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Research Papers in Economics
No. 1/24

Monetary Policy and Climate Change: Challenges and the Role of Major Central Banks*

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Abstract

Climate change poses significant challenges through rising temperatures, extreme weather events, and the exposure of economic (and societal) systems to these dangers. The irreversible and potentially non-linear nature of climate change, together with evolving technological and policy landscapes, complicates matters and predictions. We review the theoretical and empirical literature on climate change's effects on prices, output, and monetary policy transmission. In addition, we describe central banks' responses, including a timeline of efforts, potential actions, data sources, and a comparison of the five largest central banks.

Keywords: Central Banks, Climate Change, Financial Stability, Macroprudential Regulation, Monetary Policy.

* We would like to thank Lucas Hänsel for excellent research assistance.
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1. Introduction

Climate change is one of the biggest challenges of mankind. Climate change-induced risks result from the interplay of increased average temperatures, frequent extreme weather events, and the vulnerability and exposure of economic (and societal) systems to these dangers. These risks can be categorized into (i) the gradual warming of the planet and the consequential physical alterations, such as elevated sea levels or shifts in precipitation patterns and (ii) natural disasters, such as hurricanes, floods, and heatwaves.

The economic and financial dimension of these risks affects central banks and their conduct of monetary policy. In principle, their reaction to climate change can be expressed with the phrase *one problem, two philosophies* and is best illustrated with the following quotes:

> "This matters to our mission, which is to promote the good of the people of the United Kingdom by maintaining monetary and financial stability. And that puts climate change at the heart of our prudential, financial stability and monetary policy objectives and the way we run our operations."
> — Bank of England Website[1]

> "But without explicit congressional legislation, it would be inappropriate for us to use our monetary policy or supervisory tools to promote a greener economy or to achieve other climate-based goals. We are not, and will not be, a 'climate policymaker.'"
> — Federal Reserve Chairman Jerome H. Powell, 01/2023

Apart from the fact that all central banks have to deal with the consequences of climate change, these might take on an *active* role and put climate change explicitly or (at least) implicitly into their objectives. Moreover, they might foster an orderly transition and support policies to reduce carbon emissions. Alternatively, they just could take a *passive* role and deal with the consequences of climate change. To some extent, this distinction resembles the lean vs. clean debate when it comes to financial stability. However, irrespective of the role central banks take, climate change is a unique challenge because of its irreversible nature and the potential (and yet unknown — the lack of historical data is an additional challenge) non-linearities in that regard, which might emerge once certain tipping points have been reached. Finally, technological innovation and mitigation policies change the relationship between economic activity and climate change over time. This dynamic shift further complicates central banks' ability to predict the economic consequences of global warming.

In this article, we survey the existing theoretical and empirical literature that analyses the effects of climate change on prices, output, and monetary policy transmission in Section 2. This is the environment, in which all central banks have to operate. In

[1] https://www.bankofengland.co.uk/climate-change.

Section 3, we provide an overview of central banks' potential and actual responses to climate change. We start with a timeline of climate change-related efforts by central banks, discuss their potential actions, outline several sources of data, and compare the five largest central banks in their effort when it comes to managing the consequences of climate change. Section 4 concludes and outlines some open issues for policymakers.

2. Effect of Climate Change on Prices, Output, and Monetary Policy Transmission

2.1. Theoretical Considerations

The theoretical literature identifies three main channels that relate climate change to monetary policy:[2] (i) the monetary policy transmission channel, (ii) the natural rate of interest channel, and (iii) the macroeconomic objectives channel. The transmission channel of monetary policy is mainly affected through the banking sector and financial markets. The transition towards a low-carbon economy could potentially cause large swings in asset prices and generate substantial volumes of stranded assets, putting (enormous) stress on the banking sector. Similarly, extreme weather events could cause credit losses. The natural rate of interest is expected to fall due to climate-related factors. This would limit the possibility for central banks to resort to conventional monetary policy measures. Both channels could threaten the macroeconomic and financial stability of countries. Even more critically, however, is the fact that climate change might jeopardize the ability of central banks to achieve their macroeconomic objectives. Climate change might affect the economy through the supply side and the demand side. Accordingly, the overall environment in which central banks operate and aim to fulfill their objectives is altered.

On the supply side, there might be disruptive effects on labor supply due to extreme temperatures and an increase in international migration. Moreover, declines in agricultural productivity and yields are to be expected as a consequence of global warming. The capital stock has to be restructured in favor of greener resources and there have to be reconstruction investments due to the consequences of extreme weather events (cf. Fankhauser and Tol 2005; Moore and Diaz 2015; Acevedo et al., 2020). Lower labor productivity due to heatwaves and less human capital accumulation might also have a detrimental effect on the economy (cf. Deryugina and Hsiang 2014; Somanathan et al. 2021).[3] Political and social instability that follow from higher temperatures might cause a lower factor accumulation and productivity growth (cf. Carlsmith and Anderson 1979; Burke and Leigh 2010). On the flip side of the coin,

[2] For a detailed description of these channels, see also ECB (2021a).
[3] For example, Graff Zivin and Neidell (2014) show substantial reductions in labor supply on hot days in the US industries with high exposure to weather, while Seppanen et al. (2006) document that the performance at office tasks decreases at high temperature.

climate policies might serve as a potential driver of innovation and improve supply-side conditions.

One the demand side, energy demand might decrease during winters, but increase during summers. The effect on investment is ambiguous as well. On the one hand, there are changing preferences towards more sustainable investments and there is also a need for reconstruction investments. On the other hand, uncertainty about climate events may delay investments. Similarly, consumption patterns might change towards more sustainable goods and services. However, wealth destruction due to extreme weather events might negatively affect consumption. Similarly, higher temperature anomalies can discourage open air activities, which could reduce time allocated to outdoor leisure and shop retail sales (Roth Tran, 2023). Finally, geophysical changes, like rising sea levels, disrupt trade routes and particularly affect foods prices.

Based on these considerations, we can conjecture that there will be relative price changes due to shifting preferences and alterations in comparative cost advantages. Moreover, inflation is likely to become more volatile, particularly in the markets for food, housing, and energy. This should also be reflected in more sudden and frequent revisions to inflation expectations. Lower labor productivity could put a downward pressure on wages, but the effect is most likely to be heterogeneous across sectors and countries. In this context, a reallocation of workers and increased training needs are also of particular relevance. With respect to output, climate change-induced consequences, such as lower labor productivity, infrastructure destruction (including the loss of arable land), and the disruption of supply chains, are expected to have a detrimental effect, whereas the diversion of investments towards greener projects can be beneficial in the medium to long-run.

2.2. State of the Empirical Literature

Empirically, there is a growing literature on the temperature-inflation nexus, which yields a mixed picture. Faccia et al. (2021) analyze the impact of country-specific summer temperature anomalies on inflation for 34 advanced economies and 15 emerging and developing economies over the period 1980–2018. They find that extreme temperatures have a short-term positive effect on inflation, particularly for emerging market economies. Mukherjee and Ouattara (2021) study the response of inflation to temperature shocks for a sample of developed and developing countries over the period 1961–2014. They document that temperature shocks lead to persistent inflationary pressures for developing countries. Kabundi et al. (2022) investigate how climate shocks affect consumer prices in a broad range of countries of differing income status and monetary regimes. The authors find that inflation tends to decline in advanced economies following a temperature shock in the medium term, while in the short term, inflation is generally well anchored thanks to central banks' credibility. Natoli (2023) constructs temperature shocks from the 1970s up to the end of 2019 to

explore their effects on the US economy. He finds that unfavorable temperature surprises have a significant negative effect on the consumer price index. Focusing on the euro area, Ciccarelli et al. (2023) investigate the effect of weather shocks on inflation using indicators based on high-frequency meteorological data and inflation rates disaggregated by type of product. They find heterogeneous and asymmetric effects of weather shocks on inflation and output, depending on the country, product, and season. Finally, Cevik and Jalles (2023), using a panel covering 173 countries over the period 1970–2020, document that following a temperature shock headline inflation declines significantly until reaching its trough four years after the shock.

Regarding the relationship between economic growth and climate change, Dell et al. (2012) link temperature and precipitation data for each country in the world from 1950 to 2003 to a country's economic performance. They document large negative effects of higher temperatures on growth, but only in poor countries. Burke et al. (2015) show increased temperatures to have a negative effect on GDP growth, but do not find differentiated impacts between rich and poor countries. Colacito et al. (2019) find that that seasonal temperatures, particularly summer ones, have significant and systematic effects on the U.S. economy. Kahn et al. (2021) document that a series of positive (or negative) weather shocks has a long-term negative effect on per capita GDP growth, with the effects being larger in low-income countries. De Bandt et al. (2021) study the impact of climate change on 126 low- and middle-income countries over the period 1960–2017 and find that a sustained 1°C increase in temperature lowers annual growth in real GDP per capita by 0.74 to 1.52 percentage points. Berg et al. (2023) also document an impact of higher temperatures on GDP where the impact differs between developing (positive impact) and the developed ones (negative impact).

The results of these historical studies, however, cannot be easily extrapolated into the future due to the (expected) non-linearities in the effects of climate change, in particular if certain tipping points have been reached. It remains unclear whether climate change-induced supply or demand shocks will be dominant over the next years. Hence, it is challenging for central banks to deal with the macroeconomic consequences of climate change, notably in terms of price stability. Indeed, while central banks can manage demand-side shocks, they tend to struggle when confronted with supply-side shocks. Hence, a comprehensive assessment of climate risks on inflation and output and the identification of the nature of shocks is an important element for the conduct of monetary policy and for central banks' ability to achieve their objectives.

3. Central Banks' Response to Climate Change

In the following discussion, we focus on the five biggest central banks based on total assets and currency allocation. These are the European Central Bank (ECB), the US Federal Reserve (Fed), the People's Bank of China (PBoC), the Bank of Japan (BoJ),

and the Bank of England (BoE).[4] The BoE and the ECB distinguish themselves by adopting a framework in their monetary policy, which extends beyond the traditional pursuit of price stability. While their primary mandate remains the maintenance of price stability, these two institutions have additionally assumed a secondary mandate aimed at supporting the economic policies of their respective jurisdictions. In the ECB's case, this also includes the objective of working towards the sustainable development of Europe based on a high level of protection and improvement of the quality of the environment (ECB, 2021). This contrasts the Fed, which primarily focuses on the dual objectives ensuring price stability and — more narrowly in the context of supporting real economic activity — achieving maximum sustainable employment. Reviewing the IMF Central Bank Legislation Database, Dikau and Volz (2021) classify the mandates of central banks considered in this section as non-sustainable (BoJ, Fed, PBoC) and implicit sustainable (BoE, ECB). However, they emphasize that, in practice, activities depend not only on the formal mandate but also on its (ambiguous) interpretation.

3.1. Timeline

Issues related to climate change were first recognized by central bankers in several speeches. Since then, the role of central banks evolved slowly in the 2010s, with structural measures beginning to take shape in 2017 when the Network for Greening the Financial System (NGFS, see also below) was launched.

10/2010:	Speech by Vítor Constâncio (Vice-President ECB, 2010 – 2018)
	mentions the target of limiting climate change referring to the *Europe 2020* strategy paper by the European Commission
06/2011:	Speech by George Provopoulos (Governor Bank of Greece, 2008 – 2014)
	recommends more attention by central banks regarding environmental issues while presenting the *Report of the Climate Change Impacts* for Greece
12/2017:	Launch of the NGFS (among others, BoE and PBoC as founding members)
	eight central banks and supervisors established the Network of Central Banks and Supervisors for Greening the Financial System at the Paris *One Planet Summit*
06/2020:	First climate-related financial disclosure by the BoE
11/2020:	First comprehensive report on climate-related risks by the ECB
	"Guide on climate-related and environmental risks" assessed near 200 banks holding total assets of over €25tn

[4] Total assets of central banks' balance sheets (2022/2023) in US$ (annual average exchange rates, OECD): ECB 8.4tn, Fed 7.9tn, PBoC 6.3tn, BoJ 5.2tn, BoE 1.3tn. Currency allocation percentage of worldwide foreign exchange reserves (IMF, 2023): US Dollar 54.64%, Euro 18.36%, Yen 5.07%, Pound Sterling 4.51%, Renminbi 2.40%.

03/2021: Technical report by the NGFS about central bank instruments

"Adapting central bank operations to a hotter world – Reviewing some options"

06/2021: Results of the first climate-related stress test by the BoE

the *Climate Biennial Exploratory Scenario* (CBES) explored the financial risks posed by climate change for the largest UK banks and insurers

07/2021: Strategy on Climate Change by the BoJ

Haruhiko Kuroda (Governor BoJ 2013 – 2023) presented the strategy in a speech

09/2021: Strategy review by the ECB

"Climate change and monetary policy in the euro area" on approx. 200 pages

07/2022: Results of the first economy-wide climate stress test by the ECB

based on a qualitative questionnaire and an assessment of the quantitative information submitted by the euro area's largest banks

04/2023: Latest update of the NGFS charter[5]

BoE, ECB, and PBoC are part of the NGFS Steering Committee among eleven permanent members

3.2. Potential Actions by Central Banks

Central banks have a variety of actions available to assess potential climate risks, reduce negative consequences caused by climate change, and — for a more active approach — to foster carbon transition. These initiatives can be separated in six categories.

Climate-related data collection. First, the combination of (i) emissions data and (ii) macroeconomic measures or asset holdings helps to illustrate carbon intensity. For data on emissions, central banks have to rely on firms' disclosures, external data providers like Bloomberg or MSCI, and national GHG inventories.[6] Second, central bank could also survey banks and other economic agents. For example, the ECB's "Survey on the access to finance of enterprises" (SAFE) included specific questions related to the impact of climate change on euro area firms for the first time in 2023. Specific metrics are described in the next subsection.

Research and analysis. In recent years, a growing number of papers, (meta) studies, and reports have been published.[7] Topics include (inter alia) modelling the long-run

[5] Our data extends until 11/2023.
[6] National data are provided by the United Nations Framework Convention on Climate Change (UNFCCC). However, there is typically a two-year delay.
[7] In the appendix, we list all climate-related (working) papers by the five major central banks starting in 11/2018.

economic losses of global heating, the effects on capital and labor reallocation and (foreign direct) investments, expectation formation in the wake of climate change including the increased role of uncertainty, and climate risk-pricing in financial markets. This central bank-led research also contributed to the state of the literature described in Section 2. All major central banks are largely involved (with the PBoC being an exception). In particular, the *ECB Occasional Papers* — articles for a wider audience — have a share of about 20% in 2022/2023 when counting the climate-related topics.

Climate risk assessment. The outcomes of the two previous categories are used to assess financial and macroeconomic risks in a warming and more hostile environment. In the short run, extreme weather events can cause supply side shocks and in the long run, economic activity in some areas may be severely hampered, entailing existing assets to be depreciated. Due to this long-term nature, central banks adopt longer time-horizons (10-year and more in contrast to the three-to-five-year supervisory horizon). As an overview, the Basel Committee on Banking Supervision (BCBS) published a survey in 2020 on climate-related financial risks.

Monetary policy transmission. As outlined in Section 2, climate change can (inter alia) affect price stability, influence investments, and affect the banking sector. A comprehensive report (2021) by the ECB describes possible implications for the (i) asset price, (ii) credit, (iii) exchange rate, (iv) expectations, and (v) interest rate channel, which have to be taken into account when setting monetary policy. In general, a less smooth transmission of monetary impulses has to be expected due to climate change-induced problems. Moreover, central bank communication in that field plays an increasingly important role. According to the Bank for International Settlements (BIS) speech database, the relative frequency of the phrase “climate change” started to increase as of 2018 after a peak in 2015, the year of the Paris Agreement.

Collaboration and international initiatives. The NGFS is an international organization founded in 2017 that consists of financial regulators, for example, the BIS and (all major) central banks. Its primary mission is to promote sustainable and environmentally responsible practices in the financial sector. The NGFS conducts research, shares best practices, and collaborates on initiatives aimed at addressing climate-related risks and promoting green finance within the global financial system. An NGFS (2022) study examines scenarios in categories like *orderly*, *disorderly*, and *hot house world* (3°C or more of warming) to analyze potential long-run economic losses.[8]

[8] In this approach, physical climate models project the climate's response to a given level of GHG emissions. Transition models forecast economic changes needed to achieve the emissions targets. Macroeconomic models transform these projections into country-level GDP impacts, enabling the creation of economic scenarios used in conventional financial models to assess and plan for climate-related risks.

Since 2021, the BCBS (as part of the BIS) and the Financial Stability Board (FSB) have been working on adopting (macro)prudential policies related to climate change. Furthermore, with insurance as a key factor in a more uncertain environment, the Sustainable Insurance Forum (launched in 12/2016) serves as a platform for international collaborative action on climate issues (with the NGFS, BIS, BoE, and many other central banks as members). The FSB also created the Task Force on Climate-related Financial Disclosures (TCFD) in 2015 to improve and increase reporting of climate-related financial information. Many reports or studies rely on the preparatory work of the TCFD.

Prudential policies and sustainable finance initiatives. Finally, central banks can privilege low-carbon bonds to foster carbon transition in line with the Paris Agreement. For instance, the BoJ provides zero-interest loans to banks supporting the decarbonization process and the ECB accounts for climate change in its corporate bond holdings, collateral framework, disclosure requirements, and risk assessment. Additionally, regulative requirements can be designed in a way that minimizes uncertainty in the private sector. With the collaboration of the European Systemic Risk Board, the comprehensive ECB (2022) report "The macroprudential challenge of climate change" takes up the categories data, analysis, and risk assessment and carries out how existing and future insights could be transferred to prudential policies. For that purpose, a (world-wide) collaboration between monetary authorities and supervisors amplifies this impact.

3.3. Climate-Related Data and Metrics

The Statistics Committee of the European System of Central Banks categorizes climate-related measures into indicators on (i) sustainable finance, (ii) carbon emissions, and (iii) physical risk. According to their assessment, the first category complies with the highest quality requirements, while the other categories are subject to serious limitations. Developing these indicators is challenging due to the need to harmonize diverse cross-country and micro-level datasets or to devise suitable methods for imputing missing data. Most metrics are backward-looking, while data on physical risk can be used for forward-looking purposes.

Backward-looking. The weighted average carbon intensity (WACI) assesses the carbon footprint of an asset portfolio. It is widely used in the financial world and recommended by the TCFD. To evaluate physical assets, the Energy Performance Certificate (EPC) provides information about the energy efficiency of a property. Environmental, Social, and Governance (ESG) criteria are a set of standards that investors, businesses, and other stakeholders use to evaluate a company's performance in areas beyond traditional financial metrics.

Forward-looking. For climate risk metrics to be practically useful, they should (i) have a forward-looking perspective and (ii) be presented in a way that allows for a seamless

integration into the frameworks used in risk management decisions within the financial industry. The Implied Temperature Rise metric offers insights into how companies and investment portfolios align with global climate targets set by the Intergovernmental Panel on Climate Change and the Paris Agreement. This metric is grounded in the concept of a carbon budget, determining a company's or portfolio's implied temperature rise based on projected emissions and their alignment with the necessary limitations for a 2°C warming scenario by 2100.[9] However, the methodologies for company-related data are primarily defined by private data providers. Concerning climate-related financial risks, the BIS provides an overview of measurement, methodologies, and the practical implementation by financial supervisors. Nevertheless, further developments and adjustments can be expected, primarily because most measures were introduced in the past decade and central banks assessed these only in the most recent years.

3.4. Comparison of Major Central Banks

Table 1 contains qualitative and quantitative information regarding the five major central banks. Qualitatively, we state the presence of a climate department and climate stress tests (if available) by the respective central bank. Quantitatively, we calculate the share of climate-related (i) working papers over the past five years and (ii) topics in speeches. Furthermore, we show the beginning of NGFS membership (starting in 12/2017), the year of the net-zero goal for the physical institution (if available), and a score by Barmes and Eames (2022) that ranks central banks are by green monetary and financial policies in four categories (research and advocacy, monetary policy, financial policy, and leading by example).

4. Discussion

Subsequent to the Paris Agreement in 2015, central banks and financial supervisors took steps toward carbon transition and adapting to climate change. Of the five major monetary authorities, the ECB and BoE take a leading role, followed by the Asian central banks. The Fed lacks behind, which might be explained by its more narrow (interpretation of the) mandate (cf. the quote by Chairman Powell in Section 1). In addition, international collaborations like the NGFS provide concentrated knowledge and publish studies that model economic and financial consequences of climate change. These studies might serve as an input to monetary and prudential policies.

However, the Institute and Faculty of Actuaries (Joshi et al., 2023) demonstrates how current modelling approaches exclude numerous impacts to be expected from climate change, such as tipping points and second-order impacts. In particular, the effects

[9] Also see the Implied Temperature Rise methodology by MSCI (2021).

related to extreme weather, sea-level rise, or the broader societal effects stemming from migration and conflict have not been considered in the above mentioned NGFS (2022) study. This leaves space for future research that should capture the possible impact of a hotter world more comprehensively and the uncertainty of future scenarios more accurately. More precisely, in combining physical, monetary, and macroeconomic models — under central banks' supervision — the banking and insurance system should be supported to operate in a riskier environment.

Finally, the question of how central banks should interpret their mandates remains open. On the one hand, there is the undisputed goal of price stability, which faces challenges due to an increasing number of negative supply shocks. On the other hand, the active pursuit of a carbon transition, for instance, by suitable prudential policies, might be questioned within the existing mandates. Since climate change is undoubtedly one of the overarching challenges in the 21st century, policymakers should at least discuss a broadening of central banks' mandates not only to cope with the consequences of climate change, but also to facilitate the transition towards a greener economy. From an intertemporal point of view, the latter might clearly be the more cost-efficient approach.

Table 1: Comparison of Major Central Banks

	Bank of England	**Bank of Japan**	**European Central Bank**	**Federal Reserve**	**People's Bank of China**
climate department	Climate Hub	Climate Coordination Hub	Climate Change Centre	---	---
climate stress test	Climate Biennial Exploratory Scenario	Pilot Scenario Analysis Exercise on Climate-Related Risks Based on Common Scenarios	Single Supervisory Mechanism	Climate Scenario Analysis	*implemented but no specific name*
climate-related articles[a]	1.7%	8.5%	5% (9.1%)	2.3% (2.8%)	11.5%
"climate change" in speeches[b]	0.13%	no data	0.26%	0.1%	no data
NGFS member	founding member	since 11/2019	since 08/2018	since 12/2020	founding member
net-zero plan with reduction goal	2040 (62% by 2030)	2050 (government)	2050 (55% by 2030)	2050 (government)	2060 (government)
2022 scorecard[c]	43% rank 5/20	27% rank 8/20	45% rank 4/20	12% rank 16/20	41% rank 6/20

[a] Available online at the respective central bank, 11/2018 – 10/2023. Values in parentheses: *Occasional/Discussion Papers* (ECB) and *International Finance Discussion Papers* (Fed). In the appendix, we list all climate-related (working) papers.
[b] Relative frequency of "climate change" in central banker speeches in 2021 based on the BIS speech database. Analysis by van't Klooster et al. (2023).
[c] *The Green Central Banking Scorecard* report: G20 central banks are ranked by green monetary and financial policies in four categories (research and advocacy, monetary policy, financial policy, and leading by example). Scores are converted into percentages.

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