 2022)

Aloui, D., Benkraiem, R., Guesmi, K., Vigne, S., 2023. The European Central Bank and green finance: How would the green quantitative easing affect the investors' behavior during times of crisis? International Review of Financial Analysis, 85, 102464. https://doi.org/10.1016/j.irfa.2022.102464.

Altaghlibi, M., van Tilburg, R., Sanders, M., 2022. How much of a help is a green central banker? Sustainable Finance Lab. Working Paper, February. Available at: https://sustainablefinancelab.nl/nl/paper/how-much-of-a-help-is-a-green-central-banker/ (accessed 13 June 2022)

Americo, A., Johal, J., Upper, C., 2023. The energy transition and its macroeconomic effects. Bank of International Settlements (BIS). BIS Papers No. 135, 25 May. Available at: https://www.bis.org/publ/bppdf/bispap135.pdf (accessed 21 July 2023)

Andersson, M., Baccianti, C., Morgan, J., 2020. Climate change and the macroeconomy. European Central Bank. Occasional Paper Series No. 243, June. Available at: https://ww.ecb.europa.eu/pub/pdf/scpops/ecb.op243~2ce3c7c4e1.en.pdf (accessed 25 May 2023)

Annicchiarico, B., Carli, M., Diluiso, F., 2022. Climate policies, macroprudential regulation, and the welfare cost of business cycles. Centre for Economic and International Studies, Tor Vergata University. Research Paper Series 20(5), No. 543. http://dx.doi.org/10.2139/ssrn.4257945.

Arrobas, D.L.P., Hund, K.L., Mccormick, M. S., Ningthoujam, J., Drexhage, J.R., 2017. The growing role of minerals and metals for a low carbon future. World Bank. Working Paper No. 117581, 30 June. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/ (accessed 24 May 2023)

Arseneau, D.M., Drexler, A., Osada, M., 2022. Central bank communication about climate change. Board of Governors of the Federal Reserve System. Finance and Economics Discussion Series (FEDS) Paper No. 2022-031, 7 July. https://doi.org/10.17016/FEDS.2022.031.

Association for Financial Markets in Europe, 2023. A common path to improve European climate risk stress testing and scenario analysis. June. Available at: https://www.afme.eu/publications/reports/details/a-common-path-to-improve-european-climate-risk-stress-testing-and-scenarios-analysis (accessed 25 June 2023)

Augoyard, S., 2021. Introducing SUSREG - A framework for sustainable financial regulations and central banks activities. World Wildlife Fund. Available at: https://wwfint.awsassets.panda.org/downloads/susreg__final_april_2021_.pdf (accessed 29 May 2023)

Augoyard, S., Durrani, A., Fenton, A., Volz, U., 2021. Assessing the effectiveness and impact of central bank and supervisory policies in greening the financial system across the Asia-Pacific. International Conference on "Statistics for Sustainable Finance", 14-15 September, Paris. Available at: https://www.bis.org/ifc/publ/ifcb56_06.pdf (accessed 3 June 2023)

Baker C., 2022. Derivatives and ESG. American Business Law Journal, 59(4), 725–772. https://doi.org/10.1111/ablj.12215.

Banco Central do Brasil (BCB), 2021. Public Consultation 85. New regulation on risk management and social, environmental and climate responsibility. 7 April. Available at: https://www.bcb.gov.br/content/financialstability/ruralcreditdocs/BCB_PublicConsultation85.pdf (accessed 25 May 2023)

Bank for International Settlements (BIS), 2022. Incorporating climate-related risks into international reserve management frameworks. Consultative Group on Risk Management. Available at: https://www.bis.org/publ/othp54.pdf (accessed 11 June 2023)

Bank of England (BoE), 2019a. Life Insurance Stress Test 2019. Scenario Specification, Guidelines and Instructions. Prudential Regulation Authority. 18 June. Available at: https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2019/life-insurance-stress-test-2019-scenario-specification-guidelines-and-instructions.pdf (accessed 19 May 2023)

Bank of England (BoE), 2019b. General Insurance Stress Test 2019. Scenario Specification, Guidelines and Instructions. Prudential Regulation Authority. 18 June. Available at: https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2019/general-insurance-stress-test-2019-scenario-specification-guidelines-and-instructions.pdf (accessed 19 May 2023)

Bank of England (BoE), 2022. Results of the 2021 Climate Biennial Exploratory Scenario (CBES). 24 May. Available at: https://www.bankofengland.co.uk/stress-testing/2022/results-of-the-2021-climate-biennial-exploratory-scenario (accessed 19 May 2023)

Bank of England (BoE), 2023. Bank of England report on climate-related risks and the regulatory capital frameworks. 13 March. Available at: https://www.bankofengland.co.uk/prudential-regulation/publication/2023/report-on-climate-related-risks-and-the-regulatory-capital-frameworks (accessed 19 May 2023)

Baranović, I., Busies, I., Coussens, W., Grill, M., Hempell, H., 2021. The challenge of capturing climate risks in the banking regulatory framework: Is there a need for a macroprudential response?. European Central Bank. Macroprudential Bulletin Issue No. 15. Available at: https://www.ecb.europa.eu/press/financial-stability-publications/macroprudential-bulletin/html/ecb.mpbu202110_1~5323a5baa8.en.html (accessed 9 September 2021)

Barmes, D., Livingstone, Z., 2021. The Green Central Banking Scorecard: How green are G20 Central Banks and Financial Supervisors? Positive Money. Available at: https://positivemoney.org/publications/green-central-banking-scorecard/ (accessed 3 August 2024)

Barrot, J.N., Sauvagnat, J., 2016. Input specificity and the propagation of idiosyncratic shocks in production networks. Quarterly Journal of Economics, 131(3), 1543-1592. https://doi.org/10.1093/qje/qjw018.

Bartholomew, L., Diggle, P., 2021. Climate change and central banks: The case for violating neutrality. Centre for Economic Policy Research (CEPR), VoxEU, 12 August. Available at: https://cepr.org/voxeu/columns/climate-change-and-central-banks-case-violating-neutrality (accessed 20 June 2022)

Bartsch, F., Busies, I., Emambakhsh, R., Grill, M., Simoens, M., Spaggiari, M., Tamburrini, F., 2024. Designing a macroprudential capital buffer for climate-related risks. ECB Working Paper No. 2024/2943, May. Available at: www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2943~1bf261835d.en.pdf (accessed 3 July 2024)

Batten, S. 2018. Climate change and the macro-economy: A critical review. Bank of England. Staff Working Paper No. 706, January. https://doi.org/10.2139/ssrn.3104554.

Batten, S., Sowerbutts, R., Tanaka, M., 2016. Let's talk about the weather: The impact of climate change on central banks. Bank of England. Staff Working Paper No. 603, May. https://doi.org/10.2139/ssrn.2783753.

Batten, S., Sowerbutts, R., Tanaka, M., 2020. Climate change: Macro-economic impact and implications for monetary policy. In: Walker, T., Gramlich, D., Bitar, M., Fardnia, P. (eds.), Ecological, Societal, and Technological Risks and the Financial Sector. Springer International Publishing, 13-38.

Battiston, S., Caldarelli, G., May, R.M., Roukny, T., Stiglitz, J.E., 2016. The price of complexity in financial networks. Proceedings of the National Academy of Sciences. 113(36), 10031-10036. https://doi.org/10.2139/ssrn.2594028.

Battiston, S., Dafermos, Y., Monasterolo, I., 2021. Climate risks and financial stability. Journal of Financial Stability, 54, 100867. https://doi.org/10.1016/j.jfs.2021.100867.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., Visentin, G., 2017. A climate stress-test of the financial system. Nature Climate Change, 7(4), 283-288. https://doi.org/10.1038/nclimate3255.

Basel Committee on Banking Supervision (BCBS), 2021a. Climate-related risk drivers and their transmission channels. Bank for International Settlements. April. Available at: https://www.bis.org/bcbs/publ/d517.pdf (accessed 18 May 2023)

Basel Committee on Banking Supervision (BCBS), 2021b. Climate-related financial risks – measurement methodologies. Bank for International Settlements. April. Available at: https://www.bis.org/bcbs/publ/d518.pdf (accessed 24 April 2021)

Beirne, J., Renzhi, N., Volz, U., 2021. Bracing for the typhoon: Climate change and sovereign risk in Southeast Asia. Sustainable Development, 29(3), 537-551. https://doi.org/10.1002/sd.2199.

Benmir, G., Roman, J., 2020. Policy interactions and the transition to clean technology. Grantham Research Institute on Climate Change and the Environment. Working Paper No. 337, April. Available at: https://www.lse.ac.uk/granthaminstitute/publication/policy-interactions-and-the-transition-to-clean-technology/ (accessed 19 May 2023)

Birindelli, G., Bonanno, G., Dell'Atti, S., Iannuzzi, A.P., 2022. Climate change commitment, credit risk and the country's environmental performance: Empirical evidence from a sample of international banks. Business Strategy and the Environment, 31(4), 1641-1655. https://doi.org/10.1002/bse.2974.

Bloom, D.E., Fink, G., 2024. The economic case for devoting public resources to health. In: Farrar, J., Hotez, P.J., Junghanss, T., Kang, G., Lalloo, D., White, N.J., Garcia, P.J. (eds.), Manson's Tropical Diseases 24th edition, Elsevier Health Sciences, 49-56. https://doi.org/10.1016/b978-0-7020-7959-7.00007-5.

Board of Governors of the Federal Reserve System, 2020. Financial Stability Report. November. Available at: https://www.federalreserve.gov/publications/files/financial-stability-report-20201109.pdf (accessed 10 August 2023)

Board of Governors of the Federal Reserve System, 2022. Principles for Climate-Related Financial Risk Management for Large Financial Institutions (Docket No. OP- 1793). December. Available at:

https://www.federalreserve.gov/newsevents/pressreleases/files/other20221202b1.pdf (accessed 12 August 2023)

Boehm, H., 2022. Physical climate change and the sovereign risk of emerging economies. Journal of Economic Structures, 11(31), 1-41. https://doi.org/10.1186/s40008-022-00284-6.

Böffel, L., Schürger, J., 2023. Sustainability: A current driver in EU banking and insurance regulation. In Böffel, L., Schürger, J. (eds.), Digitalisation, Sustainability, and the Banking and Capital Markets Union. Palgrave Macmillan Cham, 229-272. https://doi.org/10.1007/978-3-031-17077-5_8.

Bolton, P., Despres, M., da Silva, L.A.P., Samama, F., Svartzman, R., 2020. The green swan. Central banking and financial stability in the age of climate change. Bank for International Settlements; Banque de France. Available at: https://www.bis.org/publ/othp31.pdf (accessed 24 May 2023)

Boneva, L., Ferucci, G., Magnelli F.P., 2021. To be or not to be "green": How can monetary policy react to climate change? European Central Bank. Occasional Paper No. ~~265~~ 285, November. https://doi.org/10.2139/ssrn.3971287.

Boneva, L., Ferucci, G., Magnelli, F.P., 2022. Climate change and central banks: What role for monetary policy?. Climate Policy, 22(6), 770-787. https://doi.org/10.1080/14693062.2022.2070119.

Boyd, J.H., Levine, R., Smith, B.D., 2001. The impact of inflation on financial sector performance. Journal of Monetary Economics, 47(2), 221-248. https://doi.org/10.1016/s0304-3932(01)00049-6.

Breeden, S., 2019. Climate crisis requires action now. Financial system needs to support an early and orderly transition. The Official Monetary and Financial Institutions Forum (OMFIF). OMFIF Summer Bulletin, 10(3), 12-13. Available at: https://www.omfif.org/wp-content/uploads/2020/01/0319-min.pdf (accessed 17 December 2023)

Brei, M., Mohan, P., Strobl, E., 2019. The impact of natural disasters on the banking sector: Evidence from hurricane strikes in the Caribbean. Quarterly Review of Economics and Finance, 72, 232-239. https://doi.org/10.1016/j.qref.2018.12.004.

Breitenfellner, A., Pointner, W., Schuberth, H., 2019. the potential contribution of central banks to green finance. Vierteljahrshefte zur Wirtschaftsforschung, 88(2), 55-71. https://doi.org/10.3790/vjh.88.2.55.

Bremus, F., Dany-Knedlik, G., Schlaak, T., 2020. Price stability and climate risks: Sensible measures for the European Central Bank. Deutsches Institut für Wirtschaftsforschung (DIW). DIW Weekly Report, 10(14), 206-213. https://hdl.handle.net/10419/220013.

Brunetti, C. Dennis, B., Gates, D., Hancock, D., Ignell, D., Kiser, E.K., Kotta, G., Kovner, A., Rosen, R.J., Tabor, E.K., 2021. Climate change and financial stability. Board of Governors of the Federal Reserve System. Finance and Economics Discussion Series (FEDS) Notes, 19 March. https://doi.org/10.17016/2380-7172.2893.

Bruneau G., Ojea-Ferreiro,J., Plummer, A., Tremblay, M.-C., Witts, A., 2023. Understanding the Systemic Implications of Climate Transition Risk: Applying a Framework Using Canadian Financial System Data. Bank of Canada Staff Discussion Paper 2023-32.

December. Available at: https://www.bankofcanada.ca/wp-content/uploads/2023/12/sdp2023-32.pdf (accessed: 24 April 2024)
Buch, C., 2022. Time for structural change in central bank statistics? How to support the transition to a climate-friendly economy. Speech at the 11th Biennial Irving Fisher Conference (IFC), Basel, 25 August. Available at: https://www.bis.org/review/r220914a.htm (accessed 29 May 2023)
Calvo, D., Crisanto, J.C., Hohl, S., Gutiérrez, O.P., 2018. Financial supervisory architecture: What has changed after the crisis?, Financial Stability Institute (FSI). FSI Insights No. 8, April. Available at: https://www.bis.org/fsi/publ/insights8.htm (accessed 20 May 2023)
Campiglio, E., 2016. Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. Ecological Economics, 121, 220-230. https://doi.org/10.1016/j.ecolecon.2015.03.020.
Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., Tanaka, M., 2018. Climate change challenges for central banks and financial regulators. Nature Climate Change, 8, 462-468. https://doi.org/10.1038/s41558-018-0175-0.
Capasso, G., Gianfrate, G., Spinelli, M., 2020. Climate change and credit risk. Journal of Cleaner Production, 266, 121634. https://doi.org/10.1016/j.jclepro.2020.121634.
Carattini, S., Heutel, G., Melkadze, G., 2021. Climate policy, financial frictions, and transition risk. Review of Economic Dynamics, 51, 778-794. https://doi.org/10.1016/j.red.2023.08.003.
Carattini, S., Sen, S., 2019. Carbon taxes and stranded assets: Evidence from Washington State. CESifo. CESifo Working Paper No. 7785. https://doi.org/10.2139/ssrn.3434841
Carleton, T.A., Hsiang, S.M., 2016. Social and economic impacts of climate. Science, 353(6304), aad9837. https://doi.org/10.1126/science.aad9837.
Carney, M., 2015. Breaking the tragedy of the horizon – climate change and financial stability. Speech at Lloyd's of London, London, 29 September. Available at: https://www.bis.org/review/r151009a.pdf (accessed 24 May 2023)
Carney, M., 2016. Resolving the climate paradox. Text of the Arthur Burns Memorial Lecture, Berlin, 22 September. Available at: https://www.bis.org/review/r160926h.pdf (accessed 17 December 2023)
Central Bank of Nigeria (CBN), 2012. Nigeria Sustainable Banking Principles. 24 September. Available at: https://www.cbn.gov.ng/out/2012/ccd/circular-nsbp.pdf (accessed 11 September 2023)
Cevik, S., Jalles, J.T., 2022. This changes everything: Climate shocks and sovereign bonds. Energy Economics, 107, 105856. https://doi.org/10.1016/j.eneco.2022.105856.
Chamberlin, B., Evain, J., 2021. Indexing capital requirements on climate: What impact can be expected?, Institute for Climate Economics. Climate Report. 23 September. Available at: https://www.i4ce.org/en/publication/indexing-capital-requirements-on-climate-what-impacts-can-be-expected (accessed 20 May 2023)
Chaves, M., Grill, M., Parisi, L., Popescu, A., Rancoita, E., 2021. A theoretical case for incorporating climate risk into the prudential framework. European Central Bank. Macroprudential Bulletin Issue No. 15. Available at: https://www.ecb.europa.eu/pub/financial-stability/macroprudential-

bulletin/focus/2021/html/ecb.mpbu_focus202110_2.en.html (accessed 11 September 2022)
Chen, B., Villoria, N.B., 2019. Climate shocks, food price stability and international trade: Evidence from 76 maize markets in 27 net-importing countries. Environmental Research Letters, 14(1), 014007. https://doi.org/10.1088/1748-9326/aaf07f.
Chen, C., Pan, D., Huang, Z., Bleischwitz, R., 2021. Engaging central banks in climate change? The mix of monetary and climate policy. Energy Economics, 103, 105531. https://doi.org/10.1016/j.eneco.2021.105531.
Chenet, H., Ryan-Collins, J., van Lerven, F., 2021. Finance, climate-change and radical uncertainty: Towards a precautionary approach to financial policy. Ecological Economics, 183, 106957. https://doi.org/10.1016/j.ecolecon.2021.106957.
Coelho, R., Restoy, F., 2023. Macroprudential policies for addressing climate-related financial risks: Challenges and trade-offs. Financial Stability Institute (FSI). FSI Briefs No. 18, April. Available at: https://www.bis.org/fsi/fsibriefs18.htm (accessed 5 April 2023)
Coleton, A., Font Brucart, M., Gutierrez, P., Le Tennier, F., Moor, C., 2020. Sustainable finance: Market practices. European Banking Authority (EBA). EBA Staff Paper Series No. 6, January. https://doi.org/10.2139/ssrn.3749454.
Correa, R., He, A., Herpfer, C., Lel, U., 2022. The rising tide lifts some interest rates: Climate change, natural disasters, and loan pricing. Board of Governors of the Federal Reserve System. International Finance Discussion Papers No. 1345, June. https://doi.org/10.17016/ifdp.2022.1345.
Cortés, K.R., 2014. Rebuilding after disaster strikes: How local lenders aid in the recovery. Federal Reserve Bank of Cleveland. Working Paper No. 14-28. https://doi.org/10.26509/frbc-wp-201428.
Cortés, K.R., Strahan, P.E., 2017. Tracing out capital flows: How financially integrated banks respond to natural disasters. Journal of Financial Economics, 125(1), 182-199. https://doi.org/10.1016/j.jfineco.2017.04.011.
Costa, M., 2024. What would a green dual interest rate environment look like? Green Central Banking, 15 February. Available at: https://greencentralbanking.com/2024/02/15/green-dual-interest-rate-environment (accessed 15 June 2024)
Cullen, J., 2023. Central banks and climate change: Mission impossible?. Journal of Financial Regulation, 9(2), 174-209. https://doi.org/10.1093/jfr/fjad003.
Curtis, H., 2022. The effect of climate change on the pricing and transactional volume of real estate. Capitol Economics Journal, 2(1). https://doi.org/10.4079/cej.v2i1.3,
Czarniawska, B., 2004. Narratives in Social Science Research, Sage.
D'Orazio, P., Popoyan, L. 2019a. Dataset on green macroprudential regulations and instruments: Objectives, implementation and geographical diffusion. Data in Brief, 24, 103870. https://doi.org/10.1016/j.dib.2019.103870.
D'Orazio, P., Popoyan, L., 2019b. Fostering green investments and tackling climate-related financial risks: Which role for macroprudential policies?. Ecological Economics, 160, 25-37. https://doi.org/10.1016/j.ecolecon.2019.01.029.

D'Orazio, P., 2021. Towards a post-pandemic policy framework to manage climate-related financial risks and resilience. Climate Policy, 21(10), 1368-1382. https://doi.org/10.1080/14693062.2021.1975623.

D'Orazio, P., Popoyan, L., 2022. Realising central banks' climate ambitions through financial stability mandates. Intereconomics: Review of European Economic Policy, 57(2), 103-111. https://doi.org/10.1007/s10272-022-1039-4.

Dafermos, Y., Gabor, D., Nikolaidi, M., Pawloff, A., van Lerven, F. 2021. Greening the eurosystem collateral framework. New Economics Foundation. March. Available at: https://neweconomics.org/uploads/files/Collateral-Framework.pdf (accessed 20 May 2024)

Dafermos, Y., Gabor, D., Nikolaidi, M.,van Lerven, F., 2022. An environmental mandate, now what?.SOAS University of London; University of Greenwich; University of the West of England; INSPIRE. January. Available at: https://eprints.soas.ac.uk/36190/1/Dafermos%20et%20al%20%282022%29%20An%20environmental%20mandate.pdf (accessed 20 May 2023)

Dafermos, Y., Kriwoluzky, A., Vargas, M., Volz, U., Wittich, J., 2021. The price of hesitation: How the climate crisis threatens price stability and what the ECB must do about it. Greenpeace; German Institute for Economic Research; SOAS University of London. September. Available at: https://greencentralbanking.com/research/price-of-hesitation-climate-crisis-ecb-price-stability/ (accessed 23 May 2023)

Dafermos, Y., Nikolaidi, M., van Lerven, F., Gabor, D., 2020. Decarbonizing the Bank of England´s pandemic QE. New Economics Foundation. August. Available at: https://neweconomics.org/uploads/files/NEF-Decarbonise-BoE-report.pdf (accessed 20 May 2023)

Daumas, L. 2024. Financial stability, stranded assets and the low-carbon transition–A critical review of the theoretical and applied literatures. Journal of Economic Surveys, 38, 601-616. https://doi.org/10.1111/joes.12551.

Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Sanchez Chico, A., Stantchevam, S., 2022. Fighting climate change: International attitudes toward climate policies. Organisation for Economic Cooperation and Development (OECD). OECD Economics Department Working Papers No. 1714. https://doi.org/10.1787/3406f29a-en.

Dees, S., Wegner, O., De Gaye, A., Thubin, C., 2023. The transition to carbon neutrality: Effects on price stability. Banque de France. Bulletin de la Banque de France No. 245/3, March-April. Available at: https://www.banque-france.fr/system/files/2023-05/bdf245-3_en_greenflation_web.pdf (accessed 19 April 2023)

Delgado, M., 2023. The role of central banks in sustainable finance. 11th Funseam International Business Symposium. Sustainable finance: Challenges and opportunities. Banco de España. February. Available at: https://www.bis.org/review/r230427e.pdf (accessed 20 June 2022)

Delis, M., De Greiff, K., Ongena, S., 2024. Being stranded on the carbon bubble? Climate policy risk and the pricing of bank loans. Financial markets, Instruments and Institutions, 12189. https://doi.org/10.1111/fmii.12189.

Demekas D.G., Grippa, P., 2021. Financial regulation, climate change, and the transition to a low-carbon economy: A survey of the issues. International Monetary Fund (IMF).

Working Paper No. WP/21/296, December. https://doi.org/10.5089/9781616356521.001.
Dennis, B.N., 2023. Climate change and financial policy: A literature review. International Review of Environmental and Resource Economics, 17(2-3), 231-318. http://dx.doi.org/10.1561/101.00000153.
Dikau, S., Robins, R., Smoleńska, A,. van't Klooster, J., Volz, U., 2024. Prudential net zero transition plans: The potential of a new regulatory instrument. Journal of Banking Regulation, 00247. https://doi.org/10.1057/s41261-024-00247-w.
Dikau, S., Ryan-Collins, J., 2017. Green central banking in emerging markets and developing country economies. New Economics Foundation. Available at: https://neweconomics.org/2017/10/green-centralbanking-emerging-market-developing-country-economies (accessed 21 May 2023)
Dikau, S., Volz, U., 2019. Central banking, climate change and green finance. In: Sachs, J., Thye, W., Yoshino, N., Taghizadeh-Hesary, F. (eds). Handbook of Green Finance. Sustainable Development. Springer, 1-23. https://doi.org/10.1007/978-981-10-8710-3_17-1
Dikau, S., Volz, U., 2021. Central bank mandates, sustainability objectives and the promotion of green finance. Ecological Economics, 184, 107022. https://doi.org/10.1016/j.ecolecon.2021.107022.
Diluiso, F., Annicchiarico, B., Kalkuhl, M., Minx, J.C., 2021. Climate actions and macro-financial stability: The role of central banks. Journal of Environmental Economics and Management, 110, 102548. https://doi.org/10.1016/j.jeem.2021.102548.
Doherty, O., 2018. Informational cascades in financial markets: Review and synthesis. Review of Behavioral Finance, 10(1), 53-69. https://doi.org/10.1108/rbf-05-2016-0030.
Dollar, D., Gatti, R., 1999. Gender inequality, income, and growth: Are good times good for women?. World Bank. Policy Research Report on Gender and Development Working Paper Series No. 1. Available at: http://documents.worldbank.org/curated/en/251801468765040122/Gender-inequality-income-and-growth-are-good-times-good-for-women (accessed 18 May 2023)
Drudi, F., Moench, E., Holthausen, C., Weber, P.F., 2021. Climate change and monetary policy in the euro area. European Central Bank. Occasional Paper Series No. 271. September. Available at: https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op271~36775d43c8.hr.pdf (accessed 22 May 2023)
Dunz, N., Naqvi, A., Monasterolo, I., 2021. Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. Journal of Financial Stability, 54, 100872. https://doi.org/10.1016/j.jfs.2021.100872.
Durrani, A., Rosmin, M., Volz, U., 2020. The role of central banks in scaling up sustainable finance—what do monetary authorities in the Asia-Pacific region think? Journal of Sustainable Finance and Investment, 10, 92-112. https://doi.org/10.1080/20430795.2020.1715095.
Eames, N., Barmes, D., 2022. The green central banking scorecard: 2022 edition. Positive Money. Available at: https://positivemoney.org/publications/green-central-banking-scorecard-2022/ (accessed 17 June 2023)

Eliet-Doillet A., Maino A.G., 2022. Central banks' "Green Shift" and the energy transition. The Oxford Institute for Energy Studies (OIES). OEIS Paper No. E10. Available at: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2022/03/Central-Banks-Green-Shift-and-the-Energy-Transition-ET10.pdf (accessed 30 May 2023)

Elsenhuber, U., Skenderasi, A., 2020. ESG investing: The role of public investors in sustainable investing. Evolving Practices in Public Investment Management: Proceedings of the Seventh Public Investors Conference. Available at: https://www.publicinvestorsconference.com/proceedings/conference_7/EPPIM7_Paper003.pdf (accessed 12 June 2023)

European Banking Authority (EBA), 2022. The EBA publishes its roadmap on sustainable finance. 13 December. Available at: https:///www.eba.europa.eu/publications-and-media/press-releases/eba-publishes-its-roadmap-sustainable-finance (accessed 13 December 2022)

European Banking Authority (EBA), 2021. EBA report on management and supervision of ESG risks for credit institutions and investment firms. EBA Report No. 2021/18. Available at: https://www.eba.europa.eu/sites/default/files/document_library/Publications/Reports/2021/1015656/EBA%20Report%20on%20ESG%20risks%20management%20and%20supervision.pdf (accessed 18 May 2023)

European Central Bank (ECB), 2020. The monetary policy strategy review: Some preliminary considerations. Speech by Christine Lagarde at the "ECB and Its Watchers XXI' conference, Frankfurt am Main, 30 September. Available at: https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200930~169abb1202.en.html (accessed 30 May 2023)

European Central Bank (ECB), 2021. What is monetary policy?. 25 August. Available at: https://www.ecb.europa.eu/ecb/educational/explainers/tell-me/html/what-is-monetary-policy.en.html (accessed 25 May 2023)

European Central Bank (ECB), 2022a. ECB takes further steps to incorporate climate change into its monetary policy operations. 4 July. Available at: https://www.ecb.europa.eu/press/pr/date/2022/html/ecb.pr220704~4f48a72462.en.html (accessed 10 August 2023)

European Central Bank (ECB), 2022b. 2022 climate risk stress test. July. Available at: https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climate_stress_test_report.20220708~2e3cc0999f.en.pdf (accessed 14 January 2023)

European Central Bank/ European Systemic Risk Board (ECB/ ESRB), 2022. The macroprudential challenge of climate change. 26 July. Available at: https://www.esrb.europa.eu/pub/pdf/reports/esrb.ecb.climate_report202207~622b791878.en.pdf (accessed 30 March 2023)

European Central Bank/ European Systemic Risk Board (ECB/ ESRB), 2023. Towards macroprudential frameworks for managing climate risk. December. Available at: www.esrb.europa.eu/pub/pdf/reports/esrb.report202312~d7881028b8.en.pdf (accessed 3 June 2023)

Erneuerbare-Energien-Gesetz (2016). Erneuerbare-Energien-Gesetz (Renewable Energy Law). Teil I Nr. 49, 2258–357. Available at: Bundesgesetzblatt BGBl. Online-Archiv 1949 - 2022 | Bundesanzeiger Verlag (accessed 19 April 2023)

European Commission (EC), 2022. Feedback statement of the targeted consultation on improving the EU's macroprudential framework for the banking sector. Available at: https://finance.ec.europa.eu/system/files/2022-06/2021-banking-macroprudential-framework-summary-of-responses_en.pdf (accessed 30 June 2022)

European Insurance and Occupational Pensions Authority, 2022. Methodological principles of insurance stress testing – climate change component. Working Paper No. EIOPA-BOAS-21-579. January. Available at: https://www.eiopa.europa.eu/system/files/2022-02/methodological_principles_of_insurance_stress_testing_-_climate_change_component.pdf (accessed 18 May 2023)

European Systemic Risk Board (ESRB), 2016. Too late, too sudden: Transition to a low-carbon economy and systemic risk. Reports of the Advisory Scientific Committee No. 6, February. Available at: https://www.esrb.europa.eu/pub/pdf/asc/Reports_ASC_6_1602.pdf (accessed 29 May 2023)

European Union (EU), 2022. Commission Implementing Regulation (EU) 2022/2453 of 30 November 2022. Official Journal of the European Union. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R2453 (accessed 29 December 2022)

Fender, I., McMorrow, M., Sahakyan, V., Zulaica, O., 2019. Green bonds: The reserve management perspective. Bank of International Settlements (BIS). BIS Quarterly Review, 22 September. Available at: https://www.bis.org/publ/qtrpdf/r_qt1909f.htm. (accessed 2 August 2023)

Fender, I., McMorrow, M., Sahkyan, V., Zulaica, O., 2020. Reserve management and sustainability: The case for green bonds? Bank of International Settlements (BIS). Working Paper No. 849. Available at: https://www.bis.org/publ/work849.htm (accessed 5 August 2023)

Ferrari A., Landi V.N., 2023. Toward a green economy: The role of central bank's asset purchases. European Central Bank. Working Paper Series No. 2779, February. Available at: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2779~a4eca2101a.en.pdf (accessed 30 November 2023)

Ferrari, A., Landi, V. N., 2024. Whatever it takes to save the planet? Central banks and unconventional green policy. Macroeconomic Dynamics, 28(2), 299-324. https://doi.org/10.1017/s1365100523000032.

Financial Stability Board (FSB), 2020a. The implications of climate change for financial stability. November. Available at: https://www.fsb.org/wp-content/uploads/P231120.pdf (accessed 18 May 2023)

Financial Stability Board (FSB), 2020b. Stocktake of financial authorities' experience in including physical and transition climate risks as part of their financial stability monitoring. July. Available at: https://www.fsb.org/wp-content/uploads/P220720.pdf (accessed 18 May 2023)

Fisman, R., Svensson, J., 2007. Are corruption and taxation really harmful to growth? Firm level evidence. Journal of Development Economics, 83(1), 63-75. https://doi.org/10.1016/j.jdeveco.2005.09.009.

Flavelle, C., 2019. As wildfires get worse, insurers pull back from riskiest areas. New York Times, 20 August. Available at: https://www.nytimes.com/2019/08/20/climate/fire-insurance-renewal.html (accessed 24 May 2023)

Ford, G., Kedward, K., Krebel, L., Ryan-Collins, J., Vaccaro, J., van Lerven, F., 2022. Fat tails, tipping points and asymmetric time horizons: Dealing with systemic climate-related uncertainty in the prudential regime. Bank of England Climate Capital Conference, October. http://dx.doi.org/10.2139/ssrn.4245871.

Frangoul, A., 2023. France bans short-haul flights as it looks to cut transport emissions. CNBC. 24 May. Available at: https://www.cnbc.com/2023/05/24/france-bans-domestic-short-haul-flights.html (accessed 25 May 2023)

Fratzscher, M., Grosse-Steffen, C., Rieth, M., 2020. Inflation targeting as a shock absorber. Journal of International Economics, 123, 103308. https://doi.org/10.1016/j.jinteco.2020.103308.

Fritz-Morgenthal, S., Hiber, J.-A., Funaro, D., 2018. Preventing disaster: How banks can manage operational risk. Bain & Company. Available at: https://www.bain.com/contentassets/f0199ad9887e402cb37cd1fd316f5ee3/bain_brief_how_banks_can_manage_operational_risk.pdf (accessed 25 May 2023)

Fuerst, F., Warren-Myers, G., 2021. Pricing climate risk: Are flooding and sea level rise risk capitalised in Australian residential property?. Climate Risk Management, 34, 100361. https://doi.org/10.1016/j.crm.2021.100361.

Gillan, S.L., Koch, A., Starks, L.T., 2021. Firms and social responsibility: A review of ESG and CSR research in corporate finance. Journal of Corporate Finance, 66, 101889. https://doi.org/10.1016/j.jcorpfin.2021.101889.

Ginglinger, E., Moreau, Q., 2019. Climate risk and capital structure. Management Science, 69(12), 7492-7516. https://doi.org/10.1287/mnsc.2023.4952.

Giuzio, M., Krušec, D., Levels, A., Melo, A.S., Mikkonen, K., Radulova, P., 2019. Climate change and financial stability. European Central Bank (ECB) Financial Stability Review, May. Available at: https://www.ecb.europa.eu/press/financial-stability-publications/fsr/special/html/ecb.fsrart201905_1~47cf778cc1.en.html (accessed 21 May 2023)

Gray, I., Bakke, G., 2019. Pacific Gas and Electric is a company that was just bankrupted by climate change. It won't be the last. Washington Post, 30 January. Available at: https://www.washingtonpost.com/news/monkey-cage/wp/2019/01/30/pacific-gas-and-electric-is-a-company-that-was-just-bankrupted-by-climate-change-it-wont-be-the-last/. (accessed 24 May 2023)

Grünewald, S., 2021. Climate change as a systemic risk in finance: Are macroprudential authorities up to the task?. In: Busch, D., Ferrarini, G., Grünewald, S. (eds.), Sustainable Finance in Europe, Palgrave Macmillan Cham, 227-257. https://doi.org/10.1007/978-3-031-53696-0_8.

Grünewald, S., 2023. Macroprudential policies and climate risks. European Banking Institute (EBI). Working Paper No. 133. https://dx.doi.org/10.2139/ssrn.4327142.

Hansen, L. 2021. Central banking challenges posed by uncertain climate change and natural disasters. Journal of Monetary Economics, 125, 1-15. https://doi.org/10.1016/j.jmoneco.2021.09.010.

Harvey, F., 2023. Banks still investing heavily in fossil fuels despite next zero pledges – study. The Guardian, 17 January. Available at: https://www.theguardian.com/environment/2023/jan/17/banks-still-investing-heavily-in-fossil-fuels-despite-net-zero-pledges-study (accessed 22 May 2023)

Hickel, J., 2019. The limits of clean energy. Foreign policy, 6 September. Available at: https://foreignpolicy.com/2019/09/06/the-path-to-clean-energy-will-be-very-dirty-climate-change-renewables/ (accessed 24 May 2023)

Higgs, N., Huber, B. M., Long, A. S., Naib, O., Mainwaring, A., Behar, D., 2022. Federal Reserve proposes climate risk guidance for large financial institutions. Global Financial Regulatory Blog. 9 December. Available at: https://www.globalfinregblog.com/2022/12/federal-reserve-proposes-climate-risk-guidance-for-large-financial-institutions/ (accessed 10 August 2023)

Hočevar, S., Kuparinen, A., 2021. Marine food web perspective to fisheries-induced evolution. Evolutionary Applications, 14(10), 2378-2391. https://doi.org/10.1111/eva.13259.

Hodgson, C., Romei, V., Thomas, N., 2021. Bank of England given new mandate to buy 'green' bonds. Financial Times, 3 March. Available at: https://www.ft.com/content/f436d69b-2bf0-48cd-bb34-644856fba17f (accessed 15 February 2024)

Holt, A., 2019. Investors fail to see value of S and G factors of ESG, notes study. IR Magazine. 3 September. https://www.irmagazine.com/esg/investors-fail-see-value-s-and-g-factors-esg-notes-study (accessed 22 May 2023)

Honohan, P., 2019. Should monetary policy take inequality and climate change into account. Peterson Institute for International Economics (PIIE). Working Paper No. 19-18, October. https://doi.org/10.2139/ssrn.3478285.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., Houser, T., 2017. Estimating economic damage from climate change in the United States. Science, 356(6345), 1362-1369. https://doi.org/10.1126/science.aal4369.

Huang, H. H., Kerstein, J., Wang, C., Wu, F., 2022. Firm climate risk, risk management, and bank loan financing. Strategic Management Journal, 43(13), 2849-2880. https://doi.org/10.1002/smj.3437.

International Association of Insurance Supervisors, 2023. Public consultation on climate risk supervisory guidance – part one. March. Available at: https://www.iaisweb.org/uploads/2023/03/climate-risk-supervisory-guidance-part-one.pdf (accessed 1 April 2023)

International Energy Agency, 2021. Financing clean energy transitions in emerging and developing economies. World Energy Investment 2021 Special Report. Available at: https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies (accessed 31 May 2023)

Ilhan, E., Sautner, Z., Vilkov, G., 2021. Carbon tail risk. Review of Financial Studies, 34(3), 1540-1571. https://doi.org/10.1093/rfs/hhaa071.

International Monetary Fund (IMF), 2019. Global financial stability report: Lower for longer. Available at: https://www.imf.org/en/Publications/GFSR/Issues/2019/10/01/global-financial-stability-report-october-2019 (accessed 29 January 2020)

Jackson, T., 2009. Prosperity without growth? The transition to a sustainable economy. Sustainable Development Commission. https://doi.org/10.4337/9781781951415.00015.

Jamali, D., Safieddine, A.M., Rabbath, M., 2008. Corporate governance and corporate social responsibility synergies and interrelationships. Corporate Governance: An International Review, 16(5), 443-459. https://doi.org/10.1111/j.1467-8683.2008.00702.x.

Jargalsaikhan, H., Leduc, S., Oliveira, L.E., 2022. How are businesses responding to climate risk? Federal Reserve Bank of San Francisco (FRBSF). FBSF Economic Letter No. 6, March. Available at: https://www.frbsf.org/research-and-insights/publications/economic-letter/2022/03/how-are-businesses-responding-to-climate-risk/ (accessed 18 May 2023)

Johnston, R.B., 2022. Adapting macroprudential frameworks to climate change risks. Toronto Centre. Available at: https://www.torontocentre.org//videos/Adapting_Macroprudential_Frameworks_to_Climate_Change_Risks_Updated_Links.pdf (accessed 6 April 2023)

Jones, H., Bruce, A., 2022. Bank of England tells banks to take climate action now or face profit hit. Reuters, 24 May. Available at: https://www.globalfinregblog.com/2022/12/federal-reserve-proposes-climate-risk-guidance-for-large-financial-institutions/ (accessed 10 August 2023)

Jung, J., Herbohn, K., Clarkson, P., 2018. Carbon risk, carbon risk awareness and the cost of debt financing. Journal of Business Ethics, 150, 1151-1171. https://doi.org/10.1007/s10551-016-3207-6.

Kalfaoglou, F., 2021. ESG risks: A new source of risks for the banking sector. Bank of Greece. Economic Bulletin No. 53. Available at: https://doi.org/10.52903/econbull20215305 (accessed 18 May 2023)

Kleimeier, S., Viehs, M., 2018. Carbon disclosure, emission levels, and the cost of debt. Working Paper No. 2719665. https://doi.org/10.2139/ssrn.2719665

Koetter, M., Noth, F., Rehbein, O., 2020. Borrowers under water! Rare disasters, regional banks, and recovery lending. Katzhttps://doi.org/10.1016/j.jfi.2019.01.003.

Kotecki, L., 2023. Potencjalny wpływ celów i ryzyk klimatycznych na prowadzenie polityki pieniężnej i działalność banku centralnego. Studia BAS, 2(74), 25-41. https://doi.org/10.31268/studiabas.2023.10.

Krebel, L., 2021. The Bank of England's new 'net zero' mandate could be a game changer. New Economics Foundations, 6 May. Available at: https://neweconomics.org/2021/05/the-bank-of-englands-new-net-zero-mandate-could-be-a-game-changer (accessed 10 August 2023)

Krogstrup, S., Oman, W., 2019. Macroeconomic and financial policies for climate change mitigation: A review of the literature. International Monetary Fund (IMF). IMF Working Paper No. 2019/185. https://doi.org/10.5089/9781513511955.001.

Kroll, M., Kühne, K., 2024. 'Climate bailout': a new tool for central banks to limit the financial risk resulting from climate change. International Environmental Agreements: Politics, Law and Economics, 24, 217-232. https://doi.org/10.1007/s10784-024-09630-4.

Kyriakopoulou, D., Antonakaki, T., Bekiari, M., Kartapani, A., Paisiou, K. Rapti, E., 2022. Central banks and climate-related disclosures: Applying the TCFD's recommendations. INSPIRE. The INSPIRE Sustainable Central Banking Toolbox Policy Briefing Paper No 03. Available at: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/05/INSPIRE-Sustainable-Central-Banking-Toolbox-Policy-Briefing-Paper-3.pdf (accessed 3 June 2023)

Lamperti, F., Bosetti, V., Roventini, A., Tavoni, M., Treibich, T., 2021. Three green financial policies to address climate risks. Journal of Financial Stability, 54, 100875. https://doi.org/10.1016/j.jfs.2021.100875.

Lamperti, F., Bosetti, V., Roventini, M., Tavoni, M., 2019. The public costs of climate-induced financial instability. Nature Climate Change, 9, 829–833. https://doi.org/10.1038/s41558-019-0607-5.

Landau J., Brunnemeier M., 2020. Central Banks and climate change. Centre for Economic Policy Research (CEPR), VoxEU, 12 January. Available at: https://cepr.org/voxeu/columns/central-banks-and-climate-change (accessed 20 May 2023)

Lang, Q., Ma, F., Mirza, N., Umar, M., 2023. The interaction of climate risk and bank liquidity: An emerging market perspective for transitions to low carbon energy. Technological Forecasting and Social Change, 191, 122480. https://doi.org/10.1016/j.techfore.2023.122480.

Le Quang, G., Scialom, L., 2022. Better safe than sorry: Macroprudential policy, Covid 19 and climate change. International Economics, 172, 403-413. https://doi.org/10.1016/j.inteco.2021.07.002.

Lehmann, A., 2022. Geopolitical risks and banking sector vulnerabilities: Implications for the SSM. Economic Governance Support Unit (EGOV), Directorate-General for Internal Policies. Available at: https://www.bruegel.org/report/geopolitical-risks-and-banking-sector-vulnerabilities-implications-ssm (accessed 31 March 2023)

Mallucci, E., 2022. Natural disasters, climate change, and sovereign risk. Journal of International Economics, 139, 103672. https://doi.org/10.1016/j.jinteco.2022.103672.

Masciandaro, D., Russo, R., 2022. Central banks and climate policy: Unpleasant trade-offs? A principal–agent approach. Baffi CAREFIN Centre for Applied Research on International Markets, Banking, Finance, and Regulation. Bocconi University. Working Paper No. 181. https://doi.org/10.2139/ssrn.4139124

Matikainen, S., Campiglio, E., Zenghelis, D., 2017. The climate impact of quantitative easing. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science. Policy Paper, May. Available at: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/05/ClimateImpactQuantEasing_Matikainen-et-al-1.pdf (accessed 23 May 2023)

Mauderer, S., 2022. The economic power of sustainability and energy transition. Speech at the Lufthansa Cargo Sustainability Conference 2022, Frankfurt am Main, 14 July. Available at: https://www.bis.org/review/r220718a.htm (accessed 3 June 2023)

Mazzucato, M., Semieniuk, G., 2017. Public financing of innovation: New questions. Review of Economic Policy, 33(1), 24–48. https://doi.org/10.1093/oxrep/grw036.

Miller, H., Dikau, S., 2022. Preventing a 'climate Minsky moment': Environmental financial risks and prudential exposure limits. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science. Policy Report, March. Available at: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/03/Preventing-a-climate-Minsky-moment.pdf (accessed 29 April 2022)

Miller, H., Dikau, S., Svartzman, R., Dees, S., 2023. The stumbling block in 'the race of our lives': Transition critical materials, financial risks and the NGFS climate scenarios. Banque de France Working Paper No. 907, February. https://doi.org/10.2139/ssrn.4356692.

Monasterolo, I. 2020. Climate change and the financial system. Annual Review of Resource Economics, 12, 299-320. https://doi.org/10.2139/ssrn.3479380.

Monasterolo, I., De Angelis, L., 2020. Blind to carbon risk? An analysis of stock market reaction to the Paris Agreement. Ecological Economics, 170, 106571. https://doi.org/10.1016/j.ecolecon.2019.106571.

Monasterolo, I., Mandel, A., Battiston, S., Mazzocchetti, A., Oppermann, K., Coony, J., Stretton, S., Stewart, F., Dunz, N., 2022. The role of green financial sector initiatives in the low-carbon transition: A theory of change. World Bank. Policy Research Working Paper No. 10181, Available at: https://doi.org/10.1596/1813-9450-10181 (accessed 21 May 2023)

Monasterolo, I., Zheng, J.I., Battiston, S., 2018. Climate transition risk and development finance: A carbon risk assessment of China's overseas energy portfolios. China and World Economy, 26(6), 116-142. https://doi.org/10.1111/cwe.12264.

Mongelli, F.F., Pointer, W., Van den End, J.W., 2024. The effects of climate change on the natural rate of interest: A critical survey. Wiley Interdisciplinary Reviews: Climate Change, 15(2), e873. https://doi.org/10.1002/wcc.873.

Monnin, P., 2021. Systemic risk buffers – the missing piece in the prudential response to climate risks. Council on Economic Policies. CEP Policy Brief, June. Available at: https://www.cepweb.org/wp-content/uploads/2021/06/Monnin-2021.-Climate-systemic-risk-buffer-for-Europe-Final.pdf (accessed 20 June 2021)

Morck, R., Wolfenzon, D., Yeung, B., 2005. Corporate governance, economic entrenchment, and growth. Journal of Economic Literature, 43(3), 655-720. https://doi.org/10.3386/w10692.

Muñoz, D.R., Cabrales, A., Sánchez, A., 2022. Central banks and climate change. Fit, opportunity and suitability in the law and beyond. European Banking Institute (EBI). EBI Working Paper Series No. 119. http://dx.doi.org/10.2139/ssrn.4054908.

Naffa, H., Dudás, F., 2020. Country-level ESG indicators as predictors of social well-being?. In: Kovács, E. (ed.), Living Longer, Working Smarter, Ageing Well Conference Proceedings, 110-114. Available at: https://www.researchgate.net/profile/Peter-

Vekas/publication/344429575_Living_Longer_Working_Smarter_Ageing_Well_-_2 (accessed 26 May 2023)

Nagel, J., 2023. Climate change and central banks – supporting the green transition by pursuing price stability. Speech at the Deutsche Bundesbank Spring Conference 2023 on Climate Change and Central Banks, 12 May. Available at: https://www.bis.org/review/r230515d.htm (accessed 12 June 2023)

Nasim, A., Downing, G., 2023. Energy shocks and bank performance in the advanced economies. Energy Economics, 118, 106517. https://doi.org/10.1016/j.eneco.2023.106517.

Neszveda, G., Siket, B., 2023. Green ECB speeches matter. Journal of Sustainable Finance and Investment, 1-18. https://doi.org/10.1080/20430795.2023.2253205.

Nieto, M.J., 2018. Banks, climate risk and financial stability. Journal of Financial Regulation and Compliance, 27(2), 243-262. https://doi.org/10.1108/jfrc-03-2018-0043.

Nwagwu, I., 2020. Driving sustainable banking in Nigeria through responsible management education: The case of Lagos Business School. International Journal of Management Education, 18(1), 100332. https://doi.org/10.1016/j.ijme.2019.100332.

Organisation for Economic Co-Operation and Development (OECD), 2017. Investing in Climate, Investing in Growth. OECD Publishing. http://dx.doi.org/10.1787/9789264273528-en.

Organisation for Economic Co-Operation and Development (OECD), 2020. OECD Business and Finance Outlook 2020: Sustainable and Resilient Finance. OECD Publishing. https://doi.org/10.1787/eb61fd29-en.

Organisation for Economic Co-Operation and Development (OECD), 2021a. Green Economy and Energy Transition in Emerging Markets 2021. EMnet Working Group on Green Economy in Emerging Markets. Available at: https:// www.oecd.org/dev/Key_Messages_EMnet_Green_Economy_EnergyTransitionEmergingMarkets.pdf (accessed 19 April 2023)

Organisation for Economic Co-Operation and Development (OECD), 2021b. Strengthening Macroprudential Policies in Emerging Asia: Adapting to Green Goals and Fintech. The Development Dimension, OECD Publishing. https://doi.org/10.1787/6f1ed069-en.

Oehmke, M., Opp, M., 2023. Green capital requirements. European Central Bank (ECB). ECB Banking Supervision Conference. May. Available at: https://www.bankingsupervision.europa.eu/press/conferences/shared/pdf/20230502_research_conference/Oehmke_paper.pdf (accessed 19 May 2023)

Ohtaki, E., 2023. Climate change, financial intermediation and monetary policy. Tokyo Centre for Economics Research (TCER). Working Paper No. E-179. Available at: https://www.tcer.or.jp/wp/pdf/e179.pdf (accessed 1 December 2023)

Ortega, F., Taşpınar, S., 2018. Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market. Journal of Urban Economics, 106, 81-100. https://doi.org/10.1016/j.jue.2018.06.005.

Oyegunle, A., Weber, O., 2015. Development of sustainability and green banking regulations – Existing codes and practices. Centre for International Governance Innovation (CIGI). CIGI Paper No. 65. Available at:

https://www.cigionline.org/sites/default/files/cigi_paper_no.65_4.pdf (accessed 7 April 2023)

Papoutsi, M., Piazzesi, M., Schneider, M., 2021. How unconventional is green monetary policy. Stanford University. Working Paper. Available at: https://web.stanford.edu/~piazzesi/How_unconventional_is_green_monetary_policy.pdf (accessed 29 May 2023)

Parker, M., 2018. The impact of disasters on inflation. Economics of Disasters and Climate Change, 2(1), 21-48. https://doi.org/10.1007/s41885-017-0017-y.

Parrique, T., Barth, J., Briens, F., Kuokkanen, A., Spangenberg, J.H., 2019. Evidence and arguments against green growth as a sole strategy for sustainability. European Environmental Bureau. Available at: https://www.almendron.com/tribuna/wp-content/uploads/2019/11/decoupling-debunked.pdf (accessed 24 May 2023)

Peng, W., Xiong, L. 2022. Managing financing costs and fostering green transition: The role of green financial policy in China. Economic Analysis and Policy, 76, 820-836. https://doi.org/10.1016/j.eap.2022.09.014

Pescaroli, G., Alexander, D., 2015. A definition of cascading disasters and cascading effects: Going beyond the "toppling dominos" metaphor. Planet@ Risk, 3(1), 58-67. Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5e056c0990d341ce554b98d25d2bca935623ad76#:~:text=In%20order%20to%20explain%20a,feature%20of%20most%20catastrophic%20events (accessed 18 May 2023)

Philipponnat, T., 2020. Breaking the climate-finance doom loop. Finance Watch. 8 June. Available at: https://www.finance-watch.org/policy-portal/sustainable-finance/breaking-the-climate-finance-doom-loop/ (accessed 8 February 2022)

Powell, J.H.., 2023. Panel on "Central Bank Independence and the Mandate—Evolving Views", Board of Governors of the Federal Reserve System, 10 January. Available at https://www.federalreserve.gov/newsevents/speech/powell20230110a.htm (accessed 21 July 2024)

Prentice, C., 2022. U.S. Fed proposes plan for banks to manage climate-linked financial risk. Reuters, 2 December. Available at: https://www.reuters.com/business/sustainable-business/us-fed-proposes-framework-how-banks-manage-climate-related-financial-risk-2022-12-02/ (accessed 29 December 2023)

Puttachai, W, Phadkantha, R., Yamaka, W., 2022. The threshold effects of ESG performance on the energy transitions: A country-level data. Energy Reports, 8, 234-241. https://doi.org/10.1016/j.egyr.2022.10.187

Reinders H.J., Schoenmaker, D., Van Dijk, M., 2023. Climate risk stress tests underestimate potential financial sector losses. Centre for Economic Policy Research (CEPR), VoxEU, 28 June. Available at: https://cepr.org/voxeu/columns/climate-risk-stress-tests-underestimate-potential-financial-sector-losses (accessed 3 July 2023)

Roncoroni, A., Battiston, S., Escobar-Farfán, L.O.L., Martinez-Jaramillo, S., 2021. Climate risk and financial stability in the network of banks and investment funds. Journal of Financial Stability, 54, 100870. https://doi.org/10.1016/j.jfs.2021.100870.

Rudebusch, G.D., 2019. Climate change and the Federal Reserve. Federal Reserve Bank of San Francisco (FRBSF). FRBSF Economic Letter No. 2019-9. Available at:

https://www.frbsf.org/research-and-insights/publications/economic-letter/2019/03/climate-change-and-federal-reserve/ (accessed 29 May 2023)
Ruiters, M., Charteris, A., 2020. Gender equality in labour force participation, economic growth and development in South Africa. Development Southern Africa, 37(6), 997-1011. https://doi.org/10.1080/0376835x.2020.1772042.
S&P Global, 2020. What is the "S" in ESG? 24 February. https://www.spglobal.com/en/research-insights/articles/what-is-the-s-in-esg (accessed 22 May 2023)
Safarzyńska, K., van den Bergh, J.C.J.M., 2017. Financial stability at risk due to investing rapidly in renewable energy. Energy Policy, 108, 12-20. https://doi.org/10.1016/j.enpol.2017.05.042.
Saul, J., 2022. Fixing the S in ESG: How to move from net zero to net impact. Stanford Social Innovation Review. 22 February. Available at: https://ssir.org/articles/entry/fixing_the_s_in_esg (accessed 22 May 2023)
Schmieder, C., Peronaci, R., Quang, P.B., Triebskorn, E., Izzati, N., Artman, M., 2021. Sustainable finance data for central banks. Irving Fisher Committee (IFC) on Central Bank Statistics Report No. 14, December. Available at: https://www.bis.org/ifc/publ/ifc_report_14.pdf (accessed 19 December 2021)
Schnabel, I., 2020. When markets fail – The need for collective action in tackling climate change. Speech given at the European Sustainable Finance Summit, Frankfurt am Main, 28 September. Available at: https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200928_1~268b0b672f.en.html (accessed 20 May 2023)
Schnabel, I., 2021a. Climate change and monetary policy. Finance and Development, September 2021, 53-55. Available at: https://www.imf.org/en/Publications/fandd/issues/2021/09/isabel-schnabel-ECB-climate-change (accessed 21 May 2023)
Schnabel, I., 2021b. From green neglect to green dominance? Speech given at the "Greening Monetary Policy – Central Banking and Climate Change" held at the Cleveland Fed Conversations on Central Banking, 3 March. Available at: https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210303_1~f3df48854e.en.html (accessed 21 April 2023)
Schnabel, I., 2021c. From market neutrality to market efficiency. Speech given at the ECB DG-Research Symposium "Climate Change, Financial Markets and Green Growth, 14 June. Available at: https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210614~162bd7c253.en.html (accessed 21 May 2023)
Schnabel I., 2022. A new age of energy inflation: Climateflation, fossilflation and greenflation. Speech at a panel on "Monetary Policy and Climate Change" at "The ECB and its Watchers XXII" Conference, Frankfurt am Main, 17 March. Available at: https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220317_2~dbb3582f0a.en.html (accessed 30 May 2023)
Schoenmaker, D., 2021. Greening monetary policy. Climate Policy, 21(4), 581-592. https://doi.org/10.1080/14693062.2020.1868392.

Schoenmaker, S., van Tilburg, R., Wijffels, H., 2016. What role for financial supervisors in addressing systemic environmental risks? Comparative Economic Studies, 58(3), 317–334. https://doi.org/10.1057/ces.2016.11.

Schreiber P., 2022. Managing inflation by supercharging a clean energy transition. What the ECB should do. Reclaim Finance. Available at: https://reclaimfinance.org/site/wp-content/uploads/2022/09/Report-Supercharging-a-EU-clean-energy-transition-ECB.pdf (accessed 20 May 2023)

Schüwer, U., Lambert, C. and Noth, F., 2019. How do banks react to catastrophic events? Evidence from Hurricane Katrina. Review of Finance, 23(1), 75-116. https://doi.org/10.1093/rof/rfy010.

Semieniuk, G., Campiglio, E., Mercure, J.F., Volz, U., Edwards, N.R., 2021. Low-carbon transition risks for finance. Wiley Interdisciplinary Reviews: Climate Change, 12(1), e678. https://doi.org/10.1002/wcc.678.

Senni C.C., Pagliari M.S. van't Klooster, J., 2023. The CO2 content of the TLTRO III scheme and its greening. De Nederlandsche Bank N.V. Working Paper No. 792. Available at: www.dnb.nl/media/amgjspuo/working_paper_no-792.pdf (accessed 1 December 2023)

Sgaravatti, G., Tagliapietra, S., Zachmann, G., 2023. Adjusting to the energy shock: The right policies for European industry. Bruegel. Policy Brief No. 11/2023. Available at: https://www.bruegel.org/sites/default/files/2023-05/PB%2011%202023_1.pdf (accessed 5 January 2024)

Škare, M., Hasić, T., 2016. Corporate governance, firm performance, and economic growth – theoretical analysis. Journal of Business Economics and Management, 17(1), 35-51. https://doi.org/10.3846/16111699.2015.1071278.

Smoleńska, A., van't Klooster J., 2022. A risky bet: Climate change and the EU's microprudential framework for banks. Journal of Financial Regulation, 8(1), 51-74. https://doi.org/10.1093/jfr/fjac002.

Steele, G., 2020. Confronting the 'Climate Lehman Moment': The case for macroprudential climate regulation. Cornell Journal of Law and Public Policy, 30, 109-157. Available at: https://ssrn.com/abstract=3542840 (accessed 19 May 2023)

Steffen, W., Rockström, J., Lenton, J.T.M., Folke, C., Liverman, D., Summerhayes, C.P., Barnosky, A.D., Cornell, S.E., Crucifix, M., Donges, J.F., Fetzer, I., Lade, S.J., Scheffer, M., Winkelmann, R. and Schellnhuber, H.J. Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Sciences, 115(3), 8252-8259. https://doi.org/10.1073/pnas.1810141115.

Stuber, W., 2014. Brazil: The social and environmental responsibility policy of the Brazilian financial institutions. Mondaq. Available at: https://www.mondaq.com/brazil/financial-services/311440/the-social-and-environmental-responsibility-policy-of-the-brazilian-financial-institutions (accessed 25 July 2023)

Sukhera, J., 2022. Narrative reviews: Flexible, rigorous, and practical. Journal of Graduate Medical Education, 14(4), 414-427. https://doi.org/10.4300/jgme-d-22-00480.1.

Svartzman, R., Bolton, P., Destpres, M., Pereira Da Silva, L.A., Samama, F., 2021. Central banks, financial stability and policy coordination in the age of climate uncertainty: A

three-layered analytical and operational framework. Climate Policy, 21(4), 563-580. https://doi.org/10.1080/14693062.2020.1862743.
Szczygielski, J.J., Charteris, A., Obojska, L. & Brzeszczyński, J. What does energy price uncertainty reveal about the global energy crisis. Working Paper.
Taskforce on Climate-related Financial Disclosures (TCFD), 2017. Recommendations of the Task Force on Climate-related Financial Disclosures. Available at: https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf (accessed 19 April 2023)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2019. A call for action: Climate change as a source of financial risk. April. Available at: https://www.ngfs.net/sites/default/files/medias/documents/synthese_ngfs-2019_-_17042019_0.pdf (accessed 11 January 2020)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2020a. Climate change and monetary policy: Initial takeaways. June. Available at: https://www.ngfs.net/en/climate-change-and-monetary-policy-initial-takeaways (accessed 30 April 2023)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2020b. Guide for Supervisors: Integrating climate-related and environmental risks into prudential supervision. Available at: https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_for_supervisors.pdf. (accessed 5 November 2020)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2021a. Adapting central bank operations to a hotter world: Reviewing some options. March. Available at: https://www.ngfs.net/en/adapting-central-bank-operations-hotter-world-reviewing-some-options (accessed 5 May 2023)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2021b. Guide on climate-related disclosure for central banks. December. Available at: https://www.ngfs.net/en/guide-climate-related-disclosure-central-banks (accessed 1 August 2024)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2022a. Final report on bridging data gaps. July. Available at: https://www.ngfs.net/en/final-report-bridging-data-gaps (accessed 16 July 2022)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2022b. NGFS Climate Scenarios for central banks and supervisors. September. Available at: https://www.ngfs.net/en/ngfs-climate-scenarios-central-banks-and-supervisors-september-2022. (accessed 12 September 2022)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS), 2023. NGFS Climate Scenarios Technical Documentation. V. 4.2. November. Available at: https://www.ngfs.net/sites/default/files/media/2024/01/16/ngfs_scenarios_technical_documentation_phase_iv_2023.pdf (accessed 8 August 2024)
The Central Banks and Supervisors Network for Greening the Financial System (NGFS)-INSPIRE (2021). Biodiversity and financial stability: Building the case for action. NGFS Occasional Paper. October. Available at:

https://www.ngfs.net/sites/default/files/medias/documents/biodiversity_and_financial_stablity_building_the_case_for_action.pdf (accessed 15 July 2023)

Toczynski, J., Burlon, L., Dimou, M., Barbero, F., 2022. Dual interest rates and the transmission of monetary policy. Centre for Economic Policy Research (CEPR), VoxEU, 13 October. Available at: https://cepr.org/voxeu/columns/dual-interest-rates-and-transmission-monetary-policy (accessed 20 May 2024)

Tufail, S., Avil, S., Hoang V., Wilson C., V., 2024. The effects of conventional and unconventional monetary policies of the US, EU and China on global green investment. Energy Economics, 134, 107549. https://doi.org/10.1016/j.eneco.2024.107549.

Van Eyck, V., 2024. The ECB is wrong. Green dual interest rates are possible – and necessary. Green Central Banking, 9 January. Available at: https://greencentralbanking.com/2024/01/09/green-dual-interest-rates-ecb-emmanuel-macron/ (accessed 2 June 2024)

Van Steenis, H., 2019. The Future of Finance Report. Bank of England. June. Available at https://www.bankofengland.co.uk/-/media/boe/files/report/2019/future-of-finance-report.pdf (accessed 19 April 2023)

Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jansen, D.J., Heeringa, W., 2018. An energy transition risk stress test for the financial system of the Netherlands. De Nederlandsche Bank N.V. Occasional Studies Paper No. 16-7. Available at: www.dnb.nl/media/pdnpdalc/201810_nr-_7_-2018-_an_energy_transition_risk_stress_test_for_the_financial_system_of_the_netherlands.pdf (accessed 18 May 2023)

Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jansen, D.J., Heeringa, W., 2021. The heat is on: A framework for measuring financial stress under disruptive energy transition scenarios. Ecological Economics, 190, 107205. https://doi.org/10.1016/j.ecolecon.2021.107205.

Volz, U., 2017. On the role of central banks in enhancing green finance. United Nations Environment Programme. Inquiry Working Paper No. 17/01. Available at: https://www.unep.org/resources/report/role-central-banks-enhancing-green-finance-inquiry-working-paper-1701 (accessed 18 May 2023)

Volz, U., Beirne, J., Ambrosio Preudhomme, N., Fenton, A., Mazzacurati, E., Renzhi, N., Stampe, J., 2020. Climate change and sovereign risk. SOAS Centre for Sustainable Finance at SOAS University of London, Asian Development Bank Institute, World Wide Fund for Nature Singapore, and Four Twenty Seven. Available at: https://eprints.soas.ac.uk/33524/1/Climate%20Change%20and%20Sovereign%20Risk_final.pdf (accessed 18 May 2023)

Weyzig, F., Kuepper, B., van Gelder, J.W., van Tilburg, R., 2014. The Price of Doing Too Little Too Late. The impact of carbon bubble on the EU financial system. Green New Deal Series. 11. Available at: https://gef.eu/wp-content/uploads/2017/01/The_Price_of_Doing_Too_Little_Too_Late_.pdf (accessed 18 May 2023)

Weidmann, J., 2019. Climate change and central banks. Welcome address at the Deutsche Bundesbank's second financial market conference, Frankfurt am Main, 29 October. Available at: https://www.bis.org/review/r191029a.htm (accessed 25 May 2023)

Whelan, T., Fink, C., 2016. The comprehensive business case for sustainability. Harvard Business Review. Available at: https://hbr.org/2016/10/the-comprehensive-business-case-for-sustainability (accessed 19 May 2023)

World Economic Forum (WEF), 2023. The Global Risks Report 2023, 18th edition. Available at: https://www3.weforum.org/docs/WEF_Global_Risks_Report_2023.pdf (accessed 27 May 2023)

Xie, Q., Zhang, Y., Chen, L., 2022. Does green credit policy promote innovation: A case of China. Managerial and Decision Economics, 43(7), 2704-2714. https://doi.org/10.1002/mde.3556.

Zhang D., 2018. Energy finance: Background, concept, and recent developments. Emerging Markets Finance and Trade. 54, 1687–1692. https://doi.org/10.1080/1540496x.2018.1466524.

Zhou, F., Endendijk, T., Wouter Botzen, W.J., 2023. A review of the financial sector impacts of risks associated with climate change. Annual Review of Resource Economics, 15, 233-256. https://doi.org/10.1146/annurev-resource-101822-105702.