Finance Watch

Making finance serve society

Finance in a hot house world

A call for economic models that do not mislead, scenario analyses that prepare the market, and a new prudential tool

A Finance Watch Report

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Author: Thierry Philipponnat
Editor: Greg Ford
Graphics and typeset: Camila Dubois
Cover photo: Adobe Stock
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Executive Summary

Global greenhouse gas emissions are on track to cause temperature increases of +3°C or more, a situation that climate experts call the *"hot house scenario"*. If this scenario becomes reality, more than 3 billion people will find themselves living in areas that are highly vulnerable to climate change, much of which will become uninhabitable.

Yet policy makers are unprepared for the economic disruption this will bring. Poor modelling practices have led them to underestimate the economic losses of events that climate scientists consider likely in a hot house scenario. And even if economic loss estimates are revised upwards, financial supervisors lack the prudential tools they need to prepare the financial system for them.

Chapter I

The economic risks of climate change are currently modelled in a similar way to traditional financial risks. But unlike past financial losses, the losses from climate change will be disruptively large, unpredictable and permanent. Tipping points and feedback mechanisms, such as melting permafrost, the slowdown of the Atlantic Meridional Overturning Circulation and burning forests could accelerate losses to levels far above those from recent financial crises.

Yet policy makers' economic models predict only a benign level of losses from climate change. The theories behind dynamic stochastic general equilibrium models (DSGE) and integrated assessment models (IAMs) are not suitable for modelling an economy disrupted by climate change, because they rely on backwards-looking data and make assumptions about economic 'equilibrium' that may no longer apply.

The scenario analyses conducted by financial supervisors all use these models. As a result, they are working with highly unrealistic predictions, in which climate losses accumulate at a slow constant rate, peaking in the next century at levels that can be easily absorbed. These predictions stand in stark contrast to the sudden, large, non-linear real-world disruptions that climate scientists expect in the hot house scenario to which we are currently headed.

The core aspects of the methodologies in these economic models date from the 1990s and still dominate policy thinking, often leading to absurd results. For example, the FSB predicted that an average global temperature increase of +4°C (a level considered catastrophic by climate scientists) would decrease asset prices by a mere 2.9% to 9.7% with asset price volatility staying inside normal daily trading ranges. The NGFS's recent estimate of climate losses excluded all costs arising from extreme weather, sea-level rise, migration and conflict.

Such outputs fail the common-sense test and serve only one purpose: to provide an alibi for those who do not want to look the economic reality of climate change in the eyes.

If we continue to under-estimate the future economic impacts of climate change, we will distort the cost/benefit analyses on which policy makers decide how much to invest in combatting climate change. This will reduce our resilience, increase future costs and feed disasters.

For more plausible predictions, we need a better choice of economic models and more realistic assumptions.

Chapter II

In March 2023, the European Commission asked the European Supervisory Authorities, the European Central Bank and the European Systemic Risk Board to complete a one-off scenario analysis exercise by Q1 2025.

The exercise will consider events that could threaten either the viability of the financial system or the EU's ability to achieve its climate and environmental goals. For perhaps the first time, the analysis will combine regular macrofinancial adverse scenarios with a climate shock scenario.

This is an opportunity to help prepare the financial system for the economic effects of climate change, so long as the exercise includes three features:

- A realistic assessment of economic damage. The modelling element used to predict economic losses, known as the 'damage function', must be able to capture the change in acceleration around tipping points and other special features of climate change. The 'quadratic' damage function, used in all financial supervisors' current models, cannot do this and so other approaches including 'exponential' and 'logistic' damage functions should be modelled alongside it. In line with the precautionary principle, only results that are compatible with the adverse scenarios provided by climate scientists should be retained.
- Financial losses from stranded fossil fuel assets must be quantified, because they are a major threat to financial stability. Finance Watch last year estimated that the sixty largest global banks have a combined exposure to fossil fuel assets of $1.35 trillion, including $240bn from EU banks. If financial supervisors calculated their own version of this figure and extended it to insurance companies, pension funds and investment funds, they could then estimate what proportion of those exposures are at risk of becoming stranded, should the world act to remain within the carbon budget for a given temperature increase such as +2°C. Supervisors could then take the appropriate prudential action to safeguard the financial system against stranding risk.
- The 2030 time horizon of the exercise should be extended by several decades. On current emissions trends, climate risks will probably not jeopardise the financial system before 2030. While extreme weather events are already accelerating, the disruptions and losses of climate change are not expected to threaten the global economy until around 2050, after which they could accelerate and reach catastrophic

levels between 2060 and 2080. Decisions taken as a result of the current exercise should help to determine the level of losses that occur in the later period, which must therefore be included in the time horizon of the analysis.

There is still time for financial markets to adjust to the future economic impacts of climate change. But this window of opportunity for investors and supervisors to avoid a climate 'Minsky' moment will not last.

The EU's one-off scenario analysis exercise is a unique opportunity to help prepare the financial system for a hot house scenario by providing credible information about its effects on the economy. If the exercise follows the proposals above, it would be a game changer for the effectiveness of prudential supervision, risk management at financial institutions, and investment decisions.

Chapter III

Policy makers broadly agree that climate risk is a systemic threat to banks but that existing macroprudential tools are poorly suited to managing that risk. In response, some experts have proposed adapting existing macroprudential tools, such as the systemic risk buffer and concentration limits, to link directly to climate risk.

We support this approach and suggest extending it with a new 'loan-to-value' (LTV) tool for banks' exposures to fossil fuels. This would trigger a capital surcharge once a certain threshold of climate-related risk has been reached. The LTV threshold we propose would be set in proportion to the amount of fossil fuels to which a bank is exposed that can be safely exploited within the carbon budget for a given temperature increase.

For example, the remaining global carbon budget to keep temperature increases within +2°C is estimated at around 800 GtCO2, or about 23% of the carbon that would be released if all the world's existing fossil fuel reserves were fully exploited and combusted. To calibrate the LTV tool for a +2°C temperature increase, the LTV threshold would therefore be applied at 23% on bank loans that finance existing fossil fuel reserves, with a capital surcharge applying to any portion of the loan above this level.

The proposed LTV tool would combine borrower-based and capital-based features, activating the capital feature in direct proportion to the additional systemic risk caused by the loan. It would follow transparent rules and metrics and focus on the highest-emitting activities at risk of stranding.

Lending for new fossil fuel exploration creates even higher systemic risks and should be managed differently, we suggest either with a lending cap or full equity funding (the 'one-for-one' rule proposed earlier by Finance Watch), in line with the International Energy Agency's (IEA) recommendation not to expand existing fossil fuel reserves.

Introduction

The consensus is growing that the world is headed for a global warming of 3°C or higher by the end of the century. Assuming a constant level of annual global CO2 emissions of 40 GtCO2 , this prediction is the simple reflection of the fact that *"the annual mean global near-surface temperature for each year between 2023 and 2027 is predicted to be between 1.1°C and 1.8°C higher than the 1850-1900 average"*[1] (WMO's best estimate at 1.5°C) , and that the IPCC tells us that *"for every 1000 GtCO2 emitted by human activity, global surface temperature rises by 0.45°C (best estimate, with a likely range from 0.27°C to 0.63°C)"*.[2] In reality, assuming a constant level of CO2 emissions is more than conservative: CO2 emissions are highly likely to keep increasing, as long as global economic activity and emissions remain coupled and so many self-proclaimed net zero policies lack credibility.[3] These realities are only reinforced by a geopolitical context characterised by a global failure to take meaningful action to reduce the use of fossil fuels, a very low level of cooperation between jurisdictions, increasing and ubiquitous fossil fuel subsidies at $7 trillion in 2022 and expected to rise to $8.2 trillion by 2030[4] and a massive and generalised pushback against policies with a sustainability objective. All in all, we unfortunately see no reason to assume lower global CO2 emissions in the foreseeable future and the most probable situation is one where emissions will keep on increasing until the climate crisis becomes so acute that policy makers have no choice but to take action on the scale required.

The preparation of the financial system for a global warming of 3°C or more must, in our view, include at least two pillars: 1 - the scenario analyses conducted to inform public and private decision-makers of the economic and financial consequences of climate change must be plausible and not shy away from reality; 2 – the tools at the disposal of prudential authorities, whether microprudential or macroprudential, to manage the financial risks arising from climate change must be effective.

When it comes to studying and understanding the impact of climate change on the economy and on the financial system, the Network for Greening the Financial System (NGFS), a network of 127 central banks and supervisors worldwide,[5] plays a special role and it must be credited with having raised the awareness of the central banking community on the subject of climate change. Its purpose is to *"share best practices and contribute to the development of environment and climate risk management in*

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1 *World Meteorological Organization (WMO)*, May 2023

2 IPCC, *Climate change report 2023 – Summary for policy makers*, B.5.2, page 25

3 Finance Watch, '*The problem lies in the net*', June 2022

4 International Monetary Fund, 'Fossil Fuel Subsidies', 2023. IMF's estimates include both explicit and implicit subsidies whereas IEA's estimates standing at $1 trillion for 2022 include only '*Fossil Fuel Consumption Subsidies*'

5 As of June 2023, *the NGFS consists of 127 members and 20 observers*

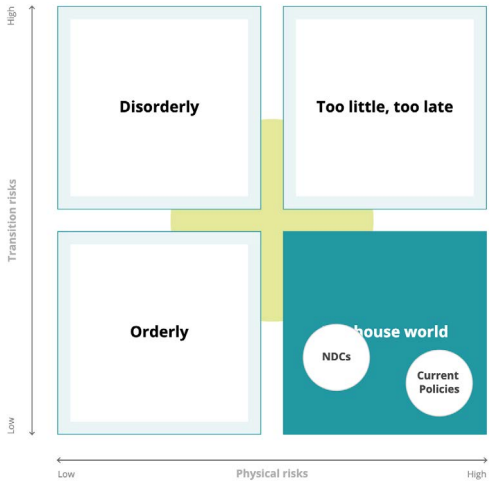
the financial sector and to mobilize finance to support the transition toward a sustainable economy".[6] With its unique combination of financial, economic and supervisory expertise the NGFS is at the heart of the endeavour to prepare the financial system for the consequences of climate change and support the goals of the Paris agreement.

Among the tasks undertaken by the NGFS since its launch in 2017, defining climate scenarios has been essential to *"provide a window into different plausible futures"*[7] and forming the basis of the scenario analyses, sometimes dubbed (improperly) *"climate stress tests"*, conducted by many central banks to assess the resilience to climate change of the financial institutions they are in charge of supervising. Designing plausible climate policy scenarios is to climate scenario analyses what laying foundations is to house building. Just as solid foundations are a prerequisite for a solid building, plausible climate policy scenarios are a prerequisite to assessing the impact of climate change on the economy and deriving useful conclusions for the resilience of the financial system. Plausibility is the name of the game.

The NGFS has designed a set of hypothetical climate scenarios described as follows:

NGFS Scenarios portal

Figure 1



Source: www.ngfs.net/ngfs-scenarios-portal

Orderly scenarios assume climate policies are introduced early and become gradually more stringent. Both physical and transition risks are relatively subdued.

Disorderly scenarios explore higher transition risk due to policies being delayed or divergent across countries and sectors. Carbon prices are typically higher for a given temperature outcome.

Hot house world scenarios assume that some climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming. Critical temperature thresholds are exceeded, leading to severe physical risks and irreversible impacts like sea-level rise.

Too little, too late scenarios would assume that a late transition fails to limit physical risks. While no scenarios have been specifically designed for this purpose, this space can be explored by assuming higher physical risk outcomes for the disorderly scenarios.

6 NGFS, *Origin and purpose*

7 NGFS Scenarios Portal

In the economic and political context described above, the hot house world scenarios are the only scenarios corresponding to reality among the scenarios proposed by the NGFS. This reality is only reinforced by the collective action issue facing the combat against climate change: climate change is a global problem and if jurisdiction A takes action while jurisdiction B does not, jurisdiction A makes the collective effort benefiting both jurisdictions and jurisdiction B is a free-rider. In a world with hundreds of mainly uncooperative jurisdictions, the problem is at best very difficult and, the pessimists would argue, impossible to solve.

The Sixth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC)[8] report published in 2023 leaves no doubt that the world is headed, at best, for a hot house scenario: some climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming. Critical temperature thresholds are exceeded, leading to severe physical risks and irreversible impacts. The major difference with the NGFS approach is that irreversible impacts are not limited to sea-level rise[9] but extend to droughts, desertification and, most importantly, to the fact that *"approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change"*,[10] which will inexorably translate into a very large number of climate migrants and the inevitable chaos and disruption of human societies that will come with it. Importantly, the IPCC states that *"estimates of future CO2 emissions from existing fossil fuel infrastructures without additional abatement already exceed the remaining carbon budget for limiting warming to 1.5°C"*[11] and describes *"a rapidly narrowing window of opportunity to enable climate resilient development"*.

For all those reasons, this report builds on the conviction that, in the absence of a 'too little too late' scenario, the 'hot house' is the only plausible scenario and that it will bring with it dramatic consequences for human societies. Along with amplifying their climate change mitigation efforts, policy makers must apply a precautionary approach and prepare society for the consequences of climate change, including its potential to destabilise the financial system. Financial stability is a public good and society must work by all possible means to preserve it and avoid cumulating a financial crisis potentially of a magnitude never seen before with the gathering climate crisis. Keeping in mind the urgency to act, the proposals we explore in the following pages aim not only to remove barriers to action in political and economic policymaking but also to limit the damage that climate change will have on the financial system.

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8 IPCC, *Synthesis Report of the Sixth Assessment Report*, 2023

9 With the irony and the paradox that the NGS does not consider sea-level rise when it assesses the impact of climate change on the economy… (see section I).

10 IPCC, *Climate change report 2023 – Summary for policy makers*, A.2.2 page 5

11 IPCC, *Climate change report 2023 – Summary for policy makers*, B.5.3, page 26

Key Recommendations

1. For economic policy makers and financial supervisors dealing with climate risk:

Make the assessments of the economic consequences of climate change realistic

a. Ensure that economic models account for the specificities of climate change, including its magnitude and irreversibility

b. Ensure that the conclusions of economic models are compatible with the conclusions of climate science, including by rejecting the use of quadratic-only damage functions in loss assessments

c. Conduct unbiased and rigorous analyses of the results

2. For the European Commission, ESRB, ESAs and ECB:

Make the EU's one-off scenario analysis exercise useful

a. Ensure that economic models can capture the full effects of climate change in line with the Article 191 TFEU precautionary principle

b. Quantify financial institutions' stranded fossil fuel assets exposures

c. Extend the time horizon by several decades beyond 2030

3. For the European Commission and macroprudential financial supervisors:

Develop a new borrower-based macroprudential tool to address the climate-related threat to financial stability

a. Design a loan-to-value threshold that triggers a capital surcharge, applied to fossil fuel assets at risk of stranding

b. Make it effective to absorb future losses arising from stranded fossil fuel assets and avoid the build-up of risk

c. Base its application by macroprudential supervisors on the quantification of financial institutions' stranded fossil fuel assets exposures resulting from the EU one-off climate scenario analysis exercise

I. Economic modelling is misleading us about the effects of climate change

Most economic models understate the effects of climate change by a large margin, with dangerous consequences for decision-making. Some relatively simple changes can make them useful again.

a. Specific nature of climate change-related economic and financial risks

Climate risk is not the only risk borne by the economy and by the financial system, but it is of a specific nature. The risks borne by the financial system because of climate change are inherently different from the risks financial institutions are used to dealing with and they make for a pattern that economists and financial supervisors are not used, nor traditionally well equipped, to deal with.

Climate change-related financial risks have a number of specificities:

- Climate change is already happening and is certain to increase in the future. In contrast, traditional financial risks are probabilistic events, i.e. events that can be described by a probability distribution even if many of them, in particular sudden and violent financial crises such as market crashes, are effectively outside of mainstream Gaussian probability distributions.
  - → Probability of climate change (P): $P = 1$
  - → Probability of other financial risks (P): $P \in]\,0, 1\,[$
- Climate change is irreversible[12] whilst other sources of financial risk, whether unexpected random events such as market crashes or cyclical crises such as real-estate crises, are reversible. Reversing climate change once it has happened is beyond human possibility, in contrast with financial crises triggered by economic problems that can be tackled by policy action, if at an enormous cost to society. In contrast, climate change follows a one-way only pattern.
- Climate change will accelerate around what climate scientists call tipping points[13] and its consequences on the world (damages) will not only also accelerate but they will do so at an increasing rate. No other financial risk displays this characteristic combined with irreversibility and the fact that it is beyond human control. Some

12 IPCC, *Climate change report 2023 – Summary for policy makers*, B.3.2 page 18, C.1.3 page 24

13 Steve Keen gives the following list of tipping points page 43 of 'Loading the DICE against pension funds': 1. Loss of summer sea ice in the Arctic; 2. Slowdown of the Atlantic Meridional Overturning Circulation (AMOC); 3. Increased variability of the Indian summer monsoon; 4. Release of carbon from permafrost; 5. Release of carbon from ocean methane hydrates; 6. Dieback of the Amazon rainforest; 7. Disintegration of the Greenland Ice Sheet; and 8. Disintegration of the West Antarctic Ice Sheet. (Dietz et al. 2021a, p. 8)

economic or financial crises display characteristics of acceleration, for instance market crashes when financial markets get into stampede mode and fire sales provoke an acceleration of the collapse of listed financial assets prices, but the main difference lies in the fact that policy makers, market authorities and regulators have tools at their disposal to manage economic crises, stop financial market crashes and control financial crises (e.g. economic policy measures, budgetary support, liquidity injections by central banks, bail-outs, resolutions and, more generally, regulation), when human societies will be watching powerless at the acceleration of climate change and its impact on society, on the economy and on the financial system.

- Climate change will lead to a disruption of human societies for a duration impossible to anticipate but certainly counting in centuries or more. In contrast, traditional economic troubles have never impacted human societies for more than a relatively limited number of years, even when they have been extremely severe and caused enormous damage. In retrospect, the financial crises of 1929 and 2008-2009 (which saw 50 million workers, i.e. roughly 0.7% of the then world population, lose their job and led to a massive worldwide bail-out of private financial interests with public money), will be considered as anecdotes in human history in comparison with the mass migrations and disruption of the world as more than 3.3 billion human beings (about 40% of the world population) find that the part of the world they were born in becomes increasingly uninhabitable.[14]

Apprehending the specific nature of climate change-related risks and their differences from traditional economic and financial risks is a prerequisite to conducting meaningful analysis or policy action. The next section looks at why this is not happening.

b. The economic consequences of climate change for the economy will not be benign

The debate on the economic consequences of climate change is characterised by an absence of consideration for the results of climate science research, flawed thinking and a lack of common sense. This has led most economic and scenario analyses to derive benign conclusions that have justified a level of public action clearly insufficient to reduce greenhouse gas emissions globally and, despite all the rhetoric, a generalised business-as-usual approach by the private sector.

Apprehending disruption risk

Disruption risk is the biggest climate change-related risk for society and for the economy. Over the past decade, the circles of specialists looking into the economic and financial consequences of climate-change have been discussing and analysing transition risk, physical risk and, to a lesser extent, litigation risk. The reality of those three types of risk is not to be disputed. However, reading the research produced by climate scientists,

14 Source: IPCC Sixth Assessment Report, A.2.2 page 5

the risk that the economy is severely hampered and eventually stops functioning as global temperatures keep on rising seems overwhelming.

Finance Watch coined the concept of disruption risk in its June 2020 'Breaking the climate-finance doom loop'[15] report and defined it (page 20) as *"the fact that, in the light of the environmental and geostrategic upheavals that climate change will bring, there is no plausible scenario where the world economy as we know it will continue to function. In all likelihood, the economy will endure, at best, a considerable slowdown and, most probably, a prolonged depression because of climate change, its structures will be redesigned, and the financial system will be shaken to its roots, if not destroyed. In a nutshell, disruption risk is the fact that climate change will disrupt human societies, which will disrupt the world economy, which will disrupt the financial system."*

Three and a half years on, climate change-related disruption risk is becoming more and more obvious each day but, despite that reality, it is still not considered by economists or actuaries when they assess the consequences of climate change on financial portfolios or on financial institutions' balance sheets. Quite the contrary, most studies of the impact of climate change on the economy and, subsequently, of its impact on the financial system derive benign conclusions that reinforce society's and policy makers' short-termism and inaction biases.

This phenomenon needs to be analysed and understood.

In our view, the ignorance of climate-related disruption risk by economists stems from four factors:

1 - An overconfidence in the power of economic models

This issue is broader than the climate-related question addressed in this report. It concerns the entire economics profession and its use of models. It deserves significant attention in its own right and we will address it only briefly here.

As a general remark, policy makers, decision makers and the general public tend to derive an unfounded sense of confidence from the extensive and most of the time ill-understood use of mathematical techniques by economists. This situation leads frequently to an overreliance on the results of simulations conducted using mathematical models.

The missing piece of this reasoning is that a model is, by construction, the reflection of a theory and theories deserve a thorough epistemological approach if we want to derive from them meaningful conclusions.

Three points must be kept in mind to use the results of economic modelling in a relevant manner:

15 Finance Watch, *Breaking the climate-finance doom loop*, June 2020

i. By and large, economic modelling is done using a Walrassian general equilibrium logic. This is the case whether it is conducted with traditional macroeconomic models, their alternative and more sophisticated dynamic stochastic general equilibrium (DSGE) models or integrated assessment models (IAMs). DSGE models combine microeconomic principles and general equilibrium theory, whereas IAMs integrate a damage function with a view to assessing the impact of climate change on GDP whilst keeping a general equilibrium framework.

   ➔ **Issue:** given the shock that will be imposed on the economic system by climate change, the hypotheses underlying general equilibrium models are not realistic, thus making their use at best fragile.

ii. Economic modelling is, by construction, a formalisation of hypotheses and logical links of the type *"if A, then B"*. This is true whether the modelling is done with traditional macroeconomic models, DSGE models or IAMs.

   ➔ **Issue:** the mere fact of choosing a method when writing a model creates a straightjacket that no model, whether static or dynamic, macro-founded or micro-founded, can escape from. Once a method and hypotheses have been chosen, there remains no degree of latitude for a model to add anything: it will only spit out what it was programmed to spit out.

iii. Regardless of the family they belong to, the models assessing the impact of climate change on the economy seem to be ignoring the critique formulated by Robert Lucas in 1976[16] that the effects of an economic policy cannot be predicted using data from a period when that policy was not in place.

   ➔ **Issue:** the Lucas critique is widely recognised as valid. Surprisingly, the models estimating the impact of climate change on the economy seem to be ignoring this fundamental critique despite the fact that climate change is an entirely new situation rendering historical data of limited use to predict the future, in particular with climate scientists warning of acceleration of damages, irreversibility and unpredictable consequences when tipping points are reached. The generalised lack of necessary data and the ill-founded use of available data[17] regarding the consequences of climate change not only reinforces the Lucas critique but also leaves us dubious about the current call by regulators and supervisors to use oxymoronesque 'forward-looking data' to estimate the economic consequences

16 Lucas, Robert (1976), 'Econometric Policy Evaluation: a critique'

17 See for instance, Carbon Tracker Initiative's '*Loading the DICE against pension funds*' page 32: "These economists have used a set of strikingly invalid assumptions to develop predictions of relatively minor economic damages from global warming. These include, but are not limited to: 1. That industries not exposed to the weather will be unaffected by global warming. 2. That today's data on temperature and GDP across regions and countries can be used to predict the future impact of global warming on GDP, by using the geographical relationship between temperature today and income today as a proxy for the economic impact of global warming over time. 3. That data on change in temperature and GDP can be used to predict the future impact of global warming on GDP, by extrapolating the relationship between the change in global temperature between 1960 and 2014 and GDP to predict the impact of further temperature increases on GDP between now and 2100."

of climate change. Economists must integrate an epistemological approach and be able to defend the validity of their conclusions if they want them to be plausible and useful.

2 – A reliance on flawed economic modelling

Even without putting blind faith in the models used to predict future economic states of the world, the least that can be asked from an economic model is that it uses plausible assumptions and modelling techniques able to reflect the world it aims to make predictions on. This is an obvious prerequisite for its results to be meaningful.

Unfortunately, the models used to predict the impact of climate change on the economy, mainly IAMs, do not pass this test.

A report launched by the Carbon Tracker Initiative (CTI) in July 2023 and authored by Professor Steve Keen, 'Loading the DICE against pension funds,[18] explains how flawed economic thinking and a lack of consideration for climate science have led economists to grossly underestimate the impact of climate change on the economy. The report does not speak of 'disruption risk' in those words but it deals with the very same subject and it brings a number of powerful and rigorous responses, even if in our view not all, to the question of why economists ignore so blatantly climate science when they analyse the economic consequences of climate change. The following section refers extensively to CTI's important report and we encourage the reader to refer to it for a complete understanding of the subject.

The main argument developed by Steve Keen is that the quadratic form of the damage function on which IAMs rely is mathematically inappropriate to capture the economic impact of climate change given the latter's characteristics, and in particular the phenomenon of acceleration around tipping points, a simplistic approach to taking temperature rises into account and rigged assumptions. This may sound like an obscure technical debate to non-specialists but, as we will see, it has enormous consequences for the results of the simulations conducted, and subsequently for the ability of policy makers, financial actors and supervisors to take the decisions they should be taking.

Steve Keen notes (page 29) that *"ever since (Nordhaus 1991), economists in this research tradition have normally assumed that damages from global warming will be equal to the temperature increase squared, multiplied by a small constant, so that 2°C of warming does four times as much damage as 1°C, 3°C does nine times, and so on. This assumption has been strongly criticized by Pindyck, Stanton, and Weitzman (Pindyck 2017; Stanton, Ackerman, and Kartha 2009; Weitzman 2012)"* and he quotes Pyndick[19] (page 30) stating that *"The damage function used in the Nordhaus DICE*

18 Carbon Tracker Initiative, '*Loading the DICE against pension funds*', July 2023

19 Pyndick, 'The Use and Misuse of Models for Climate Policy', Review of Environmental Economics and Policy, 2017, pp. 103-104

model, for example, is a simple inverse quadratic relationship … this damage function is made up out of thin air. It isn't based on any economic (or other) theory or any data. Furthermore, even if this inverse quadratic function were somehow the true damage function, there is no theory or data that can tell us the values for the parameters or the correct probability distributions for those parameters, or even the correct means and variances." Further on (page 34), he states that *"a quadratic is, as many critics have argued, a singularly inappropriate function to use to model the economic damages from global warming (Ackerman and Munitz 2012; Ackerman, Stanton, and Bueno 2010; Diaz and Moore 2017; Pindyck 2017)"*, and he points out (pp. 38 and 39) the dramatic consequences of this choice of model to estimate the impact of climate change on the economy: "*When these functions are mapped against time, the quadratic returns the usual predictions of economists, that most damages will occur in the 22nd and subsequent centuries. The exponential and the logistic, on the other hand, imply that the vast majority of economic damages from climate change will occur this century. Since these functions cannot be distinguished from each other based on their fit to current data, then, given the huge differences in their implications about both the threat from global warming and its immediacy, it is vitally important to decide which functional form is more plausible.*

The quadratic can be ruled out because its mathematical characteristics contradict the concept of tipping points (Lenton et al. 2008b, 2008a). In particular, a quadratic cannot show a change in the acceleration of damages from global warming, and the economic damages resulting from it. Yet damage will accelerate as tipping points add to the increase in temperature caused by the increase in anthropogenic greenhouse gas emissions alone.

Both the exponential function and the logistic can show such an acceleration, and their numerical implications are closer to the expectations of scientists than any paper in the mainstream economics literature."

In an illustration of how a combination of flawed economic modelling, absence of consideration of the results of climate science by economists and lack of a common sense filter can lead economists to derive absurd conclusions, Keen shows[20] the results of a simulation where a quadratic function predicts a decline of GDP of 11.5% for a global warming of + 6°C. This result has to be put in perspective with the unanimous description of the impact of global warming by climate scientists as *"dangerous at 1.5°C"*, *"catastrophic at +3°C"* and *"unknown, implying beyond catastrophic, including existential threats at 5°C and more"*. [21 and 22] In short, the dominant quadratic modelling predicts that GDP will decline by 11.5% (from a level much higher than today, meaning a world significantly richer than today despite a 6°C global warming) if the

20 Supporting document to 'Loading the DICE against pension funds', page 31

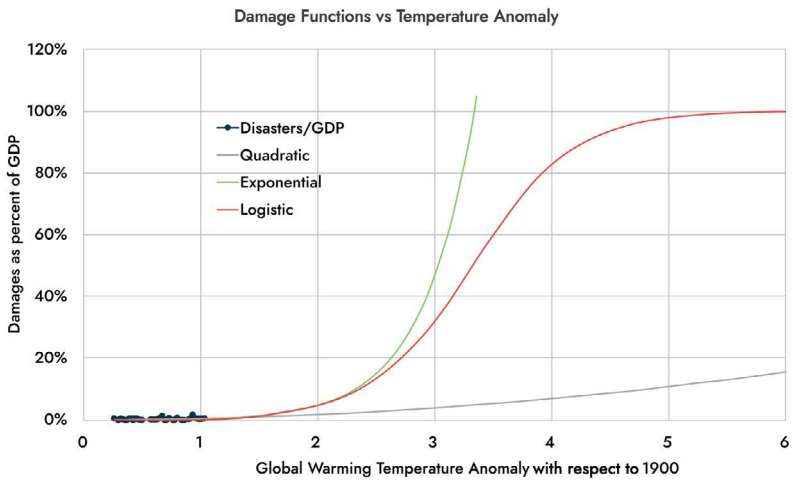
21 Kemp et al. 2022, pp. 4,8

22 Xu and Ramanathan 2017, p. 10315

habitable world has come to an end and human societies have stopped functioning! Conversely, the same quadratic model concludes that GDP would decline only 5% for a hypothetical decrease of global temperatures of 5°C (theoretical global cooling). Even if obviously purely theoretical, equating a 5°C decrease in temperatures with a 5% GDP decline shows to what level of absurdity a lack of common sense can lead when one realises that such cooling conditions would put the Northern hemisphere under several hundred meters of ice or more.

Concretely, the most important point made by Steve Keen is that using a quadratic function leads to an estimation of a negative impact equal to a negligible few points of GDP in 50 years' time (and, here again, on a GDP level much higher than today, implying effectively a society much richer than today despite climate change) whilst using an exponential or a logistic function, which have a much better capability to reflect the characteristics of climate change, leads either to the conclusion of a complete collapse of GDP (exponential function) or very severe impact on GDP (logistic function) for the same time horizon (see Figure 2). By the same token, a quadratic function predicts a 20% impact on GDP at a temperature increase of 6°C, whilst an exponential function predicts 100% damages to the economy at 3.3°C and a logistic function 100% damages at 5°C (50% at 3.3°C). The messages could not be more divergent and it is surprising in that context that all the scenario analyses conducted by supervisors so far have been done using exclusively quadratic functions without attempting, in a spirit of open intellectual debate, to at least show and discuss the outcomes that would have resulted from the use of exponential or logistic functions.

Figure 2



Source: Carbon Tracker Initiative, July 2023

Interestingly, the UK Institute and Faculty of Actuaries and the University of Exeter develop similar arguments in research also dated July 2023.[23] In their paper, these two highly reputable institutions conduct a critical analysis of the flaws of the dominant modelling

23 IFA, University of Exeter – *The Emperor's New Climate Scenario*, July 2023

of the economic consequences of climate change and bring clear support to the points made by CTI in its 'Loading the DICE against pension funds' report. They also analyse the consequences for the insurance sector: *"The pace of warming is also uncertain. However, some scientists now estimate warming of 0.3℃ per decade or around 1℃ every 30 years, which would imply warming of greater than 2℃ by 2050 and 3℃ by 2080. This is well within life expectancy for many in workplace schemes now and in range for the European Insurance and Occupational Pensions Authority (EIOPA) who have specified 80 years as long range for the Own Risk and Solvency Assessment (ORSA). Put another way, at what point do we expect 50% GDP destruction – somewhere between 2070 and 2090 depending on how you parameterise the distribution. It is worth a moment of reflection to consider what sort of catastrophic chain of events would lead to this level of economic destruction"*.

When it comes to estimating the economic consequences of climate change, there is indeed a suspicion that, as inferred by the title of the report from the Institute and Faculty of Actuaries and the University of Exeter, the emperor is currently naked.

3 – A general reluctance to consider that climate change could have a negative impact on growth

The reluctance to even consider that climate change could have a negative impact on economic growth is palpable in the publications from central banks, supervisors, public institutions and most academic economists. It leads to a situation where reality is denied. This is highly undesirable but it should not constitute a surprise given that the possibility of a lasting negative impact on growth is perceived as contradicting the system we operate in. Our economic model is built on growth and relies on growth. In the absence of growth, the current system falls over very much like a bicycle without momentum. This reality is, and will be, difficult to reconcile with a world impacted by climate change and the accompanying disruption of the economy.

We give below four illustrations of this uninspiring situation where academia, central banks and supervisors shut their eyes to a reality that they do not want to see, at the risk of defying common sense and plausibility:

Illustration 1: Mainstream economics

Let us first pay honour where honour is due with William D. Nordhaus, 2018 co-recipient of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (commonly, if incorrectly, referred to as the Nobel Prize in Economics) for his work on integrating climate change in macroeconomics and in particular for developing Integrated Assessment Models.

William D. Nordhaus first addressed the question of the impact of climate change

on the economy in a paper published in 1991.[24] In this paper, he applies a traditional cost-benefit analysis to climate change with the logic that *"the optimal degree of GHGs comes where the current cost of reducing GHG emissions equals the present value of the damage from higher concentrations"* (page 926). Ignoring whether discounted cashflow is a sensible way to assess the effects of climate change, Nordhaus continues *"climate change is likely to produce a combination of gains and losses with no strong presumption of substantial economic damages"* (page 933), he comes to the conclusion that an equilibrium would be reached at *"a 3°C rise in global mean surface with the associated changes in climate"* (page 936) adding that *"the flow of damages identified from this climate change is estimated to be 0.25% of output"* and that *"there are clearly unmeasured and unmeasurable impacts, which might raise this impact to 1%, or at most 2% of total output"*.

Nordhaus also states that 87% of economic sectors in the US would be *"negligibly affected by climate change"* (page 930), that *"for the bulk of the economy it is difficult to find major direct impacts of the projected climate changes over the next 50 to 75 years"* (page 932) and that *"a preliminary reading of the evidence is that other advanced industrial countries will experience modest impacts similar to those of the United States"* (page 933).

For the anecdote, but it may be more than an anecdote, Nordhaus asserts in the same paper that due to global warming *"investments in water skiing will appreciate while those in snow skiing will depreciate"* (p. 932).

Three points must be noted regarding the work conducted by William Nordhaus on the economic impact of climate change:

- Despite the evidence accumulated of the damages caused by climate change since he wrote his 1991 paper and its obvious disconnect from reality, Professor Nordhaus has not amended his mechanical cost-benefit analysis approach. This has led him to draw similar conclusions in a paper published in 2018[25] in which he states that climate change will lead to *"a damage of 2.0 percent of income at 3°C, and 7.9 percent of global income at a global temperature rise of 6°C"*, only a minor modification from an estimate from an earlier paper which assumed *"damages are 2.1 percent of global income at 3°C warming and 8.5 percent of income at 6°C warming"* (page 345).
- Despite Nordhaus's disconnection from the work conducted by climate scientists (all climate scientists warn of tipping points triggering around 2°C global warming

24 William D. Nordhaus, '*To Slow or Not to Slow: The Economics of The Greenhouse Effect*', The Economic Journal, July 1991, Vol.101, No. 407, pp. 920-937

25 2018. '*Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies*', American Economic Journal: Economic Policy, 10: 333–60

and catastrophic consequences beyond 3°C,[26] something obviously not compatible with the prediction of a puny damage of 2% of income or, even more blatantly absurd, 7.9% at 6°C), Professor Nordhaus still serves as the best alibi for all those who refuse to face the reality of the impact of climate change on the economy. The prestige derived from receiving the *"Nobel Prize in Economics"* for his work on the subject is obviously not indifferent to this question.[27] Arguments from authority end up winning the day more often than not, even when they lead to nonsensical conclusions.

- The logic of finding the *"optimal level of global warming"* (3°C in Nordhaus's view) prevails in economic thinking as evidenced, among many others, by a publication ('The climate and the economy') published by the European Central Bank in March 2023 that we discuss in the following section.

Illustration 2: European Central Bank (ECB)

In March 2023, the ECB published a report called 'The climate and the economy'.[28] A striking feature of this publication is its obvious bias towards discounting on non-rigorous grounds any idea of significant economic damages arising from climate change: throwing doubt on the effect of climate change on the economy,[29] confusing weather and climate,[30] citing only economists giving benign effects of climate change on the economy, abstaining from references to climate scientists, calling *"large"* an impact of 2% on GDP which is the smallest and most optimistic estimate produced by economists, relying on wishful and groundless 'technology-will-save-us' rhetoric[31] without giving concrete examples of technologies that could make a difference at scale, estimating between 45 and 97 million the number of working-age climate migrants over the course of the 21st century[32] when the IPCC Sixth Assessment Report mentions that between 3.3 billion and 3.6 billion people live in zones that are highly vulnerable to climate change and therefore at risk of becoming uninhabitable.

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26 E.g. Steffen et al. 2018, pp 8253-4; Xu and Ramanathan 2017, p. 10315 (Keen DICE page 19)

27 On a different subject but in a similar demonstration of its ability to reward the most fruitful economic ideas, the jury of the Bank of Sweden also awarded its "Nobel Prize in Economics" to Eugene Fama in 2013 for his work on financial markets efficiency and the impossibility of financial crises (J).

28 ECB, '*The climate and the economy*', March 2023

29 Page 3: "the effect of increasing emissions on the climate is intrinsically uncertain…there is a wide range of climate – and from there, economic – outcomes, ranging from the benign to the catastrophic". Note: we would very much like to see serious estimates of a benign climate outcome of increasing emissions.

30 Page 4: quote from Marcel Proust: "A change in the weather is sufficient to recreate the world and ourselves."

31 Page 9: "the real effect of climate policy crucially depends on the response of the technology". Calling on non-existing or non-scalable technologies is a classic argument pushed in the climate change debate by incumbent enterprises with no intention to change their operating model (witness the debate on Carbon Capture and Storage which represents today 0.1% of CO2 emissions and that no expert believes can be made to work at scale).

32 Page 27

→ The European Central Bank plays an important role in assessing the resilience of the financial system to climate change. The climate risk stress test it conducted in 2022[33] was a useful learning exercise for financial supervisors. It is surprising therefore that in the report of March 2023 the ECB effectively shuts its eyes to the impact of climate change on the economy. This is not the right message to send to decision makers concerned with the resilience of the financial system.

Illustration 3: Network for Greening the Financial System (NGFS)

With 127 central banks around the table, the NGFS operates in a complex political environment. This has led to the paradoxical situation where it develops a strong, and in our view adequate, narrative to describe how serious the climate and the environmental crises are and, simultaneously, derives surprisingly benign conclusions about the impact of climate change on the economy. As is the case for all modelling exercises, these conclusions are the direct result of its methodological choices. In defense of the NGFS, we are conscious that it operates in an environment where considering a dramatic negative impact on economic growth is anathema and that it repeats on many occasions warnings on the methodological limitations of the quantitative exercises it runs. However, we argue that its choice of models and its use of debatable and (very) partial assumptions when it simulates the impact of climate change on the economy have the result of making the NGFS an alibi for those who refuse to look the reality of the economic consequences of climate change in the eyes. Unfortunately, the methodological warnings to be found in NGFS literature do not make this situation any better as those warnings are simply forgotten or neglected by all those who are too happy to keep the conclusions without the caveats. Only a more diverse choice of models and a use of more realistic assumptions leading to plausible results would make a difference.

Examples:

- GDP losses calculated by the NGFS are based on the methodology set out in Kalkhul and Wenz (2020)[34] for which damages are a quadratic function of the warming level (i.e. a function treating unrealistically the damages as a function of the change of temperature squared) and which, unsurprisingly given this latter characteristic, concludes that *"an increase in global mean surface temperature by about 3.5°C until the end of the century would reduce global output by 7–14% in 2100"*.

  → This defies the findings of climate scientists and does not pass the common sense filter we discussed previously.

- NGFS's simulations rely on Integrated Assessment Models (IAMs) and Computable General Equilibrium (CGE) models[35] which rely themselves on a general equilibrium logic.

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33 European Central Bank, *2022 climate stress test*

34 Kalkhul and Wenz, '*The impact of climate conditions on economic production*', Journal of Environmental Economics and Management, 2020

35 NGFS, '*Guide to climate scenario analysis for central banks and supervisors*', June 2020

→ The general equilibrium logic is by definition not fit for the purpose of this exercise: climate change is the biggest disruptive event ever experienced by human societies and human-built economies and, as discussed above, it will not lead to a state of general equilibrium.

- NGFS's *"methodology does not include impacts related to extreme weather, sea-level rise or wider societal impacts from migration or conflict"*[36] leading to the estimation that *"the impacts on the economy will be modest, and even positive depending on how smoothly the transition occurs"*.[37]

  → Looking at the impact of climate change without including *"the impacts related to extreme weather, sea-level rise or wider societal impacts from migration or conflict"* is most surprising. What is the point of trying to estimate the impact of climate change without looking at extreme weather, sea-level rise and their human consequences? Isn't climate change about extreme weather, sea-level rise and wider societal impacts from migration or conflict? It is incomprehensible that the NGFS should not consider sea-level rise while describing the hot house scenario… as characterized by sea-level rise.[38] No wonder it concludes with only modest or even positive impacts on the economy.

- By the NGFS's own admission, *"Carbon Dioxide Removal (CDR) assumptions play an important role in IAMs"*.[39] Depending on the models used, NGFS CDR assumptions go from (almost) zero today to between 3 GtCO2 and 6 GtCO2 by 2060.

  → According to the first comprehensive assessment of the current state of CDR,[40] 99.9% of the 2 GtCO2 per year CDR comes from traditional land, afforestation, reforestation solutions whilst novel, i.e. technology-based, solutions (Carbon Capture and Storage, Direct Air Carbon Capture and Storage…) represent today only 0.1% of CO2 of emissions (i.e. 0.002 GtCO2). The report sums up the CDR gap facing the world as follows: *"Closing the CDR gap requires rapid growth of novel CDR. Averaging across scenarios, novel CDR increases by a factor of 30 by 2030 (and up to about 540 in some scenarios) and by a factor of 1,300 (up to about 4,900 in some scenarios) by mid-century. Yet no country so far has pledged to scale novel CDR by 2030 as part of their Nationally Determined Contribution, and few countries have so far published proposals for upscaling novel CDR by 2050."* How does the NGFS expect us to believe under these conditions in its *"CDR assumptions (that) play an important role in (the) IAMs"* it uses? The probability that (on paper indispensable) CDR novel

36 NGFS, '*NGFS Climate Scenarios for central banks and supervisors*', June 2021, page 30

37 NGFS, '*NGFS Climate Scenarios for central banks and supervisors*', June 2021, page 4

38 According to *NGFS Scenarios portal*, the hot house scenario is characterised as follows: "Critical temperature thresholds are exceeded, leading to severe physical risks and irreversible impacts like sea-level rise".

39 NGFS, '*Climate scenarios for central banks and supervisors*', September 2022, page 28

40 '*The State of Carbon Dioxide Removal*', January 2023

solutions will be deployed at scale by 2030 / 2050 is puny.

Illustration 4: Financial Stability Board (FSB)

The remarks made by the FSB on pages 7 and 8 of its publication 'The implications of Climate Change for Financial Stability'[41] are worth a careful consideration:

- *"Central estimates of the impact of physical risks on asset prices appear reasonably contained, but vary considerably with the expected degree of global warming. Under a scenario where the increase in global mean temperature above pre-industrial levels is likely to remain within 2ºC, estimates of the mean reduction in global financial asset values are between 0.7 and 4.2% (US$1–6tr), depending on the study and discount rate. Under a 'baseline' scenario in which policies to mitigate climate change that were in place in 2010 are extended indefinitely but there is no additional action to reduce emissions, the expected temperature increase is around 4ºC and the estimated mean reduction in asset prices is between 2.9% and 9.7% (US$4-14tr), depending on the chosen discount rate. Other studies based on different methodologies estimate central case outcomes for a reduction in financial asset values that are of a similar order of magnitude.*

  The uncertainties associated with the future path of climate change and its impact on asset prices mean that these potential outcomes are subject to considerable tail risk. For example, while the central estimate of the reduction in asset prices associated with a 2.5ºC increase in temperatures by 2105 is relatively modest (i.e. 1.0-1.8%), it is estimated with 5% probability that it could exceed 4.8%, and with 1% probability that they could exceed 16.9% (US$24tr). Under the baseline scenario, the most severe reported reduction in asset prices are 30.1% (US$43tr), which occurs with a 3% probability by 2105 under an assumed low discount rate.

  An acceleration in the progression of climate change, and in the manifestation of physical risks, could have a destabilising effect on the financial system. The studies discussed above assume that increased physical risks will materialise gradually over time, with the majority of the impact on asset prices occurring in the latter half of the 21st century. Such a reduction in asset prices may, however, occur suddenly and be more likely to have a destabilising effect on the financial system. This could arise in part from how the dynamics of climate change may be self-reinforcing. Increases in global temperatures may have positive feedback effects, whereby a small perturbation in temperatures alters the dynamics of climate in a way that causes further increases in temperature. This raises the possibility of rapid non-linear short-term changes in physical, ecological and societal systems due to climate risks, whose impacts would be felt far sooner, and may be greater, than those captured by some central estimates. This has led some to call for more emphasis to be placed on research about the extreme tails of distributions rather than central tendencies."

41 FSB, '*The implications of Climate Change for Financial Stability*', November 2020

- The headline estimate coming out of the FSB assessment (the one everybody quotes, remembers and refers to) is that a temperature increase of 2.5°C will decrease asset prices between 1.0% and 1.8% and 4°C between 2.9% and 9.7%. Needless to say that these estimates do not pass the 'compatibility-with-climate-science' test: who can believe that the end of the economic world as we know it would trigger such ridiculously low decreases of asset prices?
- Using traditional normal distribution arithmetic, a daily asset price decline of 1.0% corresponds to an annualized volatility of approximately 16%, and a 1.8% decline a 29% volatility. As these levels read like the range of usual stock market volatility, the FSB estimate sends the implicit message to asset and risk managers that climate change means business as usual and that there is nothing special to worry about when it comes to asset prices (a one standard deviation market event taking place in several years' times or decades is not worth one minute of the time of an asset manager).
- The FSB uses probability estimates that make no sense in the context of climate change: what is the true probability distribution of the events contemplated? Normal? Log-normal? Poisson? There is obviously no answer to this question given the characteristics of climate change. Using probabilities in this context is mathematically nonsensical and it gives an unfounded (and therefore dangerous) sense of security to decision makers acting on the basis of the analysis conducted by the FSB.
- The FSB combines a lenient 'nothing to worry about on physical risk before the latter half of the 21st century' with a warning about possible accelerations. However, given that such an acceleration would mean concretely going from +2.5°C to +4°C more quickly than expected, and given that the FSB estimates that a +4°C increase in temperature would mean an easily absorbable 3% to 10% decrease of asset prices, the net effect of this additional message is to double down on the initial 'nothing special to worry about' message (notwithstanding the fact that many other non-climate-related events with an impact of 3% to 10% on financial markets will occur before the latter half of the 21st century).

4 – Lack of common sense (again)

Considering climate change-related disruption risk and its economic or financial consequences necessitates common sense. The key question we should be asking ourselves is whether the results we are deriving from sophisticated economic modelling exercises are plausible given what climate scientists tell us and what we can observe.

Bringing in disruption risk as a dimension of the analysis of the impact of climate change on the economy is about asking simple questions such as: *"Are the conclusions of the analysis conducted compatible with the fact that 3.5 billion people live in zones that are highly vulnerable to climate change, which could make them uninhabitable over the coming decades?"*, *"Is the low impact predicted by economists compatible with the floods, droughts, wildfires, rising sea levels, disruption of food chains and pandemics predicted by the IPCC as a consequence of climate change?"* or *"Will human societies*

keep functioning given the inevitable human struggles for habitable space and clean water that will accompany global warming?". Despite the growing evidence of the disruption of the world brought by climate change, simple questions such as these have still not found their way into economists' predictions and supervisors' scenario analyses. Asking those questions is not about being pessimistic, it is about using judgement as a sanity check when we are confronted with the results of sophisticated quantitative exercises which we tend to take religiously as undisputable truths.

All in all, recognising disruption risk is about preparing our economies and our financial system for the reality that human societies will be increasingly facing as years go by. Not recognizing the risk of climate-induced disruption and deriving benign economic consequences from climate scenario analyses distorts the debate on the cost of combating climate change and, subsequently, gives the wrong information to political and economic decision makers who need to take action today. Climate scenario analyses that quantify the consequences of climate change on financial institutions' balance sheets in basis points or assume economic growth, i.e. the exact opposite of disruption, feed flawed cost-benefit analyses where the cost of investing today to combat climate change is considered but the costs that will be incurred tomorrow in the absence of meaningful action are grossly underestimated. This a recipe for ill-founded decisions or inaction and will feed future disasters.

II. The EU one-off scenario analysis exercise as a unique opportunity

The EU one-off scenario analysis exercise is a unique opportunity to prepare the financial system for the consequences of climate change, but only if it is looking for the right things.

In March 2023, the European Commission requested that the European Supervisory Authorities (ESAs), the European Central Bank (ECB) and the European Systemic Risk Board (ESRB) conduct a one-off scenario analysis exercise[42] to *"anticipate shocks to the financial system that could jeopardise the viability of financial institutions or the financial system as a whole, or the EU's ability to achieve its climate and environmental goals, and to be ready to react swiftly to any such adverse shocks"*.

The letter sent by John Berrigan, European Commission Director-General for Financial Stability, Financial Services and Capital Markets Union, also stated that *"Such adverse shocks may be climate-related and materialise in the form of transition risks (the impact of a switch to a more sustainable economy on financial assets) or through the impact that the anticipation of increasing physical risks may have on asset valuations."* (…) and also that *"While it will be useful to get a better understanding of how vulnerable our financial system may already be in the near term to climate-risk related shocks, we cannot assume that such shocks will only occur in a benign macrofinancial environment. It would therefore be desirable to simulate also the materialisation of climate-risk related shocks in an adverse macrofinancial scenario, possibly by combining a climate shock scenario and (elements of) adverse scenarios used in regular stress-testing exercises."*

The request to go beyond the now traditional assessment of transition and physical risks[43] and to simulate the impact of an adverse macrofinancial scenario is most welcome and potentially ground-breaking. However, this exercise, which is to be completed by Q1 2025 or earlier, runs a high risk of being another missed opportunity unless i) particular attention is paid to assessing realistically the economic damages that will stem from climate change, ii) a quantification of fossil fuel stranded assets is realised and iii) the time-horizon of the exercise is extended.

a. Specifying the exercise

We detail in this section the three points that we consider as indispensable conditions to make the EU one-off climate scenario analysis exercise useful, i.e. leading to meaningful action.

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42 European Commission, '*Request for a one-off scenario analysis exercise*', 8 March 2023

43 It must be noted that, while transition risks and physical risks have become a normal part of central banks' climate scenario analyses, most of those analyses concede that a lack of data on physical risks makes the assessment of physical risks difficult and thus prone to underestimation.

1. A realistic assessment of the economic impacts of climate change

In order to fulfil the request *"to simulate also the materialisation of climate-risk related shocks in an adverse macrofinancial scenario"* the analysis of climate change-related economic impacts must in our view meet the following conditions:

- At least three different models integrating quadratic, exponential and logistic damage functions must be run in parallel, unless justified (see below), in a comply or explain logic.
- The suitability of the models and the damage functions chosen must be explained in detail and made transparent. The explanation must include, among other things, a demonstration of the ability of the models and damage functions chosen to capture the specificities of climate change, and in particular the change in acceleration around tipping points.
- If any of the three families of damage functions (quadratic, exponential and logistic) is not used, the choice must be justified.
- All economic and macrofinancial simulations must be tested for plausibility against the result of the research conducted by climate scientists. For instance, simulations resulting in moderate or relatively moderate GDP decreases for global warming scenarios that climate scientists describe as *"catastrophic"*, *"beyond catastrophic"*, *"unpredictable consequences"* or including *"existential threats"* must be systematically filtered out or, if kept, duly justified.
- The result of the different simulations conducted must be made transparent.
- The conclusions and recommendations of the one-off scenario analysis exercise must be based on the simulation giving the central damage results. If only two simulations have been run, the conclusions and recommendations must be based on the most adverse damage function output in coherence with the precautionary principle established by Article 191 of the Treaty on the Functioning of the European Union (TFEU).[44] It will be most important for the three ESAs, the ECB and the ESRB to consider this particular point when they conduct the exercise as Article 191 TFEU makes the precautionary principle a legal obligation and refers explicitly to *"in particular combating climate change"*.

2. Quantifying exposures to fossil fuel assets at risk of stranding

In order to fulfil the request to estimate the *"adverse shocks (that) may be climate-related and materialise in the form of transition risks (the impact of a switch to a more sustainable economy on financial assets) or through the impact that the anticipation of increasing physical risks may have on asset valuations"*, the analysis must result in a precise assessment of the future fossil fuel stranded assets exposures (and thus of their converse, i.e. assets related to exploitable fossil fuel resources) of financial institutions.

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44 *Article 191 of the Treaty on the Functioning of the European Union*

Many economic assets may suffer stranding because of climate change in the future,[45] but the biggest and most direct risk for financial stability arises from the stranding of fossil fuel assets. Therefore, estimating the level of fossil fuel assets sitting on the balance sheets of financial institutions that will be stranded if the global carbon budget is maintained in the future is an absolute priority and a minimum baseline for the one-off exercise. Absent this estimation, the exercise will not fulfill the stated objective of assessing *"the impact of a switch to a more sustainable economy on financial assets"*. Estimating stranded fossil fuel assets will not give the full picture of all the economic assets that will be stranded because of climate change, but as a first step it will have the double merit of addressing the most direct climate-related threat to financial stability and of being methodologically more simple (and therefore less controversial) than estimating the value of all future stranded assets in the general economy. It can be thus considered as both indispensable and feasible. Research released by Finance Watch in October 2022[46] showed that, out of the total exposure of $1.35 trillion to fossil fuel assets of the sixty largest global banks, close to $240 billion belonged to EU banks ($358 billion including the UK and Switzerland). Estimating the level of stranded fossil fuel assets of EU financial institutions comes down to confirming or refining this number, extending the exercise to insurance companies, pension funds and investment funds, and assessing the proportion of those assets that will have to remain unexploited because of climate change (as a reminder, the only possible alternative to leaving fossil fuel assets unexploited is to keep on exploiting them and thereby feed a further increase of global temperature that will inevitably lead to a total disruption of the economy and subsequently to a collapse of the value of all financial assets).

As will be shown in more detail in section III of this report, assessing the proportion of fossil fuel assets that will have to remain unexploited is a function of the level of global warming 'targeted' and of the related carbon budget (which is itself a function of anticipated annual CO2 emissions and existing fossil fuel reserves).

We recommend that supervisors take a 2°C global warming reference to estimate stranded fossil fuel assets. A 2°C reference makes sense in our view as a compromise between realism (a lower level is unfortunately unrealistic) and ambition (achieving 2°C would leave the world in a better situation than higher temperature increases and is still in coherence with the COP21 Paris Agreement of 2015).

A 2°C global warming reference would also be in line with the recommendation made by Steffen et al[47] in 2018 that *"Given the irreversible nature of these changes, and the drastic—possibly terminal—impact that they could have on human civilisation, Steffen et al. recommended a hard 2°C limit to the amount of global warming that should be*

45 See for instance, France Stratégie, '*Les incidences économiques de l'action pour le climat*', Mai 2023

46 Finance Watch, *A safer transition for fossil banking: Quantifying capital needed to reflect transition risk*, October 2022

47 Steffen, et al. 2018. '*Trajectories of the Earth System in the Anthropocene*', Proceedings of the National Academy of Sciences

tolerated". Considering the *"possibly terminal"* impact that a global warming beyond 2°C could have on human civilisation, we recommend that a high 83% probability (see page 39, below) be considered in the calculation.

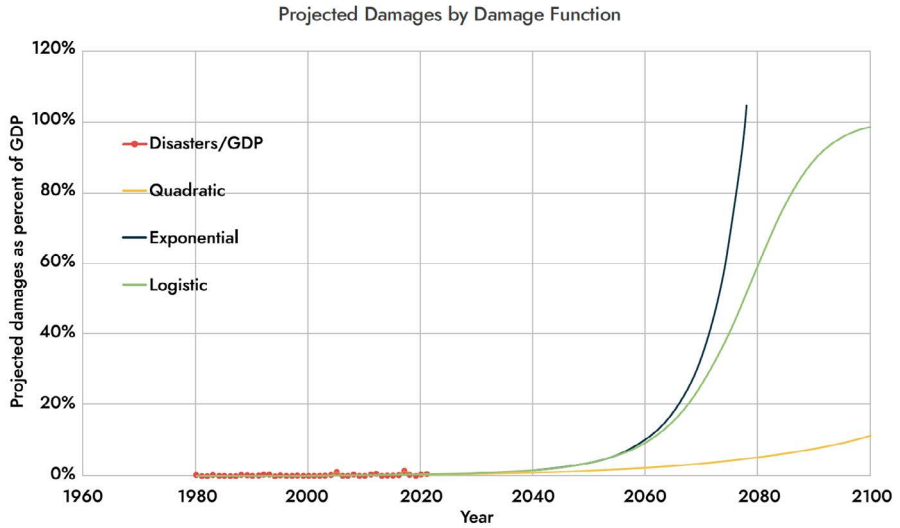
3. Revising the time horizon of the one-off scenario analysis exercise

The time horizon of the one-off scenario analysis exercise requested by the Commission must be extended if we want the exercise to be useful.

The letter addressed in March 2023 to the three ESAs, the ECB and the ESRB states that *"The Commission would welcome an assessment of the extent to which early climate risk related shocks could already generate significant stress for the financial system as a whole in the period up to 2030, taking into account contagion and second-round effects"*, that *"The Commission invites the addressees of this request to develop severe but plausible scenarios that could affect the financial system as a whole over the period up to 2030"* and that *"The Commission would welcome receiving results from this exercise ideally by the end of 2024 and in any case not later than Q1 2025, in order to provide input to the work of the new Commission."*

Figure 3, taken from Carbon Tacker's report 'Loading the DICE against pension funds' (page 39) shows clearly the reason why the time horizon of the one-off climate scenario analysis exercise must be extended beyond 2030: the climate and economic scenarios that will affect the financial system will not happen by 2030 but between 2050 and 2080 and the effect on the economy will then be extremely severe (negative GDP impact between 60% and 100% by 2080 with an increasing rate of acceleration after 2050). These forecasts are coherent with climate scientists' prediction of the acceleration of climate change-related damages with catastrophic consequences around 2°C of global warming, a level that will be reached in all likelihood around 2050.

Figure 3



Source: Carbon Tracker Initiative, July 2023

The two biggest climate-related threats to the financial system are the stranding of fossil fuel assets and the collapse of economic activity. Despite the recent multiplication of extreme weather events, we know with near certainty that stranding risk and economic collapse will not materialize by 2030. The world is unlikely to reverse its current expansion of fossil fuel consumption before that date and the collapse of economic activity induced by climate change will, as just discussed, start being significant by 2050 and accelerate to reach catastrophic levels between 2060 and 2080.

In this context, looking at *"climate risk related shocks that could generate significant stress for the financial system as a whole in the period up to 2030"* will not lead to significant conclusions. We do not need the sophisticated modelling and the huge data gathering exercise to anticipate the result of an analysis running until 2030 only: the climate change-related stress generated on the economy and on the financial system by 2030 will be almost immaterial and can be easily absorbed. Exercise done! The question is whether policy makers are interested in what will happen over the course of the coming three to five decades, not the next five years.

The choice of a 2030 time-horizon for the one-off exercise has nothing to do with climate science nor economic analysis. It is political and it sends the disturbing message that the new Commission that will start its mandate in 2025 would not be interested in the future of the EU economy and its financial system beyond the end of its mandate in 2030. What will happen to the world, to the EU, to its financial system and to its citizens beyond that date would be of no interest to the new Commission. Surely, that cannot be. The Commission cannot satisfy itself with simulations that do not spot anything because they do not look far enough to see the life-threatening danger that will strike during the lifetime of many of today's EU citizens.

b. Providing unbiased and useful analysis to investors and supervisors

Financial market investing is a game of anticipation. Surprise is its worst enemy. Putting a price on a share consists of anticipating the economic future of a company and discounting its future cash flows. Putting a price on a bond consists of calculating the probability for the issuing entity to be in a position to pay its debt back.

Reading climate scientists' literature, common sense tells us that climate change will have a very significant effect on companies' future cash flows and on issuing entities' ability to pay back their debt. Unfortunately, only a fraction of investors read climate scientists' literature, and the challenge for those who do is to convert the analysis they derive from reading climate scientists' reports into numbers and quantities, i.e. revised estimations of future cash flows and probabilities of default, that they can use to make their investment decisions.

However, even if they had that information, investors would face an additional level of complexity to integrate the economic impact of climate change into their investment decisions. Imagine an omniscient investor who would have figured out and quantified

with precision all the economic consequences of climate change on the basis of the analyses and the data available today. Imagine that this omniscient investor acts today (concretely: invests, disinvests or sells short) in line with the conviction they have has arrived at. The reality is that this investor would soon be out of a job if they were the only one to have figured out the economic consequences of climate change and acted upon their conviction. Financial market investing is a game of being right with the crowd and, ideally, an instant before the crowd (but an instant only as performance is judged on very short periods of time) in order to ride the market and capture the benefit of a position taken. 'The market is always right' goes the adage.

This phenomenon explains the well-known herd behaviour encountered in financial markets. It also explains the possibility of 'Minsky moments' which are moments when investors wake-up together to the same negative reality and act in sync, thereby feeding pro-cyclical behaviour (stampedes) and market crashes.

A reality little understood by economic decision makers is that the only way to avoid pro-cyclical behaviours (crashes) in financial markets is not to retain information but, on the contrary, to inform investors and financial market participants with sufficient lead time to allow them to make informed decisions without panic. This is where today's analyses estimating the impact of climate change on the economy in the second part of the 21st century take all their importance.

We still have the time to release meaningful and realistic analyses on the economic impact of climate change without provoking a panic on financial markets. This opportunity should not be missed as it will not last and the alternative can only be a brutal readjustment of market prices in the future. Concretely, this will require to provide adequate information both to the investing community (institutional investors, pension funds, asset managers, retail investors and pension holders) and to supervisors.

The minimum adequate climate change-related information provided to investors and supervisors should consist of a realistic assessment of climate change-related economic impacts and of a quantification of the stranded fossil fuel assets borne by investment portfolios. Killing two birds with one stone, this information can be provided by the EU's one-off scenario analysis exercise if our proposals for this exercise are followed.

Providing adequate information to investors is essential for them to make informed decisions, which obviously includes the liberty to act or not on the information provided. To take but one example of decisions not taken on the basis of adequate information, we invite the reader to refer again to Carbon Tracker's 'Loading the DICE against pension funds' report which shows how the fact that pension fund trustees can be misinformed by consultants about the economic consequences of climate change leads to a situation where long-term investments are made without considering the biggest long-term financial risk the world is facing, thereby putting UK pensioners' money at risk. Providing this information to investors would allow financial markets to gradually and smoothly price-in climate risk, thereby avoiding a dreaded and brutal future 'Minsky moment'.

Providing adequate information to supervisors is also indispensable if we want them to be able to anticipate financial crises and manage them when they happen. The (other) inconvenient truth is that today's situation is pretty grim on that front: to our knowledge, supervisors today (at least in the EU and with few reasons to believe the situation is better in other jurisdictions) are not monitoring the financial risk that climate change presents to the entities they supervise or the financial system as a whole. Worse: in the EU, supervisors (whether National Competent Authorities or European Supervisory Authorities) do not even have access to information regarding the exposures to fossil fuel assets of the entities they supervise.[48] This has the consequence that they are unable to anticipate or manage the risk of fossil fuel stranding threatening financial market participants and financial stability. This is most problematic given the mandate they have to look after the integrity of the financial system. Providing this information to supervisors would allow them to stop driving blind on the subject of climate risk and fully do their job as guarantors of the integrity of the financial system and of financial stability. With that objective in mind, EU law should be amended to include stranded fossil fuel assets estimation in the reporting requirements to Competent Authorities for all regulated financial institutions, including alterative investment funds regulated by AIFMD[49] and UCITS.[50] We will see in the third part of this report that this information would also be necessary for macroprudential supervisors to apply a new macroprudential tool in the form of a loan-to-value limit linked to exploitable fossil fuel assets.

In summary, if conducted according to the three principles we propose (realistic assessment of climate change-induced economic impacts, quantification of fossil fuel stranded assets and adequate time-horizon), the results of the EU one-off scenario analysis exercise and its macrofinancial simulation can constitute the reference for all future public and private decisions with a climate change-related risk dimension. This would be a game changer for decisions related to functions or tasks as diverse as microprudential or macroprudential supervision, risk management of private or public financial institutions, investment decisions by assets owners or asset managers, as well as the indispensable information of retail and professional customers of financial institutions, asset owners, asset managers and pension funds.

The EU one-off scenario analysis exercise is a unique opportunity to prepare the financial system for the consequences of climate change, but for that objective to be met we need to ensure it looks where we need it to look.

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48 As a testimony to this reality, the reader can refer to the '*Troisième rapport commun ACPR-AMF: Suivi et évaluation des engagements climatiques des acteurs de la Place*' published in October 2022 which states page 54 that "Deux sources de données ont été utilisées pour le calcul des expositions au charbon d'une part, et aux entreprises pétrolières et gazières d'autre part : les données d'URGEWALD (Global Coal Exit List pour le charbon, Global Oil and Gas Exit List pour le pétrole et le gaz) et celles de TRUCOST". By their own admission, the French supervisors do not have the data regarding the exposures to fossil fuel assets of the entities they supervise.

49 *Directive on Alternative Investment Fund Managers*

50 *Directive (…) relating to Undertakings for Collective Investment in Transferable Securities (UCITS)*

III. A new macroprudential tool to manage climate risk

Climate change will create systemic threats for the financial system. We propose a new macroprudential tool to help address this.

a. The challenge of addressing climate-related risks with existing macroprudential tools

Climate change is broadly recognised today by central bankers, supervisors, international organisations, academia and civil society organisations as a systemic risk threatening financial stability.

Paul Hiebert and Pierre Monnin summarise the situation neatly in the introduction to their paper on 'Climate-related systemic risks and macroprudential policy'[51] published in August 2023:

"Climate change and the transition to a net zero economy have a clear systemic dimension. Their consequences not only affect all agents in the economy, across sectors and regions, but they can also be amplified by financial system spillover effects and interlinkages (FSB, 2022). Additionally, climate-related risks build up and embed irreversible financial risks in the financial system, although the exact outcomes, time horizon and future pathways are uncertain – even if the overall trend of global temperature rise is to a large extent foreseeable (NGFS, 2019). The resulting potential systemic risk for the financial system has been highlighted by almost all international and national financial supervisors".

Finance Watch has worked on the risk that climate change represents for financial stability and on its systemic nature since the launch of its report 'Breaking the climate-finance doom loop'[52] in June 2020. Since then, the increase in the number of voices describing why and how climate change represents a threat to financial stability has been remarkable and the debate has evolved from whether climate change represents a risk for financial stability to quantifying the level of that risk in order to calibrate the right level of policy intervention and design the adequate tools to tackle it. In its 'Breaking the climate-finance doom loop' report, Finance Watch proposed an easy and effective microprudential solution to the problem, but this avenue was turned down by the EU co-legislators who, despite the evidence of the risk and the simple solution they had at their disposal to tackle it, decided not to adapt the Capital Requirement Regulation

51 Hiebert – Monnin: '*Climate-related systemic risks and macroprudential policy*', August 2023

52 Finance Watch, '*Breaking the climate-finance doom loop*', June 2020

and Solvency II when they had the opportunity to do so.[53] Remarkably, this political decision was taken after two and a half years of discussion and despite the recognition in April 2021 by an international panel of 50 banks, academics, regulators, investors and NGOs that Finance Watch's policy proposals on the subject were the most impactful and feasible to tackle the link between climate change and financial instability.[54] With microprudential solutions to tackle the risk between climate change and financial stability out of the way in the EU for the foreseeable future after this missed legislative opportunity, the macroprudential approach is taking even more importance.

Types of prudential tools

Prudential regulation aims to reduce the risk of financial instability. Financial policy makers and supervisors use a variety of tools for this, which fall into two broad categories.

- Microprudential tools aim to address risks at financial institution level. An example is risk-based capital requirements, which require banks to use more equity to fund their riskier assets, such as loans to customers with a low credit rating.
- Macroprudential tools aim to address system-level risks that affect all financial institutions. An example is the countercyclical buffer, which requires all banks to raise or lower their overall levels of equity funding depending on where we are in the financial cycle.

A number of high quality papers from reputable authors and institutions have emerged over the past two years on the possibility to use and, as the case may be, to adapt the macroprudential toolkit to address climate change-related risks. Among those papers, the following non exhaustive list can be noted:

Pierre Monnin, 'Systemic Risk Buffer – The Missing Piece in the Prudential Response to Climate Risks', June 2021[55]

FSOC, Report on Climate-Related Financial Risk, October 2021[56]

Alexander Barkawi, 'Bridging the Disconnects – From Diagnosis to Action in Addressing Climate-Related Financial Risks', October 2021[57]

53 European Parliament ECON Committee vote on 24 January 2023. See Finance Watch: '*ECON Committee Puts Interest of Banks above European Citizens*'

54 UNEP FI, Climate Safe Lending Network, '*Aligning finance for the net-zero economy*', April 2021

55 CEP, *Systemic Risk Buffers* – The Missing Piece in the Prudential Response to Climate Risks

56 FSOC, *Report on Climate-Related Financial Risk*, 2021

57 CEP, *Bridging the Disconnects* – From Diagnosis to Action in Addressing Climate-Related Financial Risks

ECB / ESRB, 'The macroprudential challenge of climate change', ECB/ESRB Project Team on climate risk monitoring, July 2022[58]

Paul Hiebert, 'A case for climate-related macroprudential policy', September 2022[59]

Pierre Monnin, 'Is the Current Macroprudential Framework Fit for Climate Systemic Risk', November 2022[60]

FSI Briefs, 'Macroprudential policies for addressing climate-related financial risks: challenges and trade-offs', Rodrigo Coelho and Fernando Restoy, April 2003[61]

Hiebert and Monnin, 'Climate-related systemic risks and macroprudential policy', August 2023[62]

Beyond the specific angles they take, those papers have a number of points in common: 1 – They make the point that climate change represents a systemic risk for financial stability and that macroprudential policy should address that risk precisely because of its systemic nature; 2 – They review thoroughly the macroprudential toolkit at the disposal of central bankers to tackle climate risk; 3 - Citing the newness of the subject for supervisors and a number of technical issues such as insufficient data and the risk of unintended consequences, most conclude with the difficulty of effectively using existing macroprudential tools to tackle climate-related risks. The general impression one gets from reading those papers is an odd combination of the broad recognition of climate-related systemic risks and of the necessity to use macroprudential policy to address them, of the general conviction that existing macroprudential tools are not fully adapted to do so as they were not designed to address those risks in the first place, and that designing and rolling-out new tools specifically designed for those risks will be *"challenging"* (an oft-repeated word that sounds sometimes like an excuse not to act) or even *"potentially counterproductive"* (a clear open door to all those who will not want to act).

The paper 'Climate-related systemic risks and macroprudential policy' by Paul Hiebert and Pierre Monnin (August 2023) represents, in the wake of the other papers by the same authors on the subject, an important evolution. Despite its recognition of the challenge of designing new macroprudential tools to address climate-related systemic risks, it describes the possible adaptation of existing macroprudential tools, namely the deployment of a 'systemic risk buffer' (SyRB) for climate-related risks and 'climate-related risk concentration limits'. Hiebert and Monnin also call for such tools to be rolled-out as swiftly as possible by macroprudential authorities.

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58 ECB/ESRB, *The macroprudential challenge of climate change*, 2022

59 VOXEU/CEPR, *A case for climate-related macroprudential policy*, 2022

60 CEP, *Is the Current Macroprudential Framework Fit for Climate Systemic Risk?*, 2022

61 FSI, *Macroprudential policies for addressing climate-related financial risks*: challenges and trade-offs, 2023

62 INSPIRE, *Climate-related systemic risks and macroprudential policy*, 2023

We find Hiebert's and Monnin's approach particularly promising. Going one step further and building on their rationale, we make in the following section a concrete proposal to develop a new macroprudential tool that would fit with their logic of developing a systemic risk buffer for climate-related risks along with climate-related risk concentration limits. The general idea of the new tool we propose is to activate a systemic risk buffer when a certain threshold of well specified climate-related risk has been reached.

b. Designing a new macroprudential tool for climate-related risk

Designing a new macroprudential tool to tackle climate-related risks must, in our view, meet certain specifications. It should:

1. be effective to absorb the climate-related risks present in the financial system;
2. be effective to limit the build-up of climate-related risks in the financial system;
3. be novel enough to be adapted to the specificities of climate-related risks;
4. be traditional enough in its principle to be adopted and implemented without difficulty by supervisors;
5. be pragmatic enough to focus on the main source(s) of climate-related financial instability, even if it does not address the entirety of the risks;
6. be based on data available to supervisors.

With these specifications in mind, we propose to extend to fossil fuel financing the loan-to-value (LTV) approach familiar to supervisors as a macroprudential tool to manage real estate risk, with the LTV threshold triggering a capital surcharge.

We first describe the mechanism and then look to what extent this new macroprudential tool meets the specifications listed above.

1. The use of loan-to-value limits by macroprudential authorities in the real estate market

Fossil fuel financing, like real estate financing, is about financing assets. In the world of asset financing the most fundamental risk management rule is to ensure a reasonable relationship between the amount of financing provided and the economic value of the asset(s) financed.

In the real estate market, a loan-to-value (LTV) ratio of 80% is usually considered as the upper prudent limit for a bank extending a mortgage, and banks will seek in many cases to respect a lower ratio. Historically, macroprudential authorities over the world have imposed LTV limits between 40% and 100% on mortgage lending, with variations depending on the economic circumstances of the markets, the periods in the real estate economic cycle and the quality of the borrowers. At the time of writing, most real estate LTV limits are between 70% and 85%.

2. Rationale and description of a loan-to-value ratio linked to exploitable fossil fuel assets (LTV_{expl})

Fossil fuel reserves have a characteristic linked to climate change that will have a drastic (and growing) impact on their value as years go by. If the world wants to limit global warming, it will have to stop exploiting the majority of the proven reserves of fossil fuel in the world (climate change is fundamentally a fossil fuel problem) and the unexploited reserves left under the ground will, by construction, lose their economic value. This stranded fossil fuel assets situation, first described in a research paper by Carbon Tracker and the Grantham Research Institute in 2011,[63] is today undisputed in the academic, central banking and climate scientist communities.

The economic value of fossil fuel assets follows a binary path: fossil fuel reserves that will be exploited have a value and will keep it; fossil fuel reserves that will be left unexploited (be stranded) will eventually have no value.

For the oil and gas industry, this is traditionally only a question of whether the reserve is geologically accessible and commercially viable. We define the 'exploitable value' of fossil fuels differently, namely as the value of the reserves that can be exploited if humanity wants to limit global warming to a certain level. For instance, if we follow the estimate of Climate Change Tracker that 77% of proven fossil fuel reserves should be left under the ground in order to limit global warming to 2°C with an 83% probability (see the following section for more detail), the exploitable value of fossil fuels would be (100% - 77%) = 23%.[64]

Given that only the exploitable portion of a fossil fuel reserve will continue to have value when action is finally taken to limit global temperature increases by curtailing fossil fuel use, fossil fuel financing should, in a macroprudential logic, be constrained by a loan-to-value mechanism, very much like real estate financing is. This is sound, basic risk management.

To illustrate how it could work, the value of a proven fossil fuel reserve, V_{proven}, would be reduced to its exploitable value, V_{expl}, by multiplying it by a percentage determined by a supervisor as suitable for a given temperature increase (for example, 23% for a target of +2°C). We then define a loan-to-value (LTV) ratio to constrain lending around that level. We call this ratio LTV_{expl}.

With that new tool in hand, macroprudential authorities would be in a position to take action when a LTV_{expl} threshold is breached. We propose to set the LTV_{expl} threshold at 100%, with a capital surcharge applying if the loan exceeds that threshold.

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63 Carbon Tracker, *Wasted capital and Stranded Assets*, 2013

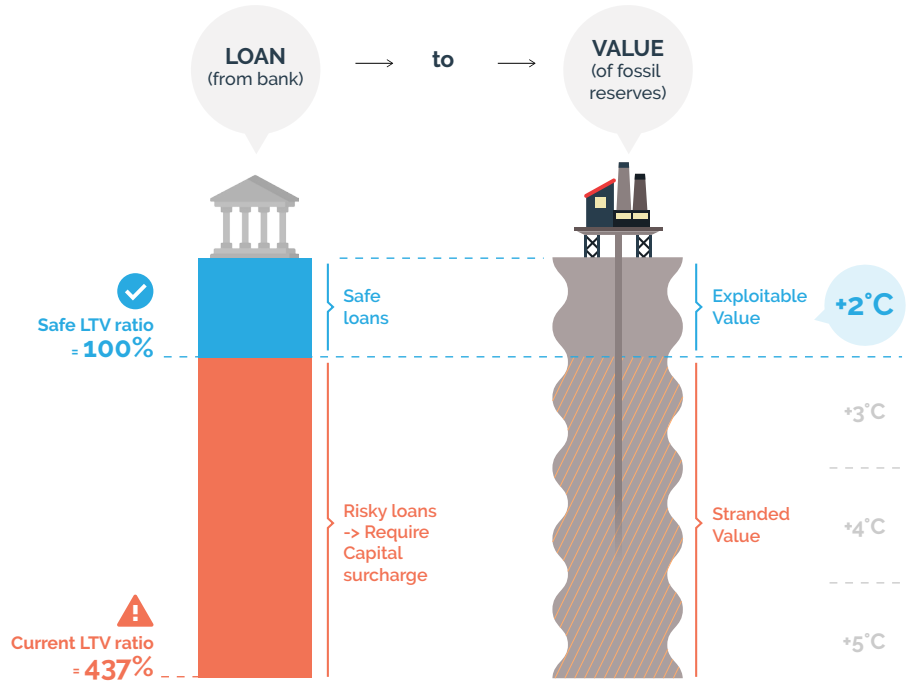
64 The exploitable value is therefore the converse of the stranded value, with the stranded value in this example being 77%

Illustration of LTV_{expl}	
Value of proven fossil fuel reserve (V_{proven})	**100**
Supervisory percentage of exploitable fossil fuel, for a target of 2°C	**23%**
Exploitable value of fossil fuel reserve (V_{expl})	**23**
LTV_{expl} threshold	**100%**
Max. loan amount within LTV_{expl} threshold (100% x 23)	**23**
Max. loan amount above LTV_{expl} threshold (triggers macroprudential tool)	**77**

As the purpose of this macroprudential tool is to address a systemic threat, it would apply equally to all bank fossil fuels exposures, regardless of how easy or difficult they are to exploit. Lenders would still need to adjust for asset-level variations in credit risk and other factors through their normal risk management and capital assessment procedures.

Figure 3

USING A LOAN-TO-VALUE RATIO (LTV) TO ASSESS FOSSIL FINANCE INDUCED MACROPRUDENTIAL RISK



3. Calibrating a loan-to-value ratio linked to exploitable fossil fuel assets (LTV_{expl})

Estimating the amount of fossil fuel assets that will be stranded in the future (or, its converse, the fossil fuel assets that will be exploited before the game ends) is a function of three parameters: i) the amount of current proven fossil fuel reserves; ii) the choice of a 'target' global warming limit; iii) the degree of confidence desired to remain below the targeted global warming limit, expressed as a probability.

In 2022, Climate Change Tracker[65] estimated that, expressed in billions of tons of equivalent CO2 (Gt CO2), the planet's carbon budget to limit global warming with an 83% probability was 100 GtCO2 for 1.5°C, 350 GtCO2 for 1.7°C and 800 GtCO2 for 2°C.[66]

According to the United Nations, global fossil fuel reserves stand today at 3,500 GtCO2.

Combining the two sets of data, we conclude in a first approach that 97% of the world's fossil fuel reserves (3,400 out of 3,500 GtCO2) would have to be left under the ground if humanity wants to limit global warming to 1.5°C with an 83% probability, 90% (3,150 out of 3,500 GtCO2) to limit global warming to 1.7°C and 77% (2,700 out of 3,500 GtCO2) to limit global warming to 2°C.

These numbers have only the ambition of sharing a logic and giving orders of magnitude, which we believe they do. The actual assessment of stranded and, in the same exercise, exploitable fossil fuel assets would require the input of independent climate scientists and energy specialists and to decide on the numbers that will serve as the base for macroprudential supervisors to set LTV_{expl} limits. This exercise should be part of the EU one-off climate scenario exercise that we discussed in the second part of this report.

For reference, a number of important papers share different methodologies for estimating stranded fossil fuel assets.[67] Some of them distinguish between coal, oil and gas and derive different numbers for these three categories of fossil fuel. Under the benefit of further investigation, this logic will probably make sense when it comes to deriving numbers usable by macroprudential supervisors.

We recommend taking a 2°C global warming reference to calibrate LTV_{expl} (see the second part of this report dealing with the EU one-off scenario analysis exercise). This would be coherent not only for the reasons already mentioned (compromise between realism and ambition as well as coherence with the COP21 Paris Agreement), but also because it would allow the assessments made in the context of the EU one-off scenario analysis exercise to feed directly into the work of macroprudential supervisors.

4. What macroprudential measures should be taken on the back of an LTV_{expl} limit?

On the back of an LTV_{expl} limit set at 100%, macroprudential authorities could either impose a cap or apply a capital surcharge.

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65 *Climate Change Tracker*

66 Expressed in a number of years and with annual emissions of around 40 Gt CO2 (and assuming constant emissions), this translated into a carbon budget of approximately 2.5 years for 1.5°C, 9 years for 1.7°C and 20 years for 2°C.

67 See for instance: UCL, '*How much of the world's fossil fuel reserves can we afford to burn*'? , Nature Climate Change, ('*Stranded fossil-fuel assets translate to major losses for investors in advanced economies*') and IPCC (B.5.2), '*Climate change 2023 – Synthesis Report*',

Using the data at our disposal, we approximate LTV_{expl} to be currently standing at 437% (3,500 GtCO2 / 800 GtCO2). In that context, a cap at 100% would not be enforceable. Pragmatically, we therefore propose to apply a capital surcharge for the part of fossil fuel assets that will end-up stranded (2,700 GtCO2 to limit global warming to 2°C with an 83% probability).

The principle of this new tool is to activate a systemic risk buffer beyond the LTV_{expl} 100% limit, with LTV_{expl} playing the role of the climate-related threshold triggering the capital surcharge.

Macroprudential authorities could impose on banks a systemic risk buffer defined as a capital requirement of 12% (150% x the standard Basel capital level of 8%, knowing that the Basel Framework provides for a risk weight of 150% for exposures deemed to be particularly risky) for existing exposures beyond LTV_{expl}.

New fossil fuel exploration and production warrant a different treatment, which we suggest could be either a hard cap or full equity funding (1250% x the standard Basel capital level of 8%) if easier to implement. Such a macroprudential policy would also have the advantage of being coherent with the International Energy Agency's recommendation not to invest into further fossil fuel assets beyond what the world has already at hand.

For the record, it must be noted that a 437% loan-to-value ratio is an extremely high number and one that, to our knowledge, has never been seen in the world of macroprudential regulation (LTV limits in the mortgage market are routinely set at 80% by authorities). If a cap on further fossil fuel exposures resulting from new fossil fuel exploration and production was not to be applied by macroprudential supervisors, we would quickly reach LTV ratios of 500%, 600%... that would defy all risk management logic and inexorably lead one day to the global destabilisation of the financial system.

5. What would be the added value of LTV_{expl} limits as a borrower-based climate-related macroprudential tool?

Taking the specifications defined above one by one:

Specification 1: There is a broad consensus among central bankers that LTV limits are effective to manage risk in the real estate market.[68] Central banks find that LTV limits have a good effectiveness as they improve the probabilities of default (PD) and the loss given default (LGD) and, as the ECB[69] puts it, *"Borrower-based policies are meant to improve the quality of banks' mortgage loan portfolios through more prudent lending standards"* and comes to the conclusion that *"We find a positive impact of*

68 See, for instance: Bank of England Staff Working Paper No. 969 '*House price dynamics, optimal LTV limits and the liquidity trap*', March 2022; ECB Working Paper Series '*The effectiveness of borrower-based macroprudential policies*', March 2023; Financial Stability Institute – BIS '*Macroprudential policies for addressing climate-related financial risks: challenges and trade-offs*', April 2023.

69 ECB, *Working Paper Series*, page 3 and 21

BBMs [borrower-based measures] on the capital ratios of banking systems, compared to the "no policy" benchmark scenario. The policy impact transmits via the improvement in the credit risk parameters attached to mortgage portfolios, the associated changes in expected losses, and risk weights. The positive impact on bank capitalization is quantitatively notable, despite the partial policy transmission to bank balance sheets only via the banks' retail mortgage portfolios." What stands for an LTV limit applied to a mortgage loan would stand for an LTV_{expl} threshold applied to fossil fuel lending. The strength of LTV limits comes from their simplicity and the fact that they can be related to a risk management practice based on common sense. LTV_{expl} limits would be effective to absorb the fossil fuel stranded assets-related risks present in the financial system provided their breach leads on to appropriate measures.

Specification 2: Following the central banks' assessments quoted above and the same logic, LTV_{expl} limits would be effective to curb the build-up of fossil fuel stranded assets-related risks.

Specification 3: Climate change is fundamentally a fossil fuel problem and the main source of climate-related financial instability in relation to transition is stranded fossil fuel assets (current estimate of the risk: $1 trillion for the global banking system, of which $190 billion for the EU banking system).[70] With its stranded fossil fuel assets focus, LTV_{expl} is by construction adapted to one of the key specificities of climate change.

Specification 4: LTV limits (also called LTV thresholds) belong to what central bankers call borrower-based measures (BBM). BBMs have been implemented in many jurisdictions and LTV_{expl} limits respond to the same logic as LTV limits in the real estate market. All this will make for a familiarity of supervisors with this new instrument.

Specification 5: LTV_{expl} limits are a pragmatic proposal: they do not pretend to cover the full spectrum of the climate-related risks incurred by the financial system but they improve significantly the situation by going to the heart of the problem, i.e. dealing with the risk represented by fossil fuel stranded assets. In other words, thanks to their focus on the most direct source of climate-related financial instability they improve considerably the ability of macroprudential supervisors to manage climate-related risks even if they do not address the entirety of the risk.

Specification 6: Estimating the value of the fossil fuel reserves at risk of being stranded and its converse, the value of reserve that will be exploited (V_{expl}), will be indispensable to estimate the level of exposure of financial institutions and hence to calibrate LTV_{expl} limits. As described in this report, we believe that this can be best achieved in the course of the EU one-off scenario analysis exercise.

Putting this proposal in perspective with the preceding reflections on the use of macroprudential tools to address climate-related risks, we can see that LTV_{expl} limits are in

70 Based on 77% of $1.35 trn globally and $240 bn for the EU, see page 28 above.

sync with the logic of the dual proposal made by Hiebert and Monnin of developing systemic risk buffers and concentration limits for climate-related risks. LTV_{expl} limits can be seen as the *"novel hybrid instrument combining borrower-based and capital-based"* that Hiebert and Monnin call for[71] and they dove-tail nicely with their wish to see supervisors i) allocate the buffer across financial institutions in proportion of their exposure to climate-related risks, ii) *"focus on the highest-emitting activities at risk of imminent stranding"*[72], and iii) follow transparent rules and metrics.

71 *Climate-related systemic risks and macroprudential policy*, page 9

72 Idem, page 11

Conclusion

Climate change mitigation and adaptation must go hand in hand.

Even if it has a long way to go to be effective at scale, climate change mitigation must remain a priority, because a world at + 3°C will be better than a world at + 4°C which will be better than a world at + 5°C, etc… The financial sector has several ways to contribute to mitigating climate change and 'make the house the least hot possible', among which Finance Watch has identified[73] shareholder engagement and the systematic inclusion of climate-related covenants in the contractual obligations of loans, equity financing and other financing arrangements[74] as the simplest and most effective.

However, mitigating climate change should not distract us from adaptation, which for financial services means preserving financial stability.

The impact of +3°C temperature increases on the financial system will be considerable, so much so that it may take it down altogether if we do not prepare for that possibility. This is needed across the financial system, from banking to insurance and investment funds, and in all jurisdictions.

Economists who analyse the consequences of climate change must not be complicit, even if unwillingly, in the inaction bias of policy makers. They bear a responsibility to open their eyes, as well as those of the financial community, of regulators and of supervisors to the economic and financial impacts of a hot house world. It must no longer be an option for economists to produce biased analyses that underestimate future costs. If economic models are not adapted, they will undermine the case for both mitigation and adaptation and make the future costs and impacts even higher.

Financial regulators and supervisors, for their part, bear the responsibility to act decisively on the basis of the unbiased analyses that we hope will soon be provided to them. With a more clear-eyed view about the future costs, they can take the prudential steps needed now to prepare the financial system.

Both responsibilities are considerable and society has a right to hold economists, regulators and supervisors to account.

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73 Finance Watch, '*The problem lies in the net*', June 2022. Pages 32 to 39

74 As proposed by Finance Watch, in order to become a reality such a mechanism would need to be imposed by law to financial institutions wishing to call themselves "green" or providing sustainable finance solutions or products ('*The problem lies in the net*', pages 36 and 37).

www.finance-watch.org

About Finance Watch

Finance Watch is an independently funded public interest association dedicated to making finance work for the good of society. Its mission is to strengthen the voice of society in the reform of financial regulation by conducting advocacy and presenting public interest arguments to lawmakers and the public. Finance Watch's members include consumer groups, housing associations, trade unions, NGOs, financial experts, academics and other civil society groups that collectively represent a large number of European citizens. Finance Watch's founding principles state that finance is essential for society in bringing capital to productive use in a transparent and sustainable manner, but that the legitimate pursuit of private interests by the financial industry should not be conducted to the detriment of society. For further information, see www.finance-watch.org

Finance Watch
Rue Ducale 67 b3
1000 Bruxelles
T: + 32 (0)2 880 0430

www.finance-watch.org

Finance Watch