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ASSESSING FINANCIAL STABILITY THROUGH THE LENS OF CLIMATE CHANGE

An in-depth look at climate stress tests

Acknowledgements

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This article seeks to demystify the workings and structure of climate stress tests. It aims to establish a stronger link between the theoretical knowledge of academia and the practical experiences of finance professionals, providing essential clues for integrating climate-related factors into financial practices. This article aims to facilitate a deeper understanding of these critical domains for practitioners, regulators, and academics.

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Contents

Acronyms

ACPR	Autorité de contrôle prudentiel et de résolution (France)
CatNat	Catastrophes Naturelles
CCR	Caisse Centrale de Réassurance (France)
CIRED	Centre de coopération Internationale en Recherche Agronomique pour le Développement (France)
CNRS	Centre National de la Recherche Scientifique (France)
EBA	European Banking Authority
ECB	European Central Bank
ENSAE	Ecole Nationale de la Statistique et de l'Administration Economique (France)
EU	European Union
FSB	Financial Stability Board
GDP	Gross Domestic Product
IAM	Integrated Assessment Model
IFI	International Financial Institutions
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
NGFS	Network for Greening the Financial System
NIESR	National Institute of Economic and Social Research
NiGEM	National Institute Global Econometric Model
SNBC	Stratégie Nationale Bas Carbone (France)
TCFD	Task Force on Climate-Related Financial Disclosures

UNEP United Nations Environment Programme

US United States

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Abstract

In the evolving landscape of financial regulation, the integration of climate risks into stress testing represents a critical stride towards ensuring the robustness of financial institutions against environmental uncertainties. **This article delves into the development and implications of climate stress tests, particularly focusing on the methodologies employed by the French Prudential Supervision and Resolution Authority (ACPR).** With the Basel Committee's 2024 updates mandating the incorporation of climate-related risks, these tests have become pivotal in assessing the resilience of banks and insurance companies to both immediate and long-term environmental impacts.

The paper outlines the dual nature of climate stress tests, examining both physical and transition risks. Physical risks pertain to direct and indirect financial losses from climatic phenomena, whereas transition risks are associated with the economic adjustments necessary for a low-carbon future. **By dissecting the ACPR's approach** in the exercises published in 2021 and 2024, the article provides a comprehensive overview of the scenario-based frameworks that guide these assessments. It highlights the iterative improvements made since the initial pilot tests in 2020-2021, reflecting on the lessons learned and the incremental integration of more refined economic and climatic models.

Moreover, the analysis discusses the limitations encountered in current methodologies, such as the challenges in scenario realism and the granularity of risk assessment. The conclusion emphasizes the need for ongoing refinement of these tests to better align with the complex dynamics of climate risks, thereby enhancing the predictive capabilities and strategic planning of financial institutions.

This article is a useful tool for both financial professionals and regulators, providing insights into current climate risk assessment practices and suggesting ways to improve financial stability as we address climate change.

1. Introduction

In 2024, the Basel Committee announced an update to its core principles aimed at integrating climate risks into the new agreement (Basel III) and systematizing climate stress tests for financial entities. Stress tests are simulation exercises used by financial institutions to assess the robustness of their balance sheets against adverse economic scenarios. Historically focused on financial and economic crises, the emergence of climate change has prompted a rethinking of these tests. Indeed, climate risk, with its potential short and long-term impacts on capital allocation, has introduced new challenges for the financial stability of banks and insurance companies. In response to this development, many regulators, including the French Prudential Supervision and Resolution Authority (ACPR), have actively engaged in the development of a stress-test exercise allowing financial actors to assess their resilience to climate risks. The results of the latest ACPR climate stress test on French insurance companies, which has undergone several methodological improvements since the pilot exercise conducted in 2020, are scheduled to be published on May 22, 2024.

This article is dedicated to analysing the integration of climate risks by financial institutions, detailing how stress tests are adapted to include emerging climate challenges. It also explores the limitations of these evaluations in the current context, highlighting crucial implications for financial resilience and the need for ongoing strategic adjustments.

1.1. Financial Stress Tests

The Basel II agreements, designed to strengthen banking supervision and improve risk management within financial institutions, introduced financial stress tests into the regulatory framework in 2004. Created to prevent financial crises by anticipating their potential impacts on the banking and insurance system, these tests identify vulnerabilities within the balance sheets of financial actors, in terms of both assets and liabilities.

To date, financial stress exercises are widely used around the world, though their adoption, frequency, and complexity can vary significantly from country to country. Most countries and international organizations (e.g., the World Bank and IMF) recognize the growing importance of these tests in assessing the resilience of their financial systems. In major economies and developed financial markets, such as the United States, France, Japan, Australia, and the European Union (EU), financial stress tests are a regular and highly regulated practice. In this regard, the EU conducts these exercises every two years through the European Banking Authority (EBA) since 2009.

The main targets of these exercises are banks and insurance companies, due to their central role in the economy and thus their exposure to economic fluctuations. To assess the resilience of these entities and thus the associated financial stability, financial regulatory authorities—such as

the EBA or the European Central Bank (ECB) in the Eurozone, or the ACPR in France—conduct these exercises. Their role is threefold: i) share common test scenarios ii) collect and analyse data provided by financial institutions iii) publish the results of these exercises. The test scenarios consist of a set of simulations based on adverse economic scenarios. The simulation of an economic and financial shock in traditional stress tests generally focuses on a single adverse scenario, specific to each country and envisioning degraded trajectories for various macroeconomic and financial variables, while targeting financial crises or immediate economic recessions whose impacts are assessed over a three-year horizon. The main simulated variables include: gross domestic product (GDP) growth rate, unemployment rate, interest rates, stock prices, and real estate prices.

From these scenarios, international financial institutions (IFIs) then assess the consequences of these shocks on their balance sheet, distinctly depending on whether they are a bank or an insurance company. On the banking side, this particularly involves the revenues from their activities, equity, and risks associated with different types of assets held. If the test results reveal an insufficient level of capital for an institution, indicating an inability to absorb the shock of an adverse scenario, the supervisor may impose a recapitalization plan. On the insurance side, the details and specific criteria may differ from those applied to banks. Indeed, the goal for insurance companies is to evaluate their solvency, liquidity, and long-term stability in the face of economic fluctuations or major shocks. Insurance scenarios will mainly include natural disasters, pandemics, sudden regulatory changes, or drastic market fluctuations.

As awareness of climate change's effects on the global economy increases, specific "climate stress tests" have been devised to evaluate the resilience and susceptibility of financial institutions to environmental challenges. These tests use climate risk-adapted scenarios and focus on assessing long-term impacts. While the objectives of these climate stress tests align with those of traditional financial stress tests, their methodologies differ significantly, emphasizing the distinct nature of climate-related risks compared to conventional financial risks.

1.2. Climate Stress Tests

Climate stress tests adapt traditional financial stress tests to evaluate how well financial institutions can handle risks linked to climate change. These tests extend efforts in financial oversight that consider environmental and climate risks, significantly shaped by Mark Carney, the former Governor of the Bank of England. Under his leadership, this institution pioneered the incorporation of climate risks into financial risk management, identifying transition risks towards a low-carbon economy, physical risks linked to the effects of climate change, and legal risks arising from changes in environmental policies. In his September 29, 2015, speech, Carney popularized the concept of the "Tragedy of the Horizons," which highlights the mismatch between the time horizons of climate impacts and those of typical economic and political cycles. The Bank of England developed a framework in 2016[1] that served as a model for other regulators worldwide. This framework was integrated and expanded by the Task Force on Climate-related Financial

[1] Mark Carney, Speech at the TCFD Summit, Tokyo, on Tuesday 8 October 2019. Available at: Link.

Disclosures (TCFD) under the auspices of the Financial Stability Board (FSB) in 2017. The TCFD develops recommendations for companies to clearly disclose their climate-related financial risks, thereby facilitating better consideration of these risks by investors, lenders, and insurers. The detailed TCFD protocols, focused on transition and physical risks, have been adopted by global financial institutions, affirming their crucial role in maintaining financial stability in the face of climate change.

The goal of climate stress tests is twofold: firstly, they aim to measure the resilience of financial actors' balance sheets against short and long-term climate risk scenarios; secondly, they seek to encourage these actors to integrate climate risk management into their operational and investment strategies. Climate scenarios target two categories of risks: those related to the manifestation of climate change, called physical risks, and those related to the politico-economic response to this disorder, called transition risks[2].

Physical risks include economic costs and financial losses resulting from the severity and increased frequency of extreme weather phenomena related to climate change (such as heatwaves, landslides, floods, fires, and storms) as well as the gradual long-term changes in the climate (such as changes in precipitation, extreme weather variability, ocean acidification, and rising sea levels and average temperatures)[3]. The effects of physical risks can be direct (damage to property, decreased productivity) or indirect (disruption of supply chains). They are classified as acute when they result from extreme events and chronic when they result from gradual changes.

Transition risks are related to the adjustment process towards a low-carbon economy. The emission reduction process is likely to have a significant impact on all sectors of the economy by affecting the value of financial assets and the profitability of companies[4]. Transition risk can arise, for example, from the rapid adoption of climate policies unfavourable to certain sectors of activity (fossil fuels, transport) or from the acceleration of technological progress.

Banks and insurance companies are essential in financing the economy and, therefore, significantly exposed to the consequences of climate change. Banks, as providers of credit, may face an increase in defaults due to the effects of climate change on economic activities (inflation, rising carbon prices, falling real estate prices, etc.). Insurance companies, for their part, must deal with a potential increase in claims related to chronic or acute climatic events (increased health costs, increased risks on assets in certain flood-prone or drought-prone areas, solvency risk).

A financial entity faces climate risks, which can be broken down into three factors: firstly, the hazard, which includes the intensity and frequency of the event; secondly, the exposure, which refers to the proportion of assets concerned; and thirdly, the vulnerability of the institutions, which measures the extent of potential damage caused by the event (financial amounts at risk for an institution)[5].

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[2] Jean Boissinot, « La Finance verte ». Published by Dunod, 2022. Available at: Link.
[3] ACPR and Banque de France, « Gouvernance et gestion des risques climatiques par les établissements bancaires : quelques bonnes pratiques », 2020. Available at: Link.
[4] ACPR and Banque de France, « Gouvernance et gestion des risques climatiques par les établissements bancaires : quelques bonnes pratiques », 2020. Available at: Link.
[5] Jean Boissinot, « La Finance verte ». Published by Dunod, 2022. Available at: Link

$$Climate\ risk = Hazard\ or\ External\ event\ x\ Exposure\ x\ Vulnerability$$

Equation 1 - Decomposition of Climate Risks

In climate stress tests, the granularity with which risks are assessed varies.

The main actors conducting these tests are also financial regulation and supervision authorities, such as the ECB or the EBA for the Eurozone and the ACPR for France. Climate stress tests are conducted, like traditional tests, in several countries, each adapting the assessment method, framework, scenarios, and modelled variables to its regional and economic specificities.

According to UNEPFI, the methodologies adopted vary from country to country and can be classified into two categories: top-down analyses and bottom-up analyses. The DNB (Bank of Norway) opts for a top-down analysis while the ACPR[6] adopts a bottom-up analysis. A top-down approach is conducted by a supervisory authority that defines and enforces a uniform framework. This includes a methodology, assumptions, scenarios, and models that must be uniformly used by all concerned entities. The goal is to ensure consistency and comparability of results across different organizations. Conversely, a bottom-up approach allows each entity to use or develop its own analytical framework. This means each entity uses the models it considers most suitable and detailed for its specific situation. This approach promotes a degree of flexibility and adaptability but can lead to less uniform results among different entities.

The coverage of risks by the tests also varies by country. For example, the Bank of England assesses both physical and transition risks, while the DNB in 2018 considered only transition risks centred on energy. Australia, focusing on both physical and transition risks, places more emphasis on risks associated with wildfires and droughts, as the country is highly exposed to this type of event. In its assessments, the ACPR considers both physical and transition risks.

To deepen the understanding of the structure of climate stress tests, from the creation of scenarios to the evaluation of their financial impact, a detailed analysis of the methodologies used by the ACPR during the climate stress tests of 2020 and 2023 has been conducted.

[6] UNEP Financial Initiative, “Comprehensive Good Practice Guide to Climate Stress Testing”, 2021. Available at: Link.

2. The construction of Climate Stress Tests: focus on the ACPR.

In this section, we focus on the climate stress tests conducted by the ACPR in France[7]. As a supervisory body, the ACPR is responsible for ensuring financial stability and protecting customers in the banking and insurance sectors. Therefore, it leads the climate stress-testing exercises to assess the resilience of financial institutions to climate risks.

For these exercises, the ACPR relies on its internal expertise, external resources, and the participation of the stakeholders involved in the tests to carry them out effectively.

2.1. Scenarios

Understanding the scope and impact of climate risks on the financial sector requires scenarios that reflect the complexity and uncertainty inherent in climate change. These scenarios are essential for climate stress-tests as they provide a coherent framework to assess how different possible climate-related futures could affect the global economy and, by extension, the financial sector.

In the construction of climate stress-tests, the scenarios used vary depending on the type of risk considered, whether they are transition risks or physical risks. This differentiation, made by scenario providers, is crucial for accurately modelling potential impacts. Rapid transition scenarios focus on risks of significant changes in climate-related policies and technologies, generally presenting less pronounced physical risks in the long term. Conversely, transition scenarios where climate action is limited highlight lesser transition risks but with an increase in physical risks, such as extreme weather events or lasting changes in climatic conditions[8].

2.1.1 Long term transition scenarios

The methodology for constructing the ACPR's climate stress-tests is carried out in close collaboration with the Banque de France (BdF), relying on scenarios developed by the Network for Greening the Financial System (NGFS), a global network of central banks and financial supervisors that assesses the impacts of climate change on the financial sector. This approach introduces sector-specific granularity and risk metrics to better reflect the French context and

[7] For additional information, please consult the sources regarding the ACPR.
[8] Jean Boissinot, « La Finance verte ». Published by Dunod, 2022. Available at: Link.

cover essential variables for conducting a stress-test. The NGFS does not conduct stress-tests itself but supports their development with its data and recommendations.

The NGFS has developed a series of reference scenarios, each modelling a socio-economic trajectory based on a given carbon budget[9]. These are also known as transition scenarios, which differ according to their narrative and ultimate goals. The scenarios proposed by the NGFS are constructed using models called "Integrated Assessment Models" (IAM), which aim to capture the interactions between socio-economic, technological, and physical systems to make projections reflecting a choice of climate actions to implement[10]. The three IAM models used by the NGFS are:

i) REMIND-MaGPIE
ii) MESSAGEix-GLOBIOM
iii) GCAM (Global Change Assessment Model)

These models are distinguished mainly by their assumptions and structure.

NGFS work involves linking these different IAMs with other models to estimate physical risk, such as damage functions and CAT NAT (Natural Catastrophes) models. They are also supplemented by the introduction of an econometric module[11], named NiGEM (National Institute Global Econometric Model). NiGEM is a global macroeconomic model developed by the National Institute of Economic and Social Research, which allows simulating the economic impact of various political and economic scenarios on a global scale. Incorporating NiGEM with the IAMs thus enhances the detail of information available to financial actors.

Each phase of the NGFS scenarios integrates different models and data updates, such as climate data and new political commitments. The new scenarios also reflect the latest trends in technologies, key mitigation technologies, the repercussions of geopolitical events on the energy market (war in Ukraine), and other factors (*cf. Figure 1)*.

[9] Institute for Climate Economics (I4CE), "Understanding Transition Scenarios", 2019. Available at: Link.
[10] Hare & Al, "Integrated Assessment Models: what are they and how do they arrive at their conclusions?" Climate Analytics, 2018. Available at: Link.
[11] National Institute of Economic and Social Research (NIESR), "National Institute Global Econometric Model (NiGEM)", 2023. Available at: Link.

NGFS - Phase III

Orderly

Net Zero 2050 (1.5°C) limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050. Some jurisdictions such as the US, EU and Japan reach net zero for all GHGs.

Below 2°C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C.

Disorderly

Divergent Net Zero (1.5°C) reaches net zero around 2050 but with higher costs due to divergent policies introduced across sectors leading to a quicker phase out of oil use.

Delayed Transition assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. CO_2 removal is limited.

Hot house world

Nationally Determined Contributions (NDCs) includes all pledged policies even if not yet implemented.

Current Policies assumes that only currently implemented policies are preserved, leading to high physical risks.

NGFS - Phase IV

Orderly

Low Demand: a new Paris-aligned orderly scenario has been added and maps out the challenging path to still reach the +1.5°C end-of-century warming limit, requiring lower energy demand and stronger behavioral changes to still reach the Paris goals in a orderly way. NEW

Net Zero 2050 (1.5°C) has shifted upwards in the framework and illustrates the higher baseline (2021-2025), leading to increased disorderliness with higher physical and transition risk.

Below 2°C has shifted upwards in the framework and shows an increased transition risk and slightly lower physical risk. It assumes that countries limit global warming to +2°C in 2100 (with 66% probability).

Disorderly

Delayed Transition has been updated without a change in its narrative, assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. Negative emissions are limited.

Hot house world

Nationally Determined Contributions (NDCs) has shifted left in the framework and foresees that currently pledged conditional NDCs are implemented fully, and respective targets on energy and emissions in 2025 and 2030 are reached in all countries, leading to a slight decrease in long-term physical risk, due to a newly announced commitments, but is still high.

Current Policies has shifted left in the framework and assumes existing climate policies remain in place, but there is no strengthening of their ambition level. This results in a slight decrease in long-term physical risk, due to newly implemented policies, but is still high.

Too-little too-late

Fragmented World: a new too little, too late scenario has been added and explores more adverse impacts as a result of climate policies being implemented in a fragmented manner, both intertemporally and geographically, meaning that countries delay the implementation ("too late"), and then diverge in their mitigation stringency, rendering efforts overall insufficient to reach net zero ("too little"). NEW

Adapted from the report "NGFS Scenarios for central banks and supervisors", November 2023

Figure 1 - Differences between NGFS scenarios of Phase III and Phase IV

Between Phase III and Phase IV, two scenarios were added[12] (*cf. Figure 2)*:

- The "Low Demand" scenario includes alignment with the goals of the Paris Agreement with significant reductions in energy demand and other behaviours in addition to implicit carbon pricing. The behaviour changes analysed in this scenario result in a lower carbon price than in the Net Zero 2050 scenario.
- The "Fragmented World" scenario involves delays and divergences in climate policy, reflecting a pessimistic future in the context of the current geopolitical situation.

Other changes stem from improved modelling of physical risks, refined based on how physical risks might materialize over the course of the scenarios.

Figure 2 - NGFS scenario framework: from Phase III to Phase IV. Movements in the scenario mapping are represented by arrows, new scenarios introduced in Phase IV are indicated with a plus (+) symbol, and the phased-out scenario is marked with a cross.

For conducting its stress-tests, the ACPR uses the NGFS's Remind-MaGPIE model, the most geographically granular model. In the current framework, the ACPR utilizes macroeconomic outputs from NGFS scenarios, specifically focusing on GDP data. This selective approach involves the Banque de France and the ACPR crafting a specialized analytical framework to carry out the pilot exercise (*cf. Figure 3)*.

[12] NGFS, "NGFS Scenarios for central banks and supervisors", 2023. Available at: Link.

	2025	2030	2035	2040	2045	2050
Reference Scenario						
EU GDP	3.2	1.7	1.7	1.7	1.5	1.5
US GDP	2.0	1.6	1.6	1.5	1.5	1.6
France GDP	2.5	1.2	1.1	1.1	1.0	1.0
France Inflation	0.9	1.4	1.4	1.4	1.3	1.3
France Unemployment	9.6	7.7	7.6	7.8	8.1	8.2
Adverse Scenario 1 (deviation from reference scenario)						
France GDP (%)	0.5	0.2	-0.7	-1.4	-1.7	-2.1
France Inflation (p.p.)	-0.3	0.2	0.6	0.2	0.1	0.1
France Unemployment (p.p.)	0.2	-0.5	0.1	0.6	0.2	0.2
Adverse Scenario 2 (deviation from reference scenario)						
France GDP (%)	0.5	0.2	-1.5	-3.2	-4.4	-5.5
France Inflation (p.p.)	-0.3	0.5	0.6	0.5	0.3	0.2
France Unemployment (p.p.)	0.2	-0.3	0.0	0.3	0.2	0.4

Figure 3 - Main macroeconomic variables in the reference scenario and impacts of disorderly transitions in adverse variants.

p.p: percentage points – GDP: Gross Domestic Product – Reference Scenario is the Ordered Transition Scenario

In the context of ACPR's stress testing, normative scenarios were used to capture transition risk. A normative scenario is a projection that defines a feasible future where a regulatory body guides economic actors towards a specific goal of carbon neutrality. This type of scenario uses the carbon budget as a reference framework, enabling the development of various possible pathways and models for the same climate goal. Although the carbon budget remains the same, it is possible to model different socio-economic trajectories, thereby allowing for multiple "pathways" to achieve the same climate ambition[13] (*cf. Figures 4 & 5)*.

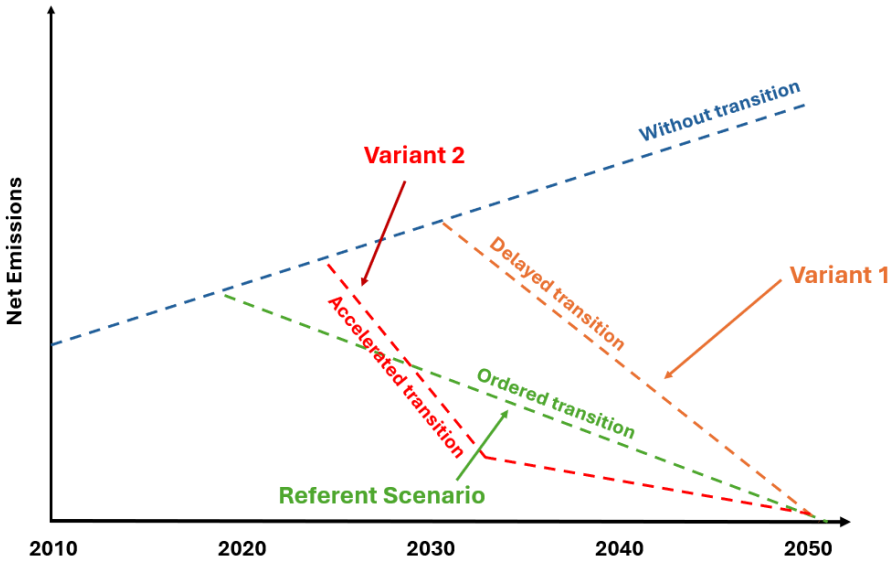
In its 2020 exercise, the ACPR selected three transition scenarios: an orderly transition scenario, corresponding to the path of the National Low-Carbon Strategy (SNBC), and two disorderly transition scenarios, one anticipating delayed action and the other accelerated but more costly and technologically constrained action. Each scenario thus combines different assumptions related to the trajectory of the carbon price and the levels of total factor productivity.

The ACPR's 2023 exercise, on the other hand, is based on two long-term transition scenarios: the orderly "Below 2°C" scenario and the disorderly "Delayed Transition" scenario, which allow modelling the evolution of carbon emissions and carbon prices over time.

[13] Skea & Al, "Intergovernmental Panel on Climate Change: Transparency and integrated assessment modeling. Wires Climate Change", 2021. Available at: Link.

		Ordered Transition "Below 2°C"		Delayed Disordered Transition "Delayed Transition"		Accelerated Disordered Transition	
		Exercise 2020	Exercise 2023	Exercise 2020	Exercise 2023	Exercise 2020	Exercise 2023
		Progressive increase in carbon prices, including adjustments without major shocks, allowing the net zero carbon target by 2050. Economic adjustments are significant but gradual.		Delayed due to lack of decisive political measures, resulting in higher prices for carbon emissions in 2030. Goals are more difficult to achieve due to higher economic and climatic costs, thus pushing up the cost of carbon beyond 2030.		Sharp decline in carbon prices with direct measures imposed on high emission industries. Change driven by cost reduction in renewable energy and advances in technology, offsetting costs and reducing reliance on carbon-intensive sectors.	
Carbon price in the world US$2020/tCO2 (REMIND-MAgPIE)	2020	9.73	11.01	9.73	11.01	9.73	*Not present in this exercise*
	2035	61.99	61.71	127.37	119.11	38.64	
	2050	134.85	135.73	386.01	349.57	50.67	

Figure 4 - Summary of the transition and physical risk scenarios included in the ACPR's exercises.



Source : ACPR and Banque de France data – Methodological Document, 2023

Translation in English by the authors

Figure 5 - Schematic representation of the scenarios in the ACPR exercise.

2.1.2 Short-term transition scenarios

In 2023, the ACPR, in collaboration with the Banque de France, is developing a short-term scenario covering the period 2023-2027. This scenario incorporates acute physical risks, including prolonged droughts and heatwaves, as well as localized flooding from 2023 to 2025, primarily affecting insurers' liabilities. A market shock is also anticipated for the second quarter of 2025, characterized by a devaluation of assets in the most polluting sectors. Currently, the ACPR does not use Integrated Assessment Models (IAMs) for its short-term scenarios but utilizes models of linearized shocks. The ACPR's short-term scenario is produced with the help of the NiGEM model, which is also used in the NGFS scenarios. The conduct line of the short-term scenario thus replicates that of the NGFS long-term scenarios. Therefore, the various scenarios of the exercise, despite having different temporal horizons, maintain high consistency among them in responding to the various implemented shocks, says Paul Champey, a member of the NGFS secretariat, in an interview conducted in April 2024.

The assumption for short-term transition risks is that major climatic events in 2022 and 2023 would lead to an abrupt adjustment of financial markets. These markets would anticipate swift carbon regulation in key economies such as the EU and the US. This would result in a sudden increase in financing costs for companies in high greenhouse gas emission sectors, with a financing shock of 40 basis points higher than that of other sectors. Contagion mechanisms would cause an increase in interest rate spreads across all sectors, with an initial rise in credit spreads of 150 basis points during the first two semesters of 2025, which would then stabilize around 100 basis points until the end of 2027. Simultaneously, a widespread increase in market volatility would lead to a fall in stock prices. The Eurozone's GDP would suffer a contraction of 1.6% in 2025, and inflation would retract by about 1 percentage point year-over-year after two years.

Future climate stress tests conducted by the ACPR could eventually incorporate the NGFS's short-term scenarios, stemming from IAMs, which are under development for the end of 2024. Of the five planned scenarios, three titled "Highway to Paris," "Green Bubble," and "Sudden Wake-up Call" present significant transition risks. Another scenario, called "Diverging Realities," explores both significant transition and physical risks.

2.1.3 Long-term physical risk scenarios

Regarding the assessment of long-term physical risks, the ACPR adopted in 2020 a methodology based on the IPCC's (Intergovernmental Panel on Climate Change) RCP 8.5 scenarios, anticipating a significant increase in the frequency and intensity of extreme weather events. This evaluation considered the rising cost of claims, the spread of diseases and other health impacts related to climate, and their consequential implications for property and health insurance. The IPCC scenario is analysed internally by the ACPR and the Banque de France to be integrated into climate stress tests.

In the 2023 exercise, the IPCC's RCP 4.5 scenario was used to assess physical risks. This marks a difference from the 2020 pilot exercise, which had been evaluated based on the RCP 8.5 scenario and corresponded to an assumption of a temperature rise between 1.4°C and 2.6°C by 2050 (compared to 0.9°C and 2.0°C in 2050 for the RCP 4.5 scenario). Indeed, it was considered that RCP 4.5 provided greater consistency with the temperature trajectories of the chosen NGFS scenarios. The differences by 2050, including concerning the occurrence of extreme hazards, are limited between RCP 4.5 and RCP 8.5. However, the Central Reinsurance Fund (CCR) offers damage projections corresponding to the average of the RCP 4.5 scenario while considering more adverse impacts.

Depending on the chosen IPCC RCPs, natural disaster (CATNAT) and health scenarios are modelled to assess the impact of climatic events on financial entities.

CATNAT scenarios in France project perils such as droughts, floods, marine submersions, and cyclones. They are modelled by external providers (Central Reinsurance Fund and AON). These providers produce damage functions based on very granular Météo France data (*cf. Figure 6)*.

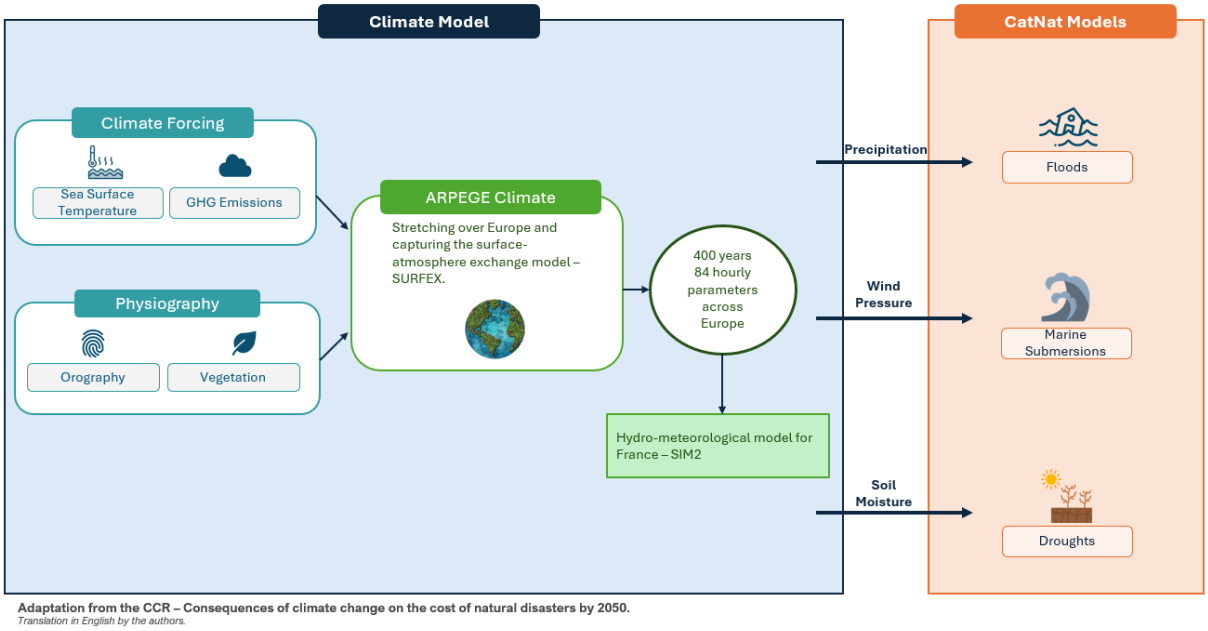


Figure 6 - The climate modelling chain implemented by Météo-France and its integration by the CCR.

The Health scenarios are based on assumptions regarding the evolution of mortality tables and healthcare costs by geographic areas and by age of the population, provided by AON (a French insurance and reinsurance service) and based on the temperature trajectories of the RCP 8.5 scenario in the 2020 exercise.

2.1.4 Short-term physical risk scenarios

Modelling of short-term physical risks only exists in the 2023 exercise. The analysis of the impact of the provided variables must be done with an assumption of a static balance sheet per year, from 2023 to 2027.

A drought and heatwave event observed in 2022 is expected to recur in 2023 and 2024.

Note that the NGFS secretariat is developing a study to create a new function for assessing damage related to chronic physical risks, with a focus on distinguishing between chronic and acute damages. The damage function is being developed by academic climate scientists[14], which the NGFS implements in its scenarios. The aim of a damage function is to capture physical risk as comprehensively as possible. The new function's main addition would be the inclusion of physical risk transmission channels and consideration of their persistent effects on the economy's growth rate (instead of just an impact on GDP level, as was the case with the previously used damage function). This new function is thus more realistic.

Additionally, of the five short-term scenarios currently being developed by the NGFS, two physical risk scenarios could eventually be used by the ACPR. One scenario, named "Low Policy Ambition and Disasters," highlights high short-term physical risks. Another scenario, called "Diverging Realities," explores both significant transition and physical risks.

2.2. From the climate variable to financial impact: explanations.

The impact of climate risks on the assets and liabilities of financial entities can be summarized in three stages: scenario design, financial risk assessment, and the outcome. The scenario design was detailed above and allows for measuring economic, financial, and physical shocks. Financial risk assessment begins with the macroeconomic impacts stemming from climate shocks and then translates into effects on default rates, lender revenues, and asset prices. The results of this assessment are two main types of risks: credit counterparty risk and liquidity risk (*cf. Figure 7)*.

[14] Kots & Al, “The economic commitment of climate change”. Nature, 2024. Available at: Link.

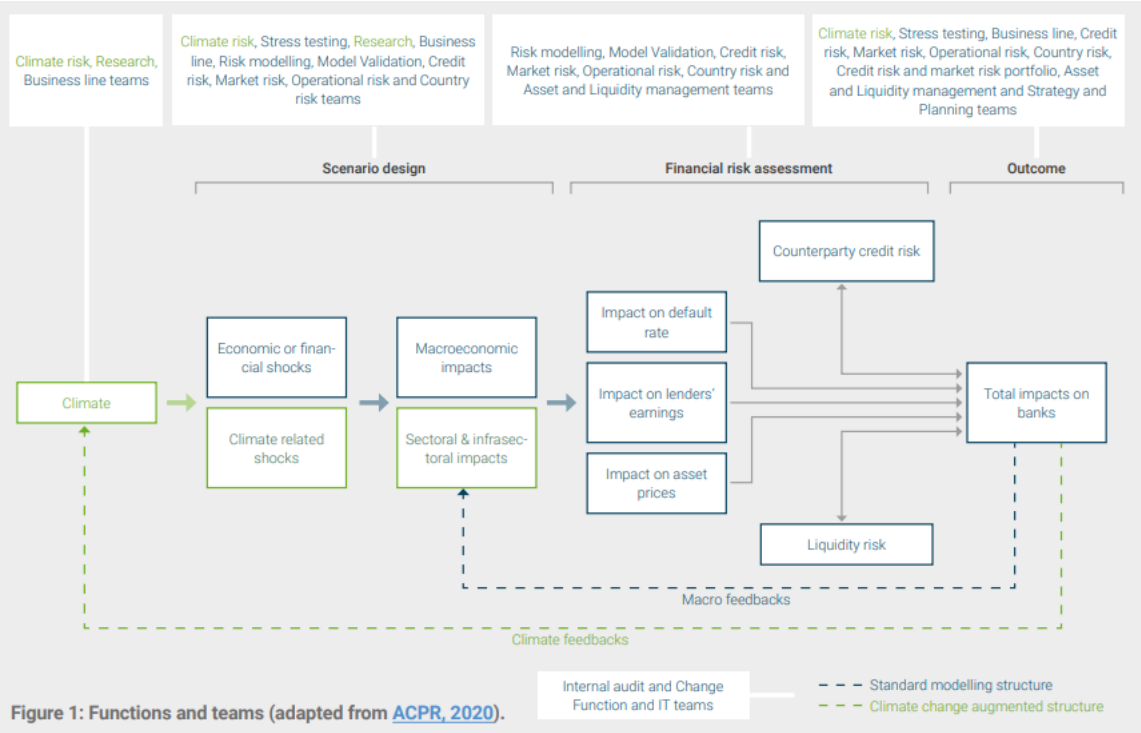


Figure 7 - Diagram of the development of a financial impact from a climate risk.

2.2.1 Long-term transition risks

For transition risks, the ACPR evaluated the impact of banking and market risk scenarios for banks, and asset risk for insurance companies. The transition scenarios reviewed reflected various trajectories of carbon price increases and technological advancements needed to meet the goals of the Paris Agreement. Financial institutions were encouraged to reallocate their corporate portfolios based on these scenarios starting from 2025, focusing particularly on reducing exposures to sectors most impacted by transition scenarios.

For credit risk, institutions had to estimate the impact of different scenarios on accounting provisions for the following exposure segments: households, non-financial corporations, and sovereigns. Loss projections are made for the 20 sectors considered most impacted or sensitive, as projecting across all 55 NACE sectors can be costly. Loss projections for households are based on macroeconomic and financial assumptions using variables typically used in traditional stress-testing exercises (unemployment rate and GDP, in particular). Two segments are studied: mortgage loans and consumer loans.

Regarding market risk, losses are analysed through the revaluation of portfolios (only the trading portfolio is considered) and counterparty risk. The goal of portfolio revaluation is to address the issue of stranded assets, which occur when there is no longer a net return on a past investment, significantly diminishing a company's value. Based on asset price projections by sector and the evolution of sectoral credit spreads contingent on the analysed scenarios, institutions must assess the impact on the value of their bond and equity portfolios from these shocks. The measurement of counterparty risk aims to determine, from a selection of counterparties in

exposed sectors, the market value of the institutions' transactions and calculate potential losses in case a number of them default (bonds) and equity assets lose significant value.

The transition risks covered by ACPR's 2023 exercise are market risks.

Transition risks for the insurance sector are primarily evaluated at the asset level. The goal is to capture the impact that holding stranded assets would have on insurers' balance sheets. Indeed, insurers' portfolios are valued at market value (Solvency II principle[15]), so any decrease in the asset prices of a given sector is directly reflected in the asset valuation. A table of shocks provided allows for projecting the market value, by scenario, of bonds and stocks. The amount of investments in other asset classes (like real estate) is only supposed to increase by the amount of inflation.

2.2.2 Short-term transition risks

These risks were only evaluated in the ACPR 2023 exercise. The methodology applied is the same as for the long term, but with the assumptions explained above (1.b.).

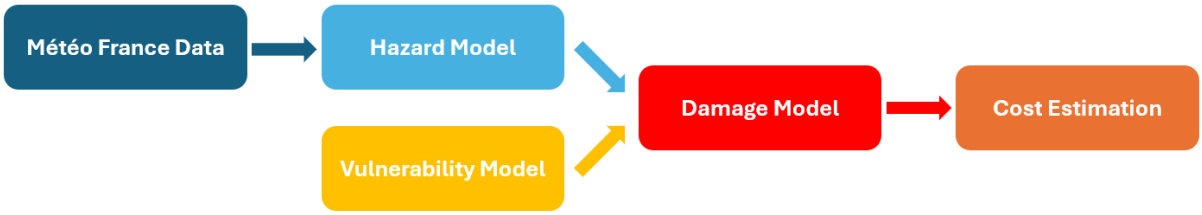
2.2.3 Long-term physical risks

Physical risks are determined by various climate hazards. It is the interaction of these hazards with exposure and vulnerability that turns these phenomena into a risk for economic actors[16].

Natural Disasters (CATNAT)

To construct a damage function, it is crucial to identify the physical assets (buildings, infrastructure) or investments that will be exposed to the event being studied. The function is designed to establish a relationship between the intensity of the climatic event and the extent of expected financial losses. For example, for a building located in a flood-prone area, damage is estimated based on the water level and the threshold at which the building begins to suffer damage. The damage function is supported by empirical data on past losses and studies on the vulnerability of different types of assets to climatic conditions. The financial loss from damages to the building is then assigned to the financial entity, allowing for the conversion from a climatic metric to a financial metric (*cf. Figure 8*).

[15] Solvency II, implemented on January 1, 2016, is a set of rules establishing the solvency regime applicable to insurance companies in the European Union. For more details: link.
[16] Jean Boissinot, "La Finance verte". Published by Dunod, 2022. Available at: Link.



Source : Météo France
Translation in English by the authors.

Figure 8 - Integration Process of Météo France Data into the CCR Modelling Chain.

Long-term physical risks were modelled in the 2020 exercise by projecting the frequency and intensity of risks for the period 2021-2050. The impact of CATNAT hazards was assessed using data from the CCR, which provided an increase in claims by department.

For insurance companies, physical risks are primarily evaluated on the liability side. Indeed, the risks associated with an increase in the frequency and cost of extreme weather events have direct consequences on the liabilities of insurance bodies and on their pricing. Insurers have had to project a considerable increase in insurance premiums to maintain a constant claims-to-premiums ratio, reflecting the expected increase in claims. This highlights the potential for a significant increase in insurability risk in certain geographic areas or exposed sectors.

Property and automobile activities are mainly impacted by an increase in the frequency and intensity of climatic disasters (floods, droughts, marine submersions, and cyclonic storms (for the overseas departments)). The insured sums in France are subject to shock assumptions at a given geographic perimeter (20 km) and their impact is assessed using the CCR. For exposures located outside of mainland France, insurance bodies can rely on the set of assumptions developed by the NGFS. The information to be provided by insurers includes the number of insured risks per municipality, the insured values per municipality, and the issued CatNat premium per municipality.

The long-term physical risks for the 2023 exercise are modelled as in the pilot 2020 exercise, and the variables to be provided by the institutions are also the same, with an update of the data relative to the first exercise.

Regarding physical risks for banks, banks did not consider physical risks as a major concern for themselves, as they felt these risks were primarily managed by insurance companies. Therefore, in 2019, it was planned to consider this risk by studying how changes in insurance policies, such as premium adjustments and coverage policies, could influence the credit risks of banks (probability of default and loss given default). Banks had to identify parts of their loan portfolios that were most likely to be affected by climate change (loans secured by real estate in areas vulnerable to climatic phenomena and loans to businesses in climate-sensitive sectors). Then, banks had to estimate the impact of climate risks and changes in insurance coverage on their credit portfolio. For example, they had to consider how an increase in the frequency of climatic events could devalue the property used as collateral for loans, thereby increasing the financial risk to the bank if the loan defaults. For businesses, banks had to assess how business

interruptions or crop losses due to climate could reduce company revenues and increase their risk of payment default.

Health

The Health sector of insurance is also impacted by physical risks (expansion of certain diseases or pandemics, pathologies due to air quality). AON, based on the RCP 8.5 scenario (2020 exercise), provides assumptions on the evolution of mortality rates, additional care costs, additional disability, and incapacity rates, as well as additional work stoppage rates for the entire French territory. An average shock for the entire French territory is also provided to allow for the calculation of an impact without segmenting the liability portfolio of insurers.

For the 2023 exercise, life insurance activities base their assumptions of mortality and health care costs on data provided by AON, associated with the heatwaves of 2022. In early 2025, a localized flood hazard leading to a dam break at Serre-Ponçon would occur. The data for the dam break are provided in the methodological guide (location, affected surface, magnitude), and the claims from this event would amount to €1.3 billion according to AON. Insurers can assess the impact of this dam break on life claims through the mortality assumptions provided by AON and can simulate their losses through their number of insureds and gross capital at risk from reinsurance. The impact on non-life claims is assessed by the CCR using the same modalities as for CatNat flood claims in the long-term scenario.

2.2.4 Short-term physical risks

The 2020 pilot exercise does not study short-term scenarios.

In the 2023 exercise, insurers apply claims levels comparable to those observed in 2022 for the CatNat drought and agricultural insurance peril (non-life insurance) for each data point between 2023 and 2027.

2.3. The role of ACPR

To conduct climate stress tests, the ACPR requires detailed data from the concerned financial entities, such as information on assets and liabilities, financial statements, income statements, and implemented strategies.

The 2020 climate stress test included 9 banking groups and 15 insurance groups, covering 85% of the banking balance sheet and 75% of the total balance sheet of insurers. The 2023 exercise focuses exclusively on the insurance sector and covers 90% of the total balance sheet of insurers.

The ACPR plays a central role in the development of climate stress test scenarios, by defining the parameters and risk assumptions to be used. It utilizes various scenarios developed by the Network for Greening the Financial System (NGFS), a global network of central banks and financial supervisors assessing the impacts of climate change on the financial sector.

The ACPR designs the templates[17] that financial institutions must fill out *(cf. Figure 9)*. These templates are designed to collect specific data on exposure to climate risks, the assets involved, and the mitigation strategies considered. The goal is to standardize the information collected to ensure consistency and comparability of data among all tested entities.

Description	Long Term Reference	Variant 1 Long Term	Variant 2 Long Term	Short Term Reference	Variant 1 Short Term	Variant 2 Short Term
General Balance Sheet Info	Balance Sheet					
Solvency	Solvency	Solvency	Solvency	Solvency	Solvency	Solvency
Asset List				List of Assets	List of Assets	List of Assets
Non-life P&L Account Details	Non-life Technical P&L	Non-life Technical P&L	Non-life Technical P&L	Non-life Technical P&L	Non-life Technical P&L	Non-life Technical P&L
Life P&L Account Details	Life Technical P&L	Life Technical P&L	Life Technical P&L	Life Technical P&L	Life Technical P&L	Life Technical P&L
Natural Catastrophe Details	CAT NAT	CAT NAT	CAT NAT	CAT NAT	CAT NAT	CAT NAT
Disease Outbreak Details	Health – Widespread Disease	Health – Widespread Disease		Health – Widespread Disease	Health – Widespread Disease	Health – Widespread Disease
Pollution Incident Details	Pollution	Pollution				
Damage to Property Details	Property Damage – Drought, Flooding	Property Damage – Drought, Flooding				

Figure 9 - Example of a template provided by the ACPR.

Template translated in English by the authors.

Inputs from Stakeholders: From Risk Assessment to Financial Impacts.

Financial institutions begin by assessing their exposure to the risks identified in the ACPR scenarios, across various time horizons. They then analyse how these risks might specifically affect their financial portfolios based on their geographic and sectoral coverage. This involves reviewing the location and sector of their investments to identify the most vulnerable areas and industry sectors. Financial impacts are then calculated by estimating potential losses or asset depreciations, and these estimates are integrated into their forecast balance sheet, reflecting the overall financial impact of the climate scenarios. All data points are supposed to be completed, but it is the effort that is required, not the result (*cf. Figure 10*).

[17] *More details about the templates:* Link..

Risk Category	Type of Risk Studied	Concerned Exposures	Geographical Areas	Portfolio Segmentation	Projected Parameters
Market Risk	Revaluation of the portfolio to fair value	Portfolio of assets	Segmentation by country or zone available: France, Euro zone, etc.	Sectorial segmentation and spread of credit risk affecting sovereign debt securities	Market value of portfolios for 2025, 2030, 2035, 2040 and long-term scenarios up to 2070 for the short-term scenarios 2024, 2025, 2026, and 2027
Health Risk	Evolution of the main components of the profit and loss account (premiums, claims, financial balance, reinsurance balance)	Health portfolio	French exposures: distinction possible by large information systems, Entire organization, Otherwise	Segmentation by fees and other body damages (incap/invalidity)	Value of the profit and loss account for 2025, 2030, 2035, 2040 for 2020, 2024, 2025 long term for 2027, 2040, and 2070 for the short-term scenarios
Technical Risks (non-life)	Evolution of the main components of the profit and loss account (premiums, claims, financial balance, reinsurance balance, revaluation rate, PPB)	Non-life portfolio	French exposures: distinction possible by large information systems, Entire organization, Otherwise	Segmentation by lines of activity (vehicle insurance, temporary deaths, and others)	Value of the profit and loss account for 2025, 2030, 2035, 2040 for 2020, 2024, 2025 long term for 2027, 2040, and 2070 for the short-term scenarios
Non-life Technical Risks (non-health)	Evolution of the main exposures (number of risks insured, number of catastrophic risks, inaccessible premium prices for long-term insured values, CAT NAT claims)	Non-life portfolio impacted by natural disasters	Foreign exposures: by country or geographical zone	Segmentation by type of perils (droughts, inundations, marine submersions, cyclones)	Value of the profit and loss account for 2025, 2030, 2035, 2040 for 2020, 2024, 2025 long term for 2027, 2040, and 2070 for the short-term scenarios

Figure 10 - Statements requested from insurers by the ACPR in 2023.

This article does not provide details on the results of the ACPR's stress tests. However, you can consult them through the following links:

ACPR 2020 Exercise: Link.

ACPR 2023 Exercise: Link.

3. Limits

Among the participants in the ACPR exercise, the risk assessment managers from a French insurer in charge of the 2023 ACPR stress-test identified several limitations in the exercise. First, there is a general feeling of task repetition, involving reiterating the same analysis processes for each scenario. This is especially evident in the long-term scenarios, where the differences between scenarios are the least significant, which could have made the analysis more stimulating. Furthermore, they consider the ACPR's scenarios unrealistic and out of sync with the current economic situation, as they uniformly apply shocks across all sectors. This generalized approach complicates detailed sector-specific evaluations and hinders clear differentiation of the specific impacts of climate scenarios from severe financial scenarios.

However, conducting sector-wide climate stress tests can encourage actors to enhance their method of evaluating climate risks. As this insurer notes, while their entity already conducts risk assessments internally, the regulatory framework has nonetheless pushed insurers to use climate scenarios more quickly than anticipated. It is likely that they will continue to base future risk assessments on scenarios proposed by the ACPR. However, this analysis has not yet led to the development of new risk management strategies within the entity.

Furthermore, building on existing interactions with reinsurers and enhancing collaboration with France Assureur could further refine and deepen future stress-test sessions. This could facilitate a more integrated creation of these tests within the insurance sector, involving France Assureur, reinsurers, and the regulator. Such developments would allow for more tailored approaches that align closely with the specificities of the insurance sector.

While the practical implementation of climate stress tests reveals some gaps, the theoretical aspects also reveal notable shortcomings. Paul Champey, an expert in sustainable economics and finance at the Banque de France and a participant in the development of NGFS scenarios, points out significant limitations in the scenarios developed by the NGFS for climate stress tests. He first notes that perpetually positive growth curves do not reflect economic reality in the event of severe climate shocks, such as extreme events or sudden energy transitions that could induce recessions. This can lead to an underestimation of financial losses linked to climate risks. Additionally, using a fixed temporal horizon until 2050 with linear interpolations every five years may not capture short-term fluctuations, making the scenarios less accurate in reflecting the impacts of climate policies or technological innovations. Finally, the lack of specific risk metrics complicates the accurate assessment of portfolio losses due to climate risks.

NGFS scenarios are based on Integrated Assessment Models (IAM) and an econometric module (NiGEM) which may themselves have limitations in their construction for climate stress tests. The think-tank Theia Finance points out that NGFS scenarios could greatly underestimate the economic impacts of climate change by not accounting for the secondary effects of social and natural risks. They note a significant variation in results between models, as in the projections of gas energy production capacity where divergences are marked between the MESSAGE and REMIND models. Moreover, the sensitivity of stress tests to scenario choices may

obscure the diversity of possible impacts of the climate transition, suggesting the utility of a broader range of scenarios to better reflect potential futures.

Certain limitations can also be noted regarding the current Integrated Assessment Models (IAMs) and the means of their implementation, which could undermine the foundation of political or financial decisions based on these scenarios. Consequently, the decisions made might not be sufficiently robust or suitable, negatively affecting risk management in the financial sector and environmental public policies.

In their article published in 2021 in Opinions & Debats ("Scenarios and models economy-climate: a reading grid for sustainable finance")[18], Jean-Charles Hourcade, Frédéric Ghersi, Peter Tankov, and Stéphane Voisin scrutinize several aspects of the modelling architecture used by the NGFS. They highlight the overly partial nature of the effort to synchronize the two types of models employed (IAM for technical systems, NiGEM model for macroeconomics), which only covers a very limited number of the variables common to these models, thus leaving room for significant inconsistencies. Moreover, they point out the limitations of the NiGEM model, whose aggregate production functions are notoriously unsuited for a controlled representation of the technical costs underlying efficiency gains and changes in the energy mix derived from IAMs. These limitations are reflected in the sectoral disaggregation tool that the Banque de France and the ACPR graft onto NGFS modelling to produce their own stress test[19]. More extensive coupling methods are needed to ensure that the modelling architecture deployed combines the relevancies of the economist's and the engineer's viewpoints.

Furthermore, **regarding the challenges of constructing scenarios sufficiently adverse to be genuinely useful for stress tests, Frédéric Ghersi (CNRS, CIRED), in an interview conducted in May 2024,** recalls a central fact: following the pioneering work of William Nordhaus, IAMs model climate damages as reductions in actual production on a given date. Theoretically, this allows them to erase all consequences of punctual damages (such as those from an extreme event) from one projection year to the next. Research from CIRED and other institutions shows that the extent of growth losses suffered is significantly more substantial when damages are modelled by erasing a portion of the productive capital stock. By acting on a stock (productive capacity) rather than the flow resulting from it (production), any damage assumption reverberates until the end of the projection, endowing the modelling with a 'path dependency' property likely to significantly influence the growth trajectories produced. The relevance of such approaches for constructing scenarios marked by 'extreme events' is evident.

Antoine Mandel also believes that climate stress-test scenarios and their implementation are too focused on carbon footprint. According to him, it is necessary to adopt a broader perspective considering the evolution of the entire production system. Additionally, there are differences in how models adapt to the needs of banks and insurance companies, with the latter being more aligned with scenarios involving extreme and specific shocks, unlike banking models which predict more linear developments. **Moreover, data on physical risks for banks are very**

[18] Opinions & Débats, “Climate-economic scenarios and models: a reading guide for sustainable finance”, 2021. Available at: Link.
[19] Opinions & Débats, “Climate-economic scenarios and models: a reading guide for sustainable finance”, 2021. Available at: Link.

sparse. Indeed, timing constraints and the late delivery of assumptions have not allowed financial institutions to initiate specific work on these issues. Only two institutions were able to submit a complete template based on ad-hoc assumptions established by the ACPR**. Finally, problems with the localization of loans and activities by banks, and insufficient sectoral granularity in the ACPR's data,** are areas where progress is still needed to refine the results of climate stress tests.

Conclusion

Climate stress tests are becoming crucial tools for assessing the preparedness of financial institutions for the effects of climate change. The ACPR's initiative, aligned with NGFS guidelines, demonstrates an evolution from stress tests as mere exercises in financial resilience to comprehensive evaluations incorporating complex and diversified environmental risks. While the ACPR's approach, consistent with NGFS guidelines, was initially pioneering, similar frameworks are now widespread, including at regional levels and on a broader European scale with initiatives like the ECB's 2022 climate stress test. These tests no longer just verify the robustness of balance sheets in conventional economic scenarios but also seek to understand how banks and insurance companies can withstand and adapt to energy transition scenarios and extreme climate shocks. However, despite progress, the ACPR exercise highlights the need for improved data accuracy and model adaptation to the specificity of climate risks. Deepening the scenarios and standardizing evaluation methods remain essential to refine the understanding of the financial implications of climate change and to guide mitigation and strategic adaptation policies within the financial sector.

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