The Coalition of Finance Ministers for Climate Action

The urgent need for Ministries of Finance to factor systemic climate risk into their economic analysis and modeling approaches and principles for doing so: a view from the insurance and pensions industry

Institute and Faculty of Actuaries

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A contribution to the 'Compendium of Practice from a Global Community of Ministries of Finance and Leading Organizations: Economic analysis and modeling tools to assist Ministries of Finance in driving green and resilient transitions'

Topic: Addressing the climate policy questions facing Ministries of Finance: the economic and fiscal impacts of climate change

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Key findings—realistic economic analysis to support Ministry of Finance decisions

1. Ministries of Finance have to support important government decisions on the prioritization of climate change, e.g., how much effort to expend on countering it, relative to the effort that must be spent on other issues. They use integrated assessment models (IAMs) to assess economic implications of climate change risks and opportunities, including policy decisions on incentives to accelerate the transition and how to build resilience into societies to withstand anticipated climate impacts.
2. However, IAMs have significant limitations, meaning they can understate both the climate risks and the economic opportunities arising from the energy transition. Basing policy decisions on these models may lead to inadequate adaptation, loss of resilience, and missed economic opportunities.
3. To address these limitations, MoFs should adopt a set of principles to develop realistic economic assessments of climate impacts and opportunities, including adopting a precautionary-principle approach, developing risk management capacity, and providing decision-makers with better information.
4. MoFs should lead the development of National Transition Plans (NTPs)—strategic pan-economy plans that direct private sector action around financing, incentivizing, coordinating, and enabling the transition. NTPs should include requirements for realistic risk assessment to support policy decisions to accelerate mitigation and build resilient infrastructure.
5. The backdrop to this analysis is that global warming has accelerated, and the 12-month average temperature is now above the 1.5°C goal. Record high temperatures are occurring continuously across the globe, with multiple locations now experiencing 40°C–50°C peaks. Polar regions are experiencing temperatures 30°C–40°C higher than normal. This trend will likely continue as emissions are ongoing and other factors, such as forest fires, ice loss, and loss of aerosol cooling, are driving warming.
6. This trend is having increasingly severe impacts—fires, floods, heat, and droughts. Climate change is becoming a national security issue, with food, water, and heat stresses impacting populations. If it goes unchecked, then mass mortality, involuntary mass migration events and/or severe GDP contraction are likely.
7. But warming above 1.5°C is extremely risky, with a high chance of triggering multiple climate tipping points, such as the collapse of ice sheets, permafrost melt, Amazon dieback, and halting major ocean current circulation. Impacts could be catastrophic, including significant loss of capacity to grow major staple crops, multi-meter sea-level rise, and further acceleration of climate change through the release of greenhouse gases.

Overview—climate change is a risk management problem

A ship can hit a rock and sink, even if that rock is not shown on the chart. This is a metaphor for the economic analysis of climate change. Traditional equilibrium economic models that form an important component of the IAMs used by MoFs to assess the economic implications of climate change simply do not represent the risks or opportunities of climate change well. This means the ships of national economies and the societies that support them are exposed to much higher levels of risk and economic disruption than is commonly understood. They could well sink unless they work together to change course.

Actuarial solvency and risk management processes are employed across the globe to minimize the risk of pensions and insurance failure, with these techniques employed globally across the US$55 trillion of assets in the global pensions market (Thinking Ahead Institute, 2024) and the €6.2 trillion of premiums collected in the global insurance market (Allianz, 2024). Society trusts actuaries to

minimize the risk of failure in these important societal solutions by managing the complex risks these industries face. The contribution of the UK actuarial profession to the Technical Advisory Group (TAG) seeks to provide MoFs with guidance on how to leverage actuarial principles to carry out realistic risk assessment of climate change, including the economic impacts, to justify the long-term policy actions required to avoid economic and societal collapse.

The IFoA is the UK's only chartered professional body dedicated to educating, developing and regulating actuaries based both in the UK and internationally. The IFoA regulates and represents over 32,000 members worldwide, overseeing their actuarial education at all stages of qualification and development throughout their careers. It sets examinations, continuing professional development, professional codes, and disciplinary standards for its members.

Over the last few years, the IFoA has worked collaboratively with Earth system scientists at the Climate Crisis Advisory Group and the University of Exeter to produce a series of flagship reports highlighting areas of risk and uncertainty in relation to the Institute's approach to mitigating climate change (Trust et al., 2022, 2023, 2024). This series of reports sought to combine actuarial risk management principles with cutting edge science to shine a light on areas of risk and uncertainty, with the objective of improving the risk management of climate change.

The UK actuarial profession views climate change as a risk management problem on a global scale. There is a level of global warming humans will be unable to adapt to; *in extremis* there is a risk of ruin. Many countries are already facing water, food, and heat stress. This will accelerate and spread, with mass mortality and/or involuntary mass migration events resulting if global warming continues. If we want to avoid severe disruption to the economy and global society then action needs to be taken to reduce emissions, limit warming, mitigate the extent of future climate risks, and adapt to those that cannot be avoided.

The need for science and risk to collaborate on climate change

The actuarial approach to risk analysis is different from that followed by most in the scientific community. Scientists are geared toward making predictions that are as accurate as possible. In contrast, actuaries are often concerned with assessing low-probability—high-impact events. A caricature of this is:

- Science—we should not typically say that there is an iceberg until we are fully confident there is one present (*scientific reticence*).
- Risk—there could be an iceberg, so we should typically steer well clear of it (*precautionary principle*).

This risk management approach is referred to as the precautionary principle, which emphasizes caution if it is possible that a given course of action may cause significant harm, particularly where there is high uncertainty. One of the most important expressions of the precautionary principle internationally is the Rio Declaration from the 1992 United Nations Conference on Environment and Development.[1] It is in common use as a concept by national governments including the EU and UK. Risk management also emphasizes taking appropriate action to mitigate the risks faced. Combining science and risk is important: science provides a deeper understanding of the issues faced, while risk assesses the consequences and recommends actions to mitigate or avoid them.

Actuaries have spent more than two centuries developing techniques for managing risk and uncertainty over long timescales. They show how well-established risk-management techniques such as the precautionary principle can be applied to the climate-change problem to inform policy choices, including what action to take to mitigate the tail risks of climate breakdown. These tail risks are complex, poorly understood, and too often sidelined in policy formulation. This is because, as well as

1 https://www.iau-hesd.net/sites/default/files/documents/rio_e.pdf (see Principle 15).

suffering from scientific reticence, climate science has unfortunately become highly politicized and consensus driven, meaning that risks and unlikely events are not communicated well to policymakers.

Extending our analogy, rather than climate models providing information to policymakers that there might be an iceberg that could sink the ship, policymakers are being told that, on average, it is unlikely that an iceberg will be seen, even though the consequences would be catastrophic.

Ministries of Finance, society, the economy, and climate change

Ministries of Finance have a strong interest in the economic strength of a country and how policy decisions might impact key economic factors including taxation, the balance of trade, employment, and economic activity, which can all be affected by climate change.

Traditional economics identifies labor and capital as critical inputs to the economy. If climate change is not mitigated, then labor supply and productivity will be curtailed due to water, food, and/or heat stress. For example, imminent mass mortality events are now forecast in some regions due to famine (Gaasbeek, 2024). Regions that become uninhabitable due to intolerable heat, water and/or calorific scarcity, saltwater inundation, and/or an inability to adapt to increasingly volatile conditions driven by climate change may see severe contractions in population and economic activity (GDP), as well as damages to capital stocks. Unprecedented migration is a possible consequence (Xu et al., 2020), with scientists forecasting that several major population areas may become uninhabitable. These shocks will propagate, given the interconnectedness of our global economy and lack of resilience of the food system. However, such outcomes are not recognized in current economic assessments of climate change, reducing the rationale for the long-term policy actions that need to be taken immediately to mitigate the risk and adapt appropriately.

The following section highlights the urgency around climate change and the importance of adequate climate risk management, providing the headlines for policymakers in three stages: what is happening with global temperatures; the risk implications of rising temperatures; and the mitigation actions available to policymakers.

Climate change information—accelerating warming past 1.5°C, tipping point risk[2]

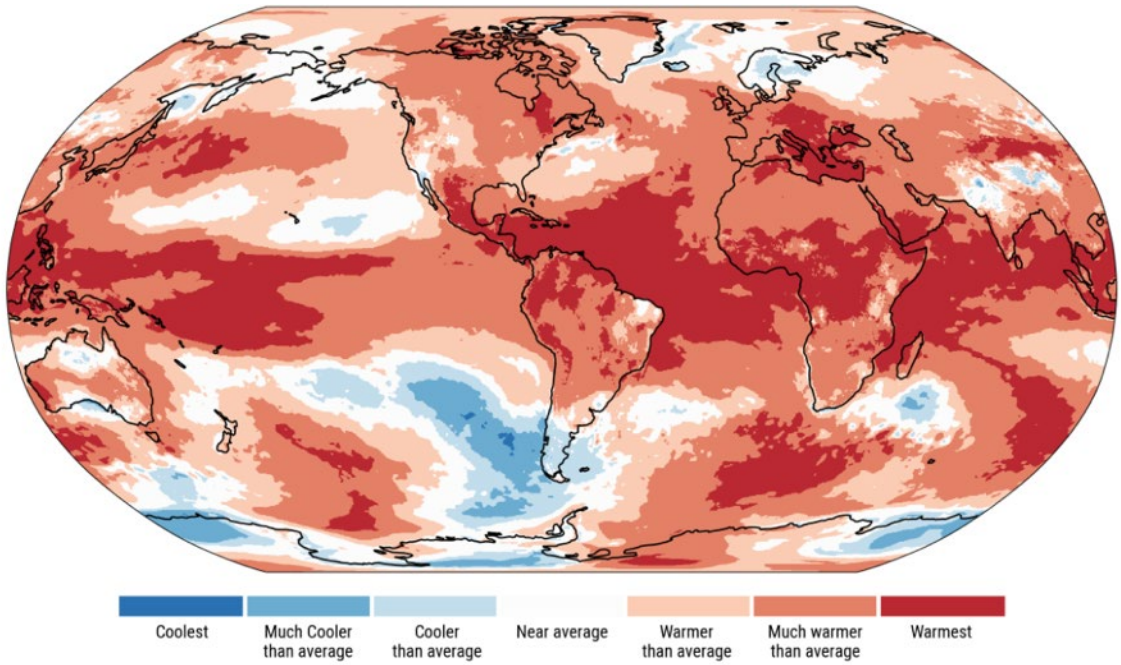
Global warming accelerated in 2023 with temperature differences passing 1.5°C, driving more severe impacts and increasing tipping point risk (Ripple et al., 2023). There is a risk Earth's climate may be more sensitive than thought, meaning it will warm more quickly than expected. Further, because it takes time for the planet to warm, there is a time lag in the warming experienced, so conditions will continue to deteriorate (Hansen et al., 2023). This reinforces the importance of pre-emptive action to mitigate warming.

- An overshoot of the 1.5°C temperature goal is now virtually certain, with emissions not yet reducing, requiring greenhouse gas removals from the atmosphere to allow temperatures to reduce below this level later in the century.[3] However, examination of the assumptions underpinning overshoot scenarios show these require implausible levels of carbon capture and drawdown that may be practically challenging to execute.
- Warming above 1.5°C is extremely risky, with a high chance of triggering multiple climate tipping points, including the collapse of ice sheets in Greenland, West Antarctica, and the Himalayas, permafrost melt, Amazon die back, and halting major ocean current circulation.[4] Passing these thresholds may constitute an ecological point of no return, after which it may be practically impossible to restore the climate to pre-industrial (Holocene) stability. Tipping points may interact to form tipping cascades, which act to further accelerate the rate of warming and climate impacts.

2 This part of the contribution draws on Trust et al. (2024).
3 https://www.ccag.earth/reports/the-overshoot-crossing-the-1-5c-threshold---and-finding-our-way-back
4 https://global-tipping-points.org/

- There is increasing evidence that other material factors such as reduced aerosol cooling, albedo loss, and tipping impacts may also accelerate warming, further reducing carbon budgets. Some scientists estimate that these other factors together with the levels of greenhouse gases are equivalent to doubling greenhouse gases, with a chance of 5°C of warming if action is not taken (Hansen et al., 2023).

Figure 1: Temperature anomaly as of May 2024, compared with the 1991–2020 mean, in degrees Celsius



Source: Copernicus Climate Change Service

The consequences: global warming is driving increasingly disruptive risks events

- Climate risks are highly nonlinear, and impacts are more severe now at much lower global temperatures than expected (Ripple et al., 2023). Each increment of warming increases the likelihood and severity of cascading, compound events, such as concurrent heatwaves and droughts, and socio-economic reactions to such events, for instance from mass migration or violent conflict driven by resource shortages (IPCC, 2021).
- Increased warming is driving more severe impacts across the planet. Climate change has arrived, with severe impacts emerging at lower temperatures than expected (Trust et al., 2024). The distribution has shifted: yesterday's tail risks are today's base case, and today's tail is frighteningly possible. Arctic warming, sea-level rises, and extreme weather events are examples of climate impacts that are progressing faster than expected (Ripple et al., 2023). Since 2020, record-breaking floods, fires, droughts, storms, temperature extremes, and ice loss have been witnessed across the globe, impacting billions of people. Some states are already seriously impacted (Nyoka, 2024; Eschenbacher, 2024; Dunne, 2024).
- Climate risks are now posing threats to lives and livelihoods. Ice sheet melt, rising sea levels, storm surges, typhoons, heat stress, and other events are occurring almost continuously across the globe, with temperature records being broken almost continuously. These and other extreme events will increase in frequency and magnitude as the planet warms further.
- Tipping points introduce nonlinear step changes in the risk environment. For example, it is possible climate change reduces or halts major ocean circulatory currents (Rahmstorf et al., 2024), which act as massive heat exchangers. Should this happen, tropical regions may see

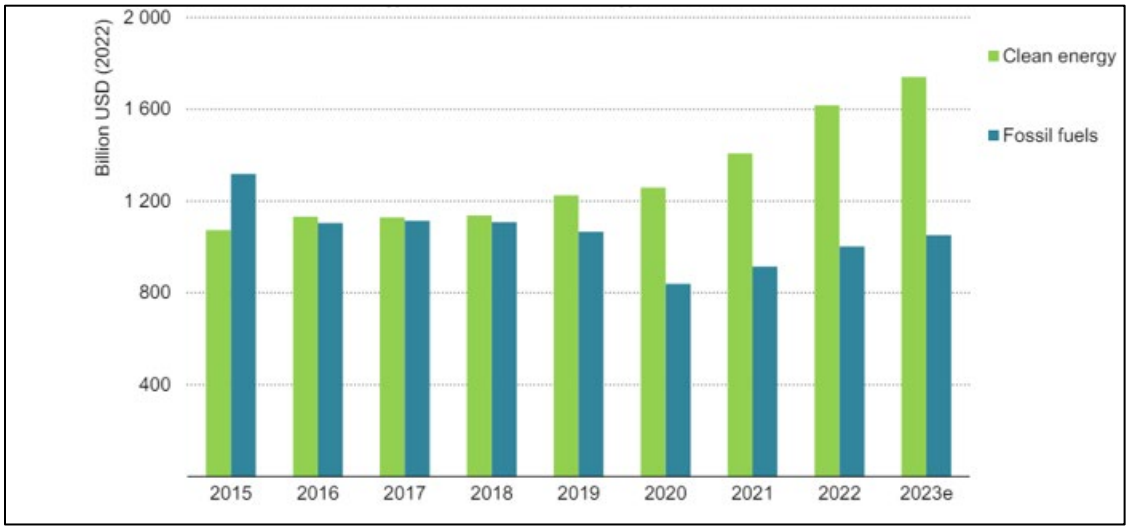
accelerated heating, while some northern hemisphere countries may see temporary cooling, which could act significantly to reduce the northern hemisphere crop-growing season by a number of months, potentially driving unprecedented food stress. Several tipping points are now showing signs of instability (Boers and Rypdal, 2021; Boers, 2021; Flores et al., 2024), including the Greenland ice sheet, tropical coral reefs, the Amazon rainforest, and permafrost.

- However, commonly used climate change risk assessments are flawed, understating climate risk and economic impacts, with many risks and complex network effects, including tipping points, often excluded from models (Keen et al., 2021; Stern et al., 2022; Trust et al., 2023). This is because economists have approached the assessment of climate risk by looking at past experience, which by definition excludes future risks that have not yet occurred. Some approaches have excluded major sectors of the economy on the flawed assertion that work indoors will not be impacted by weather. Results as low as 2% GDP damage for 3°C of warming have been produced by economists that have not interacted with climate scientists when developing their loss estimates. As a result, these models exclude many of the risks and nearly 90% of the economy from their results (Keen et al., 2021). There is thus a striking disconnect between climate science, the climate reality being experienced, and the low economic impact assessments that some models produce, with detailed critiques produced by both climate scientists and economists.
- MoFs and other government departments require realistic risk assessments. MoFs may be primarily interested in the financial and economic consequences of climate change, while other government departments may have a deeper interest in the physical resilience of a country's infrastructure, the health implications of heat or disease, or indeed implications for net migration. It will be important for departments not only to carefully select a model appropriate for their purposes but also to engage with each other, as it is the interaction between various climate driven risks that may be the biggest risk. It is absolutely critical that users of climate risk analysis understand the flaws in methodologies, particularly where these will likely underestimate climate risk. Use of these misleading results could lead to flawed cost-benefit analyses and a failure to build resilience and could act as a barrier to enacting policy shifts. Traditional equilibrium models are also not good at recognizing the economic benefits of the transition (Myllyvirta, 2024) or the learning curves of technologies, leading to further challenges in implementing long-term policy decisions (Bond et al., 2024).

The economic implications, risks, and opportunities for MoFs

- Transitioning to a lower carbon economy presents significant economic opportunities and the potential for direct contribution to GDP growth. Embracing renewable energy and green technologies can drive innovation, create jobs, enhance energy security, and lower energy costs. For instance, clean energy was a top driver in China's economic growth in 2023 (Myllyvirta, 2024), accounting for 40% of the expansion in GDP, and research shows a low-carbon energy system will generate significant savings.
- The energy transition is accelerating, particularly when supportive policy is in place, with transition finance scaling rapidly. However, ongoing investment into fossil fuels and an all-time record for coal in 2023 increase the risk of potentially stranded assets (IEA, 2024).

Figure 2: Global investment in clean energy and fossil fuels, 2015–2023

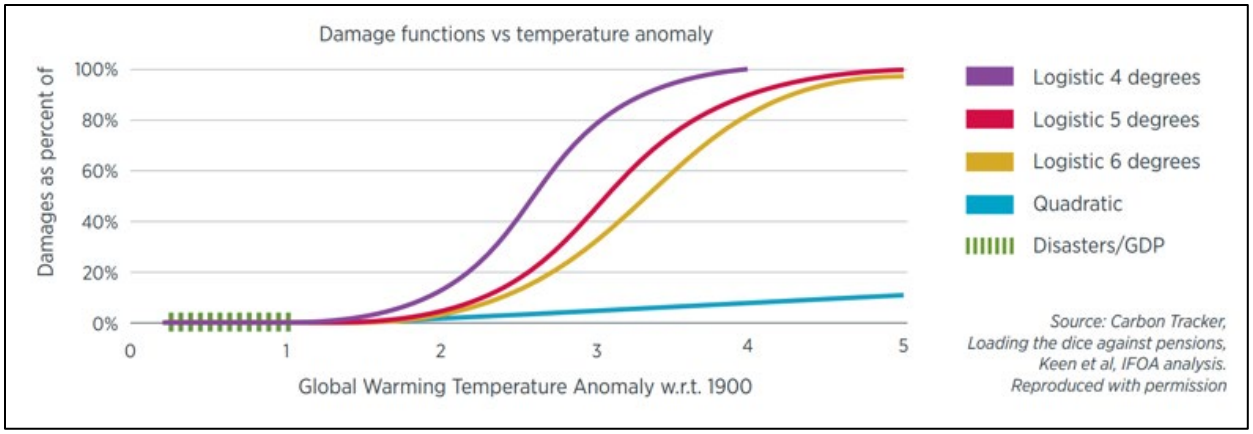


Note: 2023e = estimated values for 2023.
Source: IEA (2023)

- Failure to mitigate climate change will pose additional fiscal burden on governments. The need to react to specific weather events or to improve public infrastructure to deal with changing weather patterns will increase demands on government expenditure in ways that may be under-appreciated in current budgets, particularly if they are informed by climate models that underestimate risk.
- Governments need to consider how to adapt to insurance withdrawal and its implications. There is already a protection gap (underinsurance), and this will widen as commercial insurers withdraw from areas they deem too risky to insure.[5] The societal consequences of this are unclear but may include impacts on property values and the ongoing viability of areas to live in.
- Food and water security are threatened by a changing climate, with severe disruption to global food supplies increasingly likely as the 1.5°C threshold is breached. Impacts include severe contractions of population (mortality, migration) and economic output. Estimates of the economic impact of climate change vary widely from 50% GDP loss between 2070 and 2090 (Trust et al., 2023)[6] to 12% in GDP loss (Purton, 2024) for every 1°C rise (Adrien and Känzig, 2024) to more benign estimates that are increasingly discounted as implausible (Keen et al., 2021), as detailed above and documented in further detail in the following section.
- Decisive economy-wide action is needed to decarbonize, support greenhouse gas removal, repair broken parts of the climate system, and build resilience to climate impacts. To mitigate economic risks, adapt to the changing climate, and position for opportunities related to the energy transition, countries need to develop National Transition Plans (NTPs) (Manning et al., 2024). NTPs would sit at the center of a wider integrated transition planning ecosystem—directing, financing, incentivizing, coordinating, and enabling private sector action. MoFs will need to be key players in the development of NTPs.

5 https://home.treasury.gov/news/press-releases/jy1375
6 Loading the DICE against Pensions - Carbon Tracker Initiative

Figure 3: Global GDP loss as a function of temperature, 50% GDP loss between 2070 and 2090



Source: Trust et al. (2024) (reproduced with permission)

Strengths and limitations of commonly used climate change risk assessment approaches

Strengths of actuarial and financial risk management techniques

Actuaries have played a significant role in enabling critical societal services such as pensions and insurance that support societal functioning in the short and long term. Actuaries cannot predict the future, but the analysis of data to understand the range of uncertainty around future assumptions, considering the risks and worst-case scenarios, lies at the core of their expertise. Actuaries' advice informs the level of activity and urgency required to avoid risks. The IoA explores scenarios that could have the greatest impact, even if the probability is low or cannot be readily quantified. It is concerned with protecting against the "*risk of ruin*," with society understandably placing importance on pensions and insurance not failing.

Technically, this is referred to as financial solvency: a financial institution is said to be solvent if it has enough capital to meet its liabilities *and* cover the risks it may face. Insurance companies are required to hold enough capital to survive an unlikely but possible 1-in-200-year set of adverse events. Society might reasonably expect a similar standard for climate change and other risks faced.

The actuarial approach can be valuably applied to climate change. As well as thinking carefully about what to expect and sources of uncertainty, actuaries can also explore the risk of ruin: the point beyond which global society could no longer successfully adapt to climate change. The phrase "*Planetary Solvency*" is used by the IoA to explore how society could adapt actuarial techniques to manage global risks more effectively, with "*Climate Solvency*" being one particularly important dimension of Planetary Solvency.

Limitations of current approaches to assessing the societal and economic impact of climate change

Risk management can fail for a variety of reasons, including limited understanding of risks (such as having no knowledge of tipping points), lack of imagination (for instance, some find it hard to conceive of a food system breakdown), and communication challenges (the IPCC focuses on communicating science rather than risk). These issues are evident in the context of climate change and can be exacerbated by conflicting information. Additionally, human psychology, particularly a tendency to overlook uncomfortable truths, plays a significant role in the lack of sufficient action. Another risk

actuaries consider is "model risk," which can be broadly defined as "the risk that the use of a model will lead to an incorrect decision".[7] Model risk is a broad term but can be ascribed to three major causes:

- The wrong model has been used
- The model has been incorrectly implemented
- The model has been incorrectly used/interpreted

All these causes are present to an extent in the IoA's approach to modeling the economic impact of climate change. The specifics for climate change are explained below to support statements made previously in this document. Model risk can be a driver of risk management failure (e.g., model output users do not understand limitations) or can be weaponized by parties seeking to delay the transition (e.g., the downside risk is not bad, there is no rush).

Expanding on model risk in climate change—limitations of Integrated Assessment Models

The dominant model used for economic analysis of the impact of climate change by MoFs and other parties is the IAM. Such models are defined as:[8]

> "simplified representations of complex physical and social systems, focusing on the interaction between economy, society and the environment. IAMs aim to provide policy-relevant insights into global environmental change and sustainable development issues by providing a quantitative description of key processes in the human and earth systems and their interactions."

When designing policy interventions for climate change, Governments require modeling, to understand how much effort should be made to counter climate change relative to that which must be made on other issues. This will require information on the physical consequences of climate change (downside risks) as well as the economic implications of policy interventions. The IAM is therefore an obvious tool to carry out this analysis by providing a methodology that combines both the socioeconomic and physical aspects of this challenge.

However, as with any model, there are limitations and assumptions—the map is not the territory. IAMs are complex models, and understanding the limitations and assumptions is both critically important and nontrivial. Additionally, there are a number of well-established IAMs that contain different assumptions, resulting in potentially widely different answers for similar questions.

A number of recent papers have highlighted why IAMs may only help to inform some climate change decisions and may be significantly misleading for others, with a comprehensive review provided by Stern et al. (2022). Criticisms of IAMs are that they include:

A. Unrealistic damage functions that do not capture key risks that may be faced
B. Simplifying assumptions that exclude large parts of the economy from analysis
C. Unrealistic economic assumptions that do not hold in practice

Although a full examination of all these points is beyond the scope of this paper, high level summaries and links to more detailed reference papers are provided below.

A. Unrealistic damage functions

Some economists have estimated the economic losses from climate change to be "*as low as 2.1% of global economic production for a 3˚C rise in global average surface temperature, and 7.9% for a 6˚C rise*" (Keen et al., 2021). Such low estimates of economic damages, combined with assumptions that

7 See section 1.3 'What is model risk?' of the IoA's Model Risk Working Party presentation "Model risk: daring to open up the black box" at https://www.actuaries.org.uk/system/files/documents/pdf/model-risk-working-party-paper.pdf
8 What are IAMs? – IAMC IIASA (iamconsortium.org)

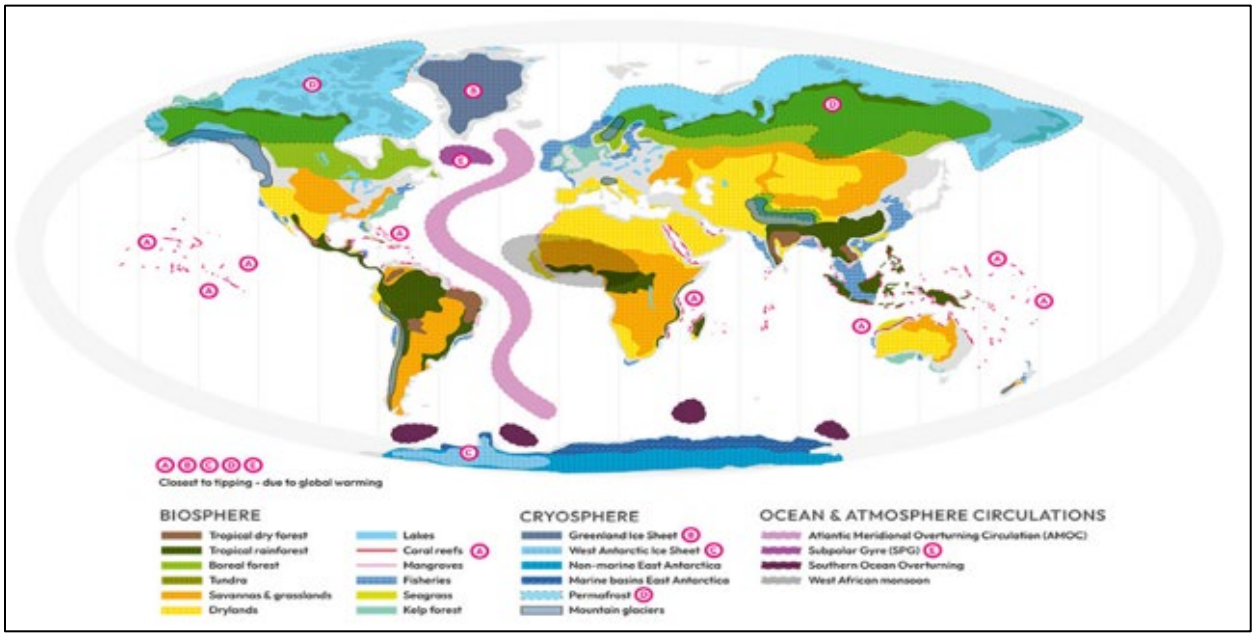
human economic productivity will be an order of magnitude higher than today, contrast strongly with predictions made by scientists of significantly reduced human habitability from climate change.

A closer examination of the assumptions underpinning these results reveals two critical assumptions that are questionable:

i. Ongoing and consistent economic growth in all emissions scenarios.
Even high warming scenarios have an underpinning assumption of ongoing economic growth as a baseline, which is implausible given the increasingly severe disruption anticipated from physical risks manifesting as temperatures rise (Trust et al., 2022, Section II.C). Some scenario sets assume the same economic growth assumption for all emissions scenarios, which is intuitively unlikely.

ii. Limited inclusion of key forward looking climate risks.
IAM methodologies typically exclude complex forward looking risks including tipping points. Typically, a subset of physical risks will be included; for example, the NGFS (a global group of financial regulators), who are a scenario provider, caution that their scenarios exclude "*impacts related to extreme weather, sea-level rise or wider societal impacts from migration or conflict. For given countries these would likely strongly increase the physical risk. These estimates also do not fully capture adaptation, which would reduce impacts but require significant investment*" (Network for Greening the Financial System 2022). As models are often calibrated on backward-looking data, they miss, by definition, future risks that have not yet occurred. This emphasizes the need for a precautionary approach.

Figure 4: Parts of the Earth system identified in Global Tipping Points report



Source: Lenton et al. (2023)

B. Simplifying assumptions that exclude large parts of the economy.

A particularly influential climate change economic analysis produced using IAMs was that by William Nordhaus, which assumed that only industries directly exposed to the weather would be impacted by climate change. This assumption resulted in 87% of the economy being excluded from modeled results (Keen et al., 2021).

The consequence of A and B is that many significant forward-looking risks *and* most of the economy are excluded from some damage functions, resulting in small loss estimates.

C. Unrealistic economic assumptions that do not hold in practice.

Further simplifications in IAMs relate to their methodological specification as computable general-equilibrium models (CGEs). These contain a number of simplifying assumptions which do not hold in the real world, including the following (McLeay et al., 2014).

- Individuals act only in their own self-interests and are dedicated to maximizing their utility.
- Individuals have perfect knowledge and perfect foresight and use this information to calculate all possible outcomes and optimize their decisions.
- CGE model results are presented as long-term outcomes, without considering possible upheaval or the length of the transition process.
- Money is "neutral" (required only to facilitate real transactions) and fixed in supply
- Banks are treated merely as intermediaries, failing to recognize their role in money creation.

An alternative approach is provided by nonequilibrium economic models. This methodological choice can again have a significant impact on the economic output from models MoFs may use to inform policy decisions. In particular (Bowdrey and Hidi, 2022):

- General equilibrium models will typically show the transition as an economic cost
- Non-equilibrium models will typically show the transition as an economic gain.

Furthermore, economic analyses are often presented against a fictional counterfactual baseline scenario of "neither climate change nor the energy transition is happening," which shows all climate change scenarios to be economically negative.

Model uncertainty in relation to carbon budgets

Two key components of climate change scenario analysis are the level of emissions expected under a specific scenario and the level of warming expected for that level of emissions. The Earth is a complex system; calculating how sensitive it is to greenhouse gases is difficult but incredibly important because that lets modelers know how much can be emitted before dangerous temperature goals are breached. There is a high risk that climate sensitivity is significantly higher than the central estimate used in climate models, which would mean carbon budgets are overestimated (i.e., too big). Given the global temperature scenario is now 1.5°C, carbon budgets will likely be negative for that temperature goal, implying significant drawdown of greenhouse gases will be required in the future (Trust et al., 2024) .

Relevance to Ministries of Finance—risks to society and the economy

Climate change drives a complex basket of interconnected risks that could threaten the basis of society and the global economy. Failure to consider these interconnections will underestimate risk. A failure to mitigate climate change will drive more volatile weather conditions, which might drive resource crises (food, water, energy), involuntary mass migration and/or mass mortality, and ultimately state collapse.

In particular, while climate risks may appear to be separate from the core agenda of MoFs (economic growth, macroeconomic stability, public finances, stability of financial markets), there is increasing evidence that climate-driven risks can be transmitted into these markets.

On a simple level, there is a direct economic cost to climate driven hazards. The consultancy Verisk provides analysis on global insured and total economic losses. It estimates total economic losses now average US$400 billion per annum, with a 5% chance of an annual insured loss of US$200 billion or more in the next decade.[9] Verisk estimates total losses are three or four times insured losses,

9 https://w4.air-worldwide.com/Global-Modeled-Catastrophe-Losses-2023

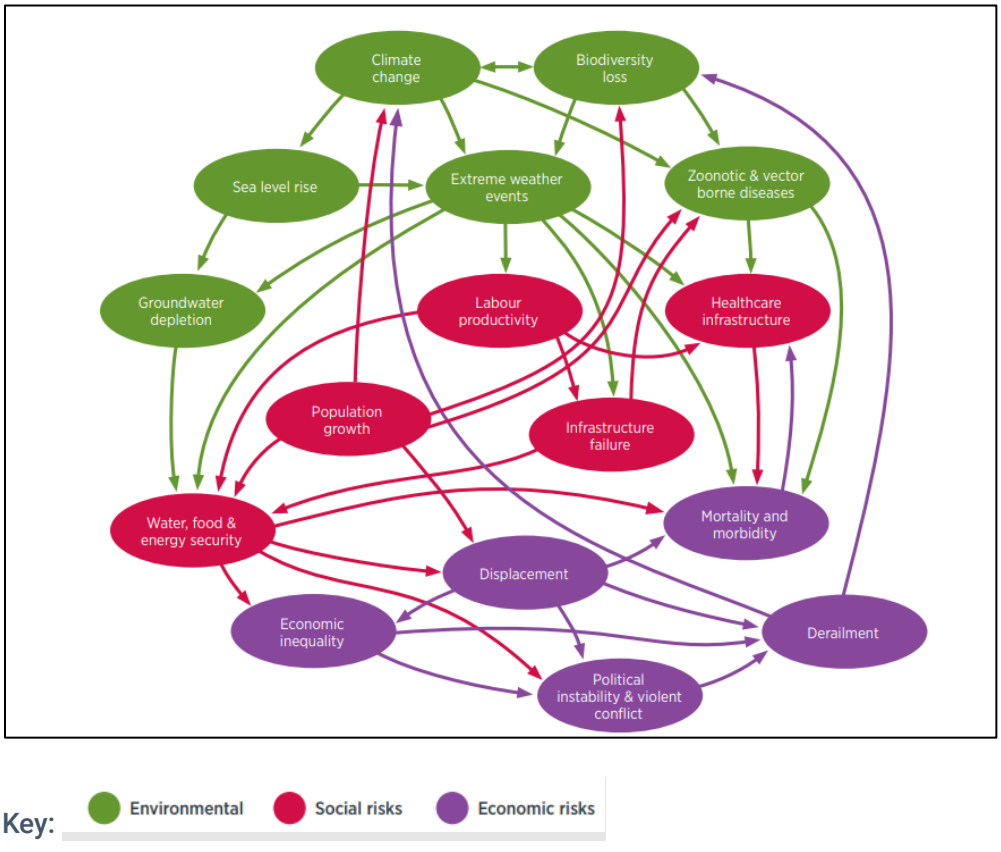
highlighting both a significant protection gap and the possibility of future total economic annual losses in excess of US$1 trillion.

Lloyd's Futureset and the Cambridge Centre for Risk Studies go further in exploring a climate-driven food system shock as a result of extreme weather leading to economic losses of US$5 trillion.[10] In their systemic risk analysis, they provide loss estimates for three scenarios ranging from major (1-in-50 years) to extreme (1-in-300 years). In the extreme scenario, they estimate the five-year global economic loss to be US$17.6 trillion. Given the shifting distribution of climate change impacts, it is reasonable to ask how long these probabilities will remain appropriate (i.e., whether the events they describe will become more likely).

The causal loop diagram in Figure 5 shows how these risks have common drivers and multiple points of interaction that could trigger or exacerbate each other. These risks all have direct effects on mortality and morbidity. They all cascade toward major systemic effects that will likely have economic implications, either through direct impacts or by impacting the availability of labor and/or capital to drive economic growth.

Food, water, and energy security can exacerbate economic inequality, fueling involuntary migration, political unrest, and violent conflict. Such crises are often assumed to focus political attention and public support to accelerate the sustainability transition. However, the risk of derailment has recently been documented. In this scenario, escalating demands to manage increasingly chaotic conditions could divert work, resources, and political support from environmental action, worsening the changes.

Figure 5: Climate change as a driver for interconnected risks: a causal loop diagram



Source: Trust et al. (2024) (reproduced with permission)

10 https://www.lloyds.com/news-and-insights/futureset/futureset-insights/systemic-risk-scenarios/extreme-weather-leading-to-food-and-water-shortage

We note the challenges in modeling this interconnectivity accurately given the complexity. Nevertheless, it is critical that MoFs update existing climate risk analysis approaches to allow for these. One approach that can be adapted from financial services is known as reverse stress testing. This is a financial services risk management technique used to identify the set of conditions that will lead to insolvency for companies. It can be applied at country level with respect to climate risks to identify the point beyond which the country is unable to adapt successfully to climate change, i.e., the risk of ruin and catastrophic impact on GDP. Given this set of scenarios, Ministries can develop mitigation and adaptation policies to withstand these scenarios and build resilience into the economy.

Furthermore, the uncertainty and complexity in modeling quantitively the climate impact on the economy should not be used as a deterrent to implementing appropriate measures to limit this risk. This is in line with the precautionary principle, whereby adequate measures and policies should be in place to address the potential threat to planetary solvency despite the uncertainty in this area. An example is the Covid-19 pandemic, whereby precautionary principles were adopted by various countries to help reduce the impact of this risk despite the uncertainty in its initial stages.

Guidelines for realistic climate risk assessment and impact on MoFs

Realistic climate risk assessment is essential for informing decisions by MoFs. Developing the tools and insight to provide a comprehensive understanding of the potential societal and economic downside will help to guide effective policy responses and build resilience. A set of principles to guide MoFs in their approach might be the following.

- Follow the precautionary principle—have a best guess about the worst case and make policy on that basis. Realistic climate risk assessments can help identify and assess tail risks, which are low-probability, high-impact events that can have catastrophic consequences, including the risk of ruin. By understanding these risks, MoFs can develop policies to mitigate the worst-case scenarios, supporting economic stability and societal resilience.
- Evaluate realistic economic impacts against a realistic baseline reflecting the impact of no climate action. Assess the economic upside of mitigating climate change, including economic opportunities from the energy transition. Compare this with potential GDP and capital stock losses that would result from climate risks materializing, such as water scarcity or mass migration. This comparison should inform fiscal policies and budget allocations to guide investments in infrastructure and social safety nets.
- Take a risk-based approach to policymaking. Climate risk assessments can help prioritize policy actions by identifying the most urgent risks and the areas where interventions can have the most significant impact. This enables MoFs to allocate resources effectively and develop targeted strategies for mitigation and adaptation.
- Use scenario analysis. MoFs can explore different pathways of climate change and their potential impacts on the economy, supplementing quantitative model output with qualitative analysis. This helps in planning for various contingencies and developing robust policies that can withstand a range of futures.
- Take long-term policy decisions. Climate risk assessments can help to provide the evidence needed to justify long-term investments in mitigation and adaptation measures. For example, the data can support the case for investing in renewable energy, enhancing energy efficiency, and building resilient infrastructure.
- Assess fiscal risks and opportunities. Identifying the fiscal risks and opportunities associated with climate change, such as increased government expenditure on disaster response and infrastructure repair, or increased revenues from renewables resulting in lower fossil fuel import costs, can help MoFs develop strategies to manage these costs. These include setting aside contingency funds and exploring innovative financing mechanisms.

- Guide international collaboration. Realistic risk assessments can demonstrate why international cooperation is needed to address climate risks. This can inform foreign policy and international agreements, supporting coordinated global action.

Providing MoFs with better information—climate risk dashboards

In risk management, risk dashboards are commonplace, providing company management with information on the status of risks, whether any are "outside appetite," and if so whether any immediate action is required. MoFs should consider appropriate Climate Risk Dashboards for their countries, to provide better information and support long-term policy decisions to both mitigate climate change and adapt to those risks that are unavoidable. This section provides an illustrative example of what such a dashboard could look like.

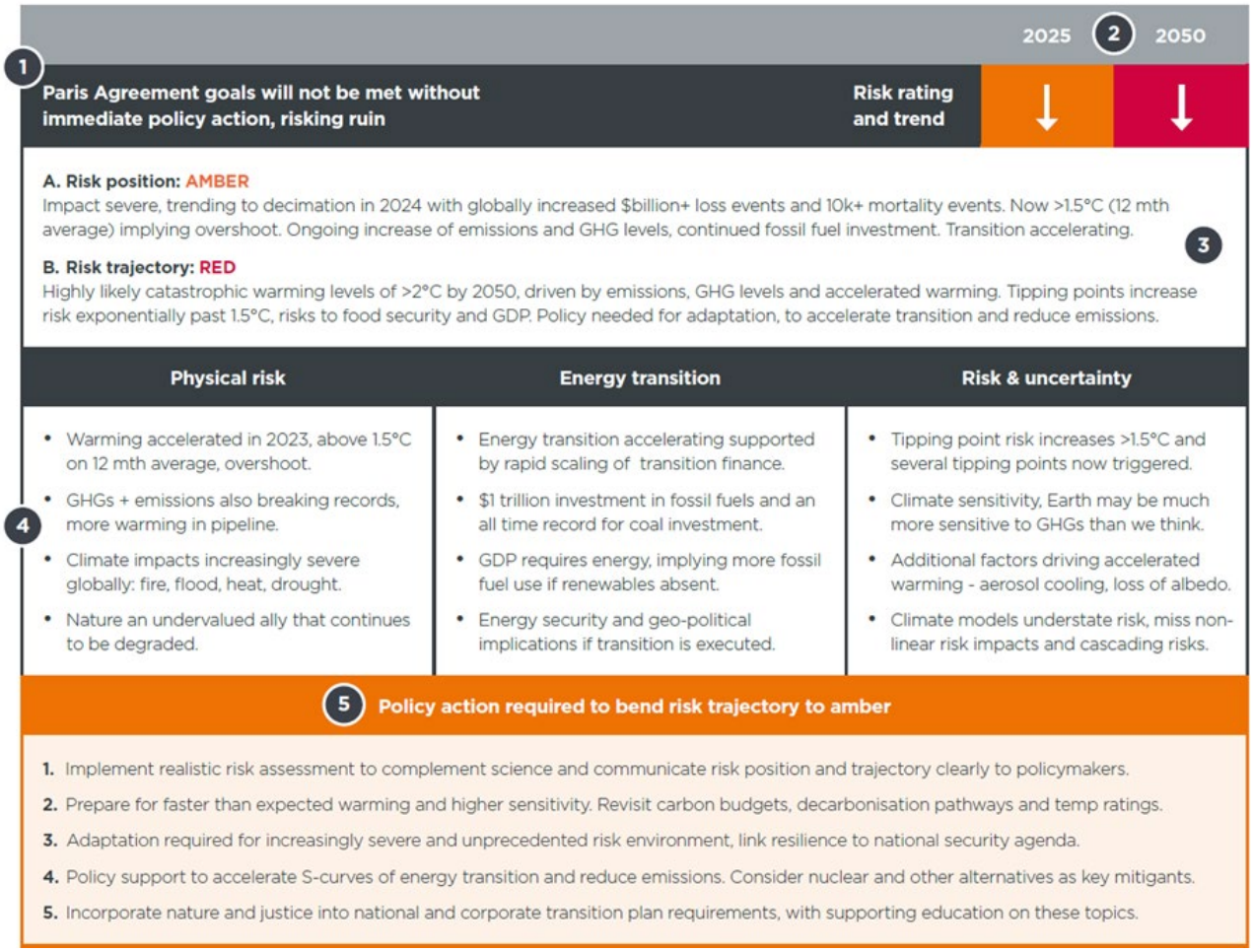
The term dashboard originates from the days of horse-drawn carriages: a board to protect carriage drivers from mud being "dashed up" by the horses. Nowadays most are familiar with dashboards or instrument panels, commonplace in all major human technologies from automobiles to helicopters to power plants. Dashboards give important information on what is happening (e.g. speed, direction, fuel level) as well as highlighting any problems (e.g. flat tires, overheating engines, low fuel, imminent collision).

Crucially, one would not try to fly a helicopter by reading the scientific papers that underpin its functionality; pilots are taught how a helicopter works, how to fly it, and how to react to the dashboard and other visual indicators. However, although human activity is now driving planetary outcomes, including climate change, there is not yet a planetary risk dashboard in existence to advise what action to take. Essentially, humans are trying to drive the planet by reading scientific papers.

Figure 6 shows what such a dashboard could look like (further details are available from the IFoA on request). The IFoA welcomes the chance to work with MoFs and other relevant parties on developing such dashboards.

A key part of risk management, to complement risk assessment, is the identification and execution of the actions required to avoid or mitigate any risks that are deemed to be too high. MoFs should then consider how to assess risk position and trajectory, as well as which key risk indicators need developing and how to develop and track appropriate action.

Figure 6: Illustrative Climate Risk Dashboard



Source Trust et al. (2025) (reproduced with permission)

An agenda for action: recommendations for MoFs and economic decision-makers

Policymakers must act decisively to accelerate the transition with long-term policy decisions, informed by up-to-date information on climate change and comprehensive risk assessments, which address the shortcomings identified in existing climate change risk assessment approaches.

To mitigate the risks faced and address the limitations outlined in this report we recommend countries take the following actions.

i. Develop National Transition Plans that require realistic risk assessment: Governments should develop strategic national transition planning to achieve Nationally Determined Contributions, as called for by Mission 2025 (We Mean Business Coalition 2024). MoFs should be at the center of these plans, and they should set the direction and provide incentives, finance, and support for transition in the wider economy. Legislation should require annual updates on progress against the plan, including adaptation and resilience measures. Plans should include the requirement for annual realistic risk assessments.

ii. Appoint Country Risk Officers (CROs) to report to MoFs: Countries should appoint CROs (analogous to Chief Risk Officers in financial services). CROs should be required to undertake realistic risk assessments of climate change and other risks. They should report to MoFs, and their analysis should inform NTPs, including adaptation and resilience measures.

iii. Legislate for realistic climate change risk assessment to support policy action: NTPs should include the requirement for a realistic risk assessment of climate change, led by CROs, that is forward looking and mitigates the shortcomings described. This may be incorporated into National Risk Assessments for countries with that capability (OECD, 2018). A mix of qualitative and quantitative techniques should be leveraged, and risk assessment exercises should include relevant Ministries and the military, leveraging the methodology established in the work undertaken by the Chinese, U.S., Indian, and UK Governments in 2015 (King et al., 2015).

    As part of this action, CROs could develop climate risk dashboards that clearly communicate risk levels, trajectories, and impacts to policymakers, synthesizing the significant scientific analysis continuously carried out on climate and other topics.

    Realistic risk assessment should be carried out in line with risk management best practices. This should consider the full range of outcomes, including tipping points, realistic worst-case scenarios, risk interconnectedness, and the risk of ruin. It should be informed by up-to-date information on global warming, greenhouse gas levels, aerosol cooling, and other material factors that may influence temperatures and risks.

iv. Provide better information for MoFs on risks and positive tipping points: Countries should invest in disseminating to policymakers in MoFs and others in leadership positions realistic climate risk assessment, emphasizing that not all societal risks can be quantified, the limitations of financial and economic models, the interconnectedness of risks (systems thinking), and how to translate this into long-term policy, including accelerating positive tipping points.

    MoFs should recognize the opportunity for economic policies to accelerate positive socioeconomic tipping points that can interact to drive rapid adoption of low-carbon technologies. With the right policy incentive framework, this presents the opportunity for a significantly faster move to a low-carbon economy than is often forecast. At a global level this move will be overwhelmingly positive economically, resulting in trillions of dollars of net savings. Furthermore, such an action would help to mitigate climate-change tail risks, providing further economic upside versus a future in which climate change is unmitigated.

v. Carry out economic analysis in MoFs against a new realistic baseline: Current climate change scenario and economic analysis is carried out against a fictional counterfactual scenario that assumes neither climate change nor the energy transition is happening. Due to certain features of the models used, results often show that *all* scenarios are economically negative (both transition and hothouse world), which is counterintuitive, misleading, and at odds with climate science.

    A practical fix may be to "invert" scenario analysis and use a reverse stress test approach, as in financial services risk management. This would start with what one wants to avoid—catastrophic climate change—then work backwards. Rather than carrying out climate-scenario analysis against a fictional world in which climate change is not happening, modelers could work from a new baseline of a best estimate (what is thought *likely*), which would show achieving the net zero transition and mitigating climate change are overwhelmingly economically positive compared with other outcomes. This would resolve the issue of having a fictional baseline that assumes neither climate change nor the energy transition is happening.

vi. **Reframe climate inaction as an imminent threat to national prosperity:** Carrying out the above activities should help to provide MoFs with clearer information on the economic downside of failing to mitigate climate change. *In extremis,* this may risk the future prosperity and viability of countries.

Risks are not distributed evenly, and countries will face different baskets of risks, which may be exacerbated or mitigated by a range of factors including the vulnerability of populations and the actions of other countries. Regardless of location and resilience, countries can expect to face, *inter alia,* heat, water, and food stress, weather extremes, and migratory issues leading to potential inflationary pressures, heightened sociopolitical tensions, conflict pressure, and negative economic consequences.

vii. **Build capacity in Earth system science and risk management in MoFs:** MoFs should build Earth system science and risk capability in relevant departments, via a mix of structured education programs and selective recruitment of Earth system scientists and risk professionals. Consideration should be given as to how to best execute this effectively. For example, regional hubs could be created to produce realistic regional and national climate change risk assessments to deliver to national governments; a global hub may be required to provide a single authority with a mandate to carry out and report a climate change experience analysis (i.e., the state of play and trajectory).

This capacity building should include education on nature, the importance of nature as the foundation on which human society rests, and the criticality of working with nature, alongside technological and other solutions to mitigate climate change.

Conclusion

As illustrated in this report and the IFoA research papers referenced, there are both significant risk and uncertainty relating to climate change. However, the current approach to climate change does not leverage well-established risk management techniques: attempts to drive the planet by reading scientific papers are not going well.

MoFs and countries need to recognize the shortcomings and the level of risk, including the risk of ruin, and put in place processes to develop a risk-led approach to climate change. This contribution has developed specific recommendations to provide MoFs with realistic and up-to-date climate change risk assessments to identify these risks and manage them in a timely manner.

There is also a gap between the climate science, economic impact, risk assessment, and policymaking. It is critical that MoFs bridge this gap by building appropriate capacity to put in place policies backed by science as well as enhanced economic models, while being clear on the limitations of models and outputs. MoFs could also call for collaboration between Ministries and countries to develop a central repository of resources and practical considerations covering climate science, economic models, and risk management. This may be particularly important for smaller MoFs that are capacity constrained.

Authors' note

The findings and recommendations in this contribution are based primarily on IFoA collaborative research on climate change, produced with Earth system scientists at the University of Exeter and the Climate Crisis Advisory Group, in particular the following three research papers:

- 2022—Climate Emergency—tipping the odds in our favour (Trust et al., 2022)
- 2023—The Emperor's New Climate Scenarios (Trust et al., 2023)
- 2024—Climate Scorpion—the sting is in the tail (Trust et al., 2024)

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