Network for Greening the Financial System

Technical document

The Macroeconomic and Financial Stability Impacts of Climate Change

Research Priorities

June 2020

Central Banks and Supervisors
Network for Greening the Financial System

NGFS
Technical document

JUNE 2020

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sec.ngfs@banque-france.fr

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Table of Contents

Summary of Research Priorities

This document lays out and discusses the NGFS research priorities related to the analysis of the macroeconomic and financial stability impacts of climate change. It builds on the research gaps identified in the NGFS technical supplement to the first comprehensive report released in April 2019, and focuses on topics which are relevant to NGFS members' current mandates. While comprehensive, the document is not intended to be exhaustive. Its aim is not only to frame and inform the member's own research efforts in this area, but also to serve as a catalyst to mobilise and coalesce our global research partners and the broader research community around the NGFS research priorities.

Research priorities are organised along two main themes: implications for financial system risk assessment, and implications for macroeconomic assessment and monetary policy. Below we discuss the main questions associated with each theme and briefly describe some potentially useful approaches and methodologies.

Theme 1: Climate-related financial system risks and transmission channels	
Q1:	What are the direct and indirect transmission channels through which physical and transition risk could affect financial stability?
Q2:	What are the climate related risk exposures (business, credit, underwriting, operational, liquidity, market, and legal risk) of financial system participants (P&L insurers and re-insurers, pension funds, banks, REITs)?
Q3:	To what extent do markets and investors price carbon-related risks? How much transition risk is factored into the value of securities?
Q4:	What is the level of resilience of the financial system and individual institutions to hypothetical adverse climate scenarios?
Q5:	What are the potential feedback and contagion effects (e.g. fire-sales, network effects) of a re-pricing of climate-related financial risks on the financial sector and the real economy?
Theme 2: Macroeconomic assessment and monetary policy	
Q6:	What are the macroeconomic impacts of more frequent and severe extreme weather events on short-term price dynamics and output gaps? How can climate factors be integrated into standard macroeconomic monetary models?
Q7:	What are the short- to medium-term macroeconomic effects of the transition to a low-carbon economy?
Q8:	What are the longer-term structural effects of global warming on productivity, potential output, and economic growth?
Q9:	What are the impacts of climate change on inflation expectations?
Q10:	What challenges may climate change physical and transitional risks pose to different monetary policy regimes and their implementation frameworks?
Q11:	How do different carbon pricing policies (e.g. carbon tax, cap-and-trade) affect the ability of central banks to gauge underlying inflationary pressures? What are the implications for fiscal and monetary policy alignment?

Detailed Discussion of Research Priorities

Theme 1: Climate-related financial system risks and transmission channels

More frequent or severe extreme weather events and/or a late and abrupt transition to a low-carbon economy could have significant impacts on the financial system, with potential systemic consequences. Extreme weather events could lead to damage of physical assets, including real estate, productive capital and infrastructure, and loss of life with consequent property and casualty insurance losses, damage to balance sheets of households and firms, increases in defaults, and potential financial sector distress. A late and abrupt transition to a low-carbon economy could lead to a sudden repricing of climate-related risks and stranded assets, which could negatively impact the balance sheets of financial institutions.

Assessing the impact of climate physical and transition risks on the financial system is one of the most urgent and prominent issues. However, the modelling toolbox for financial stability risks is less canonical than the macroeconomic approaches and has typically relied on multiple approaches, including (i) balance sheet analysis and sectoral exposures; (ii) scenario-based approaches and sensitivity analysis; and (iii) case studies (mostly to assess physical risks). Most of these do not, currently, take into account important second-round and other feedback effects. Energy sector models and IAMs are also used to assess the impact of climate-related risks on the financial system.

Modelling approaches differ strongly between physical and transition risks. Studies of physical risks are either in the form of case studies or they build on ad-hoc assumptions leveraging on climate impact literature. By contrast, a lot of the literature on the financial stability impacts of transition risk uses a combination of scenario analysis, energy models, IAMs, and network models to assess the potential for stranded assets and value and assess credit and market risk. Stock-flow consistent (SFC) models and Agent Based Models (ABMs) might also provide a valuable alternative to consider a complex adaptive system, in which heterogeneity, non-linearities and disequilibrium phenomena play a key role. As in the macroeconomic models, the timing of the transition is key in relation to financial stability. The literature suggests that a 'smooth and early' transition minimises financial stability risks, while a 'late and sudden' transition sharply increases financial stability risks.

Q1: What are the direct and indirect transmission channels through which physical and transition risk could affect financial stability?

The literature currently shows some of the theoretical channels through which physical and transition risk could affect financial stability, but there is room for additional research in more precisely identifying the possible risks, particularly in the relatively short-term. As a first step, it would be useful to understand which risks are most pressing, to have research more concretely focused on specific short-term impacts for particular sectors, geographies and asset classes as well as the macroeconomic and financial stability implications.

Real estate and agriculture suggest themselves as sectors that are both particularly important and more immediately exposed to physical impacts of climate change, which could affect banks and insurers exposed to these sectors on both the asset and liability sides of their balance sheet. Furthermore, as physical risks rise or become more unpredictable, insurers will most likely increase premiums or stop insuring some risks. The implied decrease in coverage leads to increased uninsured losses ('protection gap') in case of a catastrophic event which could negatively impact the collateral value of properties, leaving banks exposed to credit risk. Understanding the trends in insurability, the cost of insurance, the protection gap, and their spillovers to the banking sector and the economy more broadly is an important direction of research. This requires an analysis of insurers' role and behaviour, including the effectiveness of the catastrophic risk market.

Given the level of global interconnectedness, it could also be particularly helpful to identify how acute and chronic impacts of climate change are impacting countries with lower adaptive capacity, and how these could have spillover effects for other countries and the global economy (e.g. through increased sovereign credit risk, political instability, migration). Differences in country level responses to physical and transition risks could also have cross-border effects. Furthermore, the combination of regional interconnectedness with common exposure to climate physical risks could magnify its impacts.

Q2: What are the climate related risk exposures (business, credit, underwriting, operational, liquidity, market, and legal risk) of financial system participants (P&L insurers and re-insurers, pension funds, banks, REITs)?

Several studies have been recently conducted to consider financial sector exposures explicitly. For example, multiple central banks and supervisors have compared geographic distribution of insurance coverage and retail lending activity to that of extreme weather events (e.g. hurricanes and floods). Others have looked to quantify the exposure of financial portfolios to transition risk by identifying the proportion of assets (e.g. equities and corporate bonds) held in sectors most at risk from the transition to a low-carbon economy. Other approaches include the evaluation of carbon emissions and potential stranded value and assets in carbon-intensive sectors (e.g. transportation, electricity generation, real estate, infrastructure, carbon-intensive industrial technologies) accounting for embodied carbon emissions. While these approaches capture first round effects, they may not fully incorporate the wider risks of financial contagion from an unanticipated economic transition. To address those limitations, some studies have combined exposure data and scenario analysis using network models to account for second round effects, as discussed below. Some central banks have also published reports assessing the prudential risks to individual institutions.

To ensure transparency and comparability of results one important consideration is: how to measure these risks in a systematic, consistent, and repeatable way, and what are the implications for climate-related risk taxonomy and financial disclosure?

One of the key barriers to assessing climate-related exposures is the availability of granular data to support, bottom up, quantitative analysis. Central banks and supervisors must combine standard macroeconomic, financial markets and supervisory reporting data with new climate-related databases.

Q3: To what extend do markets and investors price carbon-related risks? How much transition risk is factored into the value of securities?

Some recent literature has focused on assessing the extent to which investors and markets are taking climate change risks into account. Using standard event methodology, it is possible to examine the market reaction to specific events, which could be associated with a change in market expectations about the profitability in investing in carbon-intensive agents. To date, the literature found evidence that there is a growing sensitivity to carbon risks.

Q4: What is the level of resilience of the financial system and individual institutions to hypothetical adverse climate scenarios?

Assessing the impacts of climate change can be challenging because of the uncertainties around the course of climate change itself, the breadth and complexity of the transmission channels, the primary and secondary impacts and the need to consider, in aggregate, some combination of both physical and transition risks. Given the sensitivity of results to these underlying assumptions, hypothetical scenarios can be used to explore the direction and broad scale of outcomes.

Most literature has focused either on physical risk or transition risk. It is important to consider the combination of both risks. On the physical risk side much of literature focuses on the potential impacts post 2050 and at a relatively high level. But the evolving scientific understanding of climate change risk suggests that physical impacts are manifesting more quickly than previously expected (IPCC 2018), and emerging understanding of 'climatic tipping points' suggest that physical impacts could accelerate even further under certain conditions. This suggest that it would be important to also assess risks in a shorter timeframe (2020-2035) and taking into account potential tipping points.

Sector- and country-specific scenarios based on current national policy need to be considered to create realistic gradual and abrupt transition scenarios to assess the impacts on multiple levels (individual firms, real economy, financial institutions, and larger financial system). Stress testing frameworks should be developed to assess the resilience of the financial system to hypothetical, extreme, yet plausible scenarios. This is done by defining, using climate scenarios as an input, stresses to the economy and financial markets and then quantifying the impacts to the balance sheet of individual institutions, ideally, considering second round and network effects.

An important question is: what are the longer-term climate change implications for the profitability/viability of particular sectors (e.g. insurance and reinsurance) and its macro-financial consequences?

Q5: What are the potential feedback and contagion effects (e.g. fire-sales, network effects) of a re-pricing of climate-related financial risks on the financial sector and the real economy?

Contagion and feedback effects from a re-pricing of climate-related financial risks could be potentially large, and may impact the resilience of the financial system as a whole. Institutional investors, for instance, may have to sell assets that have fallen below a certain rating. This may trigger further fire sales from other investors. A re-pricing of climate-related financial risks of bank loans could force banks to de-lever. Given the key role of banks in the financial system, this may have further ripple effects to other financial institutions as well as the real economy. Thus, it is important to capture these network effects.

Contagion may also occur between the financial system and the public sector. Contagion can occur from financial institutions to governments, if support is needed to bail out financial institutions which are highly exposed to regions or sectors in climate-related distress due to the materialisation of physical or transition risks. It can also occur in the opposite direction, in case of a macroeconomic shock triggered by the materialisation of physical and transition risks which affects public finances and increases perceived sovereign risk, which is passed to financial institutions through higher funding costs.

Understanding these effects is important to assess financial system resilience to a re-pricing of climate-related financial risks as well as the associated real economic costs. Key questions are the possible transmission mechanisms of feedback effects (e.g. fire-sales of financial assets, bank balance sheet deleveraging, etc), how these feedback effects can be modelled, and in which circumstances they can have noticeable effects on financial system stability and on the macroeconomy at large. Another question is the scope for international spillover effects of a repricing of assets due to climate-related financial risk.

Theme 2: Macroeconomic assessment and monetary policy

The primary monetary policy objective of most central banks is to promote and maintain price stability. Additional objectives include output stability and other macroeconomic goals like exchange rate stability, employment creation and economic growth. To achieve these goals monetary policy implementation relies on the identification of the nature, persistence and magnitude of the shocks impacting the economy as well as on the assessment of potential output, and therefore the output gap and inflationary pressures. Central banks are concerned with both short- to medium-run effects on price dynamics and the output gap, and long-run macroeconomic effects on potential output, the natural rate of interest, sectoral composition, and international competitiveness.

In the short- to medium-run, climate change physical risks imply increases in the frequency and severity of negative supply (e.g. destruction of capital stocks, disruptions to labour supply, disruption to supply chains) and demand shocks (e.g. damage to household and corporate balance sheets, reducing consumption and investment, and disruptions of trade flows). While demand shocks are typically manageable from a monetary policy perspective, supply shocks are generally more challenging as they generate a trade-off for central banks between stabilising inflation and stabilising output fluctuations. Increase in the frequency and severity of negative supply shocks increases the challenge for central banks to forecast output gaps and, by extension, inflation. Similarly, climate pricing policies along the transition to a low-carbon economy also need to be factored in, in order to gauge underlying inflationary pressures.

Perhaps more importantly, gradual global warming and the transition to a low-carbon economy, and the uncertainty associated with their paths and effects (including nonlinear climate effects, future paths of climate policies, the rate of progress in carbon neutral technologies, and socio-economic effects), pose significant challenges to the assessment of potential output and long run economic growth. Along the transition to a low-carbon economy, as relative prices adjust, there will be significant economic dislocation as the economy goes through a period of sectoral restructuring and adaptation. Significant shifts in comparative advantages, international competitiveness, and patterns of trade will also likely occur. Both changes in weather patterns and changes to the energy mix and relative prices along the transition path could also lead to increased volatility of headline inflation (food and energy prices) and potentially affect medium-term inflation expectations.

These challenges are particularly critical for emerging economies that may face disproportionate impacts of climate-related risks, limited resources for mitigation, competing socio-economic priorities, and might rely on fossil fuels and climate-sensitive natural resources. Some emerging economies tend to have a larger share of output and/or employment in agriculture and resource-based manufacturing sectors and responses may be more attentive to physical risks rather than transition risks in the near-medium term. The relevance and effectiveness of the monetary policy regime to deal with such impacts whilst being sensitive to key economic sectors requires further study.

Increase in the frequency and severity of climate related supply shocks and associated volatility of inflation and output could also pose different challenges to different monetary policy regimes (e.g. (flexible) inflation targeting, price level targeting or nominal income/GDP targeting) as they differ in their balance of output and inflation goals and their ability to tie down inflationary expectations. Climate-induced shocks may also create difficulties for central banks relying on exchange rate targeting (ERT) when the impact is asymmetric between the anchor- and the targeting country. Moreover, given that climate change could impact geographical/economic areas differently within a country or currency area, monetary policy might be too blunt as a tool, highlighting the need for coordination across policies. As the distribution of shocks becomes more "fat-tailed", the likelihood of monetary policy reaching the effective lower bound could also increase (in particular, in an environment of already low interest rates) likely forcing monetary authorities to adopt non-standard policy measures.

Below we describe the main questions associated with this theme and briefly discuss some useful approaches and methodologies to address them.

Q6: What are the macroeconomic impacts of more frequent and severe extreme weather events on short-term price dynamics and output gaps? How can climate factors be integrated into standard macroeconomic monetary models?

While significant progress has been made in identifying the channels of transmission of climate related risks to the macroeconomy, significant work remains to assess their impacts. To this end macroeconomic modellers could borrow well-advanced methodologies used by (re-)insurance firms to quantify the economic impact of physical risks from extreme weather events, including spatial analysis. Data science can also be used to analyse weather data to help explain and address macroeconomic forecast errors. In addition, empirical econometric work and case studies on specific regions/sectors would be useful to quantify impacts and inform the choice of model inputs, including the correlation and variance/co-variance structure of climate-related shocks against the background of global warming.

Progress needs to be made in the integration of climate factors into standard macroeconomic models. Despite some exceptions, dynamic stochastic general equilibrium (DSGE) models, often used by central banks in macroeconomic and monetary policy analysis, normally abstract from climate change and related policies. One avenue is to develop short-term DSGE-type models for output and inflation within the time horizon of monetary policy (2-3 years) that account for climate-related impacts, including natural disasters, labour supply effects, disruptions to supply chains and international trade. Similarly, semi-structural macro-modelling approaches could be augmented with climate-related natural disasters.

Q7: What are the short- to medium-term macroeconomic and sectoral effects of the transition to a low-carbon economy?

The transition to a low-carbon economy will likely lead to the restructuring of most economies, as relative prices adjust. Understanding the economic effects of this transition, including potential inflationary pressures, is important for central banks, but challenging. Given the uncertainty associated with the paths of global warming and the transition to a low-carbon economy, climate-economy models and scenario analysis need to be combined to develop a range of plausible macrofinancial scenarios to assess possible outcomes. Development of granular computational energy-economy general equilibrium models (CGE) would be useful for analysis of the impacts of climate change at the sectoral level. The different demand and supply channels through which climate change can impact the economy could also be spelled out more clearly in macroeconomic models, rather than limiting climate effects to some sectors of the economy (such as energy or agriculture). There is also scope for incorporating results from microeconomic analysis in macro models. For example, estimates of the impact of climate policies on firms' behaviour and performance could be used to calibrate the impact of climate policies in macro models.

The interrelationship between physical and transition risks is another key factor to take into account. Insufficient mitigation policy actions can trigger more intense and more frequent extreme weather events which can in turn spur a disorderly transition. Thus, it is important to use scenarios analyses that incorporate both physical and transition risks and carefully consider how to combine meaningfully the different modelling approaches traditionally used for their analysis.

Transition risks can be represented as the trade-off between short-term economic growth and long-term environmental quality: we need a better understanding of this trade off and of whether climate policies associated with structural reforms could lead to a positive 'green growth' effect even in the short term ("strong green growth").

Given the challenges of assessing the macroeconomic consequences of climate change another useful approach would be to conduct case studies on past historical examples of transition risk.

Q8: What are the longer-term effects of global warming on productivity, potential output and economic growth?

Long term modelling of potential productive capacity and economic growth is essential for monetary policy. To that end, it is important to capture the impact of global warming on physical, natural and human capital stock, labour supply and productivity. In particular, further work should be devoted to the modelling of the impact on total factor productivity (TFP) and of climate-related migration.

Assessing the long-term macroeconomic consequences of climate change has mostly relied on the use of Integrated Assessment Models (IAMs) which seek to capture the complex interactions between the physical and economic dimensions of climate change. Several criticisms have been raised regarding these models, in particular, their reliance on 'ad-hoc' damage functions to capture the effects of climate changes on the level of GDP. The IAM approach has also been criticised for ignoring the dynamic effects through which climate change potentially affects economic growth. This criticism could be addressed by modelling climate damage as growth, rather than level, effects. Another criticism of IAMs is that they ignore uncertainty regarding the increase in temperature and the non-linear impacts of climate change. Instead of explicitly modelling uncertainty, IAMs typically rely on sensitivity analysis. However, this approach does not reflect the impact of uncertainty on decision making. DSGE models that incorporate directly uncertainty and imperfect foresight could be developed to this end but are subject to their own limitations. For tractability, IAMs also rely on the representative agent assumption making these models poorly suited to analyse the distributional consequences of climate change. Heterogeneous agent DSGE models and Agent Based Models (ABMs) might be suitable for such analysis.

Q9: What are the impacts of climate change on inflation expectations?

There is little empirical evidence on how the effects of climate change will influence inflation expectations formation. Theoretically, there are several ways through which climate change could lead to a de-anchoring of inflation expectations. First, increase in the frequency and severity of extreme weather events could lead to greater volatility of headline inflation via food prices. If the shocks and their effects are short-lived monetary policy would usually 'look through' them without de-anchoring inflation expectations, given a credible monetary policy framework. However, if the central bank lacks credibility or the shocks are persistent, sectorial price shocks risk de-anchoring inflation expectations and triggering a second-round effect that increases inflationary pressure in the medium term. One potential avenue to explore empirically such effects is whether climate-related events have different effects on inflation expectations in regions that are more frequently hit by extreme weather events than regions that are relatively less affected, controlling for other factors.

Another way climate change can affect inflation expectations concerns the shifts in the energy mix along the transition which could persistently change energy prices – if these changes are persistent, they could feed into inflation expectations and wages, creating inflationary pressures. The direction of such changes depends on the timing and speed of transition, including the paths of carbon pricing policy and the pace of technological breakthroughs and adaptation. Macroeconomic modelling and scenario analysis can inform the likelihood and magnitude of such impacts.

Finally, further work on market-based indicators of inflation expectations could also be pursued as their high frequency could allow for a deeper understanding of the way market participants reassess and revise their outlook for inflation following an extreme weather event.

Q10: What challenges may climate change physical and transitional risks pose to different monetary policy regimes and their implementation frameworks?

There is a long debate in the literature on the choice of monetary policy regimes (e.g. (flexible) inflation targeting, exchange rate targeting, Taylor rules, price level targeting, or nominal GDP or income targeting). The literature has emphasised the importance of the nature, frequency and magnitude of shocks impacting the economy (real demand shocks, money velocity shocks, aggregate shocks, or economy wide risk shocks) on the desirability of these different rules.

As discussed above, climate change and climate policy are both expected to generate an increase in the frequency and severity of shocks, and in particular, supply shocks. These are particularly challenging for central banks which target inflation. It may become more difficult for them to look through short-lived supply shocks and tolerate temporary deviations from policy targets. These challenges may lead to a rethink of the monetary policy implementation framework, including operational targets, the policy horizon and the level of the inflation target. The asymmetry of climate related shocks and climate policies between countries could also pose significant challenges to exchange rate targeting regimes that diverge from their anchor. Understanding these different challenges and their implications is thus a priority for central banks.

Q11: How do different carbon pricing policies (e.g. carbon tax, cap-and-trade) affect the ability of central banks to gauge underlying inflationary pressures? What are the implications for fiscal and monetary policy alignment?

The design of climate policy can significantly affect how central banks can respond to their direct and indirect effects. For instance, the use of carbon-taxes and its proceeds affects the trajectory of inflation and relative prices. A tradeable permit system could also lead to higher inflation volatility as the price of carbon would depend on the relative strength of demand and supply, therefore, making inflation forecasting more difficult for central banks than in the case of a carbon tax or a hybrid approach in which carbon prices are more stable and predictable. Thus, these fiscal tools would have different implications for monetary policy, depending also on the reaction function of the central bank. An important question is whether there is a need for greater alignment between fiscal and monetary policy makers.

Acknowledgements

This NGFS Research priorities is a collaborative effort of members of the 'Macrofinancial' workstream (WS2) and the 'Scaling up green finance' workstream (WS3) of the NGFS.

The Guide was coordinated by the Bank of Canada (Miguel Molico) with support from the NGFS Secretariat at the Banque de France (Thomas Allen, Amandine Afota and Antoine Boirard) and the Chair's teams at the Bank of England (Ryan Barrett and Theresa Löber) and the Deutsche Bundesbank (Joschka Gerigk).

The Chairs of the workstream 2 (Sarah Breeden) and 3 (Sabine Mauderer) are grateful to the drafting team: Geraldine Ang (OECD), Sandra Batten (Bank of England), Valérie Chouard (Banque de France), Nicolas Cuche-Curti (Swiss National Bank), Stéphane Dees (Banque de France), Torsten Ehlers (Bank for International Settlements), Ivan Faiella (Banca d'Italia), Signe Krogstrup (Danmarks Nationalbank), Federico Lubello (Banque centrale du Luxembourg), Mengmeng Miao (People's Bank of China), Maria Nieto (Banco de España), Johannes Poeschl (Danmarks Nationalbank), Wolfgang Pointner (Oesterreichische Nationalbank), Henk Jan Reinders (De Nederlandsche Bank), Simone Russo (Central Bank of Malta), Guido Schotten (De Nederlandsche Bank), and to the NGFS Members and Observers who provided comments and feedback : Banco de España, Bank Negara Malaysia, Banque de France, Central Bank of Malta, European Central Bank and Monetary Authority of Singapore.

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