1 IN 1000

HOW CLIMATE STRESS-TESTS MAY UNDERESTIMATE FINANCIAL LOSSES FROM PHYSICAL CLIMATE RISKS BY A FACTOR OF 2-3x

About 1in1000

1in1000 is a research program by 2° Investing Initiative that brings together new & existing research projects on long-termism, climate change, and (inter-)connected future risks for financial markets, the economy, and society. Its objective is to develop evidence, design tools, and build capacity to help financial institutions and supervisors to mitigate and adapt to future risks and challenges. The programme focuses on climate change (inter-) connected risks and challenges, notably risks stemming from ecosystem services and biodiversity loss, as well as risks from social cohesion and resilience. To achieve this objective, 1in1000 operates with three main areas: i) Long-term metrics; (ii) Risk (management) tools and frameworks; and (iii) Policies & incentives.

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About our funder

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Executive Summary

The current results of financial sector stress-tests or scenario analysis exercises conducted by financial supervisors and the private sector suggest that the current financial dislocation arising from physical and transition climate risks is unlikely to reach levels where this dislocation will have implications for financial stability. However, these results are based on 'central' estimates as to climate damages and broader economic losses under "hot house" scenarios.

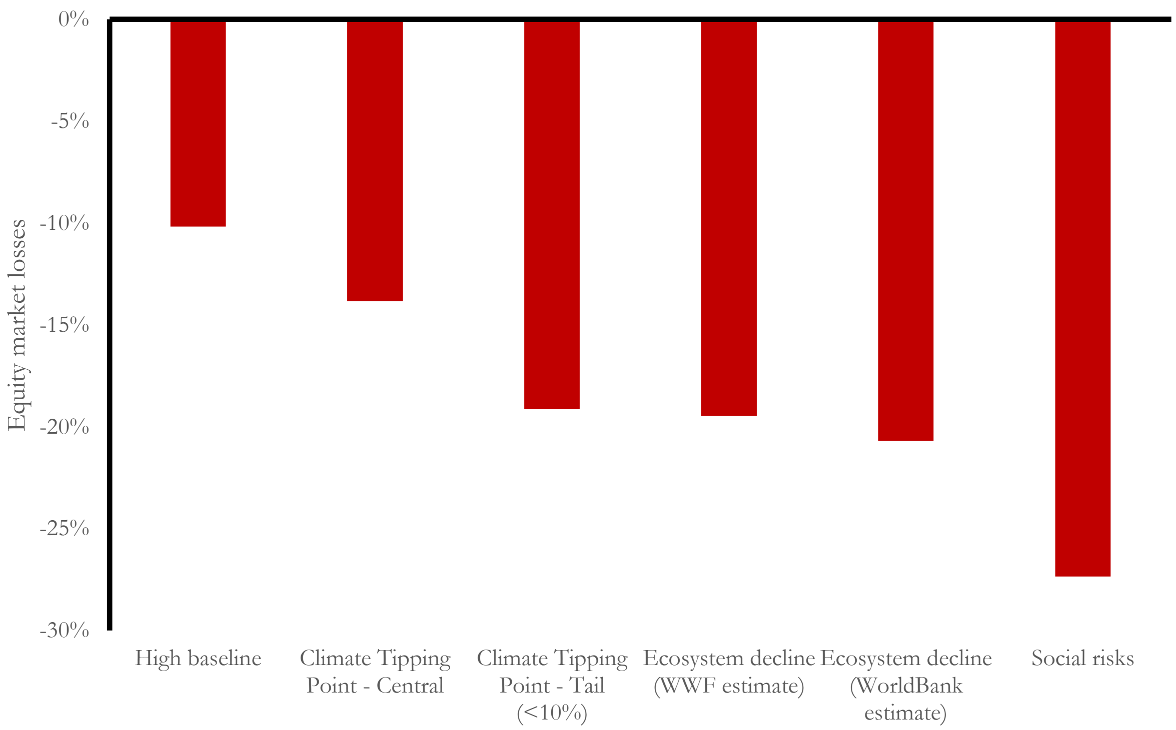
Current estimates around potential financial losses oscillate around 5-10%, although certain institutions may have higher results. More conservative estimation approaches arguably build credibility for the exercise. However, these approaches also may hide more extreme outcomes. Moreover, they typically do not account for the climate-related risks arising from shocks to ecosystem services, social conflicts, and climate tipping points.

This paper seeks to identify the potential levels of risks not captured by this approach. Climate tipping points, ecosystem decline, and social risks have the potential to amplify the financial losses in equity markets from climate change by a factor of 2.5-3.5x. Translating these losses into absolute values, potential social and ecosystem feedback loops can wipe $31 trillion off of global capital markets.

A high baseline climate risk stress-test scenario can create a 10% shock to global equity markets. A combination of climate tipping points, ecosystem decline, and social risks can increase that number to 27%, almost 3x the baseline losses. A low baseline scenario of a 4% shock in turn turns into a 14% shock when considering these other factors. These losses are dramatic as they are secular and not cyclical. It is worth flagging that this event would be unprecedented in modern financial market history.

The models and calculations used here are by design rudimentary. They are developed based on expert judgements, third-party academic and grey literature, and historical shocks involving similar events where they exist. They thus represent a first approximation rather than necessarily a complete picture.

Fig 0: Global equity market losses under a 2DII baseline (Source: Authors, based on Dietz et al. 2019, de Groot et al. 2022, SwissRe 2021, 2DII 2019)



I. Introduction

Externalities are unpriced values in the context of economic transactions (Coase 1960).

Their pricing is the responsibility of economic policymakers, unless these externalities originate within financial markets or risk management systems that fail to identify where these externalities are being internalized as a result of an economic policy response.

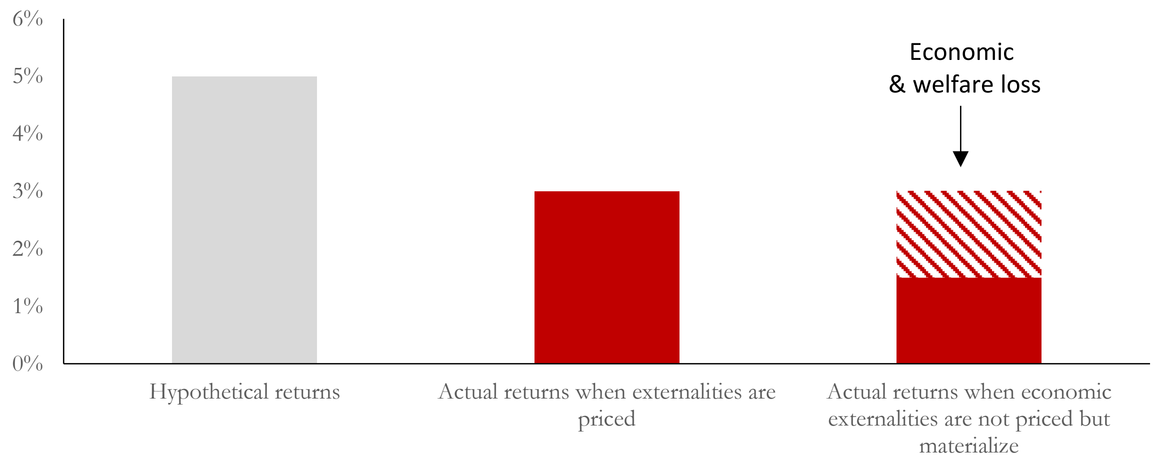
Externalities depress long-term financial returns as they result in a misallocation of capital from a macroeconomic perspective but can of course increase short- and medium-term returns for individual institutions. For externalities to have an impact, two conditions must hold.

- The externality has an economic ramification (which is not necessarily always the case, there are also non-monetary externalities);
- The non-priced externality has to be higher than the costs of avoiding the externality. An investment where total unpriced externalities represent 1% of the total investment costs may still be 'optimal' given that the investment would likely still go ahead, even if the externality was priced.

From the perspective of risk-adjusted returns in the context of climate change, this creates two potential scenarios (Fig. below).

Either policymakers require investors and banks to internalize the externality (*Actual returns when externalities are priced)* or externalities eventually materialize for the economy as a whole, depressing overall returns. In the case of the climate change, this creates an overall welfare loss since the cost of pricing externalities to the point that alternative investments become competitive is lower than the costs of letting these externalities materialize.

Fig 1: Illustrative return profiles under different externality pricing assumptions (Source: Authors)



A scenario where financial institutions operate as if they expect to achieve the hypothetical risk-adjusted returns, when in practice they should expect to realize one of the two actual returns can have two consequences:

- Lower long-term risk-adjusted returns potentially reduce the long-term resilience of the financial sector;
- A sudden internalization of externalities may create financial dislocation.

The first issue is one that warrants supervisory intervention where supervisors understand their role to ensure optimal capital allocation in financial markets from either an economic policymaking perspective and / or the objective of contributing to a more robust long-term financial sector. The second issue may be material from a financial stability perspective, depending on the overall scale of dislocation.

The current results of financial sector stress-tests or scenario analysis exercises conducted by financial supervisors and the private sector suggest that the current financial dislocation arising from physical and transition climate risks is unlikely to reach levels where this dislocation will have implications for financial stability.

Current estimates around potential financial losses oscillate around 5-10%, although certain institutions may have higher outliers. These orders of magnitude are typically those captured by traditional stress-tests and thus current capital buffers and regulatory policies suffice to ensure financial stability.

However, these estimates typically focus on long-term scenario analysis. While this is relevant to capture long-term trends, the underlying scenarios are in fact not typically extreme in the sense that they represent tail outcomes. Rather, they are typically consistent with the *central* estimates of the climate policy and modelling community around future trajectories under various scenarios. As a result, there is an inconsistency between the logic of stress-tests designed to identify potential *tail* or *low-probability* events that may be financially material, with the current suite of scenarios used in climate stress-test that in fact – for a given future (e.g. 1.5°C or 4°C) represent the central estimate as to how the future will materialize. In addition, their view of 'externalities' is narrow and does not capture the secondary effects of ecosystem decline and societal risks that may both be driven by climate change and in parallel reinforce the economic damages related to climate change.

In principle, the current approach to identify climate risk materiality on the basis of 'central' scenarios (and thus materiality that doesn't reach financial stability levels) makes sense.

In order to build credibility on the overall exercise, identify baseline trajectories under different climate futures, and ensure more robust results, given the complexity of mapping the tail events more extreme climate models identify and generate. However, these approaches also may hide more extreme outcomes. Some model approaches seek to capture second round and network effects. However, these effects are still based on an original input that is 'conservative' in the sense that they represent central outcomes under a given climate warming future.

Despite the rationale of central estimates, this paper seeks to identify the potential levels of risks not captured by this approach.

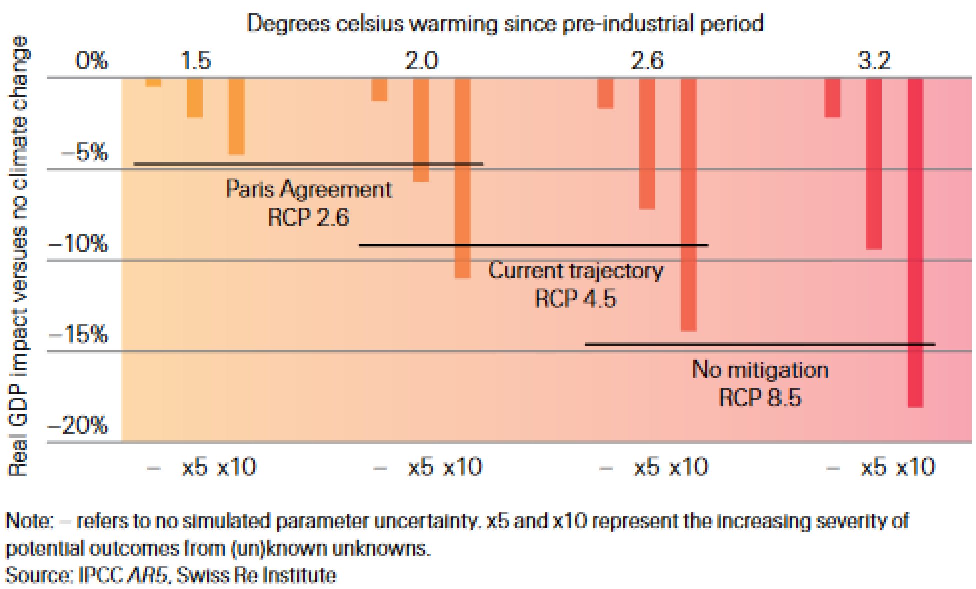
The models and calculations used here are by design rudimentary. They are developed based on expert judgements, historical shocks involving similar events where they exist, and – where information is sufficiently developed – basic credit and valuation models.

II. Approach

This paper explores the potential increased financial materiality related to what we call 'tail' physical risk scenarios based on a combination of heuristics and a simplified model approach, ecosystem decline, and societal conflict. The following summarizes the components of the model:

- **Baseline estimates.** The paper will use two baselines: The SwissRe baseline and the 2DII previous stress-test scenario baseline (2019). We use SwissRe 2021 research to identify the baseline GDP impacts of climate change by 2050 based on estimated warming of 2.3°C. SwissRe represents these estimates based on baseline projections and "(un)known unknowns" which it uses as multipliers to their projections (5x and 10x). The challenge with these multipliers is that they may duplicate partly with the issues covered in the other factors. However, overlap is likely limited given that the description does not cover the issues identified in this paper. We will use the baseline of 2°C warming by mid-century with the "moderate" multiplier of 5x (covering supply chain disruptions etc.). The more dramatic extreme scenario from SwissRe is largely consistent with the 1in1000 stress-test model from 2019 ("Storm Ahead). This scenario could thus be interpreted as being

Fig. 2: Economic impact of climate change by mid-century under various warming scenarios (Source: SwissRe 2019)

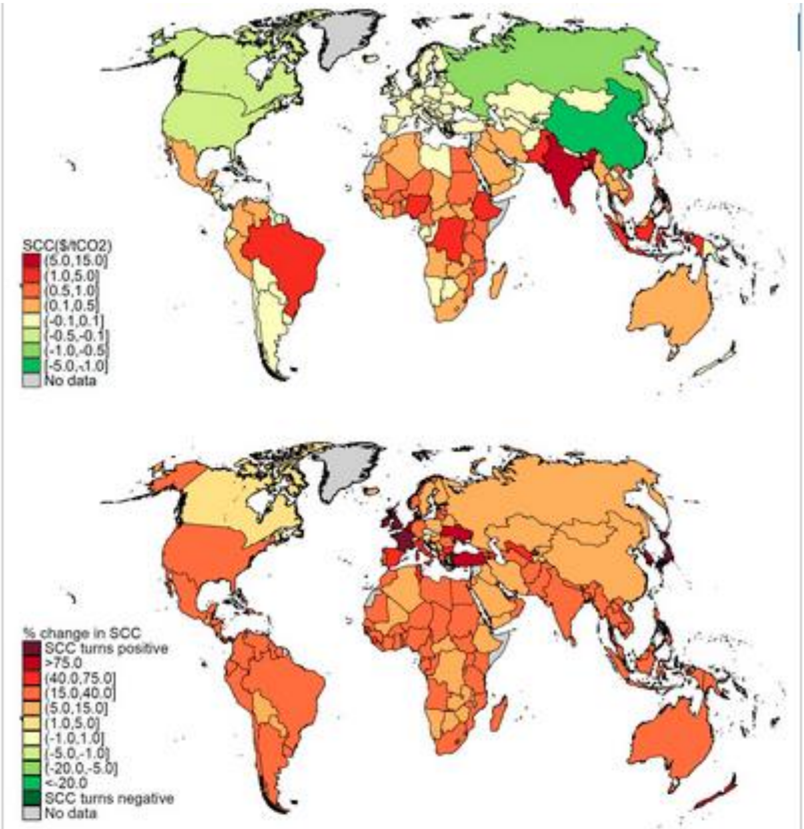


- **Tipping points:** The first component is to identify the additional ramification of so-called climate tipping points. Climate tipping points have a range of different changes to the environment and the planet's response to global warming. The additional GDP shock is extrapolated from a study by Dietz et al. that estimates the economic impacts of climate tipping points on social costs of carbon. We use the % change in social cost of carbon to suggest the additional GDP losses by 2050 relative to the baseline under their central estimate and the 10% tail probability.

  While the social cost of carbon does not equate one to one to future GDP losses, it can be used as a proxy for long-term GDP effects assuming that the stream of undiscounted damages is flat or has a shape that equates to the % uplift in 2050. The second is the % increase in marginal damages is equal to the % increase in total damages. Finally, we concentrate here the GDP impacts until 2050, which can also be contested.

  The distribution of cash flows is not provided by Diet et al., but given the assumptions above, this appears as an acceptable shorthand. While this may overstate the effects, it is worth flagging that review letters to the study suggest that it may even understate the shocks. While we recognize potential limitations to these assumptions, we consider them as a first order of magnitude relevant and appropriate. According to Dietz et al., the 2% tail probability is roughly double the 5% tail probability, so this demonstrates that even more extreme model runs are possible. This is also identified by other literature and analysis complementing that of Dietz et al. These tail probabilities it is worth noting likely represent more central estimates when considering the additional ecosystem and biodiversity ramifications associated with the tipping points materializing. While we use a global average, there are significant regional differences to the social cost of carbon which would with a more granular analysis provide more country-specific results (see Fig. below).

Fig 3: Country level impacts of climate tipping points (Source: Diet et al. 2019)



Country-level expected SCC estimates (2020 US dollars) without tipping points (Upper) and the percentage change in the expected country-level SCC due to all tipping points (Lower). Welfare changes are normalized to global mean consumption per capita. Specification comprises RCP4.5-SSP2 emissions and GDP/population growth, Hope and Schaefer PCF, Whiteman et al. beta OMH, and IPSL AMOC hosing. Monte Carlo sample size is 10,000 with 0.1% trimmed.

- **Ecosystem losses:** Projections for ecosystem losses are taken from WWF (2020) and World Bank (2021). WWF estimates are more conservative than those from the World Bank, however the World Bank estimates only go out to 2030 with subsequent assumptions around a policy response. We assume here for consistency that the effects measured by the World Bank take longer to materialize and go out to 2050. This may be a more conservative assumption as to the time horizon of the risks, but allows for more consistent and comparable analysis.

- **Social conflicts (*Social*).** The second component are social risks. We rely here on two different studies, one focused on a developed market (Northern Ireland Troubles, Dorsett 2019) and one global study from 2022 that demonstrates that over a 20-30 year period conflicts lower GDP by about 12% (de Groot et al. 2022). We take this figure as an end GDP shock and extrapolate linearly from today in terms of year on year negative GDP effects from social conflicts. This linear assumption may be contested as social conflicts may only escalate in the future and current levels of conflict may not translate to GDP effects. On the other hand, social conflicts may also escalate into more pronounced full out wars which may have more dramatic GDP effects.

These reference points are translated into financial shocks through a simple discount dividend model. The following briefly summarizes the key assumptions:

- The discount dividend model assumes a 1:1 relationship between long-term growth and long-term dividend profiles of companies. We recognize that this relationship may not hold for a number of reasons and relies on a number of key assumptions and conditions, however, there is empirical evidence for the long-run relationship at least at global level;

- We use a 4% discount rate for future cash flows. Note, results, are not very sensitive to reasonable adjustments to that assumption;

- Our baseline growth path is based on projections from the Economist Intelligence Unit of 2.5% (2020-2030); 2% (2030-2040); 1.8% (2040-2050) for an average growth rate of ~2%.

- The discount dividend model is based on a 28 year cash flow profile until 2050 and a terminal value of 0%.

- The model compounds the risks, recognizing that they may be both mutually reinforcing but also materialize in a way where the sum is less than its parts. As we seek to look at the topic from a stress-test perspective, we think this approach is appropriate.

This note will focus on potential equity losses with subsequent research set to tackle a broader universe of assets.

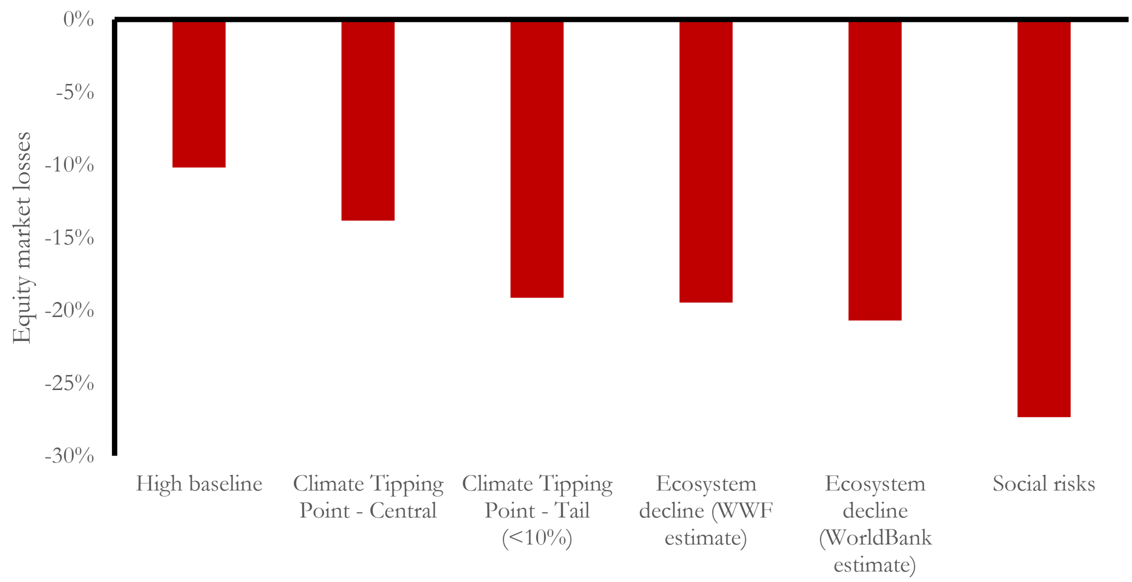
III. Results

Social and ecosystem risks have the potential to amplify the financial losses in equity markets from climate change by a factor of 2.5-3.5x.

Integrating ecosystem changes related to climate tipping and social conflicts related to global warming amplifies losses both under a low baseline climate losses scenario and a 'high' baseline as per the 2DII stress-test scenario from 2019. These losses are dramatic as they are secular and not cyclical. They represent permanent value destruction in equity markets. It is worth flagging that this event would be unprecedented in modern financial market history.

The figures below summarize the results using the SwissRe baseline and 2DII baseline reference points for losses.

Fig 4: Global equity market losses and GDP growth rates under a 2DII / SwissRe "extreme" baseline (Source: Authors, based on Dietz et al. 2019, de Groot et al. 2022, SwissRe 2021, 2DII 2019)



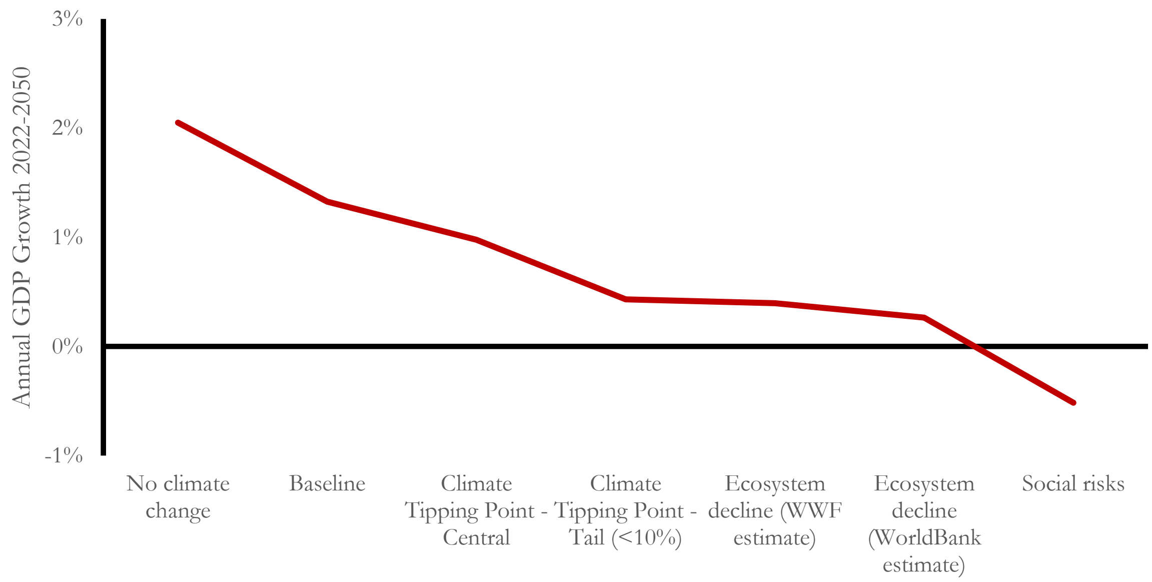
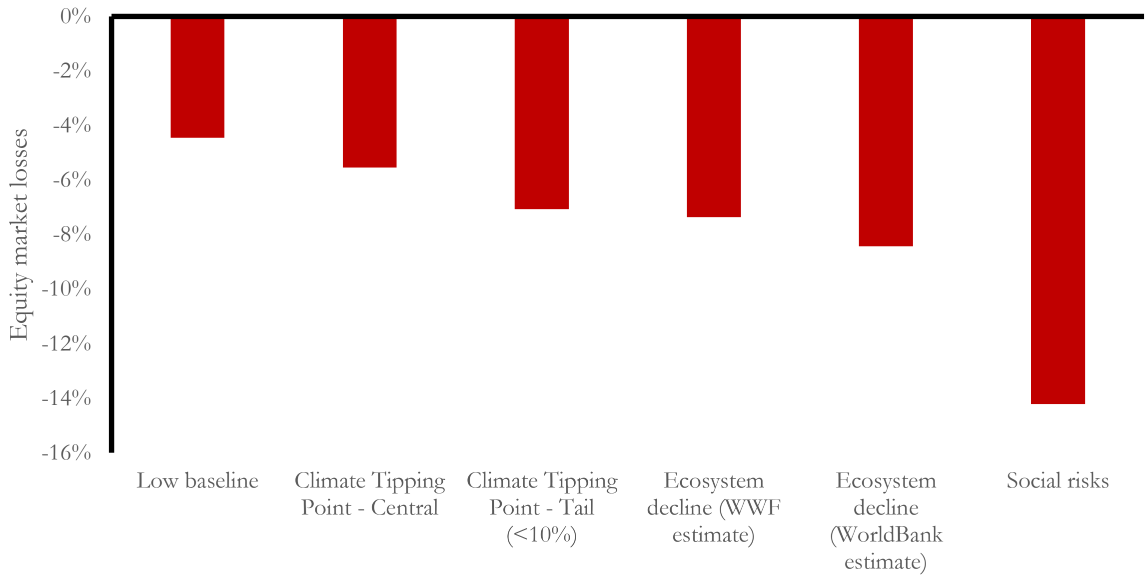
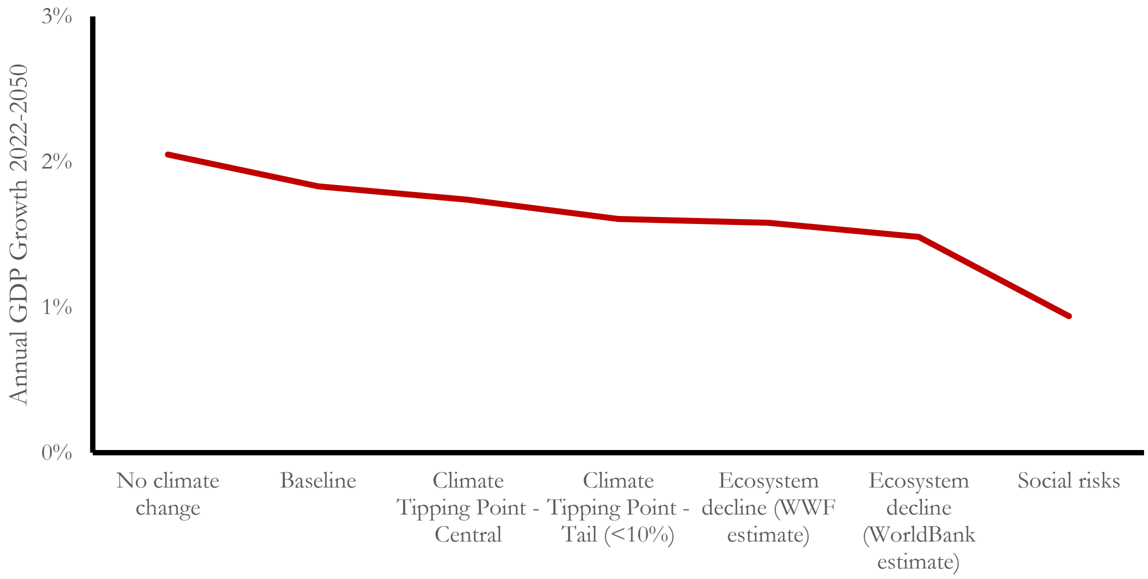


Fig 4: Global equity market losses and GDP growth rates under a SwissRe baseline (Source: Authors, based on Dietz et al. 2019, de Groot et al. 2022, SwissRe 2021, 2DII 2019)





Translating these losses into absolute values, potential social and ecosystem feedback loops can wipe $31 trillion off of global capital markets.

These findings do not draw specific inferences about financial stability but demonstrate the important relationship between climate change and social and ecosystem considerations. Estimates around global equity losses are based on a total estimated equity market size of $117 trillion (SIFMA 2022).

It is important to highlight that these losses are 'stress-test scenarios' and not central estimates or forecasts.

The paper does not comment on the probability of these losses materializing to capital markets or the individual events happening in the way they are calibrated in this paper. Rather, they are designed to demonstrate that the current suite of 'physical risk' scenario analysis and climate stress-tests do not in fact stress the full range of system stressors the economic and financial system faces under extreme climate change over the next 30 years.

It is hard to understand what a radically different world these scenarios represent, with the most extreme case leading to what is effectively a permanent global economic recession.

The average growth rate under the most extreme scenario presented here (2DII baseline + 10% tipping point outcome + social conflict) equates to an average annual growth rate of -0.3% over the next 30 years. Such outcomes are truly unprecedented – effectively a permanent recession. This dynamic may be unevenly distributed with periods of positive and negative growth, but leads to a truly different world.

The ramifications of long-term negative growth are unprecedented in modern economic history and will likely have dramatic effects for all asset classes. Real estate prices in particular correlate significantly with GDP per capita (Tripathi 2019). While these effects are not explored in this paper, they suggest the potential for a profound long-term economic and financial transformation that creates risks to financial markets currently not mapped by standard stress-test and scenario analysis exercises.

IV. Conclusion

This report represents the first attempt to bring together the potential financial risks that come from tail scenarios linking climate, ecosystem, and social risks.

The findings suggest that losses from physical risks may be a factor of 2.5-3.5 higher as a result of these broader dynamics triggered by climate change and creating feedback loops in terms of financial losses. It is worth highlighting again however the extent to which these findings are not central estimates but potential tail losses to be considered under extreme climate change scenarios.

The exercise represents a basic modelling approach to highlight the sensitivities and potential orders of magnitude of different effects based on a basic valuation model.

There are obviously a host of limitations to the analysis conducted here, notably the extent to which GDP effects translate directly into valuation effects, the extent to which some of these risks may already be priced, the lack of consideration of sectoral exposures and potential adaptation, and the focus on equity markets only. There are also other limitations which relate to the actual accuracy of the analysis, notably the uncertainty as to the timing of climate tipping point risks materializing, and the overall uncertainty around the interplay between climate tipping points, ecosystem decline, and social conflicts. However, these are not necessarily limitations in the context of stress-tests designed to test extreme scenarios.

Next steps of the research involve expanding the focus to other asset classes and better mapping the probabilistic distribution of these outcomes.

Bibliography

2° Investing Initiative (2019) "Storm ahead: A proposal for a climate stress-test scenario". https://2degrees-investing.org/wp-content/uploads/2019/02/Stress-test-report_V2.pdf

Coase, Richard (1960) "The Problem of Social Cost" *Journal of Law and Economics Vol. 3,* p. 1-44. https://www.jstor.org/stable/724810

De Groot, Olaf, Carlos Bozzoli, Anousheh Alamir (2022) "The global economic burden of violent conflict". *Journal of Peace Research. https://journals.sagepub.com/doi/full/10.1177/00223433211046823*

Diet, Simon, James Rising, Thomas Stoerk, Gernot Wagner (2021) "Economic impacts of tipping points in the climate system" *PNAS* 118 (34). https://www.pnas.org/doi/10.1073/pnas.2103081118.

Dorsett, Richard (2013) "The Effects of the Troubles on GDP in Northern Ireland". *European Journal of Political Economy* 29. P. 119-139. https://www.sciencedirect.com/science/article/abs/pii/S0176268012000638

SIFMA (2022) "Research Quarterly Equities". https://www.sifma.org/resources/research/research-quarterly-equities/

SwissRe Institute (2021) "The economics of climate change: no action not an option". https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf

Tripathi, Sabyasachi (2019) "Macroeconomic Determinants of Housing Prices: A Cross-Country Analysis". https://mpra.ub.uni-muenchen.de/98089/1/MPRA_paper_98089.pdf

WorldBank (2021) "The Economic Case for Nature". https://openknowledge.worldbank.org/bitstream/handle/10986/35882/A-Global-Earth-Economy-Model-to-Assess-Development-Policy-Pathways.pdf?sequence=1&isAllowed=y

WWF (2020) "Global Futures: Assessing the Global Economci Impacts of Environmental Change to Support Policy-making". https://c402277.ssl.cf1.rackcdn.com/publications/1299/files/original/Summary_Report.pdf?1581456250