July 2023

Loading the DICE against pension funds

Flawed economic thinking on climate has put your pension at risk

Carbon Tracker Initiative

About Carbon Tracker

The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's capital markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system in the transition to a low carbon economy.

www.carbontracker.org | hello@carbontracker.org

About the Author

Professor Steve Keen

Steve Keen is a Distinguished Research Fellow at UCL (see https://www.isrs.org.uk/people), and is supported by crowdfunding on Patreon (https://www.patreon.com/ProfSteveKeen) and Substack (https://profstevekeen.substack.com/).

He is the author of *The New Economics: A Manifesto* (Keen 2021), *Can We Avoid Another Financial Crisis?* (Keen 2017), *Debunking Economics* (Keen 2011), and about 80 refereed papers, on topics including flaws in the economic analysis of climate change (Keen et al. 2022; Keen 2020a), the role of energy in production (Garrett, Grasselli, and Keen 2020; Keen, Ayres, and Standish 2019), the causes of financial instability (Keen 2016, 2015, 1995), and flaws in Neoclassical (Keen and Standish 2010; Keen 2005, 2004a, 2004b) and Marxian economics (Keen 1993b, 1993a). He is the designer of the Open-Source system dynamics program Minsky (https://sourceforge.net/projects/minsky/).

Acknowledgements

Carbon Tracker wishes to thank **Professor Tim Lenton - Chair in Climate Change & Earth Systems - University of Exeter** for his role as an external academic referee on this paper.

We are also grateful for the assistance of external reviewers & expert contributors - some of whom wished to remain anonymous.

Table of Contents

01

Key Findings

- Investment consultants to pension funds have relied upon peer-reviewed economic research to provide advice to pension funds on the damages to pensions that will be caused by global warming.
- Following the advice of investment consultants, pension funds have informed their members that global warming of 2-4.3°C will have only a minimal impact upon their portfolios.
- The economics papers informing the models used by investment consultants are at odds with the scientific literature on the impact of these levels of warming.
- The economics of climate change is an interdisciplinary subject, but papers on the economics of climate damages were refereed by economists alone. Properly refereeing these papers required knowledge of the science of global warming that economists typically did not have. Consequently, economic referees approved the publication of papers that made claims about global warming that are seriously at odds with the scientific literature.
- These claims have been fundamental to the predictions by economists of minimal impacts on the economy from global warming.
- Economists have claimed, in refereed economics papers, that 6°C of global warming will reduce future global GDP by less than 10%, compared to what GDP would have been in the complete absence of climate change.
- In contrast, scientists have claimed, in refereed science papers, that 5°C of global warming implies damages that are "beyond catastrophic, including existential threats," while even 1°C of warming—which we have already passed—could trigger dangerous climate tipping points.
- This results in a huge disconnect between what scientists expect from global warming, and what pensioners/investors/financial systems are prepared for.
- Consequently, a wealth-damaging correction or "Minsky Moment" cannot be ruled out, and is virtually inevitable.
- Pension funds have a fiduciary duty to correct the erroneous predictions they have given their members.
- Similarly, financial regulators, who have used the same erroneous and misleading economic damage predictions to stress test the exposure of financial institutions to climate change, must drastically revise their stress test studies.
- This report calls on all stakeholders, from governments, regulators, investment professionals, all the way to civil society groups and individuals, to ensure that climate change policy is based upon the work of scientists.
- Climate change must be treated as a potentially existential threat to the economy, rather than an issue which is suitably addressed by economic cost-benefit analysis.

02

Foreword

Since 2011, when Carbon Tracker published its first report "**Unburnable Carbon: Are the World's Financial Markets Carrying a Carbon Bubble**?," Carbon Tracker's mission has been to translate climate science into financial risk in order to align our financial system within a sustainable global temperature outcome.

However, the relationship between climate science and financial risk is not a comfortable one: as this report shows, the scientific and the economic literature are conflicted on the topics of how much damage climate change will do to the economy, and when. These conflicts, and more crucially, the effects of them when assessing the risk of climate change on both people's financial futures, and the wider financial system, are the focus of this report.

Within the financial ecosystem, one of the primary areas the conflict between climate science and financial risk plays out is in pension funds.

To ensure that the world moves into a new climate secure energy system, it's crucial that pension schemes send the market the right investment signals. The signal has to be that a swift, orderly transition is in everyone's financial interests, particularly for scheme beneficiaries. Also, in the case of local government pension schemes featured in this report, early action to reduce climate risk is in the best interests of tax payers, who would likely bear the brunt of any short fall in pension fund assets.

However, if the climate risk models used to guide investment decisions trivialise the extent of the financial impacts of climate change, then it is unlikely that finance officers and trustees will have the incentives to act now. This is the worrying finding of this report.

This report is a call to action for investment professionals to look at the compelling evidence we see in the climate science literature, and to implement investment strategies, particularly a rapid wind down of the fossil fuel system, based on a 'no regrets' precautionary approach. Behaving cautiously now and acting to avoid a 1.5°C increase (let alone the 4°C outcome featured in this report) will enable future generations to secure the prosperity and quality of life that comes from a healthy planet.

Mark Campanale
Founder and Director of Carbon Tracker

03

Introduction

Mainstream economics last failed society badly prior to the Global Financial Crisis in 2008. Rather than anticipating the crisis, Dynamic Stochastic General Equilibrium (DSGE) models that dominated macroeconomic analysis predicted the immediate economic future was bright.

This led to the OECD[1] claiming in June of 2007 that:

> **"The current economic situation is in many ways better than what we have experienced in years... Our central forecast remains indeed quite benign... In line with recent trends, sustained growth in OECD economies would be underpinned by strong job creation and falling unemployment." (Cotis 2007, p. 7)**

The worst economic crisis since the Great Depression began just two months later. Only after this crisis occurred were critics of the dominant approach to macroeconomics listened to (Bezemer 2009).

Robert Solow, who was awarded the Nobel Prize for Economics for his work on growth theory, had been criticising this approach for years (Solow 2001, 2003, 2007, 2008). After the crisis began, he spoke at a United States Congressional Hearing on the topic of "Building a Science of Economics for the Real World." Solow suggested that a simple test— "the smell test"—should be applied to any macroeconomic proposition, while cautioning that economists who had developed the dominant approach to macroeconomics were incapable of carrying it out themselves:

> **"Especially when it comes to matters as important as macroeconomics, ... every proposition must pass the smell test: does this really make sense? I do not think that the currently popular DSGE models pass the smell test... The advocates no doubt believe what they say, but they seem to have stopped sniffing or to have lost their sense of smell altogether." (Solow 2010, p. 2.)**

Solow's insight is very relevant to the issue tackled in this report: the way mainstream climate change economists have assessed the dangers that global warming poses for the economy. None of the assumptions that this relatively small group of economists have made about global warming "pass the smell test." Nonetheless, they continue to produce similar studies, which reach similar conclusions about relatively trivial economic damages from relatively large increases in the global average temperature, because "they seem to have stopped sniffing or to have lost their sense of smell altogether."

This report demonstrates how work on climate change by a relatively small number of economists—work which has been heavily criticised by other economists, as well as by climate scientists—has woven its way into the global population's financial lives, with unnerving consequences for our wellbeing, both physical and economic.

1 The "Organization for Economic Cooperation and Development" is a policy analysis and advisory body with members from 38 of the world's largest economies.

04

Executive Summary

It is now 50 years since economists first disputed the warnings of ecologists and engineers about the potential dangers of climate change (Nordhaus 1973, 1974; Solow 1974; Stiglitz 1974; Forrester 1971; Meadows, Randers, and Meadows 1972; Forrester, Gilbert, and Nathaniel 1974). Just as with the OECD's assurance that the economic future was bright in June 2007, nothing could be further from the truth.

It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so.[2]

Many peer-reviewed economic studies assert that economic damages from global warming will be slight. Summarizing this literature, the 2022 IPCC Report concluded that:

"warming of ~4°C may cause a 10–23% decline in annual global GDP by 2100 relative to global GDP without warming." (IPCC 2022, p. 2459)

These estimates imply that a trajectory towards 4°C of warming by 2100 would cause global GDP in 2100 to be between 13 and 15 times larger than today, whereas without global warming, it would be about 17 times larger than today.[3] These are substantial differences in GDP in 2100, but they imply that significant global warming will cause a relatively small fall in the annual rate of economic growth until 2100.

These economic studies have been relied upon by the consulting firms which pension funds commission to calculate the impact of global warming on their members' portfolios, by central banks undertaking stress tests of the resilience of financial systems to the changes in climate, and by governments developing climate change attenuation policies. For example, the investment consultant Mercer advised the Australian pension fund HESTA that a trajectory towards 4°C of warming by 2100 would reduce the value of its portfolio by just 17%, compared to what it would have been in the absence of global warming.[4]

In contrast, research by climate scientists implies that the impact of a 3°C increase (or even lower) could be "catastrophic" (Kemp et al. 2022), that climate tipping points could be triggered even at 1°C of warming (Armstrong McKay et al. 2022),[5] and that changes to our climate which could trigger tipping points are "too risky to bet against." (Lenton et al. 2019)

While this paper does not attempt to corroborate the views of the science on the scale and timing of catastrophic climate change, we can confirm that assertions by advisors to pension funds that

2 Attributed to Mark Twain, but unverified: see https://quoteinvestigator.com/2018/11/18/know-trouble/ and http://marktwainstudies.com/the-apocryphal-twain-things-we-know-that-just-aint-so/.

3 The average growth rate of global GDP between 1960 and 2016 was 3.7% p.a. (see https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG). Assuming, for simplicity, that this growth rate would continue in the absence of global warming, these IPCC estimates imply that a trajectory towards 4°C of warming by 2100 will cause a fall in the annual growth rate of global GDP from 3.7% p.a. to between 3.35% and 3.55% p.a. This is a trivial decline in the rate of economic growth, and lies within the error range for the measurement of economic growth today.

4 HESTA, 2021, 'Our Path to Net Zero' p.17

5 "Setting aside achievability … this suggests that ~1°C is a level of global warming that minimizes the likelihood of crossing CTPs." (Armstrong McKay et al. 2022, p. 7)

the economic impact of climate change will be relatively minor are at best, inconsistent with climate science, and at worst, entirely wrong.

This inconsistency between climate science and climate economics has arisen largely because climate change economics papers have been refereed by economists only.

There is no problem with economists being the sole peer-reviewers for topics on which economists are the domain experts. However, the economic impact of climate change necessarily covers issues on which climate scientists, and not economists, are the domain experts. It therefore would have been prudent for scientists to peer-review the climate change assumptions made in economic papers. Instead, referees with domain knowledge of economics only approved the publication of opinions on global warming that climate scientists would almost certainly have disputed.

As a result, the empirical components of the vast majority of climate change economic papers are based on scientifically false assumptions. These assumptions drastically underestimate the damages that climate change could do to the economy.

Once these erroneous assumptions entered the economic literature, other weaknesses of the refereeing process that we discuss in the supporting document **How Did We Get Here?** meant that they were preserved and embellished, rather than being challenged and rejected.

The inconsistency between scientific research on climate change and the conclusions of financial trustees and their advisers is not the fault of the trustees or advisors themselves. It is entirely reasonable for them to rely on refereed economic literature. They are entitled to take the fact that a paper has been approved by academic referees at face value, rather than looking critically "behind the curtain" at the papers themselves.

This report does look "behind the curtain" at the economic and scientific literature on climate change, to show that global warming is not a relatively minor cost-benefit problem that will mainly affect future generations, as the economics literature asserts, but a major challenge to the sustainability of human civilisation, as the scientific literature asserts, and on a timescale that could occur within the lifespan of pensioners alive today.

05

Pension funds, consultants, and climate change

Pension fund trustees face an ever more challenging remit

The primary duty of any pension fund is to ensure that pension scheme members are paid their rightful benefits. In our increasingly complex financial world, funds often rely on external expert help and advice. These services are primarily provided by investment consultants.

What is the role of an investment consultant within the Pension Fund system?

Investment consultants are engaged by Pension Fund Trustees or committees to support them in developing investment strategies that deliver the long-term objectives of the scheme. Within this umbrella they sometimes assist in selecting investment managers and evaluating/monitoring the performance of the scheme's investments. Consultants also advise on compliance with the Pension Regulator's integrated risk management structure, most of which are regulated activities under the remit of the UK regulator, the Financial Conduct Authority.

Investment consultants also provide pension funds and other institutional investors information, staff training and advice on net-zero target implementation[6] and managing climate risks, which are new and rapidly evolving fields, and are often unregulated.

Why are they needed?

It is essential that trustees of pension schemes formulate an appropriate investment strategy, within acceptable risk parameters, which matches the scheme's liabilities: in plain language, the payment of the expected benefits to the fund's beneficiaries. It is reasonable to assume that pension fund trustees cannot be experts in everything, and it is also realistic to expect that they will seek advice in areas where they are not expert.

However, it must be noted that wholly delegating management of climate risk to external investment managers and advisory consultants **does not** discharge the legal duties of an administering authority to appropriately consider and manage that risk themselves.

Who are the external investment managers and consultants?

In the UK, Hymans Robertson, Mercer, Aon Hewitt, ISIO, Deloitte, Barnett Waddingham, Minerva, MJ Hudson and Willis Tower Watson are significant players. The big three pension fund consultants—Aon Hewett, Willis Towers Watson, and Mercer—advise approximately 80% of the funds.

The representative example of UK Local Government Pension Schemes (LGPS)

Within this report, due to the availability of information within the public realm, we focus our attention on how climate risk advice is being provided to LGPS public pension funds in England, Scotland and Wales – a list of which can be found in the FOIA Table in the Appendix, pages 80-82.

The Department for Levelling Up, Housing and Communities (DLUHC) which oversees the LGPS, consulted in September 2022 on the governance and reporting of climate risks,[7] and made recommendations requiring each fund obtain "proper advice." Questions about what constitutes proper advice are thus a live topic, for LGPS funds, and government regulators.

6 https://www.mercer.com/content/dam/mercer/attachments/global/investments/gl-2022-net-zero-report.pdf
7 https://www.gov.uk/government/consultations/local-government-pension-scheme-england-and-wales-governance-and-reporting-of-climate-change-risks/localrisks/local-government-pension-scheme-england-and-wales-governance-and-reporting-of-climate-change-risks

LGPS funds reliance on external consultants and investment managers

While in theory, pension trustees or committees are required by law to make their own decisions, as finance becomes more complex, in practice, as non-experts, they have outsourced the implementation of policy to investment consultants and asset managers.

In 2017, Share Action and Client Earth referred multiple LGPS funds to the Pensions Regulator over failures to manage climate risk.[8,9] The response to this referral to the Pensions Regulator[10] confirmed that many pension funds have been relying upon consultants and asset managers for their risk analysis of climate change, as these quotes indicate:

South Tyneside Council Pension Fund: "The investment decision making is with the external managers, who take account of all risks, including climate change, in the decision-making process."

London Borough of Bexley Pension Fund: "The London Borough of Bexley Pension Fund investments are all managed externally and the ESG decisions are delegated to Fund Managers who have been provided with a copy of the Fund's SRI policy."

Derbyshire Council Fund: "The Fund has no climate risk policy in place and believes that climate risk is inexorably bound-up within the decision-making processes of the appointed investment managers. There are currently no intentions of introducing a policy in this area and, given the move towards the pooling of assets within the LGPS that will commence within the next two years, policies such as this will soon become the responsibility of the asset pool rather than individual Funds (although individual Funds will be able to influence the pool)."

We now turn to the current state of the assessment of climate risk by pension funds and other financial institutions and compare this to the economic literature—with which these assessments are consistent—and the scientific literature, with which they most decidedly are not consistent.

8 https://www.room151.co.uk/local-government-pension-scheme-investment/regulator-declines-to-offer-guidance-on-lgps-and-climate-change/
9 https://www.clientearth.org/latest/documents/referral-to-the-pensions-regulator-lgps-funds/
10 https://www.clientearth.org/latest/documents/referral-to-the-pensions-regulator-lgps-funds/

06

A bright future of global warming?

Based on investment consultants' advice, many pension funds claim that substantial warming will only have a minimal impact on portfolio returns.

"*Investing in a bright future*" is the subtitle to the Australian superannuation firm Unisuper's report Climate Risk and Our Investments. It used a "worst case scenario" which implied a "4.3°C increase in global temperatures by 2100," and concluded that "the overall risk to our portfolio is acceptable." (Unisuper 2022, p. 36) The UK-based Shropshire County Pension Fund (Fund 2020) estimated a trajectory that led to 2°C warming by 2100 would actually boost returns till 2030 by 0.05% p.a.[11] (see Figure 1), while a trajectory leading to a 4°C increase by 2100 would only reduce annual returns to 2030 by 0.06% p.a:

"Over the coming decade, a 2°C outcome is, according to the model used, the best climate scenario from a returns perspective (adding 0.05% in annual returns to the asset allocation on a timeline to 2030) while a 4°C outcome is the worst of the three considered (detracting by 0.06% annually over the same period)." (Fund 2020, p. 11)

Figure 1: Shropshire County Pension Fund Climate-Related Disclosures Table 2 (Fund 2020, p. 11). The Table, produced by Mercer, shows impacts on portfolio growth rates, till 2030 and 2050 respectively, of temperature trajectories to 2,3 and 4°C of warming by 2100:

SHROPSHIRE COUNTY
PENSION FUND

Table 2: Annualised climate change impact on portfolio returns - to 2030 and 2050[3]

Scenario	Timeline	Estimated climate impact on returns
2°C	2030	+0.05%
	2050	-0.06%
3°C	2030	-0.01%
	2050	-0.05%
4°C	2030	-0.06%
	2050	-0.10%

11 https://shropshire.gov.uk/committee-services/documents/s26021/6.%20Appendix%20A%20TCFD%20Disclosure%20Final%20Report.pdf

These predictions of the minimal economic impact of global warming of 2-4.3°C are representative of the advice being given by pension funds worldwide to their members.

However, this advice is completely at odds with research by climate scientists, who are increasingly asserting that global warming is an existential threat to human civilisation, and at temperatures well below those contemplated by pension funds. Numerous scientists have expressed alarm at the damages society will face from warming of 2°C or less (Lenton et al. 2008b; Cai, Lenton, and Lontzek 2016; Steffen et al. 2018; Lenton et al. 2019; Xu et al. 2020; Brovkin et al. 2021; Armstrong McKay et al. 2022; Kemp et al. 2022; Xu and Ramanathan 2017).

A recent paper entitled "Climate Endgame: Exploring catastrophic climate change scenarios" (Kemp et al. 2022) "set global warming of 3°C or more by the end of the century as a marker for extreme climate change," and also noted that "There is ample evidence that climate change could become catastrophic … at even modest levels of warming." (Kemp et al. 2022, pp. 4, 8)[12]

Steffen et al. suggested 2°C as a critical marker, because of:

> **"the risk that a 2°C warming could activate important tipping elements, raising the temperature further to activate other tipping elements in a domino-like cascade that could take the Earth System to even higher temperatures (Tipping Cascades) … conditions that would be inhospitable to current human societies" (Steffen et al. 2018, pp 8253-4.)**

Another paper defined:

> **">1.5°C as dangerous; >3°C as catastrophic; and >5°C as unknown, implying beyond catastrophic, including existential threats" (Xu and Ramanathan 2017, p. 10315.)**

Assertions by advisors to pension funds that the economic impact of climate change will be relatively minor are clearly inconsistent with this scientific literature.

12 Kemp et al. define "catastrophic" as "The probability of a loss of 25% of the global population and the severe disruption of global critical systems (such as food) within a given timeframe (years or decades)" (Kemp et al. 2022, p. 5).

07

The gulf between science and economics

Howard and Sylvan surveyed "all economists who have published climate-related research in the field's highest-ranked academic journals" (Howard and Sylvan 2021a, p. i).[13] Question 11 asked respondents to "Provide your best estimates for how the following climate scenario would affect global GDP over time." (Howard and Sylvan 2021b, p. 36) The survey question provided estimates of global GDP in the absence of climate change, which were generated using Nordhaus's *Dynamic Integrated Climate-Economy* (DICE) model. Nordhaus's projection was that, in the absence of global warming, global GDP in 2220 would be 21 times higher than in 2025.[14]

Figure 2: Q11 in the survey: "Please provide your best estimates for how the following climate scenario would affect global GDP over time" (Howard and Sylvan 2021b, p. 36)

Scenario	Scenario 1 - 2025	Scenario 1 - 2075	Scenario 1 - 2130	Scenario 1 - 2220
Year	2025	2075	2130	2220
Temperature increase (relative to pre-industrial era)	1.2°C	3°C	5°C	7°C
Average annual temperature increase over previous 30 years	0.03°C	0.04°C	0.03°C	0.01°C
Estimated global GDP without climate change (trillions in 2019 USD)	173.3	595.1	1430.4	3654.5

Figure 3 summarises the economic damage estimates provided by the survey respondents. The median predictions were that 3°C of warming would reduce global GDP by 5%, 5°C of warming by 10%, and 7°C of warming by 20%.[15]

13 Howard and Sylvan sent their questionnaire to 2169 economists and received 738 responses. While this is a large number of survey recipients and respondents, it is still a small fraction of the total population of academic economists. There are, for example, over 65,000 economists registered with the online archive RePEc (Research Papers in Economics). Oswald and Stern also note that global warming is a minority issue in economics, with the leading 9 journals having published only 57 papers on climate change, out of a total of over 77,000 papers (Oswald and Stern 2019). See Section 2 of the supporting document: **How Did We Get Here?** for more information.

14 The two drivers of growth in DICE are population and "total factor productivity" (TFP). Nordhaus assumes that population stabilises at 10.5 billion, while TFP initially grows at 15% per decade, and declines by 1.2% per decade thereafter (Nordhaus and Sztorc 2013, p. 96). This explains the apparent discrepancy between the growth multiples noted in the Executive Summary and the multiples derived from this survey.

15 The temperature changes considered, as summarized by Tol (Tol 2022, Table 1), ranged from minus 0.6°C (i.e., a fall in global average temperature) to plus 16.7°C, while the changes to GDP at the end date ranged from plus 5.1% to minus 78.9%. For temperature increases of between 4-6°C, the estimates of effect on future GDP, compared to GDP in the absence of climate change, ranged from plus 5.6% to minus 16.1%. These figures were generated by Tol, and often cannot be found explicitly in the source papers. Tol's numerical summaries of the literature are relied upon by other researchers, despite frequent criticism of his work, and past corrections of his errors by journals (Gelman 2014, 2015, 2019; Editors 2015)

Figure 3: "Climate Damage Estimates" from (Howard and Sylvan 2021a, p. 23)

Year	2025	2075	2130	2220
Temperature increase (relative to pre-industrial era)	1.2°C	3°C	5°C	7°C
Economic damages (% of global GDP) - Median estimate	-1%	-5%	-10%	-20%
Economic damages (trillions of 2019 USD) - Median estimate	-$1.7	-$29.8	-$143.0	-$730.9
Economic damages (% of global GDP) - Mean estimate	-2.2%	-8.50%	-16.10%	-25.20%
Economic damages (trillions of 2019 USD) - Mean estimate	-$3.8	-$50.6	-$230.3	-$920.9
Standard deviation	2.9	7.6	13.3	20.7

The median prediction, that 7°C of warming by 2220 implied a global GDP two centuries hence of $2,924 trillion, is 17 times Nordhaus's estimate for global GDP in 2025, versus the 21 times ratio he expected in the absence of global warming.

In other words, these economists expected global GDP to continue growing on a trajectory towards 7°C of warming by 2220, but just more slowly than in the absence of warming. The expected difference in the annual rate of growth of GDP between no-warming and 7°C warming by 2220 is a mere 0.02% per year, which is well below the accuracy with which GDP growth is measured today. Though the accumulated effect of this slower rate of growth over two centuries is large—equivalent to four times global GDP in 2025—the effect on the annual rate of economic growth would be, according to mainstream economists who specialize in climate change, imperceptible.

This highlights the huge gulf between science and economics on global warming. 7°C is well above the 5°C level that scientists have described as "unknown, implying beyond catastrophic, including existential threats." (Xu and Ramanathan 2017, p. 10315) A level of warming that, to scientists, implies existential threats, is seen by economists as a minor impediment to continued economic growth.

The enormous disparity between the expectations of scientists and economists has not gone entirely unnoticed by scientists. In 2013, Lenton and Ciscar observed that:

> **"There is currently a huge gulf between natural scientists' understanding of climate tipping points and economists' representations of climate catastrophes in integrated assessment models (IAMs)." (Lenton and Ciscar 2013, p. 585)**

In a joint report by the Institute and Faculty of Actuaries and the University of Exeter (Trust et al. 2023), co-author Tim Lenton touched on the topic of this report, the extent to which dubious predictions of minimal damages from climate change have affected the formation of policy on climate change:

> **"some economists have predicted that damages from global warming will be as low as 2% of global economic production for a 3°C rise in global average surface temperature. Such low estimates of economic damages – combined with assumptions that 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.**
>
> **It is concerning to see these same economic models being used to underpin climate-change scenario analysis in financial services, leading to the publication of implausible results in the Task Force on Climate-related Financial Disclosures (TCFD) reporting that show benign, or even positive, economic outcomes in a hot-house world. This jars with climate science, which shows our economy may not exist at all if we do not mitigate climate change." (Trust et al. 2023, p. 4.)**

Some scientists have also strongly criticised the "cost-benefit" approach that economists have taken to climate change:

> **"Society may be lulled into a false sense of security by smooth projections of global change. Our synthesis of present knowledge suggests that a variety of tipping elements could reach their critical point within this century under anthropogenic climate change." (Lenton et al. 2008b, p. 1792.)**
>
> **"With these trends likely to continue for the next several decades at least, the contemporary way of guiding development founded on theories, tools, and beliefs of gradual or incremental change, with a focus on economy efficiency, will likely not be adequate to cope with this trajectory." (Steffen et al. 2018, p. 8257.)**

Unfortunately, this conflict between the economic and scientific analysis of climate change transcends academia and has serious consequences for everyday life. By following the advice of consultants who have relied on the damages estimates from the small group of mainstream economists who work on climate change, pension funds have unwittingly and unintentionally misled their members about the threat that global warming poses for the size and security of their pensions.

08

A divided discipline

This economic literature on climate change can be partitioned into four strands:[16]

1. Estimates of the total economic costs of global warming (the "Total Cost of Carbon", or TCC), in terms of a decline in future GDP (normally global GDP in 2100), due to a change in global average temperature (relative to pre-industrial levels) by the same date;
2. Development of "Integrated Assessment Models," (IAMs) primarily by the same economists who develop estimates of the total costs of climate change. IAMs combine a temperature-based climate model with an economic growth model to convert predictions of temperature increase from anthropogenic CO2 increase into a prediction of damages to GDP;
3. Estimates of the Social Cost of Carbon (SCC), and the development of the "Shared Socioeconomic Pathways" (SSPs), undertaken by a much larger—but still relatively small—group of economists, who use the estimates of the total cost of carbon and the IAMs developed by the first group; and
4. Criticism of all three of these research strands, sometimes by economists who had previously contributed to those research strands.

Consultants to pension funds have relied upon the first two strands of the literature, and in particular, the first: estimates of the impact of global warming upon future GDP.

Both the number of estimates of the total economic costs of global warming, and the number of economists producing these estimates, are extremely small. Tol's 2009 literature survey (Tol 2009) documented three USA-based and 13 global studies (Tol 2009): see Table 1, which lists the 13 global studies, and their 13 authors.[17]

Table 1: The numbers in (Tol 2009) to which Nordhaus fitted his DICE-2013 damage function

Authors	Year	Warming °C	Change in future GDP, relative to a world without global warming
Nordhaus	1994	3	-1.3%
Nordhaus	1994	3	-4.8%
Fankhauser	1995	2.5	-1.4%
Tol	1995	2.5	-1.9%
Nordhaus and Yang	1996	2.5	-1.7%
Plambeck and Hope	1996	2.5	+2.5%
Mendelsohn Schlesinger and Williams	2000	2.5	0.0%
Nordhaus and Boyer	2000	2.5	-1.5%
Tol	2002	1	+2.3%
Maddison	2003	2.5	-0.1%
Rehdanz and Maddison	2005	1	-0.4%
Hope	2006	2.5	+0.9%
Nordhaus	2006	2.5	-0.9%

16 There is also a fifth strand of research by economists who reject mainstream "Neoclassical" economics completely, and who analyse global warming using very different methodologies (Bovari, Giraud, and McIsaac 2018; Gourdel et al. 2021; Dunz, Naqvi, and Monasterolo 2021; Dunz et al. 2021; Howarth and Monasterolo 2017; Keen et al. 2022; Keen 2020a; Keen, Ayres, and Standish 2019; Garrett, Grasselli, and Keen 2020). However, the work of this group of scholars has not affected policy, and their work is often ignored by the mainstream economists.

17 Nine of these TCC estimates were used by the second group of economists to produce 232 estimates of the SCC (Tol 2009, Table 1 & Table 2, pp. 30 & 39). Tol notes that 9 TCC estimates can generate more than 200 SCC estimates, because the SCC estimates apply different assumptions about discount rates to the same input data, use "different projections of CO2 emissions, different representations of the carbon cycle, different estimates of the rate of warming, and so on" (Tol 2009, p. 40).

This group is also closely interrelated. As Tol noted, "The studies can be roughly divided into two groups: Nordhaus and Mendelsohn are colleagues and collaborators at Yale University; at University College of London, Fankhauser, Maddison, and I all worked with David Pearce and one another, while Rehdanz was a student of Maddison and mine." (Tol 2009, p. 30) The number of researchers and studies have increased since 2009—Tol's 2022 literature survey paper noted 61 estimates of the Total Cost of Carbon (TCC), from 33 studies (Tol 2022, p. 2; Table 1, pp. 19-20)[18]— but it still remains a close-knit community, with just 27 lead authors, 45 primary authors, and fewer than 80 authors in total.[19]

Such small and interrelated groups can potentially fall prey to groupthink, as Tol acknowledged:

> **"...[A]lthough the number of researchers who published marginal damage cost estimates is larger than the number of researchers who published total impact estimates, it is still a reasonably small and close-knit community who may be subject to group-think, peer pressure, and self-censoring." (Tol 2009, pp. 42-43)**

8.1 Dry economics

One key instance of groupthink is the fact that the first IAM—Nordhaus's DICE model—used temperature change as the sole marker of climate change, ignoring the impact of global warming on precipitation as well. Thirty years later, the practice of ignoring precipitation changes in economic IAMs continues, as acknowledged by a recent survey of economic studies of tipping points:

> **"effects on precipitation... have yet to be incorporated in economic studies. (Dietz et al. 2021b, p. 25.)**

Models developed by climate scientists—known as Global Circulation Models (GCMs)—do include precipitation effects as well as temperature. This difference alone is sufficient to explain some of the, to the lay reader, perplexing difference between the projections of scientists and economists on the impacts of climate change.

Two recent studies of the same phenomenon—the potential shutdown of the Atlantic Meridional Overturning Circulation (AMOC)—provide a striking example. The AMOC is part of an enormous circulation of seawater known as the "Thermohaline Circulation"(THC). This process links all the planet's oceans and is driven by differences in temperature and salinity.[20] The AMOC, which keeps northern Europe substantially warmer than it would otherwise be, is susceptible to being "turned off" as increased melting of Northern Hemisphere ice reduces the salinity of the North Atlantic.

18 In fact, Tol's Table 1 lists 39 studies with 70 estimates.

19 We define either the first three co-authors, or subsequently listed authors who have contributed to other studies, as primary authors. The sum of less than 80 authors in total is despite the fact that two papers had 18 (Takakura et al. 2019) and 21 (McCallum et al. 2013) co-authors respectively.

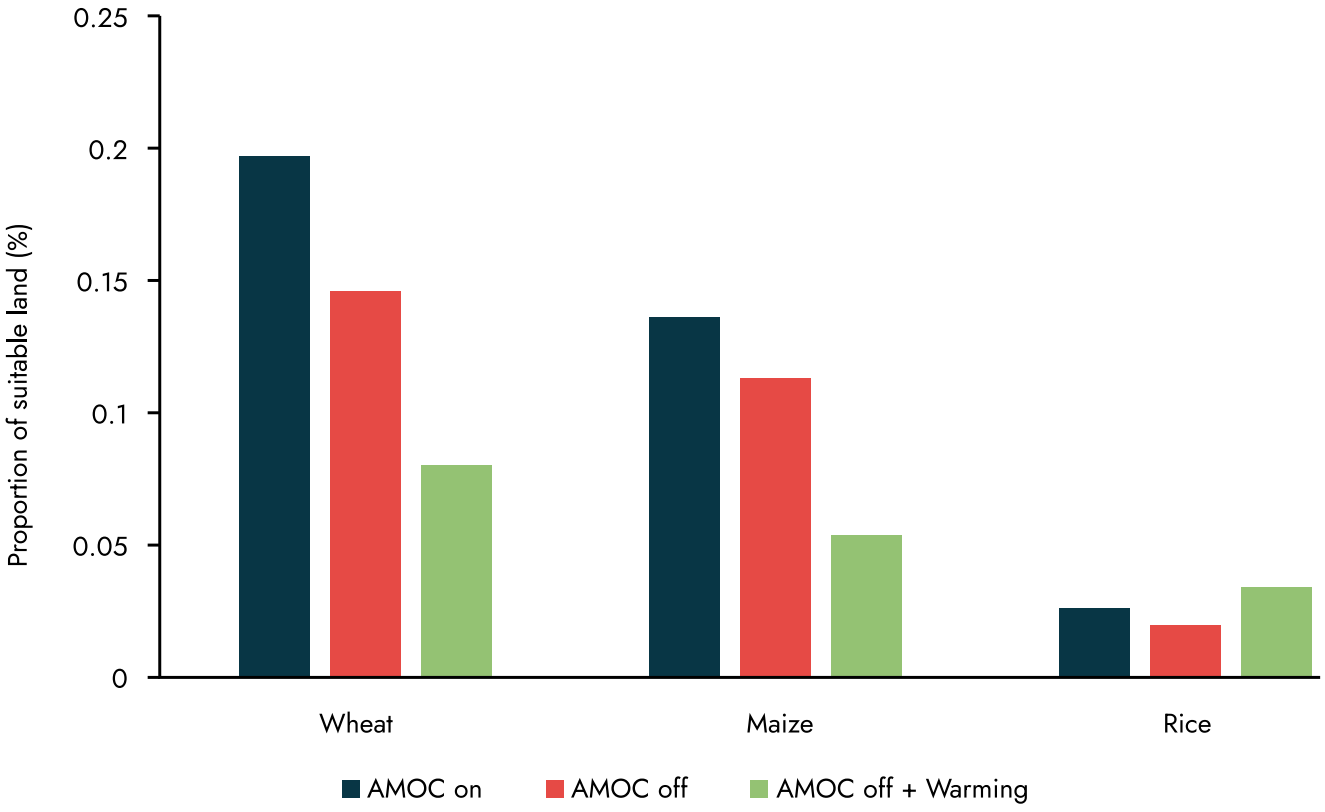
20 See https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html; the Wikipedia entry https://en.wikipedia.org/wiki/Thermohaline_circulation provides more detail.

A scientific study of the shutdown of the AMOC, commissioned by the OECD, concluded that:

> **"an AMOC collapse would clearly pose a critical challenge to food security. Such a collapse combined with climate change would have a catastrophic impact." (OECD 2021, p. 151)**

Its prediction was that an AMOC slowdown, combined with a 2.5°C rise in global average temperatures, would reduce the amount of the planet's land area that is suitable for growing wheat from 20% to 7%—see Figure 4.

Figure 4: The Fraction of Total Land Grid Boxes Suitable for Crop Growth (OECD 2021, Figure 3.20, p. 153)[21]



An economic study of the impact of weakening the Thermohaline Circulation (THC), on the other hand, predicted that global GDP would rise substantially if this tipping point were triggered:

> **"If the THC slows down a little, the global impact is a positive 0.2-0.3 percent of income. This goes up to 1.3 percent for a more pronounced slowdown." (Anthoff, Estrada, and Tol 2016, p. 604)**

21 The labelling of the Y-axis is in fractions, rather than percentages as stated in the OECD document itself.

The study's authors simply assumed that if temperature moved closer to some hypothetical optimum, then so too would precipitation:

> **"As is common, we use the change in the average annual temperature as an indicator of the severity of climate change… Integrated assessment models often assume that other climate variables scale with temperature, but the relationship may be different for greenhouse warming and THC cooling." (Anthoff, Estrada, and Tol 2016, pp. 603, 605.)**

This is a climatologically absurd assumption. However, despite this obvious failing, this study was used as the estimate of the economic impact of losing the AMOC in Dietz et al.'s study of the economic impact of tipping points. Its incorporation lessened the damages that Dietz et al. predicted (Dietz et al. 2021a, p. 7. See section 11 of this report for further details).

8.2 Ignoring internal critics

The work of climate change economists has been strongly criticised in the 4th strand in the economic literature. Eminent and well-respected economists such as Stern, Stiglitz, de Canio, Ackerman, Stanton, Weitzman and Pindyck have been strident and persistent critics of the dominant approach within economics to modelling global warming.[22] However, their criticisms appear to have had little to no impact on the way in which mainstream climate change economists do their research. Their criticisms have been noted, but they have not affected the research practices of the first three groups of economists.

Cited below are two key examples of the criticisms levelled. The first targets the use of today's temperature and economic output data as a proxy for the effects of global warming over time, while the second rejects the way that the dominant models assume that economic damages occur.

The earliest criticisms (Cline 1996; Darwin 1999; Quiggin and Horowitz 1999) relate to the use of current data on agricultural output and temperature to predict the impact of global warming on GDP (see, e.g., (Mendelsohn, Nordhaus, and Shaw 1994). Tol describes this practice as "the statistical approach", and explains that:

> **"It is based on direct estimates of the welfare impacts, using observed variations (across space within a single country) in prices and expenditures to discern the effect of climate. Mendelsohn assumes that the observed variation of economic activity with climate over space holds over time as well; and uses climate models to estimate the future effect of climate change." (Tol 2009, p. 32.)**

22 Critical works by economists include (Cline 1996; Darwin 1999; Quiggin and Horowitz 1999; DeCanio 2003; Spash 2007; Ackerman and Stanton 2008; Oreskes, Conway, and Shindell 2008; Stanton, Ackerman, and Kartha 2009; Ackerman, Stanton, and Bueno 2010; Ng and Zhao 2011; Weitzman 2011b, 2011a; Ackerman and Munitz 2012; Aldred 2012; Auffhammer et al. 2013; Pindyck 2013; Stern 2013; Howard and Sterner 2017; Pindyck 2017; Auffhammer 2018; Stern and Stiglitz 2021; Stern 2022; Stern, Stiglitz, and Taylor 2022). See Section 8.1 on pages 52-53 of the supporting document: **How Did We Get Here?** for details on these papers.

In other words, these economists assumed that the relatively weak relationship that exists today between the temperature of different regions of a country and the income of those regions could be used as a proxy for the impact that higher global temperatures will have on future global economic income. Tweets by the economist who authored the above quote elaborate upon the thinking behind this assumption:

> **"10K [10°C] is less than the temperature distance between Alaska and Maryland (about equally rich), or between Iowa and Florida (about equally rich). Climate is not a primary driver of income. (Tweet posted 17 June 2019)[23]**
>
> **"Argument is this: As there are very different living standards in almost identical climates (e.g., the two halves of Hispaniola and Korea) and almost identical living standards in very different climates (e.g., Singapore and Iceland), climate is not a dominant economic factor. (Tweet posted 9 July 2019)[24]**

Other economists rejected this assumption from the outset. Cline noted that "there are basic conceptual questions about the validity of applying cross-section analysis of present-day land values to predict future global-warming impacts." (Cline 1996, p. 1309) Quiggin and Horowitz observed that "There are strong reasons to expect that a comparative static approach will yield small estimates of global warming's impact on agriculture." (Quiggin and Horowitz 1999, p. 1045)[25]

Section 5.3 of the supporting document **How Did We Get Here?** elaborates on one key weakness of this approach, that cold, temperate, and hot regions of the planet today generate much of their incomes from sales to regions with different temperatures. Incomes of different regions of the planet today are therefore not independent from one another. The studies by these economists failed to correct for this fact, which invalidates their results, even as studies of the impact of temperature on income today.

Despite these early criticisms, this method was used in several subsequent empirical studies (Mendelsohn, Schlesinger, and Williams 2000; Mendelsohn and Neumann 1999; Nordhaus and Boyer 2000; Tol 2002b, 2002a; Hope 2006; Nordhaus 2006; Nordhaus 2008, 2013; Hope 2011). The numbers generated by these studies are still used to calibrate IAMs today (Tol 2022, Table 1). The dominant empirical estimation technique today, which uses change in temperature and GDP data to estimate the future impact of global warming (Kahn et al. 2021; Burke, Hsiang, and Miguel 2015; Kalkuhl and Wenz 2020), is simply an embellishment of this same, flawed method.

Secondly, 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).

23 https://twitter.com/RichardTol/status/1140591420144869381?s=20
24 https://twitter.com/RichardTol/status/1678040832312483840?s=20
25 We cover these issues in detail in Section 4 of the supporting document: **How Did We Get Here?**.

In 2009, Stanton, Ackerman, and Kartha observed that:

> **"Our review of the literature uncovered no rationale, whether empirical or theoretical, for adopting a quadratic form for the damage function—although the practice is endemic in IAMs." (Stanton, Ackerman, and Kartha 2009, p. 172)**

Weitzman noted that:

> **"we might be underestimating considerably the welfare losses from uncertainty by using a quadratic damages function." (Weitzman 2012, p. 221)**

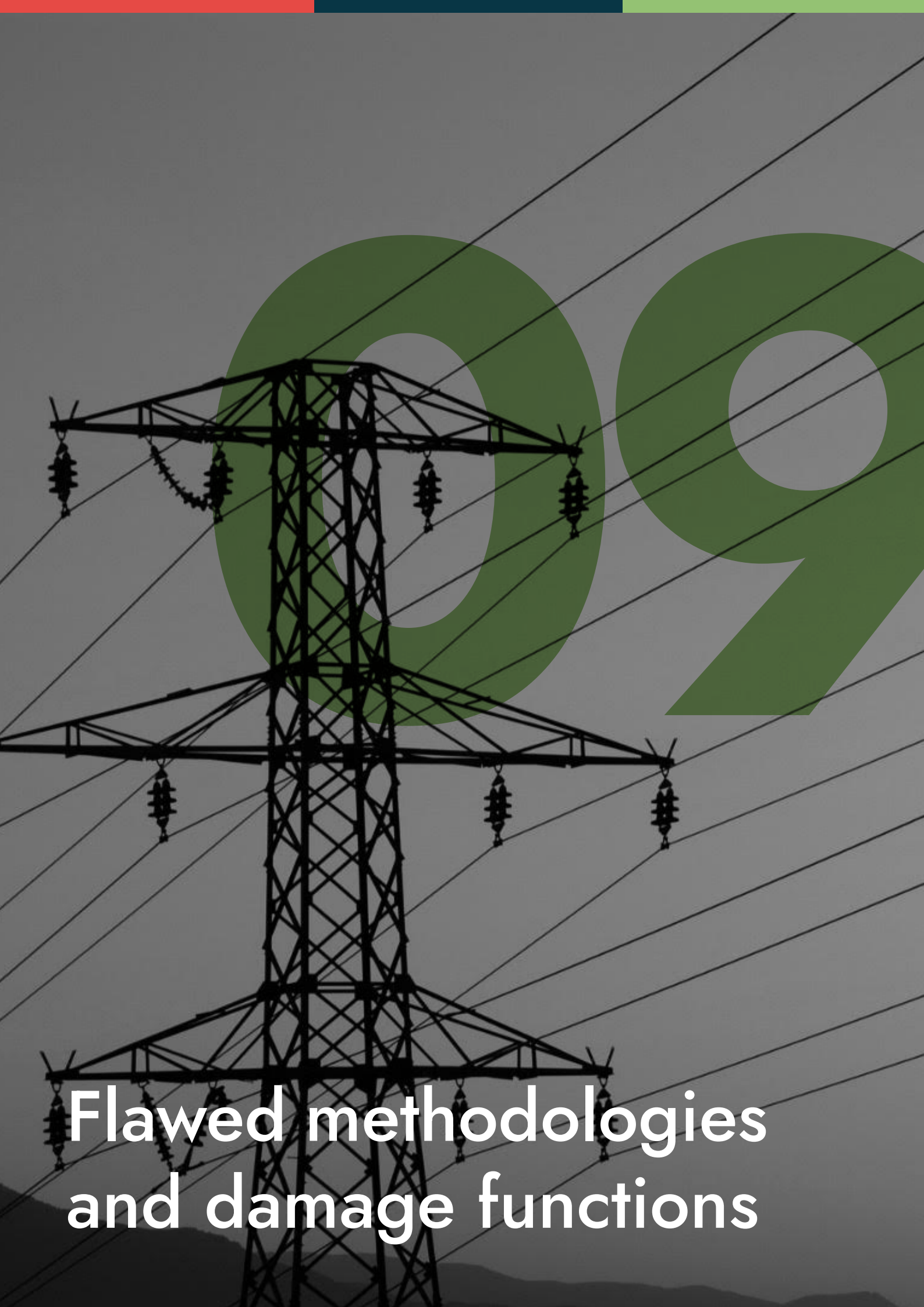
Pindyck cuttingly remarked that:

> **"The damage function used in the Nordhaus DICE 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." (Pindyck 2017, pp. 103-104.)**

Despite this criticism from within the economic fraternity itself, mainstream climate change economists have continued to use quadratic or very similar damage functions, right up to the current day: three more papers using quadratic damage functions were published in 2021 (Dietz et al. 2021a; Kahn et al. 2021; Warren et al. 2021)—including one purporting to predict the economic damages from tipping points (Dietz et al. 2021a).

The critical literature within economics has therefore had no significant effect on how estimates of the total damages from global warming are calculated by the climate economists who develop and calibrate IAMs. Nor has it altered the way in which climate risk models are translated into everything from investment advice to pension schemes, to economic policy on climate change and stress testing global financial systems.

Consequently, the approach that has dominated the economic analysis of global warming has led to governments, central banks, regulators, and financial stakeholders, all the way down to pension/savings advisors, operating under a false sense of security in the face of what, according to climate scientists, could be an existential threat (Lenton et al. 2019).



09

Flawed methodologies and damage functions

This paper proposes practical remedial actions by the finance sector later. For now, we will elaborate upon the significant and irreparable inaccuracies in the work of these economists on climate change, which completely invalidate their sanguine conclusions about the economic and financial dangers. Only an overview is provided here: with more detail provided in the supporting document **How Did We Get Here?**.

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.

Nordhaus used the first assumption, that "activities … which are undertaken in carefully controlled environments … will not be directly affected by climate change," to assert that 87% of the USA's economy would be "negligibly affected by climate change." (Nordhaus 1991, p. 930) The industries that he assumed would be "negligibly affected" are those that are not exposed to the weather:[26] manufacturing, retail and wholesale trade and services, finance and insurance, most transport and communication, and government—see Figure 5. Nordhaus also commented that:

> **"for the bulk of the economy - manufacturing, mining, utilities, finance, trade, and most service industries - it is difficult to find major direct impacts of the projected climate changes over the next 50 to 75 years." (Nordhaus 1991, p. 932)**

Figure 5: Nordhaus's Breakdown of US Industries into Severely, Moderately, and Negligibly Affected Sectors (Nordhaus 1991, p. 531)

Breakdown of economic activity by vulnerability to climatic change, U.S. 1981

Sector	National income	
	Value (billions)	Percentage of total
Total national income	2415.1	100.0
Potentially severely impacted		
Farms	67.1	2.8
Forestry, fisheries, other	7.7	0.3
Moderate potential impact		
Construction	109.1	4.5
Water transportation	6.3	0.3
Energy and utilities		
Energy (electric, gas, oil)	45.9	1.9
Water and sanitary	5.7	0.2
Real estate		
Land-rent component	51.2	2.1
Hotels, lodging, recreation	25.4	1.1
Negligible effect		
Manufacturing and mining	627.4	26.0
Other transportation and communication	132.6	5.5
Finance, insurance, and balance real estate	274.8	11.4
Trade and other services	674.6	27.9
Government services	337.0	14.0
Rest of world	50.3	2.1

26 Mining is the only exception, but later papers showed that Nordhaus was thinking of underground mining only when he wrote this paper (Nordhaus 1993, p. 15).

Section 3 of the supporting document **How Did We Get Here?** explains in detail why exposure to climate change cannot be reduced to exposure to the weather. Global warming is also caused in large measure by how we generate and use energy, so of course these industries will be affected by global warming, since they need energy in order to operate.

The second assumption, that "the observed variation of economic activity with climate over space holds over time as well," (Tol 2009, p. 32) was used to justify using regional data on temperature and income today as a proxy for the impact of global warming on global GDP. In addition to the obvious issue that space is not a proxy for time, the empirical studies done using this assumption ignored the fact that incomes across regions today are not independent: cold regions can achieve high incomes today because they can trade with temperate and hot regions. However, a hotter future global economy cannot trade with today's colder global economy.

The third assumption, that GDP and change in temperature data between 1960 and 2014 can be extrapolated to predict the impact of global warming on future GDP, ignores the likelihood that further temperature rises will trigger tipping elements (Lenton et al. 2008b). These are large-scale components of the Earth's climate whose existence and states depend upon temperature, in such a way that a substantial increase could "flip" them from one stable state to another. Examples include:

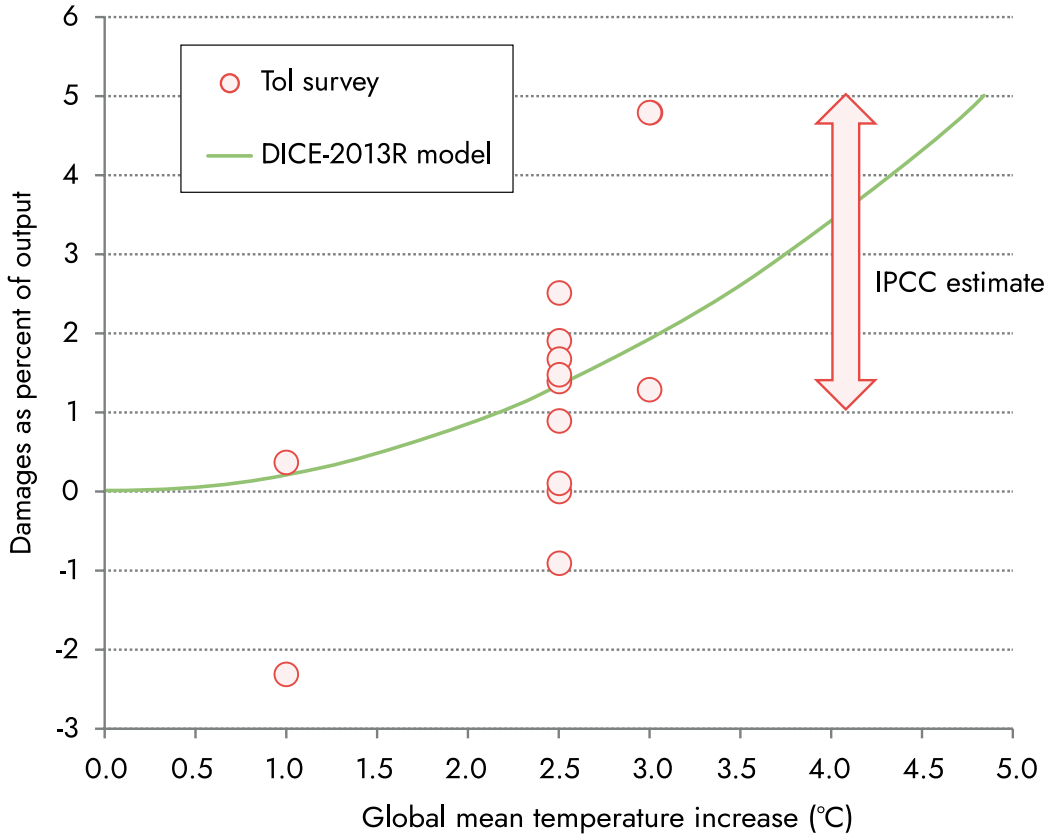
Summer sea ice in the Arctic (and Antarctic), which reflects up to 90% of the solar radiation falling on it, whereas the dark ocean it covers absorbs up to 90% of solar radiation. (Vihma 2014)

Permafrost, soil near the Poles which contains frozen organic matter with twice as much carbon as is currently in the atmosphere. This carbon could be released into the atmosphere as methane or CO2 by more warming. (MacDougall, Avis, and Weaver 2012)

Using these three assumptions, mainstream climate change economists generated a set of numbers purporting to link global warming to its impact on GDP, at global warming temperatures ranging from 1–6°C. Economists then treated these numbers as data, to which they fitted "damage functions," which purport to show the relationship between global warming and a fall in future GDP, relative to what GDP would have been in the absence of global warming. Table 1 shows the numbers published in (Tol 2009, Table 1, p. 31) to which Nordhaus fitted his damage function in the 2013 incarnation of his Integrated Assessment Model DICE.[27] Figure 6 shows Nordhaus's plot of these numbers, together with his damage function (the green curve), from his 2013 manual for DICE (Nordhaus and Sztorc 2013 Figure 2, p. 12).

27 DICE stands for "Dynamic Integrated Model of Climate and the Economy". Nordhaus adjusted his statistical fit with an arbitrary "adjustment of 25 percent of the monetized damages to reflect these non-monetized impacts" such as "(the economic value of losses from biodiversity, ocean acidification, and political reactions), extreme events (sea-level rise, changes in ocean circulation, and accelerated climate change), impacts that are inherently difficult to model (catastrophic events and very long term warming), and uncertainty (of virtually all components from economic growth to damages)." (Nordhaus and Sztorc 2013, p. 11)

Figure 6: from the DICE manual (Nordhaus and Sztorc 2013, p. 12)



The damage function in DICE-2013 is:

$$Damages\left(Temperature_{Change}\right) = 0.267\% \times \left(Temperature_{Change}\right)^2$$

This yields the prediction that economic damages from global warming will be "2.0 percent of income at 3°C, and 7.9 percent of global income at a global temperature rise of 6°C" (Nordhaus 2018, p. 345).

Given the temperature and damage to GDP numbers generated by these economists, a quadratic is as good a function as any to fit them. However, **these numbers are not data:** they are instead "hunches" (to use Nordhaus's own word from Nordhaus 1991, p. 933) based on spurious assumptions about global warming, which have been used to generate equally spurious estimates of damages to future GDP.

In the next section, we demonstrate why 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).

A better, though still flawed, method

The assumptions that (a) the impact of global warming on the economy can be discerned from current data, and (b) that the impact of global warming on the economy can be captured by smooth functions, are tenuous at best. However, these assumptions have been made by climate change economists, and they have been applied badly: the numbers they have used are not data, but hypothetical numbers generated by economists themselves; while the functions that have been fitted to these numbers cannot capture the phenomenon of non-linear step changes in the climate, normally referred to as "tipping points."

In this section,[28] we illustrate how these assumptions are the key factors that have generated the predictions by economists[29] that damages to GDP from global warming will be very modest, by:

1. Using as data a publicly maintained database of weather and climate damages, rather than the numbers generated by economists;
2. Fitting this data using three functions: a quadratic, an exponential, and a logistic, rather than a quadratic only; and
3. Judging which equations are more compatible with the scientific literature on global warming and tipping points.

The USA's National Oceanic and Atmospheric Administration (NOAA) maintains the Billion-Dollar Weather and Climate Disasters database, which records the cause and scale of every weather or climate event since 1980 that generated $1 billion or more of damages in 2015 US dollars.[30] The data spans the period 1980 till 2022, over which period global average temperature rose from 0.2°C to 1°C, compared to the average in 1900.[31]

The three functions used are a quadratic—the function habitually used by climate change economists—an exponential, and a logistic. A quadratic cannot capture the phenomenon of tipping points, while the exponential and logistic can. This is because, though a quadratic implies accelerating damages from rising temperatures, the rate of acceleration never changes.

Tipping points, however, imply an acceleration in damages after they are crossed, as factors like reduced reflection of sunlight (from the replacement of Arctic summer sea-ice, which reflects solar radiation, with ocean water, which absorbs it) or increased greenhouse gas emissions (from the release of CO2 and methane from permafrost or ocean methane hydrates) add to global warming caused by humanity's burning of fossil fuels. Both the exponential and the logistic can capture this phenomenon.[32]

Figure 7 plots this data, and fits three functions to it: a quadratic, which is the function used by most IAMs; an exponential; and a logistic.

---

28 See the supporting document: **How Did We Get Here?** to this Report for a detailed exposition of the points summarised here.

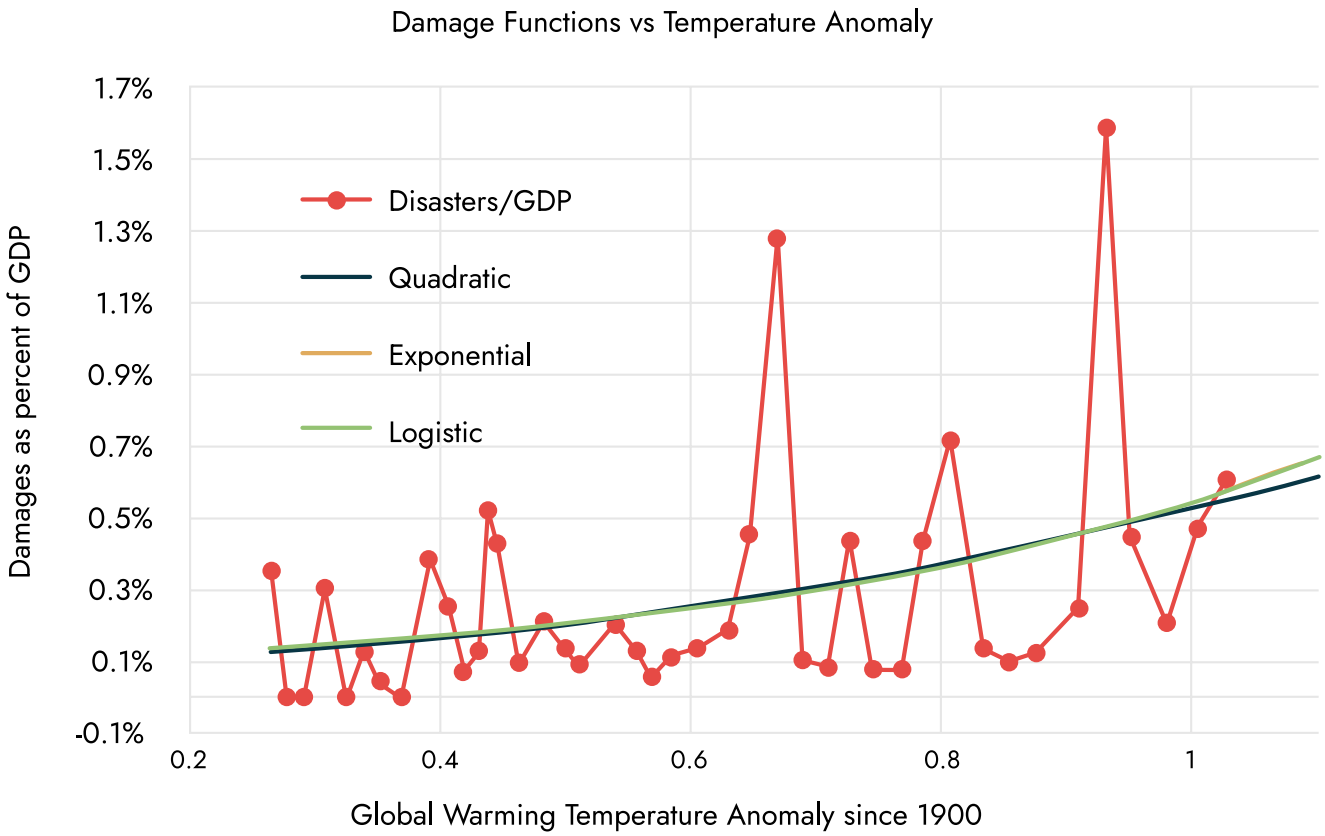
29 Whenever we say "economists" without qualification, we are referring to the mainstream economists who have specialised on the economics of global warming, and in particular, the much smaller group of mainstream economists who have developed estimates of the total economic cost of global warming.

30 https://www.ncei.noaa.gov/access/billions/.

31 https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/land_ocean/ytd/12/1880-2021.

32 A quadratic has the form $y(x)=a \cdot x^2$, where in this case x represents the increase in global average temperature and y represents the economic damages caused by that increase. The acceleration of a quadratic is 2a, which is a constant, regardless of the level of x. An exponential has the form $y(x)=e^{a*x}$. Its acceleration is $a^2 \cdot e^{a*x}$, which keeps changing as x increases. A logistic has the form $y(x)=\frac{1}{1-e^{-a*x}}$. Its acceleration term is too complicated to show here, but it too keeps changing as x increases.

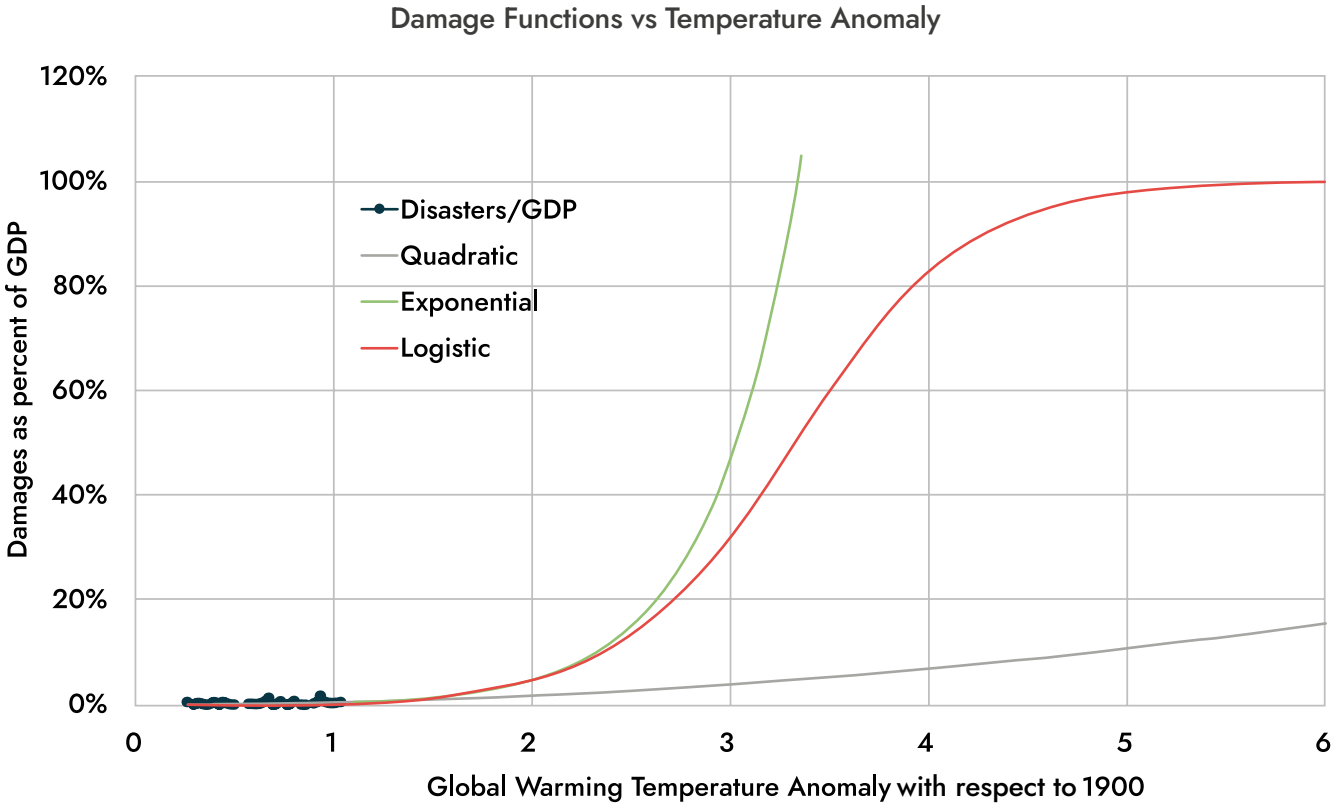
Figure 7: Temperature anomaly–>Damages data and functional regressions



It is obvious that the fit of these three functions to the current data ***cannot be distinguished from one another***. In fact, they are so similar that, between 0.2 and 0.95°C of warming, the three functions have the same values to two decimal places—hence their plots overwrite each other in Figure 7.

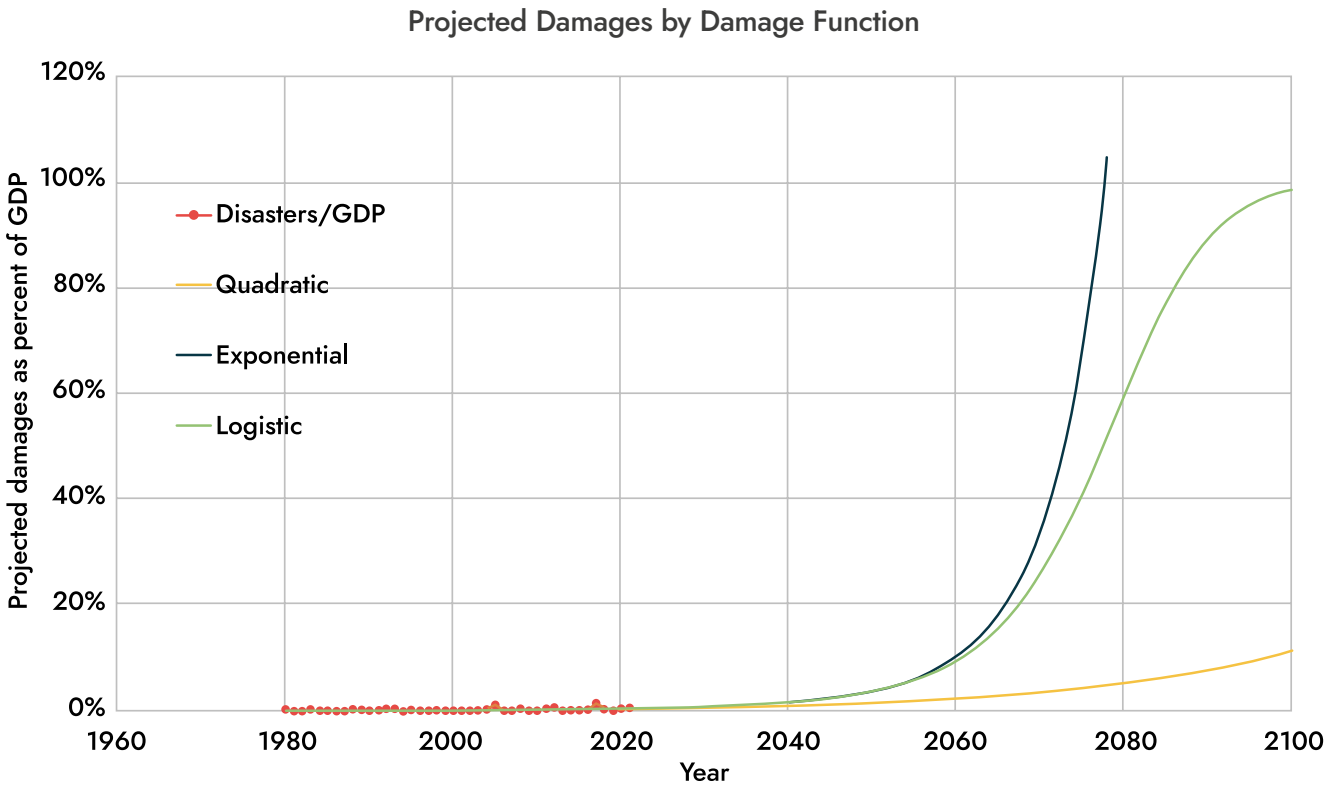
However, the functions diverge dramatically once we move beyond existing data. The quadratic fit predicts about twice the damages from 6°C of warming as Nordhaus's function, but this is still within the ballpark of IAMs. On the other hand, the exponential function predicts the total destruction of the economy at 3.3°C, while the logistic predicts total destruction by 5°C—see Figure 8.

Figure 8: Extrapolating historic damages forward against the predicted temperature anomaly



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—see Figure 9.

Figure 9: Extrapolating historic damages against time, given the temperature anomaly



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.

We emphasise that the assumption on which all work by mainstream climate change economists has been based—that current data contains a footprint of global warming from which its future economic impact can be predicted—is tenuous at best. Nevertheless, simply by replicating their empirical methods using an independently developed database, and by fitting several damage functions rather than just a quadratic, we have reached results that are not inconsistent with the scientific literature. This shows that assurances by these economists that damages from global warming are minor and distant, cannot be trusted.

We also emphasise that the gradual onset of economic breakdown implied by these functions is not at all how the process of climate-change-induced economic collapse is likely to occur, should we trip planetary tipping points. Nor is the timing implied by the relatively more realistic functions—the exponential and the logistic—an accurate guide to when significant economic damage could occur.

Nor are we proposing that economists should in future use an exponential or logistic damage function, rather than a quadratic.[33] Instead, the point of this section is to illustrate that the sanguine predictions made by economists about limited economic damages from global warming are the product of two false assumptions—that the numbers they have generated are relevant to global warming, and that damages from climate change can be modelled using a quadratic.

33 However, one of the referees to this report—the climate scientist Tim Lenton—has adapted the logistic function we proposed here, as a means to "start with what we want to avoid, then work backwards from there…" He proposed that "A relatively simple log damage function could be used that assumes 100% GDP loss at a certain level of warming, say 6˚C, 5˚C, or 4˚C, although some may argue that even 3˚C would be extremely challenging to adapt to…" (Trust et al. 2023, pp. 24-25)

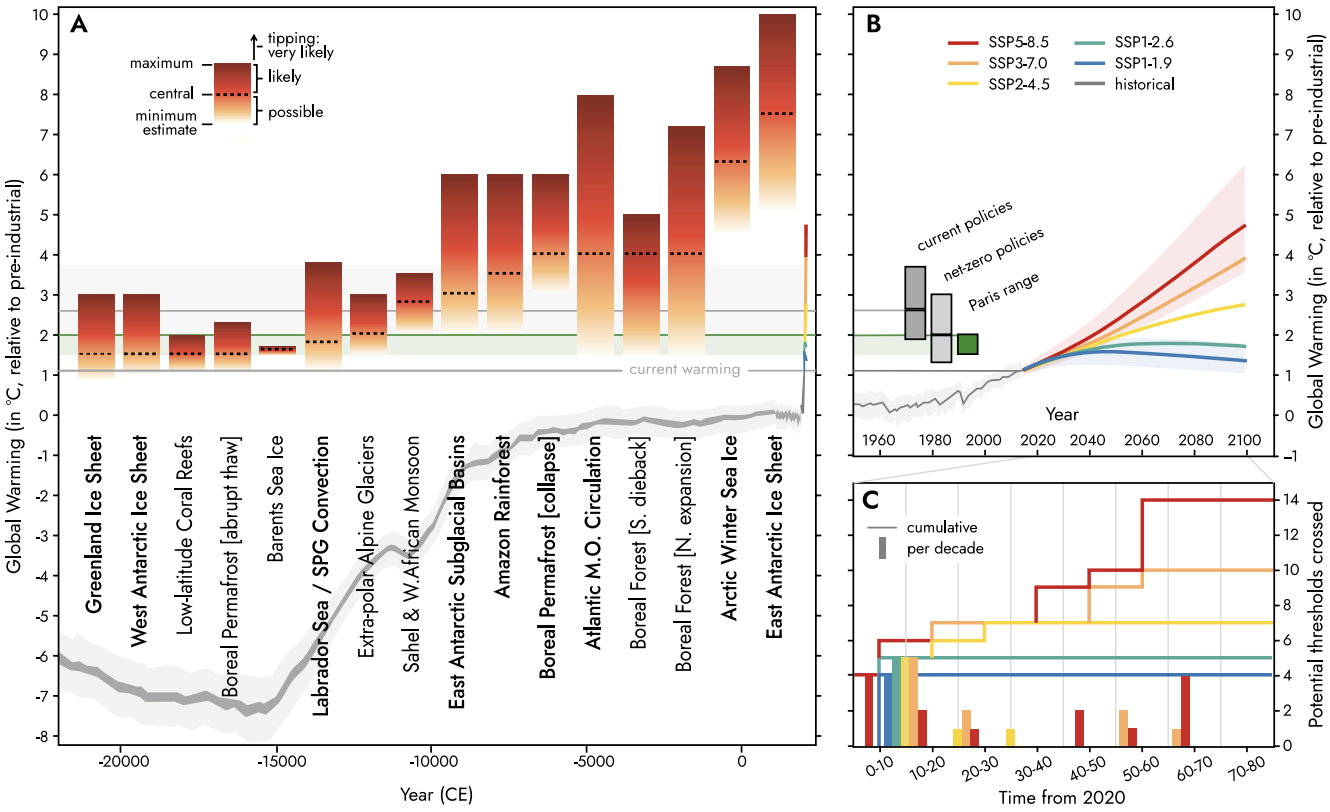
11

Tipping points and “the smell test”

Given the nature of tipping points, change in the economic impact from global warming is far more likely to be discontinuous and abrupt, rather than continuous and relatively gradual, and could occur far earlier than implied by Figure 9. Armstrong McKay et al. postulate that several tipping points could be triggered in the next decade (Armstrong McKay et al. 2022).[34]

Key candidates for sudden and near-term tipping include the loss of the Barents Sea winter ice, and the collapse of deep convection in the Labrador Sea—which would cause a more extreme seasonal climate in Europe (akin to the Little Ice Age), and significant sea level rise on northeast seaboard of USA—see Figure 10.

Figure 10: from (Armstrong Mckay et al. 2022, p. 8) global warming threshold estimates for global core and regional impact climate tipping elements.



Since global warming has already reached 1.25°C, which exceeds the minimum estimated threshold for tipping Arctic summer sea ice, and the Greenland and West Antarctic ice sheets (Armstrong McKay et al. 2022, pp. 1 & 3), the topic of tipping points and their potential impact upon both the global economy and pensions cannot be ignored by pension funds and their advisors:

> **"Setting aside achievability (and recognizing internal climate variability of ~±0.1°C), this suggests that ~1°C is a level of global warming that minimizes the likelihood of crossing CTPs." (Armstrong McKay et al. 2022, p. 7)**

Given how critical tipping points are to the dangers of global warming, a recent paper by Dietz, Rising, Stoerk and Wagner, entitled "Economic Impacts of Tipping Points in the Climate System" (Dietz et al. 2021a), deserves special mention for its underestimation of these dangers. The tipping points considered in this paper were:

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)

The paper concluded that the sum effect of triggering these eight tipping points would be to add an additional 1% of damages to those caused by temperature rise alone at 3°C, and an additional 1.4% to temperature-induced damages at 6°C:

> **"Tipping points reduce global consumption per capita by around 1% upon 3°C warming and by around 1.4% upon 6°C warming, based on a second-order polynomial fit of the data." (Dietz et al. 2021a, p. 5)**

This paper was criticised by a group of climate scientists and non-mainstream economists, who noted that:

> **"Asserting consumption would be just 1.4% lower with all tipping points breached, i.e., critical elements of the current climate destroyed—while also being much larger than today—is inconceivable, and impossible to reconcile with scientific literature." (Keen et al. 2022, p. 1)**

Dietz et al.'s response challenged the assertion that damages would be significantly larger than their estimates:

> **"Keen et al. argue the conclusions and procedures ... do not make sense, seemingly taking it as given that the economic impacts of climate tipping points will be larger than our estimates." (Dietz et al. 2022, p. 1.)**

Of course, the critics took it as given that damages from triggering these eight tipping points would be larger than a mere 1% to 1.4% of future GDP!

The climatic changes envisaged by Dietz et al. would be visible from space: the Arctic during summer would be deep blue rather than white; the Amazon would go from green jungle to brown savannah or desert; Greenland and the West Antarctic would ultimately go from white ice to brown rock. The energy content of ocean methane hydrates exceeds that of all other fossil fuel deposits (Stephenson 2018, p. 18); the carbon held in permafrost is roughly twice the current carbon content of the atmosphere (Zimov, Edward, and Chapin 2006, p. 1612). The weakening or collapse of the AMOC could plunge Europe into conditions akin to the Little Ice Age (Lehner et al. 2013) and drastically reduce the land area suitable for wheat and corn farming (OECD 2021, p. 153), while increased variability of the Indian monsoon would jeopardise the lives of over a billion people.

The claim that these changes would have effectively zero impact upon the human economy is extraordinary,[35] and it should be supported by extraordinary analysis or evidence. Instead, the paper is representative of the many weaknesses of this literature, right down to the use of quadratics to extrapolate hypothetical data.

Within the range of temperature increases contemplated by most mainstream climate change economics papers (up to 6°C), Dietz et al. assert that the impact of tipping points can be emulated by increasing damages from temperature alone by roughly 15%. Past 7°C of warming, they even claim that tipping points will attenuate damages from temperature rises alone. This is a consequence of their use of a quadratic to extrapolate their results:

> **"Using a second-order polynomial to fit the data, 2°C warming in the absence of tipping points corresponds to 2.3°C warming in the presence of tipping points, for instance... Beyond 7°C warming in the absence of tipping points, the combined effect of tipping points is to reduce the temperature response to GHG emissions." (Dietz et al. 2021a, p. 5, & bottom chart in Fig. 5., p. 6.)**

To repeat Robert Solow's observation on macroeconomic models, the conclusions of Dietz et al. do not "pass the smell test", while the reactions of Dietz et al. to criticism shows that "The advocates no doubt believe what they say, but they seem to have stopped sniffing or to have lost their sense of smell altogether." (Solow 2010, p. 2)

35 To a first order of magnitude, a 1.4% fall in GDP in the distant future is no impact at all.

This paper is now being used by other economists to claim that tipping points can be included in the estimates of the economic damages from climate change, via a small increase in the parameters for their damage functions. In his most recent revision to DICE, Nordhaus notes that:

> **"we have added the results of a comprehensive study of tipping points (Dietz et al. 2021), which estimates an additional 1% loss of global output due to 3 °C warming." (Nordhaus and Barrage 2023, p. 9)**

12

Managing risk on unsound foundations

"On two occasions I have been asked,—"Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?" ... I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question." (the inventor of the first mechanical computer, Charles Babbage 1864)

The main issue for pension funds, central banks and governments, is how this flawed analysis has effectively compromised their risk management and investment decisions with respect to climate change, and what to do about it.

Any analysis or stress testing which attempts to apply the work of these economists on climate change to real-world issues, such as portfolio choice and prudential regulation, will inherit its underlying problems, and will therefore substantially underestimate the dangers and damages.

Unfortunately, though understandably, since non-academic entities are entitled to regard peer-reviewed literature as having met scientific standards, commercial and government third parties have used the results of this unreliable economic analysis of climate change as the foundation of their risk assessment of climate change. The result is an applied form of the trivialisation of the dangers of climate change that has been the norm in academic economic publications.

12.1 How climate damage functions impact investment advice and analysis.

To gain a better appreciation of how investment consultants use these economic models to inform advice offered to institutional investors, we surveyed UK local government pension scheme (LGPS) members. Using replies from FOIA requests (refer to appendix pages 80-82) and published annual report data, one can estimate that the market share of consulting firms in the UK local government pension sector is roughly as follows:

- Mercer advise approximately ~38 clients in LGPS, LGPSS and various pooled funds;
- Hymans Robertson advise ~33 clients in LGPS, LGPSS and various pooled funds;
- Aon advise ~16 clients in LGPS, LGPSS and various pooled funds;
- MJ Hudson advise ~7 clients in LGPS, LGPSS and various pooled funds;
- Barnett Waddingham advise ~5 clients, and ISIO advise 4 clients in LGPS, LGPSS and various pooled funds; and
- 18 LGPS funds have either not disclosed their investment consultant, or don't use one.

As an example of the application of mainstream economic analysis of climate change to pension funds, we consider the advice given to LGPS pension funds by the investment consultant firm Mercer, which claims to work with 50% of the LGPS sector.[36]

12.2 Advisors—the representative example of Mercer

We would like to stress that while Mercer is used as an example, this is due to their transparency and widespread work with UK Local Government Pension Schemes (meaning some information is available under the Freedom of Information Act). In contrast to several other advisory firms, Mercer have also intentionally shared significant details on their models in public forums, as evidenced by the publication of the 2015 report *Investing in a Time of Climate Change* and its sequel.

36 https://www.mercer.com/en-gb/solutions/pensions/defined-benefit-pension-schemes/lgps/

Mercer have (with the help of Ortec Finance and Cambridge Econometrics)[37] recently updated their model to bring it closer to damages of the order that the rapidly evolving science might suggest.

Mercer are also by no means alone in relying upon this flawed economic analysis. The evidence indicates that their advice is typical of the advice offered to pension schemes by a wide range of consultants working in the investment consultant community globally.

Mercer's written advice is that "Climate change poses a systemic risk, and investors should consider the potential financial impacts of both the associated transition to a low-carbon economy and the physical impacts of different climate outcomes."[38] However, Mercer also states that it advocates "decarbonization at the right price,"[39] which implies a cost-benefit approach to this existential issue. This is indeed how they have approached the numerical estimates of the impact of climate change on pensions.

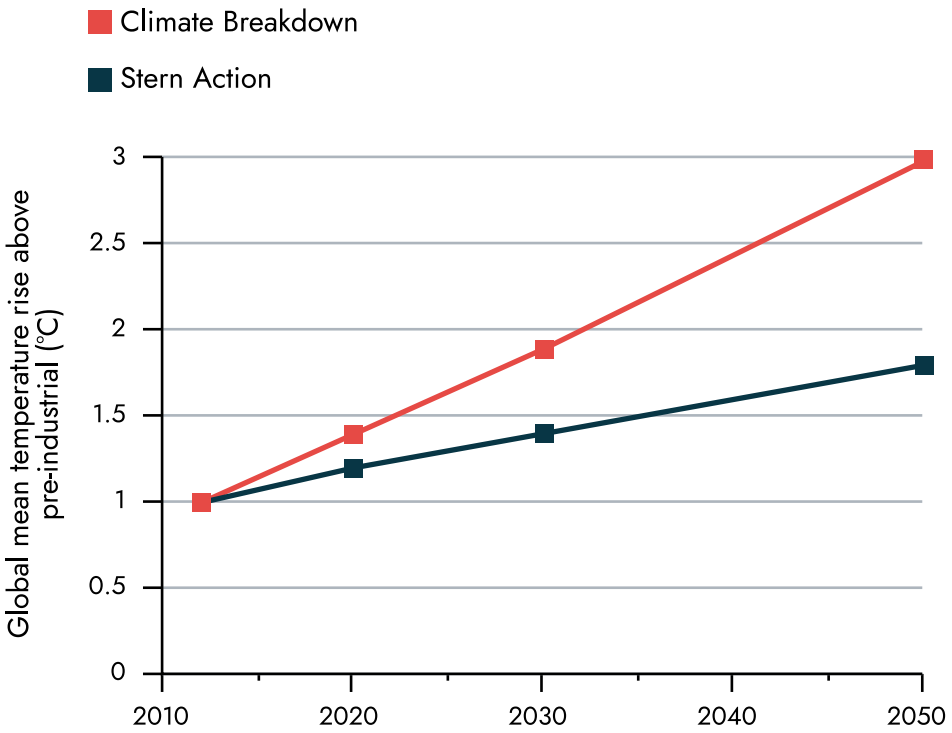
Mercer commenced its climate change consulting work in 2011, with the report Climate Change Scenarios—Implications for Strategic Asset Allocation (Mercer 2011a). The influence of climate change economists was very direct in this report, with two prominent authors of this literature acting as consultants to the Mercer team and performing the IAM simulations.[40]

The report used two IAMs, WITCH (World Induced Technical Change Hybrid) and PAGE (Policy Analysis of Greenhouse Effect), and worked with four different scenarios, rather than a simple mapping of temperature change to GDP. It manifests all the pivotal weaknesses in the economic literature, including damages being modelled by a quadratic,[41] and set to trivial values, even at 3°C warming by 2050 (see Figure 11) under its "Climate Breakdown" scenario.

37 https://www.camecon.com/news/mercer-collaborates-with-ortec-finance-and-cambridge-econometrics-on-climate-crisis-portfolio-modelling/
38 https://www.mercer.com/content/dam/mercer/attachments/global/investments/gl-2022-net-zero-report.pdf
39 https://www.mercer.com/content/dam/mercer/attachments/global/investments/gl-2022-net-zero-report.pdf. This report emphasises the importance of taking into consideration short-term movements in price caused by a disrupted energy sector, and recommends that where possible, divestment should be avoided.
40 Simon Dietz, principal author of the tipping points paper (Dietz et al. 2021a) criticised in section 10 of this Report, and the supporting document: **How Did We Get Here?**, and Sam Fankhauser, who developed one of the early "enumeration" estimates of the damages from global warming (Fankhauser 1995), that 2.5 of warming would reduce GWP by just 1.4%.
41 In fact, the polynomial power used was 1.8 (Mercer 2011b, p. 112), which is slightly less than the power of 2 that applies in a quadratic.

Figure 11: Assumed Temperature trajectories in two of the report's 4 scenarios (Mercer 2011b, p. 105)

Figure 20
Rapid warming under Climate Breakdown, lower under Stern Action

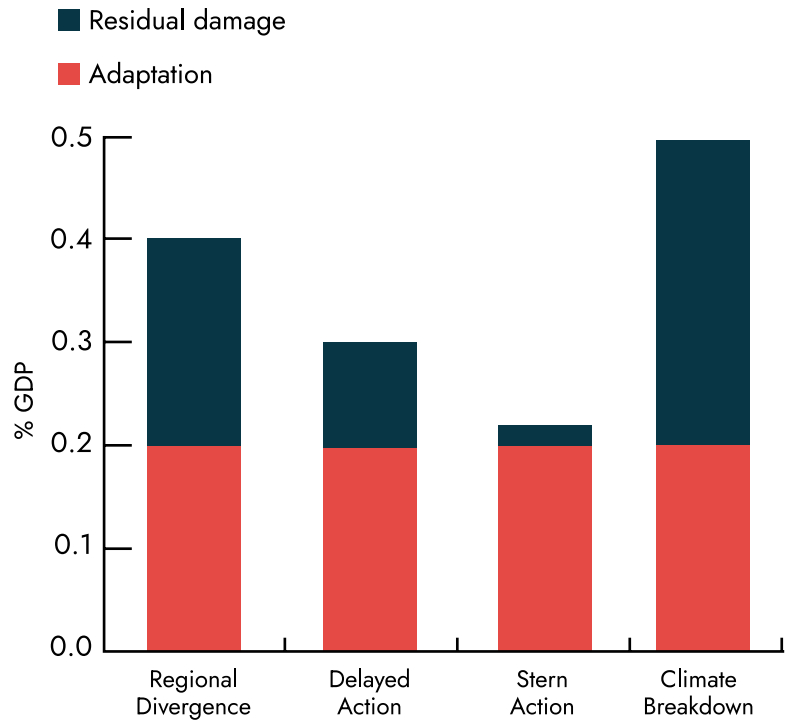


Source: Grantham LSE/Vivid Economics

Global economic damages from 3°C of warming by 2050, under the report's worst-case scenario, "Climate Breakdown," were just 0.5% of GWP. These were made up of fixed adaptation costs of 0.2% of GWP by 2050 across all scenarios, and up to 0.3% of GDP in "residual damages"—see Figure 12.

Figure 12: The report's aggregate damages by 2050 across 4 scenarios (Mercer 2011b, p. 107)

Figure 21
Residual damage costs + Adaptation costs as a percentage GDP to 2030



Source: Grantham LSE/Vivid Economics

These residual damages—damages that were not eliminated by the adaptation costs—were concentrated in the developing world, with the worst damages (3.1% of GDP) occurring in Africa and the Middle East. In contrast, the USA was shown as incurring such trivial damages (US$5.9 billion) that they rounded down to 0.0% of GDP. Europe's damages were 0.1% of GDP, as were China's and East Asia's: see Figure 13.

Figure 13: The report's damage estimates under its most severe scenario (Mercer 2011b, p. 104)

Table 26
Residual climate damages are steeply rising under Climate Breakdown and are highest in the developing world

	Residual damage costs in US$ billion and % GDP (in parentheses)			
	2012	2020	2030	2050
Climate Breakdown				
Europe	0.0 (0.0)	0.0 (0.0)	1.3 (0.0)	10.3 (0.1)
USA and Canada	0.0 (0.0)	0.0 (0.0)	0.7 (0.0)	5.9 (0.0)
OECD Pacific	0.1 (0.0)	0.0 (0.0)	1.9 (0.0)	4.8 (0.0)
China and East Asia	0.0 (0.0)	0.1 (0.0)	4.4 (0.0)	44.0 (0.1)
Russia and the former Soviet Union	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	1.2 (0.0)
Latin America and the Caribbean	6.1 (0.2)	20.3 (0.5)	70.1 (1.2)	285.4 (2.8)
Middle East and North Africa	6.3 (0.3)	20.9 (0.6)	45.8 (1.3)	154.2 (3.1)
India and South Asia	4.0 (0.2)	12.5 (0.3)	57.4 (0.7)	288.2 (1.5)
Sub-Saharan Africa	4.8 (0.3)	16.1 (0.3)	35.3 (1.3)	16.4 (3.1)

A key reason for the presumption that economic damages from climate change will be focused in developing countries, which are largely based in the tropical and sub-tropical regions of the planet, is the fact noted in section 8.1, that economic IAMs consider only temperature changes, and ignore changes in precipitation. Since developed countries are concentrated in the temperate regions of the planet, IAM's conclude that some global warming will be beneficial to these regions, by raising their average temperatures, whereas tropical areas will suffer from having their temperatures pushed even further above the optimum:

> **"The results indicate that there will be large benefits from warming in the Former Communist Bloc (the former Soviet Union and Eastern Bloc countries). The benefits in this region almost offset losses throughout the tropics in the Experimental results. The Soviet benefits account for two-thirds of the net global benefits in the cross-sectional results. The results also suggest that there will be large benefits in North America and small benefits in Western Europe. The critical factor that these benefiting countries have in common is that they are currently cool so that warming is helpful." (Mendelsohn, Schlesinger, and Williams 2000, p. 42.)**

The climatological and political assumptions implicit in this analysis are contradicted by current climatic and geopolitical events.

The Canadian wildfires of 2023, which have been amplified dramatically by declining precipitation levels in Canada's boreal forests, emphasise the folly of economic IAMs being based only upon temperature changes, and ignoring precipitation effects from global warming. Research such as the OECD's on the impact of losing the AMOC (OECD 2021) implies that developed economies will

be substantially affected by global warming, since warming is much stronger at higher latitudes than lower ones, and the rainfall altering effects of higher global temperatures could severely reduce crop yields in high latitude countries.

The Ukraine War shows that it extremely unwise to offset hypothetical losses in Africa by hypothetical gains in food output in Siberia.

These weaknesses in economic analysis are only apparent if one does not take the reported results of refereed economic papers at face value. Unfortunately, consultants relying upon only the conclusions of these papers did not notice the flimsy foundations from which these conclusions were derived.

Mercer's next report in 2015, *Investing in a Time of Climate Change* (Mercer 2015), diversified its output to include the impact on various investment portfolios, but stood on similar foundations: economic IAMs calibrated to trivial damage estimates, and using quadratics to extrapolate damages at higher temperatures.

In that report, 2°C of warming was portrayed as a possible source of portfolio gains:

> **"For example, a 2°C scenario could see return benefits for emerging market equities, infrastructure, real estate, timber and agriculture... 2°C scenario does not have negative return implications for long-term diversified investors at a total portfolio level over the period modelled (to 2050), and is expected to better protect long term returns beyond this timeframe." (Mercer 2015, p. 7.)**

Also, 4°C was seen as a negative, but only for weather-exposed industries:

> **"Under a 4°C, or Fragmentation (Higher Damages) scenario, chronic weather patterns (long-term changes in temperature and precipitation) pose risks to the performance of asset classes such as agriculture, timberland, real estate, and emerging market equities." (Mercer 2015, p. 7.)**

One positive development, compared to the 2011 report, was some criticism of IAMs in its appendix—though in the end, these IAMs still generated the numbers the report used. Mercer noted, but did not detail, that IAMs have been criticised in the economic literature.

Mercer's level of scepticism about IAMs rose further in its 2019 report Investing in a *Time of Climate Change: The Sequel 2019 (Mercer 2019)*.

Unfortunately, Mercer also took a step backwards by producing its own damage function, in response to the weaknesses it saw in economic IAMs—see Figure 14. This damage function is, if anything, even more problematic than those generated by academic economists. As Mercer documented, it is dominated by one factor—coastal flooding—and it does not include the impact of tipping points, which lead Mercer to describe its shape as linear:[42]

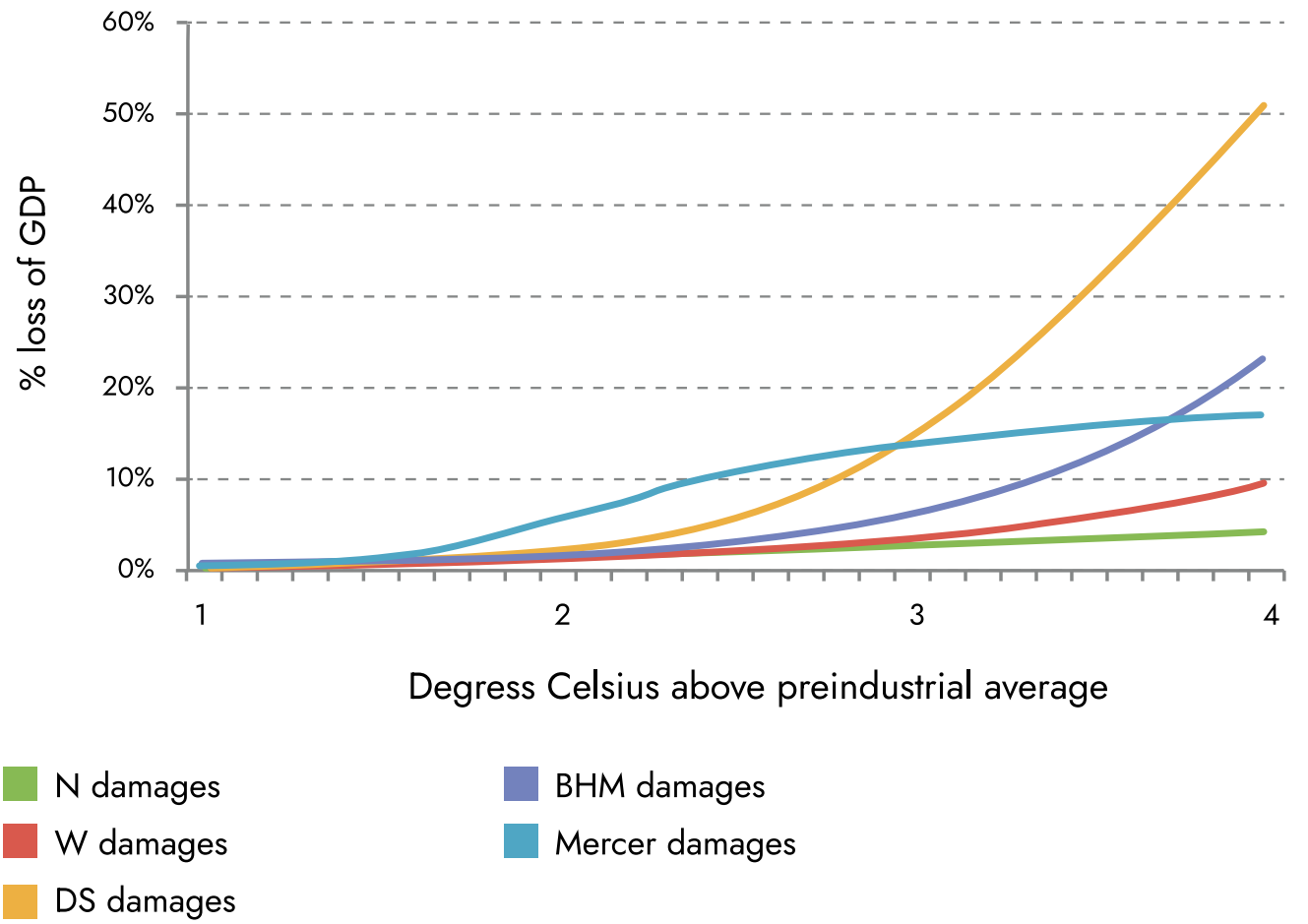
42 In fact, the shape of the Mercer damage function is more correctly described as sub-linear, since it tapers in the plotted range to well below 20% of GDP damages at 4°C. A linear extrapolation of the trend from 1.5°C to 2.5°C out to 4°C would have resulted in damage prediction closer to 30% of GDP.

"The Mercer damage function produces the highest damage ratio at 2°C of warming. It is linear in shape, primarily reflecting the coastal flood damage study used, which accounts for the majority of the Mercer damages... The Mercer damage function also does not take account of climate tipping points, which could drive nonlinearity in terms of the severity of coastal flooding or wildfire and/or the incidence and intensity of extreme events." (Mercer 2019, p. 79.)

Figure 14: Mercer's damage function compared to others, with a table showing forecast damages at 4°C (Mercer 2019, p. 79). the codes N, W, DS, and BHM stand for damages functions in (Nordhaus 2013; Weitzman 2012; Dietz and Stern 2014; Burke, Hsiang, and Miguel 2015) respectively.

Figure 34. Comparison of Various Climate Change Physical Damage Functions

N damages	W damages	DS damages	BHM damages	Mercer damages
4%	9%	51%	23%	17%



Source: Mercer

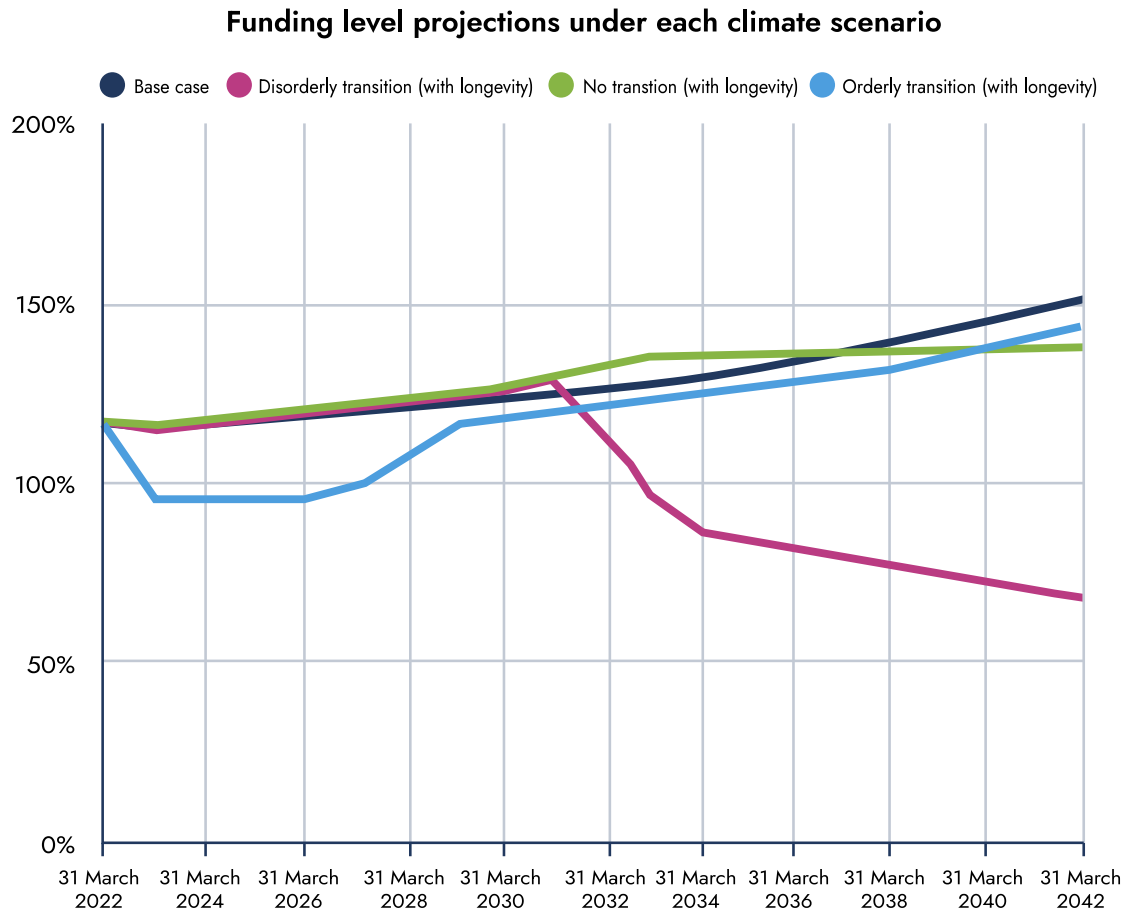
This dependence upon just one effect from global warming, and the absence of any increasing nonlinearity to its damages, let alone the cascading damages expected by climate scientists, makes Mercer's damage function unfit for portfolio management as we enter significant levels of warming—by which we mean the 1-2°C levels that concern scientists, much less the 4-6+°C levels that are contemplated by economists.

In the supporting document **How Did We Get Here?**, we detail further examples of correspondence between pension funds and members of the public on how funds have accounted for the risks of climate change. The correspondence copied below demonstrates the reliance of pension funds upon the advice of consultants like Mercer, who in turn have relied on the unsound work of mainstream economists on climate change.

12.3 Other consulting firms

The conclusions that have been reached about damage to pension portfolios from global warming are misled, not just by the work of economists, but also the specific portfolio questions posed to consultants by pension funds. For example, both Cardiff Council and Hampshire employ AON as an investment consultant, and both modelled the impacts of 4°C warming on their portfolios by 2042, yet their scenarios produced very different results. The Hampshire TCFD report scenario analysis by Aon predicted a -35% decline in funding level values by 2042, based on a "disorderly transition"[43] at 3-4°C warming —see Figure 15.5.

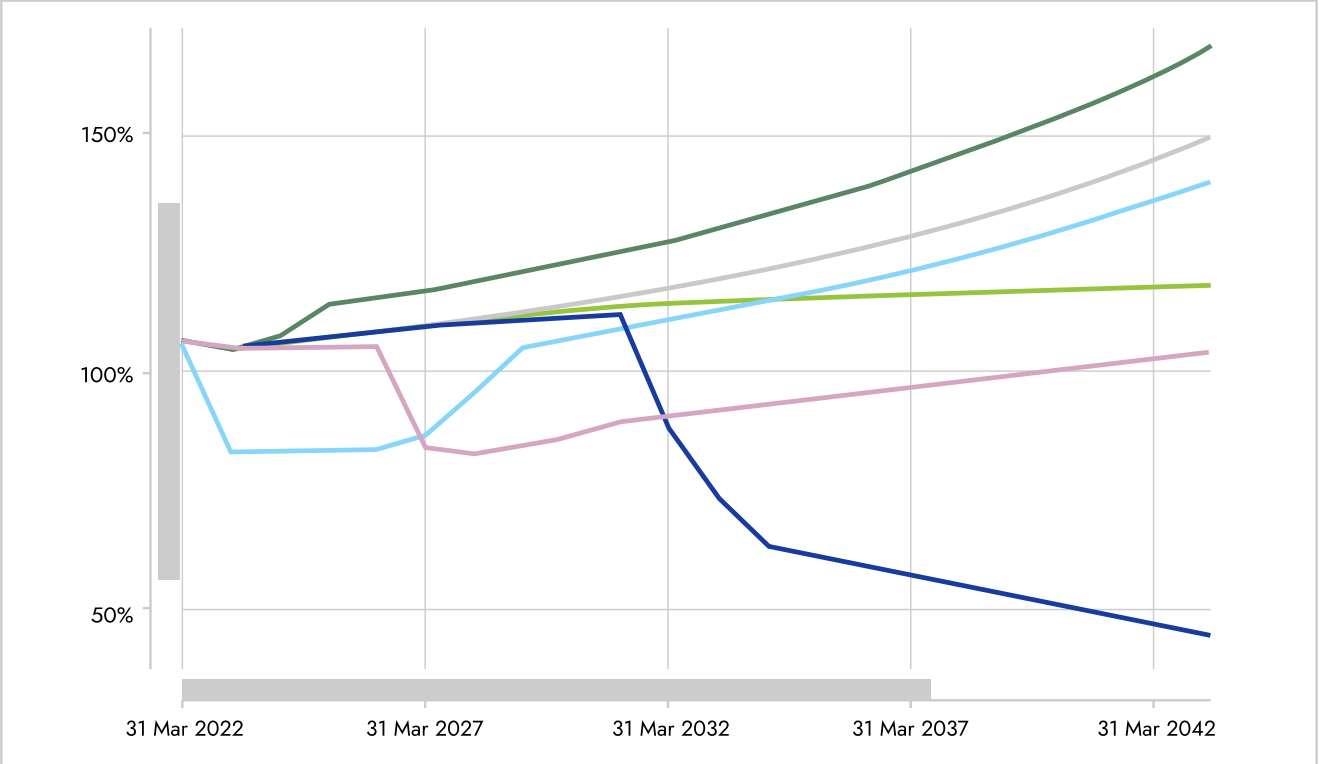
Figure 15: Hampshire Council's Projections



43 A "disorderly transition" is one of the hypothetical scenarios developed by consultants, in which coordination between countries is weak. Though "disorderly" implies serious policy failures, these scenarios rely upon economic estimates of damages from climate change, and therefore still postulate positive growth in a "disorderly transition".

Cardiff also employed scenario analysis by Aon and modelled a disorderly transition scenario at 3-4°C, to model a much steeper -55% hit to funding levels by 2042—see Figure 16.

Figure 16: Cardiff Council's Projections



Run by Aon with an effective date of 31 March 2022, using a liability basis of RPI Curve +2.05% to enable us to carry out future projections. This basis gives us the same liability value as the valuation basis as at 31 March 2022. However, the liability value excludes the short-term inflation allowance, which is included in the valuation results. Since we have excluded the short-term inflation allowance, at time 0, the funding level is higher than the valuation results. This doesn't affect the future projections as we have allowed for expected inflation.

Key

Base case
Orderly transition
Disorderly transition
No transition
Smooth transition
Abrupt transition

Given the shared reliance upon the unsound analysis of global warming by mainstream economists, both estimates are likely to seriously underestimate damages from global warming. However, LGPS fund members, taxpayers and regulators should press both the councils and consultants to understand what combination of factors explains the 20% gulf in values these funds might expect in 20 years time, under a disorderly transition scenario.

12.4 The UK Local Government Pension Scheme

The LGPS is one of the largest pension schemes in the UK with 6.2 million members and a significant UK and global investor with £342 billion of assets as of 2022. It is locally managed and funded by 86 administering authorities (AAs) in England and Wales.[44] In addition, there are a further 11 LGPSS funds in Scotland[45], with £46 billion of assets.[46]

44 https://www.gov.uk/government/consultations/local-government-pension-scheme-england-and-wales-governance-and-reporting-of-climate-change-risks/local-government-pension-scheme-england-and-wales-governance-and-reporting-of-climate-change-risks
45 https://pensions.gov.scot/local-government
46 https://commonslibrary.parliament.uk/research-briefings/cbp-7309/

Not all local authorities manage their own pension fund, but those which do are known as 'administering authorities' (AAs). AAs are already required to consider factors (including climate) that are financially material to the performance of their investments, including environmental, social, and corporate governance (ESG) matters. They also must have a policy stating how such considerations will be considered in setting their investment strategy — known as an *Investment Strategy Statement* (ISS) — (previously a 'SIP').

In addition to the administering authorities, a further layer of LGPS fund management was created by 2016 pension regulations within England and Wales, forcing individual funds to merge their assets into one of eight larger 'pools' to achieve efficiencies of scale, and in theory, reduce fund management fees.

As background research for this report, Freedom of Information Act (FOIA) requests were sent to LGPS and LGPSS (Scotland) administering authorities, requesting internal email correspondence with their investment consultants on climate risk, and examples of consultants' advice, including climate scenario analysis outputs. Links to the FOI requests and summaries of the councils' responses can be found in pages 80-82 of the appendix.

12.5 LGPS funds' reliance upon advisors

LGPS correspondence obtained by Carbon Tracker regarding climate change advice from investment consultants and related correspondence with scheme members underscores how the advice has been taken up by pension schemes.[47]

For example, the Derbyshire Pensions and Investments Committee was asked about its 2020 and 2021 Climate Related Disclosures reports at its 18 January 2023 meeting by the Derbyshire Pensioners Action Group.[48] They challenged the assertions in the related Disclosures report suggesting that a trajectory towards 3°C warming by 2100 would have a "relatively muted" effect on returns:

> **"The world will have large areas that are uninhabitable by humans if we reach 3 degrees. … The analysis that 3C warming will have a muted impact on the funds returns seems to lack recognition of the reality of what will happen and seems incredibly complacent. Can you explain where this analysis has come from and whether you think it represents a realistic analysis of the future?"[49]**

The committee's response made clear that the source of the numerical forecasts was "climate scenario analysis conducted by Mercer LLC (Mercer)" for "LGPS Central Limited's 2020 Climate Risk Report."[50]

However, it ignored the substantive challenge that its assessment of 3°C lacked "recognition of the reality of what will happen and seems incredibly complacent." Instead, the committee turned immediately to the reputation of Mercer's as a "leading consultancy firm in terms of developing, and reporting on, climate change scenario analysis, which is grounded in the latest scientific and economic research."[51]

47 See Section 8 of the supporting document: **How Did We Get Here?** for the full correspondence and public queries.
48 https://democracy.derbyshire.gov.uk/documents/s19199/2023-01-18.pdf
49 https://democracy.derbyshire.gov.uk/documents/s19199/2023-01-18.pdf
50 https://democracy.derbyshire.gov.uk/documents/s19199/2023-01-18.pdf
51 https://democracy.derbyshire.gov.uk/documents/s19199/2023-01-18.pdf

The committee's answer unwittingly exposed the core problem that this report has identified. Each layer in the process of assessing the risks of climate change has assumed that the previous layer has done its job adequately, and has relied upon the previous layer's reputation, rather than scrutiny of the work undertaken. Pension funds relied upon consultants, because of their reputation in the field; consultants relied upon academic economists, because their papers had passed refereeing.

As this report shows, the foundational layer in this inverted pyramid of trust—the refereed mainstream economic literature on climate change—did its job extremely badly. Therefore, the work of the layers above—the consultants, the funds, the financial regulators and governments—is also unsound, and fails Solow's "sniff test."

The Shropshire County Pension Fund (SCPF) Pensions Committee meeting of 17 September 2021,[52] included a response to a trade union representative's email of February 2021, at which the Fund's Climate-Related Disclosures report was discussed. That report concluded that a 4°C rise by 2100 would reduce annual returns to 2030 by 0.06%. The SCPF was asked to explain how the figure of 0.06% drop in returns could possibly be correct, given a 4-degree rise, as the science says this will cause catastrophic climate events.[53]

The committee's answer was that the impact on investment portfolios at 2°C largely reflected the cost of mitigation, while those at 4°C largely reflected the physical impacts of global warming, since SCPF's portfolio was mainly allocated to financial fixed-income assets, which the committee claimed are "relatively less sensitive to the different climate scenarios".[54] It also acknowledged that it relied upon LGPS Central, which "uses an external service provider"—Mercer, as detailed in Derbyshire's response.

Further evidence of the use of the critiqued economic models comes from Cheshire Pension Fund Joint Committee, at a public meeting on November 20th, 2020, at which a member of the public requested they:

> **'Please provide references to climate science studies that support LGPS Central's core assumption that the world will be so unaffected by 3°C and 4°C of warming that financial processes will be able to function and continue with only minimal loss of revenue... likely to present a "slight drag"[55] on the fund.'**

The committee's response[56] referred once more to Mercer's study, rather than scientific studies, and claimed that Mercer's modelling "captures developments in the collective understanding of environmental science." In fact, as this report shows, Mercer's models, and those of all consultants engaged in predicting the financial consequences of climate change, rely upon the economic literature, which is incompatible with the findings of climate science.

The influence of the trivialisation of the dangers of climate change, by the majority of mainstream economists specialising on climate change, does not stop with pension funds. This research has also been taken at face value by regulators.

52 https://shropshire.gov.uk/committee-services/documents/s29248/Draft%20Minutes%20Pensions%2017%20Sept%202021.pdf (refer to item 23 - public questions

53 https://shropshire.gov.uk/committee-services/documents/s28658/Pensions%20Committee%20Public%20Questions%20and%20Responses%2017th%20September%202021.pdf

54 https://shropshire.gov.uk/committee-services/documents/s28658/Pensions%20Committee%20Public%20Questions%20and%20Responses%2017th%20September%202021.pdf

55 https://www.cheshirepensionfund.org/members/wp-content/uploads/sites/2/2020/11/Joint-committee-20.11.20-public-Qs.pdf

56 https://www.cheshirepensionfund.org/members/wp-content/uploads/sites/2/2020/11/Joint-committee-20.11.20-public-Qs.pdf (refer pg 11)

12.6 Financial regulators

Just as advisors have taken refereed economic estimates of damages from climate change at face value, so too have financial regulators.

A number of regulatory initiatives on climate change have developed over the last decade. Central banks have formed subdivisions devoted to studying the economics of climate change, such as the Bank of England's CBES ("Climate Biennial Exploratory Scenario") to apply climate change stress tests to the financial companies that fall under its regulatory umbrella. Simultaneously, central banks have formed an overarching body NGFS ("Network for Greening the Financial System") to coordinate their studies: as of October 2022, 121 central banks had become members of NGFS.

At both the national and supranational level, these bodies have accepted the refereed economic literature as providing realistic estimates of the economic damages from climate change.

12.6.1 International: The Financial Stability Board (FSB)

The FSB brings together senior policy makers from ministries of finance, central banks, and supervisory and regulatory authorities, for the G20 countries, plus four other key financial centres – Hong Kong, Singapore, Spain and Switzerland.

The FSB report The Implications of Climate Change for Financial Stability (FSB 2020) is based on the work of climate change economists, with key citations including (Hsiang and Kopp 2018; Dietz et al. 2016; Nordhaus 2017). Though literature critical of the work of economists is also cited (Stern 2013; Lenton et al. 2019), the estimates of economic damages are clearly within the parameters set by economic IAMs, rather than by scientists. The predictable result is that levels of global warming that scientists warn pose serious risks to human civilisation are predicted to cause relatively trivial declines in asset values.

Its key publication, *The Implications of Climate Change for Financial Stability* (FSB 2020), predicted that a 4°C increase in global temperatures would reduce asset prices by between 3% and 10%:

"Under a scenario where the increase in global mean temperature above pre-industrial levels is likely to remain within 2°C, 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 4°C and the estimated mean reduction in asset prices is between 2.9% and 9.7% (US$4-14tr), depending on the chosen discount rate." (FSB 2020, pp. 7-8.)

The report Climate Scenario Analysis by Jurisdictions (FSB 2022) notes that, "Regarding financial vulnerability, it stands out that economic modelling is central in all exercises to translate climate-specific information into financial impacts," (FSB 2022, p. 20) and confirms the use of economic IAMs and damage functions in its approach to assessing financial risk:

"In the NGFS modelling framework, three integrated assessment models (IAMs) and a damage function are used to translate climate variables into a core set of macroeconomic variables, such as GDP, energy prices or carbon prices." (FSB) 2022, p. 10)

12.6.2 The Network for Greening the Financial System (NGFS)

The NGFS is a consortium of Central Banks and financial supervisors working to share best practices on addressing climate change. Over 130 Central Banks are members of the NGFS.

This lack of preparedness is a global phenomenon—again, because of the reliance on refereed economic studies. The NGFS's key publication NGFS Scenarios for central banks and supervisors (NGFS 2022), for example, relies on the damage function methodology set out in Kalkuhl & Wenz (2020). (NGFS 2022, p. 17)

Kalkuhl & Wenz's paper "The impact of climate conditions on economic production. Evidence from a global panel of regions" (Kalkuhl and Wenz 2020) is based on the third method outlined in section 3 above (which is covered in detail in section 4.4 of the supporting document **How Did We Get Here?**), of treating an extrapolation from change in temperature and GDP data as the basis for predicting the damages from climate change. The paper uses "climate and economic data at the subnational level for the years 1900–2014," (Kalkuhl and Wenz 2020, p. 6) from which it derives a damage function that, while more complicated than in Nordhaus's DICE model, still treats damages as a function of the change in temperature squared:

"Importantly, damages here are a quadratic function of the warming level." (Kalkuhl and Wenz 2020, p. 14)

This is despite the fact that the paper refers to criticisms of the use of quadratic damage functions (Kalkuhl and Wenz 2020, p. 2). The paper also makes no acknowledgement of the fact that its data sample period does not include any impact from tipping points, and yet its extrapolation to 3.5°C of global warming covers temperature increases that scientists have predicted will trigger several tipping points (Armstrong McKay et al. 2022; Brovkin et al. 2021; Cai, Lenton, and Lontzek 2016; Lenton et al. 2019; Lenton et al. 2008b), quite possibly in a cascading fashion (Steffen et al. 2018). Consequently, though they describe their predictions of future damages as "considerable," they are slight, since they are in relation to a hypothetical future global GDP in which global warming does not occur:

"Applying the panel and cross-sectional results to projected warming levels for a high-warming scenario, we project considerable production losses, around 7–14% in the year 2099 compared to a scenario of no further warming." (Kalkuhl and Wenz 2020, p. 18)

12.6.3 The Federal Reserve

Federal Reserve Board Governor Christopher Waller's speech "Climate Change and Financial Stability" summarised the consensus on climate change within the Federal Reserve with the opening statement that:

> **"Climate change is real, but I do not believe it poses a serious risk to the safety and soundness of large banks or the financial stability of the United States. Risks are risks. There is no need for us to focus on one set of risks in a way that crowds out our focus on others. My job is to make sure that the financial system is resilient to a range of risks. And I believe risks posed by climate change are not sufficiently unique or material to merit special treatment relative to others."[57] (Waller 2023, p. 1)**

This ranking of climate change as no more significant than a wide range of other risks is consistent with the economics chapter of the 2014 IPCC Report.[58] Waller observed that "There seems to be a consensus that orderly transitions will not pose a risk to financial stability," and reference the Financial Stability Board report *The Implications of Climate Change for Financial Stability* ((FSB) 2020). That report relied upon (Dietz et al. 2016) and ((EIU) 2015), both of which used Nordhaus's DICE model to estimate damages from climate change.

Waller was confident that "economic agents are already adjusting behaviour to account for risks associated with climate change," and stated that this "should mitigate the risk of these potential 'Minsky moments'." (Waller 2023, p. 7) Unfortunately, because of the fatally flawed work by economists on climate change, the Federal Reserve may be far less prepared for a "Climate Minsky Moment" than it expects.

12.7 The Economist Intelligence Unit

The Economist Intelligence Unit (EIU) is the research and analysis division of the publisher of *The Economist* magazine, which is one of the world's most influential non-academic economic publications. Its report *The Cost of Inaction: Recognising the Value At Risk from Climate Change* ((EIU) 2015) was squarely based on the research of William Nordhaus:

> **"To estimate the effect of climate change to 2100 on the changing stock of manageable financial assets, The Economist Intelligence Unit (The EIU) and Vivid Economics have used a leading, peer-reviewed forecasting model of the impact of climate change on the economy, the DICE (Dynamic Integrated Climate-Economy) model." ((EIU) 2015, p. 8)**

57 https://www.reuters.com/markets/us/feds-waller-says-climate-change-not-serious-risk-financial-stability-2023-05-11/

58 "For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (**medium evidence, high agreement**). Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change." (IPCC et al. 2014, p. 662)

Needless to say, the EIU reached results that echoed Nordhaus's trivialisation of global warming:

> **"Warming of 5°C could result in US$7trn in losses ... while 6°C of warming could lead to a present value loss of US$13.8trn of manageable financial assets, roughly 10% of the global total." ((EIU) 2015, p. 2)**

The EIU observes that, at least according to conventional finance theory, the value of stocks depends on dividends, and these in turn depend upon GDP:

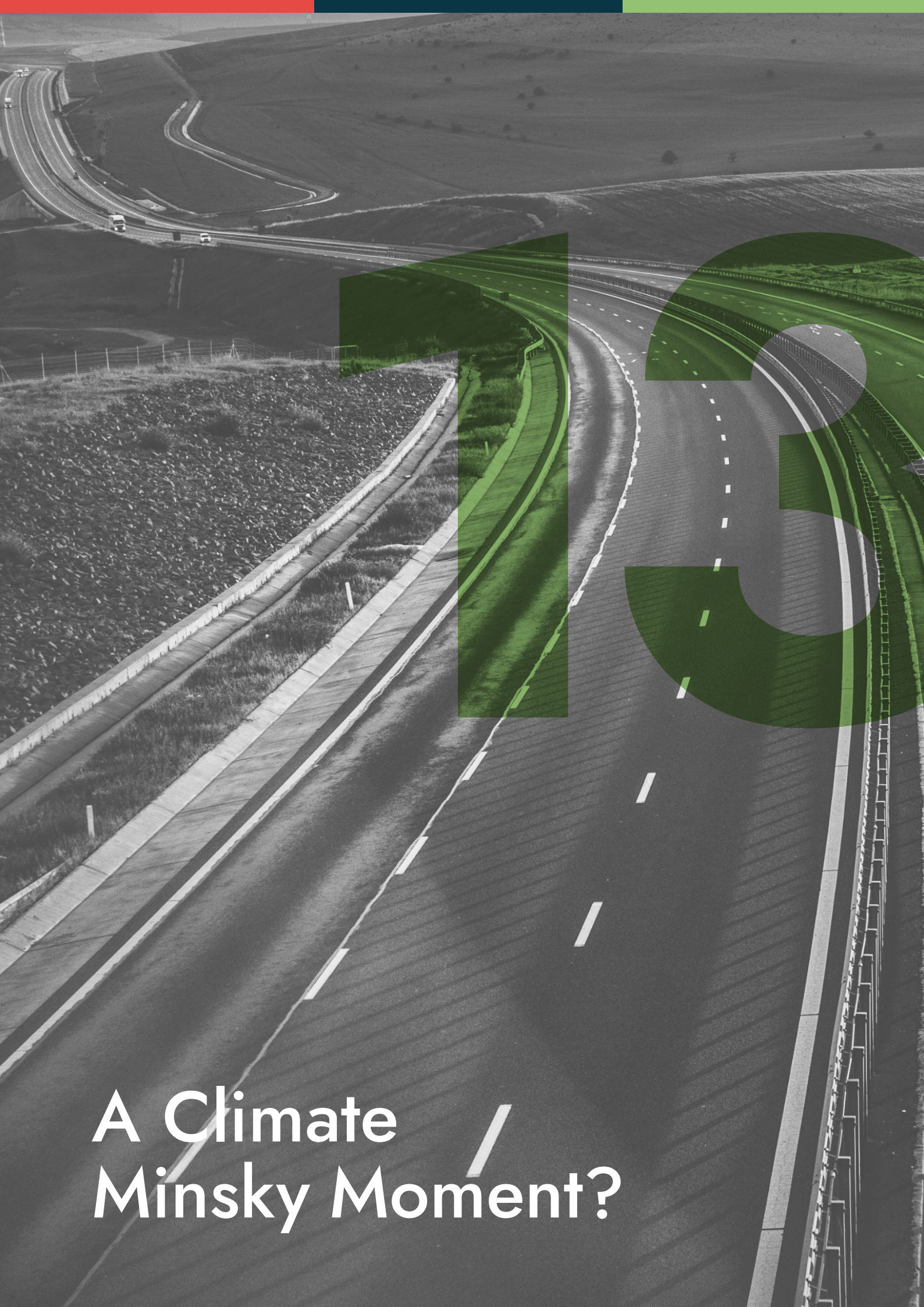
> **"This modelling recognises that, since the present value of a portfolio of equities is just the discounted cash flow of future dividends, then in the long run—i.e., over the course of a century—dividends in a diversified portfolio should grow at the same rate as GDP, because ultimately dividends are paid for from the output of the economy." ((EIU) 2015, p. 9)**

Assuming, with reason, that the majority of financial market participants accept the figures provided by The Economist Intelligence Unit—and consulting firms like Mercer, the FSB, the Bank of England, and the Network for Greening the Financial System—as accurate estimates of the impact of climate change on the financial sector, it is highly likely that stock market valuations are wildly out of step with the future course of stock prices, dividends, and GDP in a climate-changed world.

12.8 Misinformation begets financial instability

The influence of the trivialization of climate change-induced damage generated by this small band of economists is thus pervasive: it affects financial institutions, advisors, regulators, and the media alike. Since this misinformation drastically underestimates the dangers of climate change, and is shared across the financial sector, there is likely a huge disconnect between current asset prices—and the false expectations of future damages they encapsulate—and the real-world effect of global warming.

As some point, reality will drown out this misinformation—figuratively, if not literally. Asset markets will then dramatically reset in what has come to be known as a "Minsky Moment," in honour of the distinctly non-mainstream economist Hyman Minsky (Minsky 1982), the originator of the "Financial Instability Hypothesis." (Keen 1995)



13

A Climate Minsky Moment?

A Minsky Moment is a sudden major collapse of asset values (financial asset: equities, bonds and real estate) caused by the end to an unsustainable period of overly bullish activity, due to a sudden realisation of the gap between market aspirations and economic reality. The huge disconnect between what scientists expect from global warming, and what economists have claimed, means that a "Climate Change Minsky Moment" could occur at a time within the investment horizon of existing firms.

This would cause a plunge in asset market valuations, not as the result of a collapse in credit-based demand as in previous financial crises (Keen 1995, 2020b), but as the result of divergence between the optimistic predictions of economists on the one hand, and the reality of global warming on the other.

It may sound unwise to see this convergence as inevitable, since "markets can remain irrational for longer than you can remain solvent."[59] However, given the erroneous assumptions applied, the use of non-independent data, the lack of scenario analysis (including the widespread failure to use non-linear damage functions other than a quadratic), and the faith invested in this work by pension funds, consultants, financial regulators, and financial markets, we believe that an unpleasant, abrupt and wealth-destroying Minsky Moment is virtually inevitable.

There are at least three possible, and non-exclusive, routes to a Climate Minsky Moment:

- The large-scale destruction of physical assets themselves could occur because of climatic events. This would cause a write-off of their financial value as well;
- Significant government policy actions could limit fossil fuel usage, as a policy response to growing awareness of the actual, versus the expected, severity of global warming. The financial valuation of physical assets would fall; and
- Financial valuations of the key parts of the fossil fuel system, particularly coal mines, coal or gas fired power stations, oil and gas facilities particularly wells, refineries, pipelines and tankers could be written down by auditors. The costs of decommissioning and remediation could be imposed upon their owners, which would severely impair their balance sheets.

Investors, and pension funds in particular, would be wise to prepare for all eventualities. So too would governments, since—while the FOIA response received from the Hammersmith and Fulham pension fund stressed that contributions to the LGPS do not in themselves constitute "public money"— defined benefit (DB) schemes effectively guarantee retirees a certain level of income in retirement.

Should climate change overwhelm financial markets and fund returns to the point LGPS liabilities exceed fund income, any shortfall would likely be made up by the UK government. It is therefore in all our interests to ensure both climate risk advice and investment practices in the LGPS are aligned with climate science, and not operating in isolation from it.

59 Attributed to J.M.Keynes. See https://www.theguardian.com/business/economics-blog/2014/aug/12/financial-policy-committee-boom-and-bust

Taking stock

The economic analysis that has led funds to have a sanguine perspective on 2-4°C or more of global warming is not fit for purpose. Climate dangers that this research implied were minor and distant are more likely to be major and relatively immediate. The prospect cannot be ruled out that significant damages might occur in the next one to two decades.

The question then is, how to navigate from a position based on misconceptions, to one at least grounded to some extent in the reality we face?

Some economists have called for new and better studies of the economic costs of global warming (Stern, Stiglitz, and Taylor 2022; Stern 2022; Mattauch et al. 2022; Stern and Stiglitz 2021). In addition, economists should consider how economic policy could help avoid further temperature rises, and help prepare for economic disruption that current warming has already locked in.

Pension funds face many dilemmas. There is little point in solely revising portfolio allocations, when the consequences of global warming are systemic, rather than restricted to the few industry sectors that are not undertaken in "carefully controlled environments." (Nordhaus 1991, p. 930) Answers to these questions are beyond the remit of this paper, since its purpose is not financial advice. However, we would recommend at least the following actions.

14.1 Informing members

One ethical responsibility is unavoidable: ***pension funds must let their members know that the past guidance they have given on the impact of global warming on pensions is unsound***. They must be told that their pensions are much more vulnerable to climate change than they have been led to believe.

This of itself may do substantial good, since it would counter the global warming denialism and trivialisation that is still highly influential today, which is due in no small measure to the same economic research that has misled pension funds themselves. If members could realise that their personal futures will be dramatically and deleteriously impacted by future climate change, this could help shift public sentiment in favour of drastic government and private sector action in the near term to prevent further climate change.

14.2 End commercial confidentiality on climate change advice

Section 9 of the supporting document **How Did We Get Here?**, together with the FOIA Table in the Appendix to this report details the responses that Carbon Tracker has received from pension funds, councils, and consultants to questions about their climate change preparedness. Frequently, funds and consultants have refused to provide details on the basis of client commercial confidentiality.

While client confidentiality is an important safeguard of client and consultant rights in standard commercial evaluations, it should not be applied in the case of estimating the impact of climate change. Climate change is the quintessential instance of John Donne's poetic declaration that "no man is an island": what one consultant or client claims will be the impact of climate change on that client affects how the whole of the body politic interprets the dangers of climate change. This is especially so in local government, where councillors are responsible for the delivery of public services and maintaining the built environment. Especially given the poor quality of the economic research on which consultants have relied to date, both the advice given by consultants and the models that have been used to generate that advice should be publicly available.

14.3 Ask questions

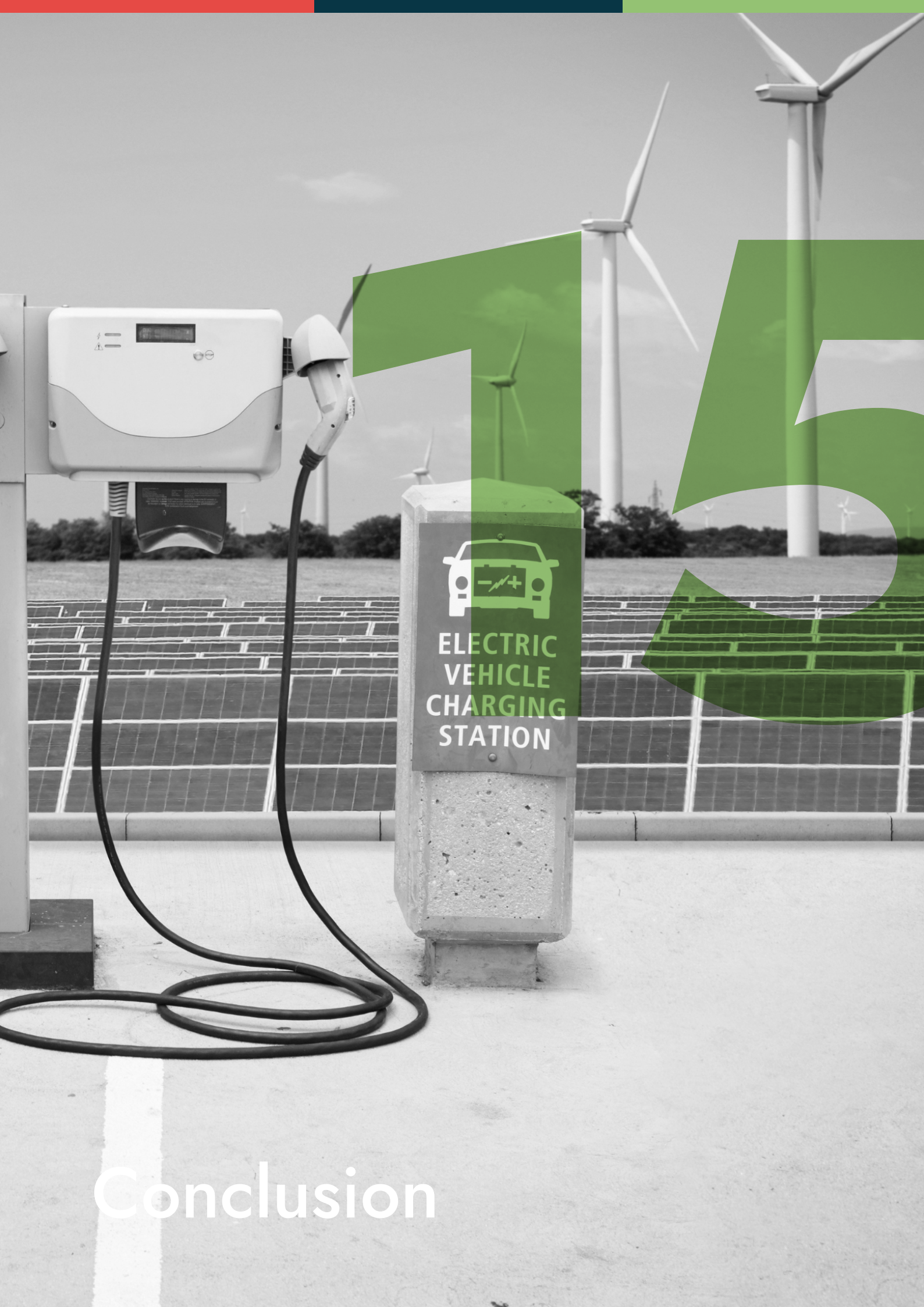
Beneficiaries of pension schemes should raise these issues with their own scheme administrators and the scrutiny committees which oversee council financial decision making to ensure that their plans are getting sound and appropriate advice.

Pension fund trustees and committees should challenge their advisors and the regulators. Trustees should be able to seek and rely on expert advice, but also be able to deeply query that advice without fear of reproach.

In particular, pension fund trustees and committees should ask consultants and investment managers to produce scenarios showing the impact upon fund valuations of a rapid wind down of the fossil fuel system in line with the 1.5C warming outcome that many net zero pledges are based upon. These assume a drop in emissions of 50% in a decade and a similar 50% drop in fossil fuel use. Scenarios like this best indicate which sectors and companies might be impacted and which components of the new energy system might benefit.

14.4 Reform academic practices on climate change

Investment advisers, regulators, central banks, and governments should be able to rely on verified and robust academic research. Given the critical importance of this issue to humanity, the issue of why academic refereeing failed so badly deserves serious investigation by academic institutions such as the UK's Economic and Social Research Council (ESRC).



15

Conclusion

The objective of this report is to alert all stakeholders to the economic dangers of climate change that, to date, have been seriously underestimated.

Pension funds have been poorly advised, inadvertently or not, on the dangers that climate change poses for their portfolios. The challenges that climate change poses to the retirement incomes of their members are not distant and small, but immediate and potentially wealth-destroying.

Given the scale of the dangers of global warming, and the penetration into our financial and political systems that this unsafe analysis has achieved, the changes needed necessarily go well beyond modifying portfolio allocations.

As well as showing that a drastic change in policy is needed, from cost-benefit analysis to the precautionary principle, this report shows that significant change is needed in academic review processes. The refereeing process, which is supposed to prevent low quality research from being published, instead resulted in low quality work being treated as valid by the non-academic individuals and institutions who relied upon it. In future, the empirical claims in economics of climate change papers should be refereed by scientists, rather than by other economists alone.

This report is a call to all stakeholders, from governments, regulators, investment professionals, all the way to civil society groups and individuals, to ensure that the critical error of taking this unsound research seriously is reversed, before it is too late.

Given the extent to which the beliefs of economists have overruled the analysis of scientists in the development of policies to combat climate change, we give the last word to scientists who have specialised in the analysis of climate tipping points. This is the conclusion to the 2019 paper "Climate tipping points - too risky to bet against" (Lenton et al. 2019):

> "If damaging tipping cascades can occur and a global tipping point cannot be ruled out, then this is an existential threat to civilization. No amount of economic cost–benefit analysis is going to help us. We need to change our approach to the climate problem…
>
> In our view, the evidence from tipping points alone suggests that we are in a state of planetary emergency: both the risk and urgency of the situation are acute…
>
> We argue that the intervention time left to prevent tipping could already have shrunk towards zero, whereas the reaction time to achieve net zero emissions is 30 years at best. Hence, we might already have lost control of whether tipping happens. A saving grace is that the rate at which damage accumulates from tipping — and hence the risk posed —could still be under our control to some extent.
>
> The stability and resilience of our planet is in peril. International action — not just words— must reflect this." (Lenton et al. 2019, p. 595.)

16

References

(EIU), Economist Intelligence Unit. 2015. "The Cost of Inaction: Recognising the Value At Risk from Climate Change." In. London: The Economist.

(FSB), Financial Stability Board. 2020. "The Implications of Climate Change for Financial Stability." In.

———. 2022. "Climate Scenario Analysis by Jurisdictions." In.

Ackerman, Frank, and Charles Munitz. 2012. 'Climate damages in the FUND model: A disaggregated analysis', Ecological Economics, 77: 219-24.

Ackerman, Frank, and Elizabeth A. Stanton. 2008. 'A comment on "Economy-wide estimates of the implications of climate change: Human health"', Ecological Economics, 66: 8-13.

Ackerman, Frank, Elizabeth A. Stanton, and Ramón Bueno. 2010. 'Fat tails, exponents, extreme uncertainty: Simulating catastrophe in DICE', Ecological Economics, 69: 1657-65.

Aldred, Jonathan. 2012. 'Climate change uncertainty, irreversibility and the precautionary principle', Cambridge Journal of Economics, 36: 1051-72.

Anthoff, David, Francisco Estrada, and Richard S. J. Tol. 2016. 'Shutting Down the Thermohaline Circulation', The American Economic Review, 106: 602-06.

Armstrong McKay, David I., Arie Staal, Jesse F. Abrams, Ricarda Winkelmann, Boris Sakschewski, Sina Loriani, Ingo Fetzer, Sarah E. Cornell, Johan Rockström, Timothy M. Lenton, Ecology Spatial, Change Global, and Sciences Environmental. 2022. 'Exceeding 1.5°C global warming could trigger multiple climate tipping points', Science (American Association for the Advancement of Science), 377: 1-eabn7950.

Auffhammer, Maximilian. 2018. 'Quantifying Economic Damages from Climate Change', Journal of Economic Perspectives, 32: 33-52.

Auffhammer, Maximilian, Solomon M. Hsiang, Wolfram Schlenker, and Adam Sobel. 2013. 'Using Weather Data and Climate Model Output in Economic Analyses of Climate Change', REV ENV ECON POLICY, 7: 181-98.

Babbage, Charles. 1864. "Passages from the Life of a Philosopher." In. London: Longmans.

Bezemer, D. J. 2009. ''No one saw this coming' – or did they?', Centre for Economic Policy Research (CEPR). https://voxeu.org/article/no-one-saw-coming-or-did-they.

Bovari, E., Gaël Giraud, and F. McIsaac. 2018. 'Coping With Collapse: A Stock-Flow Consistent Monetary Macrodynamics of Global Warming', Ecological Economics, 147: 383-98.

Brovkin, Victor, Edward Brook, John W. Williams, Sebastian Bathiany, Timothy M. Lenton, Michael Barton, Robert M. DeConto, Jonathan F. Donges, Andrey Ganopolski, Jerry McManus, Summer Praetorius, Anne de Vernal, Ayako Abe-Ouchi, Hai Cheng, Martin Claussen, Michel Crucifix, Gilberto Gallopín, Virginia Iglesias, Darrell S. Kaufman, Thomas Kleinen, Fabrice Lambert, Sander van der Leeuw, Hannah Liddy, Marie-France Loutre, David McGee, Kira Rehfeld, Rachael Rhodes, Alistair W. R. Seddon, Martin H. Trauth, Lilian Vanderveken, and Zicheng Yu. 2021. 'Past abrupt changes, tipping points and cascading impacts in the Earth system', Nature Geoscience.

Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. 'Global non-linear effect of temperature on economic production', Nature, 527: 235.

Cai, Yongyang, Timothy M. Lenton, and Thomas S. Lontzek. 2016. 'Risk of multiple interacting tipping points should encourage rapid CO2 emission reduction', Nature Climate Change, 6: 520-25.

Cline, William. 1996. 'The impact of global warming on agriculture: Comment', The American Economic Review, 86: 1309-11.

Cotis, Jean-Philippe. 2007. 'Editorial: Achieving Further Rebalancing.' in OECD (ed.), OECD Economic Outlook (OECD: Paris).

Darwin, Roy. 1999. 'The Impact of Global Warming on Agriculture: A Ricardian Analysis: Comment', The American Economic Review, 89: 1049-52.

DeCanio, Stephen J. 2003. Economic models of climate change : a critique (Palgrave Macmillan: New York).

Diaz, Delavane, and Frances Moore. 2017. 'Quantifying the economic risks of climate change', Nature Climate Change, 7: 774-82.

Dietz, Simon, Alex Bowen, Charlie Dixon, and Philip Gradwell. 2016. 'Climate value at risk' of global financial assets', Nature Climate Change, 6: 676-79.

Dietz, Simon, James Rising, Thomas Stoerk, and Gernot Wagner. 2021a. 'Economic impacts of tipping points in the climate system', Proceedings of the National Academy of Sciences, 118: e2103081118.

———. 2021b. 'Economic impacts of tipping points in the climate system: supplementary information', Proceedings of the National Academy of Sciences, 118: e2103081118.

———. 2022. 'Reply to Keen et al.: Dietz et al. modeling of climate tipping points is informative even if estimates are a probable lower bound', Proceedings of the National Academy of Sciences, 119: e2201191119.

Dietz, Simon, and Nicholas Stern. 2014. "Endogenous Growth, Convexity of Damages and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions." In. Centre for Climate Change Economics and Policy.

Dunz, Nepomuk, Arthur Hrast Essenfelder, Andrea Mazzocchetti, Irene Monasterolo, and Marco Raberto. 2021. 'Compounding COVID-19 and climate risks: The interplay of banks' lending and government's policy in the shock recovery', Journal of banking & finance: 106306.

Dunz, Nepomuk, Asjad Naqvi, and Irene Monasterolo. 2021. 'Climate sentiments, transition risk, and financial stability in a stock-flow consistent model', Journal of financial stability, 54.

Editors. 2015. 'Editorial Note: Correction to Richard S. Tol's "The Economic Effects of Climate Change"', The Journal of Economic Perspectives, 29: 217-20.

Fankhauser, S. 1995. Valuing Climate Change: The economics of the greenhouse (Earthscan: London).

Forrester, Jay W. 1971. World Dynamics (Wright-Allen Press: Cambridge, MA).

Forrester, Jay W., W. Low Gilbert, and J. Mass Nathaniel. 1974. 'The Debate on "World Dynamics": A Response to Nordhaus', Policy Sciences, 5: 169-90.

Fund, Shropshire County Pension. 2020. "Shropshire County Pension Fund Climate-Related Disclosures." In. Shropshire Shropshire County Pension Fund.

Garrett, Timothy J., Matheus Grasselli, and Steve Keen. 2020. 'Past world economic production constrains current energy demands: Persistent scaling with implications for economic growth and climate change mitigation', PLoS ONE, 15: e0237672.

Gelman, Andrew. 2014. "A whole fleet of gremlins: Looking more carefully at Richard Tol's twice-corrected paper, "The Economic Effects of Climate Change"." In Statistical Modeling, Causal Inference, and Social Science.

———. 2015. "More gremlins: "Instead, he simply pretended the other two estimates did not exist. That is inexcusable."." In Statistical Modeling, Causal Inference, and Social Science.

———. 2019. "The climate economics echo chamber: Gremlins and the people (including a Nobel prize winner) who support them." In Statistical Modeling, Causal Inference, and Social Science.

Gourdel, Régis, Irene Monasterolo, Nepomuk Dunz, Andrea Mazzocchetti, and Laura Parisi. 2021. 'The double materiality of climate physical and transition risks in the euro area (October 10, 2021). Available at SSRN: '.

Herrington, Gaya. 2021. 'Update to limits to growth: Comparing the World3 model with empirical data', Journal of Industrial Ecology, 25: 614-26.

Hope, C. 2011. 'The Social Cost of CO2 from the PAGE09 Model', Economics. The open-access, open-assessment e-journal.

Hope, Chris. 2006. 'The marginal impact of CO2 from PAGE2002: an integrated assessment model incorporating the IPCC's five Reasons for Concern', Integrated Assessment, 6: 19-56.

Howard, P. H., and D. Sylvan. 2021a. " Gauging economic consensus on climate change." In Technical report. Institute for Policy Integrity, New York University School of Law,.

Howard, Peter H., and Thomas Sterner. 2017. 'Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates', Environmental and Resource Economics, 68: 197-225.

Howard, Peter, and Derek Sylvan. 2021b. "Gauging Economic Consensus on Climate Change." In. New York: Institute for Policy Integrity, New York University School of Law.

Howarth, Candice, and Irene Monasterolo. 2017. 'Opportunities for knowledge co-production across the energy-food-water nexus: Making interdisciplinary approaches work for better climate decision making', ENVIRON SCI POLICY, 75: 103-10.

Hsiang, Solomon, and Robert E. Kopp. 2018. 'An Economist's Guide to Climate Change Science', The Journal of Economic Perspectives, 32: 3-32.

IPCC. 2022. "Climate Change 2022: Impacts, Adaptation and Vulnerability." In.

IPCC, D.J. Arent, R. S. J. Tol, E. Faust, J.P. Hella, S. Kumar, K.M. Strzepek, F.L. Tóth, and D. Yan. 2014. 'Key economic sectors and services.' in C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press: Cambridge, United Kingdom).

Kahn, Matthew E., Kamiar Mohaddes, Ryan N. C. Ng, M. Hashem Pesaran, Mehdi Raissi, and Jui-Chung Yang. 2021. 'Long-term macroeconomic effects of climate change: A cross-country analysis', Energy Economics: 105624.

Kalkuhl, Matthias, and Leonie Wenz. 2020. 'The impact of climate conditions on economic production. Evidence from a global panel of regions', Journal of Environmental Economics and Management, 103: 102360.

Keen, Steve. 1993a. 'The Misinterpretation of Marx's Theory of Value', Journal of the history of economic thought, 15: 282-300.

———. 1993b. 'Use-Value, Exchange Value, and the Demise of Marx's Labor Theory of Value', Journal of the history of economic thought, 15: 107-21.

———. 1995. 'Finance and Economic Breakdown: Modeling Minsky's 'Financial Instability Hypothesis.'', Journal of Post Keynesian Economics, 17: 607-35.

———. 2004a. 'Deregulator: Judgment Day for Microeconomics', Utilities Policy, 12: 109-25.

———. 2004b. 'Improbable, Incorrect or Impossible? The Persuasive but Flawed Mathematics of Microeconomics.' in Edward Fullbrook (ed.), A Guide to What's Wrong with Economics (Anthem Press: London).

———. 2005. 'Why Economics Must Abandon Its Theory of the Firm.' in Massimo Salzano and Alan Kirman (eds.), Economics: Complex Windows (New Economic Windows series. Springer: Milan and New York:).

———. 2011. Debunking economics: The naked emperor dethroned? (Zed Books: London).

———. 2015. 'Post Keynesian Theories of Crisis', American Journal of Economics and Sociology, 74: 298-324.

———. 2016. 'Modeling Financial Instability.' in A.G. Malliaris, Leslie Shaw and Hersh Shefrin (eds.), The Global Financial Crisis and its Aftermath: Hidden factors in the meltdown (Oxford University Press: New York).

———. 2017. Can We Avoid Another Financial Crisis? (The Future of Capitalism) (Polity Press: London).

———. 2020a. 'The appallingly bad neoclassical economics of climate change', Globalizations: 1-29.

———. 2020b. 'Emergent Macroeconomics: Deriving Minsky's Financial Instability Hypothesis Directly from Macroeconomic Definitions', Review of Political Economy, 32: 342-70.

———. 2021. The New Economics: A Manifesto (Polity Press: Cambridge, UK).

Keen, Steve, Robert U. Ayres, and Russell Standish. 2019. 'A Note on the Role of Energy in Production', Ecological Economics, 157: 40-46.

Keen, Steve, Timothy Lenton, T. J. Garrett, James W. B. Rae, Brian P. Hanley, and M. Grasselli. 2022. 'Estimates of economic and environmental damages from tipping points cannot be reconciled with the scientific literature', Proceedings of the National Academy of Sciences, 119: e2117308119.

Keen, Steve, and Russell Standish. 2010. 'Debunking the theory of the firm—a chronology', Real World Economics Review, 54: 56-94.

Kemp, Luke, Chi Xu, Joanna Depledge, Kristie L. Ebi, Goodwin Gibbins, Timothy A. Kohler, Johan Rockström, Marten Scheffer, Hans Joachim Schellnhuber, Will Steffen, and Timothy M. Lenton. 2022. 'Climate Endgame: Exploring catastrophic climate change scenarios', Proceedings of the National Academy of Sciences, 119: e2108146119.

Lehner, Flavio, Andreas Born, Christoph C. Raible, and Thomas F. Stocker. 2013. 'Amplified Inception of European Little Ice Age by Sea Ice–Ocean–Atmosphere Feedbacks', Journal of Climate, 26: 7586-602.

Lenton, Timothy, and Juan-Carlos Ciscar. 2013. 'Integrating tipping points into climate impact assessments', Climatic Change, 117: 585-97.

Lenton, Timothy M., Hermann Held, Elmar Kriegler, Jim W. Hall, Wolfgang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber. 2008a. 'Supplement to Tipping elements in the Earth's climate system', Proceedings of the National Academy of Sciences, 105.

———. 2008b. 'Tipping elements in the Earth's climate system', Proceedings of the National Academy of Sciences, 105: 1786-93.

Lenton, Timothy, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen, and Hans Schellnhuber. 2019. 'Climate tipping points - too risky to bet against', Nature, 575: 592-95.

Mattauch, Linus, Cameron Hepburn, Fiona Spuler, and Nicholas Stern. 2022. 'The economics of climate change with endogenous preferences', Resource and Energy Economics, 69: 101312.

McCallum, S., T. Dworak, A. Prutsch, N. Kent, J. Mysiak, F. Bosello, J. Klostermann, A. Dlugolecki, E. Williams, M. König, M. Leitner, K. Miller, M. Harley, R. Smithers, M. Berglund, N. Glas, L. Romanovska, K. van de Sandt, R. Bachschmidt, S. Völler, and L. Horrocks. 2013. "Support to the development of the EU Strategy for Adaptation to Climate Change: Background report to the Impact Assessment, Part I – Problem definition, policy context and assessment of policy options." In. Vienna: Environment Agency Austria.

Meadows, Donella H. 1994. "Letter to William Nordhaus about his American Scientist survey." In, edited by Wd Nordhaus. Donella Meadows Archives.

Meadows, Donella H., Dennis Meadows, and Jorgen Randers. 2005. Limits to growth : the 30-year update (Earthscan: London).

Meadows, Donella H., Jorgen Randers, and Dennis Meadows. 1972. The limits to growth (Signet: New York).

Mendelsohn, Robert, William D. Nordhaus, and Daigee Shaw. 1994. 'The Impact of Global Warming on Agriculture: A Ricardian Analysis', The American Economic Review, 84: 753-71.

Mendelsohn, Robert O., and James E. Neumann. 1999. The impact of climate change on the United States economy (Cambridge University Press: Cambridge).

Mendelsohn, Robert, Michael Schlesinger, and Larry Williams. 2000. 'Comparing impacts across climate models', Integrated Assessment, 1: 37-48.

Mercer. 2011a. "Climate Change Scenarios–Implications for Strategic Asset Allocation." In.

———. 2011b. "Climate Change Scenarios – Implications for Strategic Asset Allocation." In. Washington: International Finance Corporation.

———. 2015. "Investing in a Time of Climate Change." In. Online.

———. 2019. "Investing in a Time of Climate Change: The Sequel 2019." In. Online.

Minsky, Hyman P. 1982. Can "it" happen again? : essays on instability and finance (M.E. Sharpe: Armonk, N.Y.).

Ng, Pin, and Xiaobing Zhao. 2011. 'No matter how it is measured, income declines with global warming', Ecological Economics, 70: 963-70.

NGFS. 2022. "NGFS Scenarios for central banks and supervisors." In.

Nordhaus, William. 2008. A Question of Balance (Yale University Press: New Haven, CT).

———. 2013. The Climate Casino: Risk, Uncertainty, and Economics for a Warming World (Yale University Press: New Haven, CT).

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

Nordhaus, William, and Joseph G. Boyer. 2000. Warming the World: Economic Models of Global Warming (MIT Press: Cambridge, Massachusetts).

Nordhaus, William D. 1973. 'World Dynamics: Measurement Without Data', The Economic Journal, 83: 1156-83.

———. 1991. 'To Slow or Not to Slow: The Economics of The Greenhouse Effect', The Economic Journal, 101: 920-37.

———. 1992. 'Lethal Model 2: The Limits to Growth Revisited', Brookings Papers on Economic Activity: 1-43.

———. 1993. 'Reflections on the Economics of Climate Change', The Journal of Economic Perspectives, 7: 11-25.

———. 2006. 'Geography and macroeconomics: New data and new findings', Proceedings of the National Academy of Sciences of the United States of America, 103: 3510-17.

——. 2017. 'Integrated Assessment Models of Climate Change', NBER Reporter, 2017.

Nordhaus, William D., and Lint Barrage. 2023. "Policies, Projections, And The Social Cost Of Carbon: Results From The Dice-2023 Model." In. Cambridge, MA: National Bureau Of Economic Research.

Nordhaus, William, and Paul Sztorc. 2013. "DICE 2013R: Introduction and User's Manual." In.

OECD. 2021. Managing Climate Risks, Facing up to Losses and Damages.

Oreskes, Naomi, Erik M. Conway, and Matthew Shindell. 2008. 'From Chicken Little to Dr. Pangloss: William Nierenberg, Global Warming, and the Social Deconstruction of Scientific Knowledge', Historical Studies in the Natural Sciences, 38: 109-52.

Oswald, Andrew, and Nicholas Stern. 2019. 'Why are economists letting down the world on climate change?', Centre for Economic Policy Research. https://voxeu.org/article/why-are-economists-letting-down-world-climate-change.

Pindyck, Robert S. 2013. 'Climate Change Policy: What Do the Models Tell Us?', Journal of Economic Literature, 51: 860-72.

——. 2017. 'The Use and Misuse of Models for Climate Policy', Review of Environmental Economics and Policy, 11: 100-14.

Quiggin, John, and John Horowitz. 1999. 'The impact of global warming on agriculture: A Ricardian analysis: Comment', The American Economic Review, 89: 1044-45.

Solow, R. M. 2010. "Building a Science of Economics for the Real World." In House Committee on Science and Technology Subcommittee on Investigations and Oversight. Washington.

Solow, Robert M. 2001. 'From Neoclassical Growth Theory to New Classical Macroeconomics.' in Jacques H. Drèze (ed.), Advances in Macroeconomic Theory (Palgrave: New York).

——. 2003. "Dumb and Dumber in Macroeconomics." In Festschrift for Joe Stiglitz. Columbia University.

——. 2007. 'The last 50 years in growth theory and the next 10', Oxford Review of Economic Policy, 23: 3–14.

——. 2008. 'The State of Macroeconomics', The Journal of Economic Perspectives, 22: 243-46.

Spash, Clive L. 2007. 'The economics of climate change impacts à la Stern: Novel and nuanced or rhetorically restricted?', Ecological Economics, pp. 706-13.

Stanton, Elizabeth A., Frank Ackerman, and Sivan Kartha. 2009. 'Inside the integrated assessment models: Four issues in climate economics', Climate and Development, 1: 166-84.

Steffen, Will, Johan Rockström, Katherine Richardson, Timothy M. Lenton, Carl Folke, Diana Liverman, Colin P. Summerhayes, Anthony D. Barnosky, Sarah E. Cornell, Michel Crucifix, Jonathan F. Donges, Ingo Fetzer, Steven J. Lade, Marten Scheffer, Ricarda Winkelmann, and Hans Joachim Schellnhuber. 2018. 'Trajectories of the Earth System in the Anthropocene', Proceedings of the National Academy of Sciences, 115: 8252-59.

Stephenson, Michael. 2018. Energy and Climate Change: An Introduction to Geological Controls, Interventions and Mitigations (Elsevier: San Diego).

Stern, Nicholas. 2013. 'The Structure of Economic Modeling of the Potential Impacts of Climate Change: Grafting Gross Underestimation of Risk onto Already Narrow Science Models', Journal of Economic Literature, 51: 838-59.

———. 2022. 'A Time for Action on Climate Change and a Time for Change in Economics', The Economic Journal, 132: 1259-89.

Stern, Nicholas, and Joseph Stiglitz. 2021. "The Social Cost of Carbon, Risk, Distribution, Market Failures: An Alternative Approach." In National Bureau of Economic Research Working Paper Series, edited by National Bureau of Economic Research. National Bureau of Economic Research Working Paper Series.

Stern, Nicholas, Joseph Stiglitz, and Charlotte Taylor. 2022. 'The economics of immense risk, urgent action and radical change: towards new approaches to the economics of climate change', Journal of Economic Methodology, 29: 181-216.

Takakura, Jun'ya, Shinichiro Fujimori, Naota Hanasaki, Tomoko Hasegawa, Yukiko Hirabayashi, Yasushi Honda, Toshichika Iizumi, Naoko Kumano, Chan Park, Zhihong Shen, Kiyoshi Takahashi, Makoto Tamura, Masahiro Tanoue, Koujiro Tsuchida, Hiromune Yokoki, Qian Zhou, Taikan Oki, and Yasuaki Hijioka. 2019. 'Dependence of economic impacts of climate change on anthropogenically directed pathways', Nature Climate Change, 9: 737-41.

Tol, R. S. J. 2022. "A meta-analysis of the total economic impact of climate change." In.: arXiv.org.

Tol, Richard S. J. 2009. 'The Economic Effects of Climate Change', The Journal of Economic Perspectives, 23: 29–51.

Tol, Richard S.J. 2002a. 'Estimates of the Damage Costs of Climate Change, Part II. Dynamic Estimates', Environmental and Resource Economics, 21: 135-60.

———. 2002b. 'Estimates of the Damage Costs of Climate Change. Part 1: Benchmark Estimates', Environmental and Resource Economics, 21: 47-73.

Trust, Sandy, Sanjay Joshi, Timothy Lenton, and Jack Oliver. 2023. "The Emperor's New Climate Scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services

" In. London: Institute and Faculty of Actuaries.

Turner, Graham M. 2008. 'A comparison of The Limits to Growth with 30 years of reality', Global Environmental Change, 18: 397-411.

Turner, Graham M., Robert Hoffman, Bertram C. McInnis, Franzi Poldy, and Barney Foran. 2011. 'A tool for strategic biophysical assessment of a national economy - The Australian stocks and flows framework', Environmental Modelling & Software, 26: 1134-49.

Unisuper. 2022. "Climate risk and our investments." In. Melbourne: Unisuper Advice.

Waller, Christopher J. 2023. "Climate Change and Financial Stability." In Current Challenges in Economics & Finance. Madrid: IE University.

Warren, R., C. Hope, D. E. H. J. Gernaat, D. P. Van Vuuren, and K. Jenkins. 2021. 'Global and regional aggregate damages associated with global warming of 1.5 to 4 °C above pre-industrial levels', Climatic Change, 168: 24.

Weitzman, Martin L. 2011a. 'Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change', Review of Environmental Economics and Policy, 5: 275-92.

——. 2011b. 'Revisiting Fat-Tailed Uncertainty in the Economics of Climate Change', REEP Symposium on Fat Tails, 5: 275–92.

——. 2012. 'GHG Targets as Insurance Against Catastrophic Climate Damages', Journal of Public Economic Theory, 14: 221-44.

Xu, Chi, Timothy A. Kohler, Timothy M. Lenton, Jens-Christian Svenning, and Marten Scheffer. 2020. 'Future of the human climate niche', Proceedings of the National Academy of Sciences, 117: 11350-55.

Xu, Y., and V. Ramanathan. 2017. 'Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes', Proceedings of the National Academy of Sciences of the United States of America, 114: 10315-23.

Zimov, Sergey A., A. G. Schuur Edward, and F. Stuart Chapin. 2006. 'Permafrost and the Global Carbon Budget', Science (American Association for the Advancement of Science), 312: 1612-13.

Appendix

FOIA REQUESTS SENT TO LGPS ADMINISTERING AUTHORITIES & POOLS

Administering Authority	External Investment Consultant	FOIA Reply Status	Summary of information received	FOIA Link
Barking and Dagenham	Hymans Robertson	Denied/ S 43 (2) commercial secrecy + S 41 confidential info	Council argues information should be withheld to maintain "a confidential, private space (away from public scrutiny) for policy making	link
Barnet	Hymans Robertson	Some info received. Emails denied - s41 info in confidence & s42 legal privilege	Provided some information on climate risk modelling. Consultant emails refused citing s43(2) commercial secrecy	link
Bath & NE Somerset	Mercer	Some info provided. Emails denied - s12 cost	Provided Mercer Analytics for Climate Transition (ACT) equity portfolio review & climate policy update	link
Bedfordshire Pension Fund	Hymans Robertson	Delayed reply	No information provided - awaiting delayed response	link
Bexley	Aon	Denied/ S 43 (2) commercial secrecy + s12 cost	Disclosure likely to prejudice commercial interests of any person, incl public authority holding it. Info commercially sensitive to investment advisors	link
Bradford D.C (West Yorkshire)	Aon	Most Info Provided	Provided consultant emails ("FCA regulated) & Aon Scenario Analysis - full document	link
Brent	Hymans Robertson	Some info. Emails denied - S 43 (2) commercial secrecy + S 12 cost	Some info provided on climate change risk analysis - consultant emails were refused	link
Bromley	MJ Hudsons	Denied/ S 43 (2) commercial secrecy	Information withheld - "Council believes disclosure will prejudice commercial interests of Fund Managers, Pension Fund & Council itself."	link
Buckinghamshire	Mercer	Denied, S12 - cost, S41 trade secrets, & S 43 (2) commercial secrecy	"disclosing details of consultant reviews would likely prejudice Council's commercial interests & ability to negotiate best investments for pension fund"	link
Camarthenshire	Mercer	Denied- s12 cost	"We've only been able to provide info in the public domain as info provided by advisors is commercially sensitive & contains their intellectual property which would prejudice their commercial interests, causing them significant harm."	link
Cambridgeshire	Mercer	Some info provided. Emails denied/ S 43 (2) commercial secrecy + s12 cost	"Investment consultants' research is proprietary info which yields a prime revenue stream. Info in question is presented to Committee as private papers. We're aware competing investment consultants, & financial press, scour Committee minutes for competitor intelligence that can be found at minimum effort & cost to their own businesses." Provided TCFD report & Climate Action Plan	link
Camden	ISIO + Karen Shackleton	Denied/ S 43 (2) commercial secrecy + s 12 cost	Conflates climate risk mgmt with London CIV carbon footprinting. Council gamed key word search results to cost bar the request.	link
Cardiff	Aon	Some info provided. Emails denied citing - s12 cost	Provided useful AON scenario analysis showing -40-50% valuation impact at 3-4 deg warming by 2042	link
Cheshire West & Chester	Not disclosed	Delayed reply	No response received	link
City of London	Mercer	Denied- s12 cost, s17	Provides climate action strategy & TCFD report	link
Cornwall	Mercer	Denied - s12 cost, s43(2) commercial secrecy	Rejected on cost & commercial secrecy grounds. Refers to TCFD report and ISS	link
Croydon	Mercer (Hymans = actuary)	Some info. Emails denied s12 (cost)	Fund included TCFD climate scenario stress testing in the contribution modelling exercise for the 2022 valuation	link
Cumbria County Council	Mercer	Some info provided. Reports exempted uder s22 - Info soon to be published	Emails provided with Mercer re: TCFD consultation.	link
Derbyshire County Council	MJ Hudson Allenbridge/ Mercer	Denied/ S 43 (2) commercial secrecy	See 2022 Climate Risk Report via LGPS Central	link
Devon	Mercer	Some info provided. Scenario analysis witheld as commercially sensitive	Emails provided inc survey of Peninisula Pensions member views on climate change & divestment matters.	link
Dorset	Mercer	Info Not Held	Claim no climate risk consultancy work/ scenario analysis done	link
Durham	Aon	Denied/ S 43 (2) commercial secrecy	Emails were refused. For Aon climate scenario analysis - see slide 23 /	link
Ealing	Hymans Robertson	Denied/ S 43 (2) commercial secrecy + S 12 cost	No information provided - awaiting delayed response to internal review	link
East Riding of Yorkshire	MJ Hudson Allenbridge	Denied/ S 43 (2) commercial secrecy + S 12 cost	Council search applied overly broad term "climate" instead of climate scenario analysis as specified	link
East Sussex	Hymans Robertson/ ISIO	Denied/ S 43 (2) commercial secrecy	Emails were refused. Provided actuarial valuation & other publicly available reports	link
Enfield	Aon	Some info provided re: TCFD & scenario analysis. Contract info denied s43(2)	Some info provided re: London CIV and Enfield TCFD reporting	link
Environment Agency	Mercer	Denied s43(1)trade secret & 43(2) commercial secrecy	"we consider the materials contains trade secrets used in Mercer's business &, if disclosed, would be liable to cause real or significant harm"	link
Essex County Council	Minerva/ Hymans Robertson	Denied s 12 Cost	Emails were refused. No climate risk analysis (ACCESS). Provided climate action report	link
Flintshire C.C (Clywdd)	Mercer	Denied S 12 Cost. Internal review response delayed	Provided Mercer (climate risk) Analysis for Climate Transition (ACT) tool & TCFD report	link
Gloucestershire	Mercer	Denied S 12 Cost	Claim to have not engaged a climate risk advisor/ done scenario analysis	link
Greenwich	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	Consultant emails were refused. Provided links to public Net Zero Road Map	link
Gwynedd Council	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	Consultant emails were refused. "No extenal climate scenario analysis undertaken"	link
Hackney	Redington, prev Hymans	Denied/ S 43 (2) commercial secrecy	Consultant emails were refused. Provides links to pension investment strategy & climate targets	link

Administering Authority	External Investment Consultant	FOIA Reply Status	Summary of information received	FOIA Link
Hammersmith and Fulham	John Raisin ex LBWF s151	Denied/ S12 cost, & S43 (2) commercial secrecy	Consultant emails were refused. Climate risk advice/analysis refused. Clarification provided on extent to which LGPS = public money	link
Hampshire County Council	MJ Hudson + AON climate risk advisor	Denied/ S21 + s43(2) commercial secrecy	Provided links to public TCFD report	link
Haringey	Not disclosed	No response	No response received. Case referred to the ICO - reference: IC-231842-P2B1	link
Harrow	Aon	Info Not Held	Claim no climate risk advice sought. Hymans provide Acturial valuation	link
Havering	Hymans Robertson	Some info provided. Emails denied/ S 43 (2) commercial secrecy	Refers to 2021/22 TCFD report	link
Hertfordshire	Mercer	Denied s12 Cost	No information received	link
Hillingdon	Not disclosed	Info Not Held	Info Not Held	link
Hounslow	MJ Hudson (CO2 footprinting)	Denied s12 Cost, s43(2) commercial secrecy	No climate scenario analysis done to date, but planning on doing so in line with TCFD reporting	link
Isle of Wight	Hymans Robertson	Denied/ S 43 (2) commercial secrecy + S 12 cost	No climate risk scenario modelling undertaken. Some info provided re: ESG & Govt TCFD consultation	link
Islington	Mercer, MJ Hudson Allenbridge	Denied - s12 cost	Referred to pension sub-committee minutes on climate related issues impacting the pension fund	link
Kensington and Chelsea	Mercer	Denied/ S 43 (2) commercial secrecy	No information received	link
Kent County Council	Mercer	Denied/ S 43 (2) commercial secrecy + S 12 cost	No information received	link
Kingston upon Thames	Aon	Denied EIR 12(4)(b) cost, + 12(5)(f) information provided in confidence	Consultant emails refused. Do not hold climate scenario anlysis info	link
Lambeth	Mercer	Denied/ S 43 (2) commercial secrecy + S 12 cost	Provided internal emails re: climate risk workstream. Scenario analysis info was refused	link
Lancashire	Mercer - IFAs A Devitt E Lambert	Denied/ S 43 (2) commercial secrecy	Emails provided re scenario analysis. Claim to not hold information on scenario analysis.	link
Leicestershire	Mercer	Some Info Provided	Scenario analysis (2050) of 1.5, 1.6, & 4degC scenarios -1% annual hit to fund value only under 4degC warming?	link
Lewisham	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	No information received	link
Lincolnshire	Hymans Robertson	Info Not Held	Info Not Held	link
London Pension Fund Authority	Barnet Waddingham	All Info Provided	BW emails + Scenario analysis (part redacted) *all info 2023 only	link
Merton	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	Consultant emails refused. No climate scenario anlysis undertaken	link
Middlesbrough (Teeside)	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	Emails refused. See "Sensitivity & risk analysis: climate change" pg 18 of Valuation Report	link
Newham	Barnet Waddingham	Denied - s12 cost	No emails provided. No scenario modelling done yet. Provided committee meeting links	link
Norfolk Pension Fund	Hymans Robertson	Denied, S12 cost, S41 info provided in confidence, S43 (2) commercial secrecy	Emails with consultants refused. No scenario analysis provided	link
North Yorkshire	Aon	Denied- s12 cost	No information received	link
Nottinghamshire	Mercer	Denied - s12 cost, & s43(2) commercial secrecy	Refers to Notts 2020 TCFD report climate scenario analysis, table 2 pg 60 of 2021 Annual Report	link
Oxfordshire County Council	Not disclosed	Claim no info held	"Specific advice on climate risk has not been sought"	link
Powys County Council	Aon	Denied- s12 cost	Consultant emails refused. Refers to public investment strategy statement	link
Redbridge	Mercer	Info Not Held	Consultant emails not provided. Response refers to pension fund annual report	link
Rhonda Cynon Taff County BC	Not disclosed	Denied/ S 43 (2) commercial secrecy	Does not state what info the council holds within the scope of the request	link
Shropshire County Council	Aon - (Mercer - Actuary)	Denied s36	Response implies council pension fund members only care about returns	link
Somerset County Council	None used	Info Not Held	Claim to not use investment consultants, nor seek advice on climate risk	link
South Tyneside (Tyne & Wear)	Hymans Robertson	Denied s41 - info provided in confidence, & s43 (2) commercial secrecy	Email correspondence refused. Climate scenario analysis in Nov 2022 pension committee pack	link
South Yorkshire Pensions Authority	Hymans Robertson	Denied S 43 (2) commercial secrecy + S12 cost	"We've not engaged external investment consultants on climate risk & not commissioned scenario analyses on our portfolios."	link
Southwark	Mercer	Denied/ S 43 (2) commercial secrecy	Reply links to Investment strategy statement (ISS) & Net zero carbon investment strategy	link
Staffordshire County Council	Hymans/ Mercer, CO2 Footprinting - MSCI	Info Not Held	Claim info is now held centrally by LGPS Central	link
Suffolk	Hymans Robertson	Denied S 43 (2) commercial secrecy + S12 cost	Email correspondence was refused. No scenario analysis undertaken	link
Surrey County Council	Mercer	Denied/ S12 (cost) & 43 (2) commercial secrecy	Email correspondence was refused. Response directs to public TCFD report	link
Sutton	Hymans Robertson	Denied EIR 12(4)(b) cost unreasonable, + EIR 12(5)(f) adverse effect on provider	Email correspondence was withheld. Council does not hold climate scenario analysis info	link

Administering Authority	External Investment Consultant	FOIA Reply Status	Summary of information received	FOIA Link
Swansea	Hymans Robertson	Denied S 43 (2) commercial secrecy + S12 cost	Email correspondence was withheld.	link
Tameside (Greater Manchester)	Hymans Robertson	Denied s41 info provided in confidence & 43(2) commercial secrecy	Hymans undertook climate analysis as part of the Asset Liability Modelling exercise following the 2019 valuation exercise. Info exempt	link
Torfaen	Not disclosed	Denied - s12 cost, s41 info in confidence & s43(2) commercial secrecy	Email correspondence withheld. Refers to annual report under the 'Strategy' section at p47	link
Tower Hamlets	Mercer	Denied - s12 cost, & s43(2) commercial secrecy	Mercer have produced reports on climate change, & TCFD	link
Waltham Forest	Mercer	Denied/ S 43 (2) commercial secrecy. Awaiting internal review reply	Email correspondence & scenario analysis withheld	link
Wandsworth	Mercer	Denied/ S 43 (2) commercial secrecy	Email correspondence withheld. Some info on climate sensitivity from Actuary in Annual Report	link
Warwickshire	Hymans Robertson	Denied s41 info provided in confidence & 43(2) commercial secrecy	Email correspondence & scenario analysis withheld. Provided out of scope CO2 footprint info	link
West Sussex County Council	Not disclosed	Denied S 43 (2) commercial secrecy + S12 cost	Claim no scenario analysis undertaken	link
Westminster	Deloitte	Some Info Received	Deloitte TCFD report provided	link
Wiltshire	Mercer	Denied- s12 cost	Email correspondence & scenario analysis withheld - council gamed key word search results to cost bar the request.	link
Windsor and Maindenhead UA	Barnet Waddingham	Some info received	Provided emails with BW re: climate scenario analysis. "No emails pre-2023 discussing pension fund climate risk."	link
Wirral	Redington - prev Aon. Mercer = actuary	Denied- s12 cost. Awaiting internal review reply	Email correspondence withheld. Mercer currently working on climate sensitivity. Info not held	link
Wolverhampton	Redington (inv)/ Mercer (risk)	Denied/ s43(2) commercial secrecy, s36 "chilling effect" on public office + s12 cost	Email correspondence witheld. Claim fund returns, not climate risk of interest to members	link
Worcestershire County Council	MJ Hudson	Refused as "confidential information"	Emails were refused. Response linked to TCFD report and ISS	link
LGPS Pools				
Wales Pension Partnership	Hymans Robertson	Denied/ S 43 (2) commercial secrecy	Withheld emails. Linked to responsible investment & climate policies. No scenario analysis	link
London CIV	Not disclosed	Some Info Received	Claim to have not sought advice/ no scenario analysis. Linked to 2022 TCFD report	link
Brunel	Not disclosed	Info Not Held	Claim no scenario modelling undertaken so info not held	link
Borders to Coast	Not disclosed	Info Not Held	We have not engaged any external consultants or undertaken external climate risk analyses on our customers portfolios.	link
LGPS Central	Mercer	Denied/ S 43 (2) commercial secrecy	Emails & scenario analysis withheld.	link
ACCESS	Minerva Consulting	Info Not Held	Claim no climate risk assessment undertaken (Essex C.C) - only responsible investment policy	link
Local Pensions Partership	Mercer	Some Info Received	Emails between LPP - Barnett Waddingham & Mercer on scenarios	link
Northern LGPS	Not disclosed	Info Not Held	Claim no investment consultant - info not held	link
LGPS Scotland				
Aberdeen - NE Scotland Pension	Not disclosed	Some info received. Climate risk & negotiation info withheld as commercially sensitive	Provided pension fund manager emails on ESG (engagement) & TCFD.	link
Dumfries and Galloway	Not disclosed	Info Not Held	Claim no climate risk info is held/ was sought	link
Dundee - Tayside	ISIO	Denied s12(1)- cost/ Info not held	Email correspondence withheld. Claim climate risk info not held	link
Edinburgh - Lothian	Hymans Robinson	Info Not Held	Implausibly claim no email trail with advisors, despite relevant climate work on pro-bono basis.	link
Falkirk	Hymans Robinson	Info Not Held	Claim no email trail with advisors, despite relevant climate work on pro-bono basis with Lothian PF acting as Falkirk advisors "on some matters"	link
Fife	Not disclosed	Info Not Held	Provided SIP, investment strategy & actuarial valuation	link
Glasgow - Strathclyde	Not disclosed	Denied s12(1)- cost	Email correspondence withheld. Claim climate risk info not held	link
Highland Council	Hymans Robertson	Some Info Received	Asked our Actuary Hymans to complete stress-test modelling of climate change risk on our funding for Triennial Valuation 31 March 2023	link
Orkney	Hymans Robertson	Denied s36(2) confidential information & s33 (1b) commercially sensitive	Hymans = actuary & investment consultant. Info withheld, copy/ pasted consultants arguments against public disclosure	link
Scottish Borders	Not disclosed	s33 (1b) commercially sensitive/ info not held?	Emails & scenario analysis withheld. Provided a summary on non-requested public info. Claim consultant left & email cant be accessed	link
Shetlands	ISIO	Some Info Received	Email trail with advisors ISIO & background docs - no scenario analysis	link

Disclaimer: Information up to date for data as requested as at March 2023, with a data cut off date of June 30

Disclaimer

Carbon Tracker is a non-profit company set up to produce new thinking on climate risk. The organisation is funded by a range of European and American foundations. Carbon Tracker is not an investment adviser and makes no representation regarding the advisability of investing in any particular company or investment fund or other vehicle. A decision to invest in any such investment fund or other entity should not be made in reliance on any of the statements set forth in this publication. While the organisations have obtained information believed to be reliable, they shall not be liable for any claims or losses of any nature in connection with information contained in this document, including but not limited to, lost profits or punitive or consequential damages. The information used to compile this report has been collected from a number of sources in the public domain and from Carbon Tracker licensors. Some of its content may be proprietary and belong to Carbon Tracker or its licensors. The information contained in this research report does not constitute an offer to sell securities or the solicitation of an offer to buy, or recommendation for investment in, any securities within any jurisdiction. The information is not intended as financial advice. This research report provides general information only. The information and opinions constitute a judgment as at the date indicated and are subject to change without notice. The information may therefore not be accurate or current. The information and opinions contained in this report have been compiled or arrived at from sources believed to be reliable and in good faith, but no representation or warranty, express or implied, is made by Carbon Tracker as to their accuracy, completeness or correctness and Carbon Tracker does also not warrant that the information is up-to-date.

To know more please visit:

www.carbontracker.org

@carbonbubble

Carbon Tracker Initiative