New horizons for understanding economic consequences of climate change

A summary report

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New horizons for understanding economic consequences of climate change – A summary report
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Cover image
Braided Makarora River flowing into Lake Wanaka, South Island of New Zealand. © iStock.com / nazar_ab.

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Introduction

Enhanced interdisciplinary collaboration between physical scientists, economists, and other social scientists can overcome the long-term disconnect that has existed between these disciplines in the context of climate change. This disconnect is, amongst other causes, responsible for the serious problems with the understanding in economics of the relationship between estimates of the economic impacts of climate change and the underlying science.

The findings of physical climate science over recent decades have generated a deeper understanding of the very serious risks to human societies and ecosystems from current and future climate change. This has underpinned calls for strong mitigation and adaptation action. For example, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that "Climate change is a threat to human well-being and planetary health (very high confidence). There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all (very high confidence)." It also states: "Deep, rapid and sustained mitigation and accelerated implementation of adaptation actions in this decade would reduce projected losses and damages for humans and ecosystems (very high confidence), and deliver many co-benefits, especially for air quality and health (high confidence)"[1]. The findings of physical climate science underpin the aim of Article 2a of the Paris Agreement: "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change"[2].

Economists also have sought to understand and assess the consequences of current and future climate change. Some have developed economic models to attempt to describe potential changes in the economy, natural environment, and/or other social systems resulting from climate change, and to understand decisions and choices. Economists use models and other methods and tools to estimate the economic impacts of climate change, due to, for example, increased temperatures and extreme events. Economic assessments underpin governmental and private sector policies, finance, and strategic decisions. It is therefore critical that economic assessments reflect as well as possible current and future climate change, to inform decisions about mitigation and adaptation.

However, many economic assessments do not adequately reflect the scientific evidence of current and future climate change, for many reasons which are explained in this report. As a consequence, economic assessments can often lead to misleading portrayals of the possible economic consequences of climate change.

The problems with current assessments of the economic impacts of climate change were highlighted by the contribution of Working Group II to the IPCC Sixth Assessment Report, which pointed out: "Projected estimates of global aggregate net economic damages generally increase non-linearly with global warming levels (high confidence). The wide range of global estimates, and the lack of comparability between methodologies, does not allow for identification of a robust range of estimates (high confidence)"[3].

While many in the economics profession recognise these problems, and are working on improvements, serious issues remain; there is not yet a satisfactory mechanism for guiding future research efforts in this area.

1 Intergovernmental Panel on Climate Change. 2023. Synthesis report of the IPCC Sixth Assessment Report. Pp.12 and 27. See: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf (accessed 22 May 2023).

2 United Nations. 2015. Paris Agreement. See: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (accessed 22 May 2023).

3 Intergovernmental Panel on Climate Change. 2022. Summary for Policymakers. p.15. See https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf (accessed 5 July 2023).

Image: City of Alesund, Norway. © iStock.com / CHUNYIP WONG.

This report summarises the key findings from a two-day discussion meeting held at the Royal Society in March 2023 under the lead of Lord Nicholas Stern FRS. The purpose of this discussion meeting was to bring together physical scientists, economists, and other social scientists to explore how to collectively increase the understanding of economic consequences of climate change. In doing so, this could inform economic policy and drive the action required to implement the Paris Agreement, to create a path of sustainable and resilient development.

The report begins with sharing the key messages and research priorities that have emerged from the discussion meeting. It then summarises the findings of each theme-specific session in further detail. The meeting was attended by leading experts from across the world from economics and the physical, social and health sciences. The names of contributors to this report and participants of the discussion meeting can be found in the Acknowledgements.

Key messages

Enhanced interdisciplinary collaboration between economists and physical scientists, responding to information needs of decision-makers

Most current approaches to economic assessments of impacts of climate change do not reflect the severity of consequences that are suggested by the latest physical climate science and evidence on impacts, due to a disconnect between the economics and physical sciences disciplines.

Key aspects of the physical impacts of climate change are missing from many current economic assessments, including, for example, the full consequences of extreme weather events and the potential for cascading risks and tipping points. Interdisciplinary collaboration between physical scientists, economists and other relevant disciplines could help to better integrate the latest physical science into economic assessments, analytical approaches, and models, by sharing scientific evidence in formats that are more tailored to the needs of economists.

This dialogue needs to be two-way and address fundamental gaps in methods, such as by scientists and economists working together to develop new approaches to assessments. Working directly with decision-makers during the process of developing new approaches would further ensure their outputs address the information needs of decision-makers.

Disaggregating data and integrating local information in economic assessments

Approaches to assessing the economic impacts of climate change often use spatially aggregated data. As impacts are frequently non-linear, aggregation over large spatial or temporal domains may overlook severe local impacts. By integrating more local data in their assessments, economists could produce estimates of the economic and social consequences of climate change that are more location- and context-specific and useful for decision-makers at a range of scales.

In addition, as a lot of paradigms that underpin this type of economic assessment may not be as well or widely accepted in the Global South scholarship, collaboration between economists and scientists from the Global North and the Global South could yield a better understanding of what information needs to be included to provide robust estimates of economic impacts of climate change for the Global South.

Integrating nature and health into economic assessments

Climate change, human health, and nature are all fundamentally interlinked. Loss of natural capital can be a significant risk multiplier for climate change impacts. However, these aspects are often missing from economic assessments of impacts of climate change. Economists could work collaboratively with physical, health and social scientists to better integrate data on nature and human health into economic assessments.

This would allow economists to emphasise the importance of inclusive wealth, and the role of four types of capital — physical, human, natural and social — in their assessments of the economic impacts of climate change. Such an approach would help to represent the full spectrum of economic implications of climate change and better capture potential amplifying feedbacks. This approach could also highlight the potential co-benefits of climate action for nature and human health, compared to narrower metrics such as gross domestic product.

Increasing the focus on adaptation and development in the economic analysis of climate change

Greater attention should be paid to adaptation when assessing the economic implications of climate change, particularly at the local level. Crucially, both mitigation and adaptation must be considered together with economic development as they are fundamentally interlinked.
At present, adaptation is frequently underrepresented, or even omitted, in approaches to economic analyses of climate change. There is limited understanding of the quantified damages and risks to be adapted to and the benefits and costs of adaptation.

Adaptation has also received insufficient attention in policy and investment decisions, despite the potential for adaptation to greatly reduce the risks of climate change and support development goals. Better accounting of adaptation in economic assessments of impacts of climate change could help to inform policy decisions for resource allocation, drive practical adaptation action, and identify co-benefits for development. Further efforts could be made to also better account for the co-benefits of mitigation action in economic assessments, such as for human health.

Incorporating ethics, inequality and justice in the economic analysis of climate change

Many economic assessments of climate change adopt an approach based on standard welfare economics. As such, they do not take explicit account of the rights and obligations of current and future generations. Justice is in large measure about the respecting of rights. For example, many assessments focus on the consequences of climate change on overall or aggregated human welfare and discount the welfare and experiences of future generations using discount rates which have little basis in ethics, and which are inadequate in their treatment of potentially very bad outcomes. The treatment of discounting is often cavalier for these reasons. Many economists are increasingly uncomfortable with the way and degree to which the future is discounted within standard welfare approaches and resulting consequences for policy.

Further, there are alternative ethical frameworks and moral philosophies that would re-shape climate change economics and drive discussions about, for example, what a virtuous society would do, or how to ensure that particular human rights are respected. Assessments could integrate non-welfarist approaches that value, for example, knowledge, culture and nature. Inequality across and within countries could be better taken into account such that country-specific efforts to mitigate emissions are reconciled with ethical arguments in the context of a just transition.

Taking a storyline approach to communicate uncertainty

Physical sciences and economics often address uncertainty by presenting a likely range of estimates. However, this can underplay the policy relevance of low-likelihood, or unknown likelihood, high-impact outcomes. This means policymakers may not be aware of possible outcomes outside of the indicated likely range of estimates, potentially leading to under-preparedness for more extreme scenarios.

One alternative approach could be the use of storylines, which use conditional 'if-then' statements to show a range of plausible outcomes, including low-likelihood, or unknown likelihood, high-impact scenarios. A storyline approach to communicating the risks of climate change could help policymakers to better prepare policies and actions which take account of the full range of possible scenarios.

Assessing economic impacts of climate change in a future context

The scale of recent changes across the climate system as a whole — and the present state of many aspects of the climate system — are unprecedented over many centuries to many millions of years. Economic assessments of climate change are often based solely on observed past data and rely on unrealistic extrapolation for estimating future economic impacts of climate change. This results in a failure to consider outcomes that might occur under unprecedented levels of global warming. For example, projecting existing or past relationships of climate variability and migration may be less valid as variables that drive migration, including demographics and migration policies, are likely to change, possibly dramatically.

Economists could explore a diversity of approaches and tools to assessing the economic impacts of climate change, such as process-based models and artificial intelligence, and adopt a 'storylines' approach to better consider an uncertain future potentially way outside previous human experience.

Research priorities

Addressing the following research priorities would contribute to improving economic assessments of the impacts of climate change. Improved estimates would help to better inform strategic decisions for enhanced climate action.

Integrating extreme events and other climate-induced hazards into economic assessments

Further research is required to understand how to better integrate extreme events and climate-induced hazards into economic analyses of climate change. Understanding how to integrate data on frequently excluded hazard categories, such as wildfires and flooding, may help to create more robust economic assessments of climate change. That could, for example, improve specification and discussion of damage functions in Integrated Assessment Models (IAMs). However, the contribution of IAMs is limited in many important ways.

Even more importantly, integrating extreme events and other climate-induced hazards could contribute to further research into novel approaches, perspectives and frameworks of models that could lead to a better understanding of the economic implications of extreme events and climate-induced hazards. Further work is also required to capture the cascading global implications of climate change, such as the impacts of changing patterns of droughts on global food prices (both levels and stability), and the non-linear compounding effects of physical climate shocks with other shocks and stresses that can significantly amplify impacts.

Understanding the impacts of Earth system tipping points and non-linear processes, and integrating these into economic assessments

Further work is needed to better understand the potential physical impacts of almost all global Earth system tipping points; only the impacts of the possible collapse of the Atlantic Meridional Overturning Circulation and accelerated sea-level rise from loss of ice from the Antarctic and Greenland ice sheets have received much attention. Further physical science research is also needed to better understand regional and local tipping points, which are even less understood than global climate tipping points, and the links between ecological regime change and tipping points. Understanding tipping points and non-linear processes and integrating these into economic assessments of climate change may require international cross-disciplinary collaboration and a range of approaches to empirical data collection and modelling.

Accounting for adaptation in economic assessments of climate change

Adaptation is currently underrepresented in approaches to economic analysis of climate change. Empirical analysis and model-based research need to better understand the economic implications of existing and future adaptation responses to climate change to inform global stocktakes of adaptation. As adaptation is often a local, autonomous response, this will require research at local scales, particularly in areas of the Global South vulnerable or exposed to climate change. But consideration must also be given to adaptation needs at the national, regional and global scale, given the threats to global systems – including food, nature, water and energy – from climate change.

Furthermore, research is required to better understand climate change adaptation and its relationship with economic development, how to represent this in economic assessments of climate change, and how to communicate this to decision-makers to inform practical adaptation and development efforts. This work would also help understand 'loss and damage' and the limits to adaptation. Disasters and loss and damage are playing an ever-increasing role in international discussion, including of debt, and such discussion needs to be better informed of the scale and nature of risks.

Understanding the economic implications of climate change impacts on population displacement and migration

Climate change is expected to affect the availability of resources and the liveability of many regions. A key research need is to understand to what extent these changing conditions will influence population displacement and migration flows in the future, and subsequent economic implications within and between different countries.

Furthermore, assessments that estimate the economic impacts of climate change should integrate data on population displacement and migration. Current assessments do not tend to do this, or only in a very limited way, which can lead to an incomplete picture of the real economic impacts in regions affected by population displacement and migration. There is also a need to better understand the monetary costs of involuntary displacement of people, both temporarily and permanently, due to changes in extreme climate and weather events. Finally, further research is required to better represent population displacement and migration in novel economic assessment approaches, including future socioeconomic drivers which have not happened in the past.

All of the above research priorities face the crucial methodological challenges of how to look out for and analyse circumstances and potential events which can be way outside human experience. And they involve potentially immense systemic events and instabilities, as well as local existential events. These methodological challenges should be examined directly. All too often the economists' natural and understandable predilection for data-driven analysis leads to attempts to extrapolate past statistical associations to circumstances way outside the range of past experience.

Challenges in creating robust estimates of economic impacts of climate change

Economic analysis and modelling are used to quantify potential changes in the economy, natural environment, and/or other social systems and to understand decisions and choices. Economists can also use analysis and models to estimate the economic impacts of climate change, due to, for example, increased temperatures and extreme events. The findings of such economic assessments underpin governmental and private sector decisions about policies, finance, and strategy; it is therefore critical that they accurately reflect current and future climate change, to inform decisions about climate change mitigation and adaptation.

Whilst economists have made some progress in better understanding and modelling the interactions between climate change and the economy, there are several problems with current approaches to economic assessments of climate change. Overall, many economic analyses and models do not factor in all the latest scientific evidence of current and future climate change for the following reasons.

Firstly, significant non-market impacts of climate change, such as those on human health and natural ecosystems, are often excluded from economic assessments. For example, top-down analytical and modelling approaches, which provide a macroeconomic overview of the entire economy, often only consider market losses from climate change. Bottom-up analyses and models assess damages from climate change through individual sectors or impact channels, but there is significant variation as to which non-market losses are covered. As a result, economic assessments can grossly underestimate the severity of climate change, apparently at odds with the current understanding of the physical science.

Secondly, estimates of the economic impact of climate change are frequently only calculated at the global level. There is comparatively fewer data at national and particularly sub-national levels. This can limit the usefulness and relevance of economic assessments of climate change impacts for national and local policymakers. Impacts across the globe tend to be worst in poor regions, where the resulting losses to welfare from a given impact are the greatest. Without accounting for these differences, the true risk of climate change is unreported.

Thirdly, there are currently significant gaps in integrating systemic changes, such as Earth system tipping points and changes in the future structure of the economy, in economic analysis and modelling of climate change.

Scientists and economists are often under pressure to deliver very precise statements and results, despite multiple sources of uncertainty. A frequent way of doing so is to present the most reliable middle estimates, excluding the rest of the range of results. This means plausible but more uncertain extremes, referred to as low-likelihood, high-impact outcomes by climate scientists, can be omitted from economic estimates of climate change. This approach to framing uncertainty means that some economic assessments can underplay the potential severity of climate change and resulting economic impacts.

A more interdisciplinary approach between physical scientists, economists, and other social scientists, including those from the Global South, could help to address the current issues present in economic assessments of climate change. Greater collaboration between economists and physical scientists could help economists to better incorporate the latest science about climate change, nature, and the impacts of low-likelihood, high-impact outcomes — including Earth system tipping points. Physical scientists could work with economists to understand how best to present their data in a way that is useful and usable for economists. Other social scientists could help economists understand and consider the wider implications of climate change on individuals and societal structures, such as changes to food systems, the built environment, and social behaviour.

An interdisciplinary approach between physical scientists, economists, and other social scientists could lead to more comprehensive assessment frameworks and estimates of the economic impacts of climate change, integrating both top-down and bottom-up analytical and modelling approaches together with a range of wider physical and societal data. As a result, economic assessments would better reflect the latest science, systemic changes and non-market impacts resulting from climate change.

Image: Boreal forest in Lapland. © iStock.com / Wirestock.

Furthermore, it is important for physical scientists, economists, and other social scientists to engage directly with policymakers to better understand their needs for evidence and the scale and context of economic estimates required. Economists could then create assessments and estimates of climate change that are more useful and usable for policymakers.

Finally, it is necessary to address how uncertainty is framed and communicated to policymakers. Current approaches to framing uncertainty can misrepresent possible implications of climate change and underplay risks, due to aggregating data at large spatial scales, concealing uncertainty at more local scales, and excluding plausible extremes.

A potentially useful alternative framing of uncertainty could be to employ a 'storyline' approach when presenting the physical and economic risks of climate change. Storylines show a range of plausible outcomes, rather than a single, definitive statement to cover all scenarios, with potentially high confidence in the conditional outcomes. Storylines can explore the combinations of multiple, interacting climate drivers and hazards at different scales. Using a storyline approach alongside more localised, disaggregated data that considers wider non-market factors could better translate the physical and economic risks of climate change to policymakers. Presenting a range of plausible outcomes, rather than a central estimate, could result in more ambitious action for both climate change mitigation and adaptation.

Economic consequences of climate thresholds and Earth system tipping points

An Earth system tipping point is a critical threshold at which a small perturbation can qualitatively alter the state or development of a system, resulting in the acceleration, irreversibility or inevitability of serious impacts. Established global 'core' tipping elements include the melting and destabilisation of vast ice sheets in Greenland and Antarctica, thawing of Boreal permafrost, and the slowing down of the Atlantic Meridional Overturning Circulation. Regional tipping points include disruption to the Sahel and West African monsoon, death of low-latitude coral reefs, and melting of extra-polar mountain glaciers.

There is also the possibility of complex interaction, or 'coupling', between tipping elements. For example, as warming accelerates the Greenland ice sheet melting, the increased freshwater contributes to the slowdown of the Atlantic Meridional Overturning Circulation, which in turn can worsen droughts in the Sahel, and accelerate melt of the West Antarctic ice sheet. At current rates of warming and policy trajectories, there is a risk that thirteen known tipping elements could pass a critical threshold. This risk should be considered when developing adaptation and resilience policies, as well as mitigation policies.

There are several reasons why tipping points are not well integrated into economic assessments of the impacts of climate change.

Firstly, despite significant scientific developments over the last decade, there is still much further work needed to understand the impacts of almost all global tipping points; only the impacts of the Atlantic Meridional Overturning Circulation collapse and some of the impacts of accelerated sea-level rise from loss of ice from the Antarctic and Greenland ice sheets have received much attention. Regional and local tipping points are even less well understood. It is difficult to integrate tipping point impacts and interactions into economic assessments without a more extensive physical science base.

Secondly, although there has been some progress, even the existing knowledge of tipping points is often not being integrated into economic assessments. As a result, many analyses and models are currently underestimating the economic impacts of climate change, particularly at regional and local levels. As well as understating the magnitude of the effect of tipping points, some economists have misinterpreted the direction of impacts, for instance by predicting net economic benefits from a slowdown of the Atlantic Meridional Overturning Circulation.

If economic assessments of climate change are not including tipping points, or underestimating the magnitude of their impacts, decision-makers may not adequately consider them in their climate response strategies, despite their significance for both mitigation and adaptation. Furthermore, tipping points can fall into gaps between domestic and international responses, due to their complex global nature.

To address each of the above issues, firstly, there needs to be further research on the physical science of tipping points. This would help to increase understanding of each tipping element in more depth, interactions between them, and implications of tipping points at regional and local scales.

There also needs to be greater collaboration between economists and physical scientists around tipping point impacts. More interdisciplinary projects could enable economists and physical scientists to better understand the language and concepts of each other's disciplines. Greater collaboration could allow for better translation of physical science into novel economic analytical approaches, leading to improved estimates of the economic impacts of climate change. This especially needs to happen for adaptation economics at regional and local levels, whilst considering the distribution and inequality of impacts arising from Earth system tipping points.

Image: The Amazon rainforest in Ecuador. © iStock.com / Kalistratova.

Tipping point impacts may also mean that any limits to adaptation are reached earlier. Little is known about these limits to adaptation in different locations and for different outcomes.

Finally, there is a need for new framings and narratives of tipping points that drive action on mitigation and adaptation, to address the currently slow and inadequate policy response. Scientists and economists could support this by providing evidence of tipping point implications at national and local levels.

Limits of current approaches to modelling economic impacts of extreme events and other climate-induced hazards

A common way of estimating economic impacts of climate change is by using an Integrated Assessment Model (IAM). Broadly, IAMs combine Earth systems with societal and economic models, though there are different types of IAM, which vary significantly in their scope and complexity. For example, some IAMs focus solely on the cost-effectiveness of climate mitigation options, whilst others attempt to measure the costs of climate impacts. Using different combinations of inputs and assumptions, IAMs simulate a wide variety of processes and interlinkages between systems. This complexity can mean that IAMs may use a more simplified simulation of a system than a model that focuses on that system alone.

For example, the climate model component of an IAM is usually much simpler than models typically used in physical climate modelling, such as 3D general circulation models of the Earth system. Whilst uses vary, IAMs can produce estimates of the economic cost-benefit of future greenhouse gas emissions, the carbon budget for a 1.5°C pathway, or the economic implications of different policy decisions. However, many benchmark IAMs — baseline models used as comparators in economic studies — to date remain limited in their coverage of climate-sensitive hazards and extreme events in ways that are explained below.

First, many model-based economic damage estimates exclude entire hazard categories, such as wildfires. Second, even models that do consider climate induced hazards may do so in a limited fashion, such as by only considering deterministic capital and mortality effects from an average increase in cyclone risks. Such modelling may fail to capture the costs of increases in uncertainty, as well as broader impacts of risk changes on behaviour and the macroeconomy. Third, many models are missing interactions between extreme events and subsequent economic knock-on effects. For example, wildfires can cause increased mortality and health impacts, putting pressure on healthcare systems, which can subsequently lead to broader economic feedback impacts. Fourth, IAMs are generally not well suited to capture extremes due to their coarse temporal and spatial resolution.

Finally, many IAMs have little to no coverage of climate sensitive hazards, such as flooding, at the local level. Instead, IAMs often aggregate data at a much broader scale. Many IAMs also do not consider interactions between climate change and other environmental changes, such as freshwater aquifer depletion or the effect of carbon dioxide fertilisation on micronutrient levels on crops. As a result, depending on their inputs and assumptions, IAMs may underestimate the overall economic impacts of climate change. This can affect the strength and appropriateness of recommended climate policies.

Changes to analyses and models could bring about advances. There have been improvements in the use of IAMs for estimating the economic impacts of extreme events. For example, economists are designing more macroeconomic IAMs that attempt to quantify the costs of climate-induced hazards, such as wildfire risk, and some are incorporating structural risks from tipping points.

However, there needs to be further work on incorporating a wider array of physical risks, quantifying interlinkages between these, and on integrating data from more localised scales to account for variation in damages from extreme events across space. This would support greater attention on adaptation in both modelling and in practice, as model outputs could be made more place-specific for policymakers. To ensure there is suitable input data for IAMs and other approaches to estimating the economic impacts of climate change, there is a need for further localised data collection on the impacts of extreme events, as well as on community vulnerability and exposure to climate-induced hazards.

Image: A flooded town following extreme weather. Indonesia. © iStock.com / syahrir maulana.

Whilst benchmark IAMs will continue to be used for thinking about climate policy cost-benefit trade-offs, novel approaches are required, rather than solely adapting existing IAMs and relying on one model type. Instead, it is important to use a suite of models and use the appropriate approaches that help to best understand each particular issue. For example, a global, aggregated model may not be informative for understanding wildfire damages in one particular country, whereas another approach could help to better understand and represent this.

Using a group of models could allow scientists and economists to capture a wider range of climate-induced hazard categories, economic feedback effects, varying societal preferences, and differences between and within countries. Diversifying approaches that better account for extreme events and climate-induced hazards could help to improve estimates of the economic impacts of climate change, which in turn could encourage more ambitious climate action.

Economic effects of climate change on non-marketed goods

There is a fundamental interconnection between climate change, nature, human health, and the economy. Alongside its intrinsic value, nature is critical to economic systems, as it provides both provisioning goods, including timber, and regulating services, such as climate regulation, pollination, and nitrogen fixation. Ecosystems influence and are influenced by climate change. For example, forests can sequester carbon dioxide from the atmosphere, but release carbon dioxide if affected by wildfires. However, nature is largely missing from assessments of the economic impacts of climate change.

Climate change also affects human health. For example, climate change can exacerbate heat stress, the spread of infectious diseases, and worsen air quality impacts from wildfires. In addition, climate change can affect a wide range of social determinants of health, such as poverty levels, housing, food security and access to health services.

The worsening of human health, and the costs to address this, has a significant impact on economic productivity, in addition to the welfare impacts on individuals. It is important to note that these impacts on health vary within and between countries. Furthermore, mitigating and adapting to climate change can also have significant co-benefits for health and subsequently the economy, by improving the social determinants of health, air quality, and resilience to extreme events.

Despite its significance for the economy, health has been largely excluded from economic assessments of the impacts of climate change. Economic analyses and models have particularly neglected the health benefits of mitigating climate change, the impacts of climate change extreme events on mental health, and the variance of health impacts across space and different demographics.

Crucially, there is a significant omission of local data on nature, health and economic development from countries in the Global South when estimating the economic impacts of climate change. Countries in the Global South, particularly in the tropics, contain some of the most biodiverse ecosystems which are of global importance. This is also where some of the greatest pressure on nature is found, largely due to large-scale land degradation and deforestation.

In addition, economic assessments frequently exclude the informal economy from estimates of the impacts of climate change. The informal economy refers to all economic activity that takes place outside formal state processes and laws. This sector is a significant source of employment in much of the Global South and constitutes the vast majority of employment in Africa. With future population growth, this sector will become increasingly important.

By excluding nature, health, and the informal economy, assessments can underestimate the economic impacts of climate change and the co-benefits of mitigation and adaptation action. This leads to unreliable estimates of impacts of climate change, which affects the ability of decision-makers to take appropriate action to address climate change. There are several possible solutions to address the above issues.

Firstly, natural scientists, economists and other social scientists could collaborate to better integrate health and nature, including novel approaches, into economic assessments of climate change. This could help to better represent the costs of climate change, including non-market impacts, at a more granular level. It is also vital to better represent the Global South in these approaches and outputs, by collaborating with scientists, decision-makers and citizens from these countries, as well as integrating local data and knowledge into assessments. This could improve trust and usability in assessments of the economic impacts of climate change.

Image: Visitors to Stanley Park, Vancouver, Canada. © iStock.com / Michael Wels.

Secondly, there is a need to move towards new measures and metrics of inclusive wealth, beyond solely considering the impact of climate change on gross domestic product (GDP) and market losses. This shift requires thinking of a broader conception of sustainability and human welfare, integrating climate change mitigation, adaptation and development. Approaches to analysing and modelling the impacts of climate change could recognise that there are five types of capital – financial, physical, human, natural and social – and consider the distributional impact of losses and variations in welfare across space and time.

Moving towards new metrics of, and approaches to, inclusive wealth could improve estimates of the economic impacts of climate change, compared with focusing on market losses and impacts on aggregated GDP. This shift could also have a wider effect on policy and society as the use of models and metrics influences wider societal values and therefore what decision-makers consider to be important.

Ethical issues within current approaches to economic assessments of climate change

The economic analysis of climate change is sometimes presented as being purely descriptive and free of values. However, in the process of modelling and analysing the aggregate economic impacts of climate change, or drawing policy implications, economists have to make decisions on which data to include or exclude, and make assumptions about the weights to place on different impacts, on different people, and at different points in time.

One example is the choice of discount factors, which are weights placed on future costs and benefits compared to current costs and benefits. Discount factors are typically chosen based on the assumption that societies will become wealthier in the future. This, of course, might not be true in a future where societies are increasingly burdened by severe impacts of climate change. It is also often assumed that as individuals prefer to receive income or benefits now, rather than in the future, this impatience also exists at a societal level.

It is important that the moral philosophy and ethical frameworks that underpin such analysis and modelling are made explicit. Most assessments that estimate the economic impacts of climate change typically only consider the consequences of climate change on human welfare expressed through consumer preferences and the consumption of goods and services. In the most common economic framework of cost-benefit analysis, monetary losses from climate change are compared to monetary costs of reducing greenhouse gases. This is a narrow lens through which to consider the entire consequences of climate change. This approach excludes other individual preferences and values placed on a wide array of factors that can be impacted by climate change, such as nature and cultural loss, and usually does not fully represent the unequal impacts of climate change across geographies or between different individuals.

Furthermore, economic assessments of climate change often proceed from a particular branch of Western, consequentialist, welfarist and utilitarian ethics. This adopts a relatively narrow view of what matters. Alternative moral frameworks exist, for example, on rights or broader notions of human flourishing. Whilst these frameworks are arguably accepted by philosophers, it can be difficult to translate them into quantitative models.

Results from such models are not always disaggregated below the national level, so that the choice of weightings on factors such as inequality in income or emissions are obscured. As a result, economic models that simulate the impacts of climate change often neglect ethical implications of climate change that are important in the context of, for example, the environmental justice movement, just transition mechanisms, or the principle of 'common but differentiated responsibilities' encapsulated within the United Nations Framework Convention on Climate Change.

The narrow ethical framework typically used in economic assessments of climate change, and the lack of granular data within them, means that they may underestimate the full extent of impacts from climate change. Not all the impacts can be measured through changes in consumption, and they can be more severe in the Global South. These omissions could have important implications for policy. As an example, globally aggregated data hides the interaction between economic development and climate change impacts or mitigation efforts, even though eradicating poverty is a top priority in many countries.

Image: Aerial view of a mangrove ecosystem in the Great Sandy Region near Tin Can Bay, Queensland, Australia. © iStock.com / Andrew Peacock.

To address these issues, economists can be more mindful of the implicit moral values, including their own personal values, that are embodied in or have influenced the design of their analyses and models. This point is particularly important as most assessments of climate change impacts are carried out by economists from the Global North.

When using analytical and model outputs to inform policy, decision-makers may want to recognise that they are not value-free and will all reflect biases. Economists could consider a wider array of moral philosophies and ethical frameworks, to broaden the diversity of approaches taken to estimating the economic impacts of climate change.

Example alternatives include teleological approaches, based on what a virtuous society should do, deontological approaches that focus on ensuring that particular rights are respected (irrespective of a cost-benefit analysis), and non-welfarist approaches that value, for example, knowledge, culture and nature. Acknowledging underlying values and potentially broadening the variety of ethical approaches to economic assessments could help integrating metrics and values, such as inclusive wealth, that better reflect the full impacts of climate change than a narrow definition of consumption-based welfare and monetary costs alone.

Estimating the economic consequences of social processes such as population displacement, migration and violent conflict under climate change

Violent conflict severely undermines affected economies, and it can affect vulnerability to climate change impacts. It is therefore an important process to be considered in economic assessments of climate change impacts.

Population displacement can occur in response to natural disasters, including extreme weather events such as floods, droughts and storms. It can be temporary or permanent. Migration tends to be associated with positive effects on receiving economies. However, both population displacement and migration can exacerbate factors, such as political unrest, that can lead to conflict.

Since climate change is expected to affect the availability of resources and the liveability of geographical areas, key questions are to what extent changing economic geography will influence future population displacement and migration flows, and the overall long-term economic consequences. This similarly requires representation of population displacement and migration in climate change economic assessments.

A key issue is that population displacement, migration and violent conflict are inadequately represented in assessments of the economic impacts of climate change. This is because, amongst other reasons, analysis and modelling of economic impacts of population displacement, migration and violent conflict have been relying on damage functions — statistical correlations based on past data between a climate variable such as temperature and economic costs — that are too simplistic. These fail to capture the full range of impacts, which are strongly dependent on many causal events and factors that are not simply a multiple of temperature change.

For violent conflict in particular, many effects that are relevant to its economic impacts are not represented by damage functions. These include, for example, post-conflict development, increased vulnerability to climate change because of conflict, and non-monetised costs from adverse effects on, for example, maternal health and children.

A second issue is uncertainty around how population displacement, migration as well as violent conflict will be affected by future climate change. For population displacement, migration and violent conflict, which are highly mediated by socioeconomic factors, past relationships may not be indicative of these phenomena under future socioeconomic and climatic conditions. Population displacement in the future will continue to depend on many factors, including the resilience of societies to changes in the intensity and frequency of extreme weather events. Past variability of extreme weather events will not be an indicator of potential future trends in frequency and intensity. Migration results from a complex mix of many factors and it is uncertain how climate change will influence these factors in the future.

For violent conflict, while current evidence suggests climate change ranks low among possible causal factors of past conflicts, future climate change could influence important known determinants, such as inequality and state governing capacity. However, future socio-economic changes could also reduce the likelihood of conflict. The relative importance of indirect consequences of climate change on these known determinants of conflict remain less certain.

Image: Border crossing to the United States, Tijuana, Mexico. © iStock.com / Joel Carillet.

To improve the understanding of how population displacement, migration and violent conflict may change under climate change, analysis and modelling could take into account future climate change scenarios and other relevant changes such as demographic shifts, development trajectories and geopolitical shifts. For migration in particular, these should incorporate interactions between different climate policies, development pathways and other policies. Modelling and analysis within this future context could help to improve the understanding of how climate change mediates the drivers of population displacement and migration, and increase an appreciation of how the uncertainties associated with different scenarios of future climate change may influence the causes of conflict.

A further challenge concerns gaps in understanding around non-linear social processes. These processes include sustainability transformations, where reaching certain thresholds triggers reinforcing feedbacks. For example, electric vehicles reaching price parity with conventional vehicles can stimulate more demand for electric vehicles, which then further decreases their costs. However, non-linear social processes also include negative effects, such as reaching temperature thresholds at which outdoor labour becomes a threat to health. For sustainability transformations, it is known that their facilitation requires just transitions and transformative processes that include all communities, including empowerment of those currently marginalised. However, these factors are not currently represented by economic assessments.

Finally, there is also a lack of consensus as to whether any non-linear social processes actually constitute tipping points. Greater clarity is required as to where tipping points may be a useful concept for understanding non-linear social processes. This may require further research characterising these processes, such as understanding of their spatial distribution, estimates of what threshold they are likely to occur at, and their mechanisms from a causal perspective. These efforts should include non-linear processes at local, regional and global scales. Improving understanding of the risks and benefits from negative or positive non-linear social processes, and communicating them across disciplines, could help with incorporating them in economic assessments.

Interweaving mitigation, adaptation, and development

Mitigation, adaptation and development are too often addressed separately, both conceptually and practically. However, all three are intrinsically linked. Investment in development, for example, can enable communities to better adapt to climate change, whilst climate adaptation actions can support development. The comparative lack of attention to adaptation means that there are many unknowns, such as how much adaptation is required and what limits there are to adaptation. This means policymakers may be unaware of the need for adaptation, the costs of inaction on mitigation and adaptation, and the potential benefits of adaptation for development.

Current approaches to analysing and modelling the economic impacts of climate change are overly focused on a top-down global perspective and neglect bottom-up regional and local perspectives, including the consideration of non-climate actors that are critical to successful adaptation. For example, traditional IAM damage functions are frequently developed using aggregated data to represent global damages. Damage functions are used in these models to link climate variables, such as temperature increase, to various economic impacts. IAMs have been used to calculate the 'social cost of carbon', a cost-benefit analysis of emitting one additional tonne of carbon dioxide. Whilst significant research and development has resulted in a wide range of estimates of the social cost of carbon, these numbers are almost exclusively derived from estimates of global damages.

However, adaptation largely takes place at a local scale in response to local impacts. A range of adaptation choices are available and local actions can have either positive or negative economic impacts and effects on development. For example, early warning forecast systems can reduce storm damages as they allow local communities to greatly increase their preparedness. Alternatively, failure to adapt or maladaptation could lead to increased future costs of climate change, with subsequent impacts on development. By too often focusing on the global scale and not including more localised, granular data, economic assessments can fail to provide the information required to support successful local adaptation and development policies.

There are opportunities to take a more integrated, comprehensive approach to analysing and modelling the costs of climate change mitigation and adaptation.

Firstly, further research is required to better understand the local options for adaptation available to individuals and communities, as well as the relationship between development and adaptation. Economists could consider climate and socioeconomic scenarios in their approaches to economic assessments of climate change, by incorporating the local evolution of climate risks linked to changes in hazard, vulnerability and exposure, and the full variety of adaptation choices available to individuals and communities. Using descriptive, rather than normative, assessment approaches, economists could describe different adaptation pathways and their consequences over time. Assessments should consider residual risks associated with adaptation, which are currently typically ignored. This could help to inform policy and adaptation choices.

Image: Designed by Jakob+MacFarlane architects, *Living Landscape* is a mixed-use building set in a former landfill site in Reykjavik. Making use of a prefabricated cross-laminated timber structure will reduce the building's embodied carbon footprint by almost 80% compared to a typical concrete building, while operational emissions are minimised through an integrated waste-heat recovery system, comprehensive insulation and a renewable energy supply. © Jakob+MacFarlane.

Secondly, new approaches to modelling economic scenarios of climate change impacts, mitigation and adaptation are required to improve approaches based on traditional IAM damage functions. Using a range of alternative approaches could help to better understand the effects of future climate change on adaptation and development. For example, forward-looking, process-based impact models consider a range of socioeconomic scenarios, which may be useful for exploring future adaptation options. As adaptation is largely a local response by individuals and communities, it is crucial that analytical and modelling approaches are more granular and better integrate local data.

Both physical and social science data will be required to understand potential adaptation and development scenarios. This could enable approaches that use information across space to extrapolate and understand potential behaviour responses to a future changing climate. For example, understanding how citizens respond to heat in Greece could be used to understand possible future behaviour patterns in the United Kingdom in a warming climate. More granular data could make economic assessments more comprehensive and useful for practitioners as they could provide locally relevant information to guide development and adaptation efforts.

Finally, focused research could help to address questions about when it is useful to interweave mitigation, adaptation and development, and when this might hinder detailed studies of adaptation and delay action. In addition, to support local adaptation and development, more efforts are required to understand what is happening 'on the ground'. Further research could support the development and application of methods appropriate for the Paris Agreement's global stocktake on adaptation.

Translating evidence into decision-making

This section explores how the outputs of improved assessments of the economic impacts of climate change are best communicated to decision-makers to enable well-informed and timely action. Four core areas to improve the translation of evidence into decision-making were identified: (i) the process of analysis and modelling; (ii) the form of the analytical and model outputs, (iii) the subject matter of the analysis and models and (iv) the shortfalls of current analytical and modelling approaches and how novel approaches could improve assessments.

Firstly, the process of evidence-gathering, analysis and model-building could be more inclusive. Economic assessments will be more helpful if economists start from the information needs of decision-makers, rather than their own research interests. Models and analysis would ideally be co-developed with decision-makers from varying sectors, levels and locations, including the Global South. Overall, co-development can help ensure that assessments are more accessible and applicable to users.

Secondly, the form of the model and analytical outputs could be more useful by being granular, specific and inclusive of a wider range of impacts. Economic assessments of climate change impacts can now go beyond quantifying single, high-level metrics and statistics, such as the social cost of carbon. Useful analysis and models spell out mechanisms, such as tipping points, and impacts on health and local environments that matter to citizens. Offering ranges of potential outcomes, combined with probability of such outcomes materialising and central 'most likely' estimates, is valuable to ensure that uncertainties are identified and communicated better. Outputs should be made suitable for generating pragmatic, robust risk assessments, which are important for decision-making.

To achieve this shift in analysis, modelling and decision-making should include greater use of scenarios to explore potential low-probability high-impact outcomes, as well as high likelihood outcomes. This can be achieved using a 'storyline' approach when probabilities cannot be adequately quantified, where scenarios are understood through events and their causal links.

Furthermore, as the consequences of climate change are distributed very unequally in space and in severity, economic assessments are most useful when they offer granular spatial information and are specific about places. This ensures that valuable information about regional and local processes is not lost. Outputs of analysis and models should therefore include location-specific information, and present scenarios of economic impacts at different scales, to make them more relevant to individual countries, regions, and areas. Evidence presented on the scale required by decision-making is more readily understood and relevant.

For impacts that cannot be reliably monetised, modelling and analytical approaches can include more qualitative assessments. For example, assessing the benefits of investment in adaptation could include positive effects on private sector investment opportunities and economic development, in addition to the quantification of avoided losses.

Thirdly, economic analysis and modelling might usefully shift in focus from estimating economic damages from inaction, to instead understanding the evolution of damages at different levels of warming and different degrees of adaptation to climatic changes. In particular, damages under overshoot scenarios and also the robust differentiation of damages under temperature pathways which are fairly close together are of high policy relevance now. There remain gaps in evidence on the costs and benefits of different adaptation methods, and evidence to support different targets for climate change adaptation and resilience. There is also a need for tools for decision-makers to compare the economic impacts of mitigation and adaptation, to effectively prioritise funding to achieve both mitigation and adaptation goals, whilst recognising that a lot of both will be required. Decision-making is hindered without clear ways to compare the economic benefits of different mitigation and adaptation choices, and clear goals for adaptation and climate resilience to complement those for mitigation.

From these three areas for improvement, it can be inferred that a greater range of analytical and modelling techniques, beyond simply the continued incremental improvement of traditional IAMs is needed. The development of complementary models is important to create a shift towards more inclusive representations of impacts. A more varied collection of analytical methods and models would allow decision-makers to understand better uncertainties and potential choices.

In particular, advances in spatial data analytics through remote sensing and other big data analytics offer opportunities to ground theory-based models in empirical data. These advances mean location-specific information can be exploited, aggregation bias can be reduced, and analytical robustness can be increased compared with traditional approaches to analysis and modelling. This could, for example, include information on the location and depth of floods, or the severity and length of droughts. Bottom-up, data-driven models incorporating artificial intelligence, remote sensing and other data innovations, offer a way to represent finer spatial and time scales. These could inform decision-making more rapidly than traditional methods. This is particularly useful for areas with limited data coverage, which typically includes areas that are most vulnerable to climate change impacts.

For adaptation specifically, new tools are needed for decision-makers working at national and sub-national levels. These would take account of locally relevant factors, such as the effects of future climate hazards on locally important industries.

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