STOCKHOLM ENVIRONMENT INSTITUTE

POLICY BRIEF

Can '1°C of climate change adaptation' replace '1°C of mitigation'? Why economic models can't solve policy dilemmas

Key Findings

- **Given the scope of the climate challenge and the slow pace of mitigation, there is growing interest in the potential for adaptation measures to reduce climate impacts. However, adaptation and mitigation are complementary, not interchangeable. Adaptation occurs at different scales than mitigation, adaptive capacity varies greatly across sectors and regions, and beyond certain limits, adaptation is likely to be infeasible. Thus, the idea of "reaching the 2° target" with 3°C of warming but "1°C of adaptation" is not realistic.**
- **Most integrated assessment models (IAMs) of climate economics fail to acknowledge these issues. They seek to find optimal tradeoffs between mitigation and adaptation based on inadequate representations of the climate system, climate change and its impacts, and adaptation. In general, IAMs tend to under-estimate climate damages, over-estimate the amount of adaptation that will occur and therefore under-estimate the costs and potential benefits of adaptation. The results are particularly misleading when considering policy options under extreme climate change.**
- **While it is possible – and worthwhile – to address the weaknesses in some IAMs, policy-makers should recognize that these models have inherent limitations and the results will always be shaped by the underlying assumptions. Alternative approaches, such as risk-based frameworks and co-benefits analyses, may be more useful when designing policy or formulating negotiating positions.**

Introduction

World leaders have agreed, as part of the United Nations Framework Convention on Climate Change (UNFCCC) process, to limit global warming to 2°C above pre-industrial levels. Yet countries' mitigation commitments to date do not come close to what scientists believe is needed to meet that target. This has led, increasingly, to questions about whether additional adaptation could bridge the gap.

This policy brief, based on a scoping study for the UK Government's AVOID programme, shows why that is not a realistic option – and explains how results from many integrated assessment models (IAMs) of climate economics can be misleading if decision-makers do not properly appreciate the assumptions and over-simplifications that underpin the models.

Complementary, but not interchangeable

The need for adaptation is clear. Measurements of observed changes in climate over recent years support the growing body of research projecting future changes in climate. The world is already committed to around 1.5°C of warming as the result of previous greenhouse gas emissions, and the prospects of rapid and radical global emissions reductions are low. Adaptation will therefore be crucial.

Yet mitigation is also essential. Emissions continue to rise, and the UNFCCC mitigation pledges so far correspond roughly to a +3°C pathway. There is growing concern that current trends will lead to +4°C or beyond. Without more serious, urgent mitigation, there is a serious risk of extreme or catastrophic climate change. Once certain tipping points in the climate system have been crossed, the damages and costs may be too great to overcome through adaptation.

Waterfront houses in Dhaka, Bangladesh, are built on stilts to protect them from flooding. Such adaptations are becoming essential in many places.

In this context, it is reasonable to seek to maximize the combined benefits of mitigation and adaptation. Figure 1 shows the roles that mitigation and adaptation might play at different levels of climate change. Below a certain level ("Temperature threshold A", defined as +2°C from pre-industrial levels, but plausibly somewhere between +1.5 to +2.5°C), mitigation is impractical or prohibitively expensive. Mitigation also can't stop climate change over the next few decades caused by the delayed effects of past emissions. Adaptation, however, is highly effective within this time scale and at this level of warming.

At the other extreme, above a certain level (a still-undefined "Temperature threshold B"), adaptation may be unable to keep

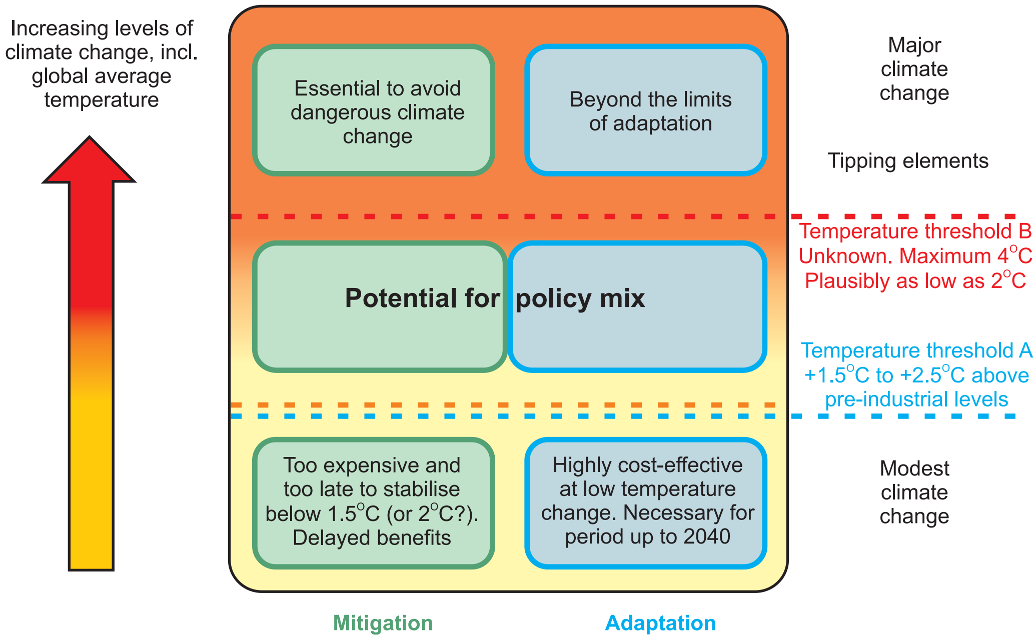

Figure 1: Climate change and adaptation policy space

pace with the rate of change or may only be possible at unacceptable social and environmental costs. The threshold is unlikely to be higher than +4°C and may be +2°C or less for some systems, sectors or locations. Mitigation is the only feasible policy option to prevent damages at this level, in the long term.

In between these two thresholds is a space in which it may be possible to achieve similar outcomes through different combinations of mitigation and adaptation. However, as noted above, it is unclear precisely what the thresholds are, and the two could, in fact, overlap, implying that there is actually no space in which to consider "optimal" trade-offs, even in theory.

Few simple trade-offs

Policy discussions – and the economic analysis tools that inform them – often frame decisions in the context of scarce resources and trade-offs: If a national government has a set budget for climate measures, for example, it may weigh the benefits of investing in emissions reduction vs. adaptation measures. Yet the trade-offs are rarely so simple; adaptation and mitigation both involve a wide range of sectors (e.g., energy, water, public health, education) and can support or compete with many other policy priorities.

Mitigation and adaptation decisions are also made at different levels. Mitigation is primarily driven by international agreements and ensuing national public policies, complemented by voluntary public- and private-sector actions; adaptation generally occurs on a more local scale, and involves a mix of private actions by affected entities, public arrangements to protect impacted communities, and national policies.

Still, there may be synergies between mitigation and adaptation. For example, reforestation schemes sequester carbon while also improving water management, soil stability and biodiversity. There may be conflicts: adaptation measures may increase emissions (e.g., water desalination), while some mitigation policies may increase vulnerability to climate impacts (e.g., if biofuels production compromises food security for vulnerable people).

The Intergovernmental Panel on Climate Change (IPCC) has noted that striking the appropriate balance between mitigation and adaptation will be difficult. The optimal mix will vary by country and over time, as local conditions and costs change, especially given our poor knowledge of climate change and other key variables, such as the rate of technological change. Calculations of optimal trade-offs will rapidly become outdated and obsolete.

A misleading picture: integrated assessment models

Integrated assessment models (IAMs) of climate economics are commonly used to derive "optimal" decisions about the timing and size of climate investments, considering resource availability, technological change, projected damages from climate change, and other factors. IAMs have been used to determine the optimal cost range for climate policies, such as carbon taxes or climate-related regulations, and also to identify the optimal level of investment in mitigation to avoid dangerous climate change.

IAMs are meant to provide an objective view of costs and benefits, but in reality, building an IAM requires multiple value judgments and assumptions, which largely determine IAMs' results. For example, critical assumptions are made when choosing how to represent climate sensitivities, climate impacts (via climate damage functions), discount rates, time horizons, equity weights, sectoral and spatial coverage, considerations of uncertainty and risk aversion. Models that incorporate adaptation also make assumptions about how, when and where adaptation will occur (often by simply assuming that adaptation will be optimal – that it will occur wherever and whenever it is cost-effective).

Climate economics is filled with uncertainty, not least given our incomplete knowledge of the climate system (the IPCC suggest the sensitivity of the global climate system to a doubling of greenhouse gas concentrations is likely to be between +2°C to 4.5°C, but possibly "as high as +6°C or more"). Our knowledge of the systems (e.g., ecosystems) that will be affected by climate change, including their tipping points, is even more uncertain. Science cannot provide IAMs with accurate information on these system dynamics, but this uncertainty is rarely – or poorly – reflected in IAMs.

Representing uncertainty: technical choices

In most cases, IAMs base their calculations on central or average estimates of changes in global mean temperature. This practice has been criticized as underestimating potential climate damages, especially because they do not fully capture the important influences of extreme events and low-probability, high-magnitude scenarios at the upper range of probability distributions.

Some economists have sought to address this issue by incorporating some form of uncertainty analysis in their models. This can produce radically different results. Considering the full range and distribution of probability in IAMs, particularly under high-end scenarios, provides decision-makers with a more accurate impression of the range of uncertainty, with its implications for climate policy.

The damage functions used by IAMs to represent the economic impact of climate change also significantly shape their results. Most IAMs use linear or quadratic damage functions, but the science suggests impacts will be highly non-linear, with tipping points and catastrophic climate change increasingly likely with higher temperatures. Quadratic functions can produce results that suggest welfare losses at unimaginably high levels of climate change are tolerable (e.g. ~50% welfare losses in a +18°C world, which is unimaginable). It is possible to incorporate more realistic damage functions in IAMs, however, and recent updates of some models do so.

The controversial issue of discount rates is also highly relevant to IAMs, in particular when considering the long-term benefits of mitigating catastrophic climate change. Non-market damages also tend to be excluded from major IAMs, with the exception of human lives, health, and to a limited extent, biodiversity, in some models.

In summary, most IAMs do not accurately represent the impacts of climate change, particularly for high-end scenarios, and thereby under value the damages that are likely to occur as a result of climate impacts.

Adaptation in IAMs

Not all IAMs consider adaptation, and those that do represent it only partially and in simplified form. In reality, it is hard to predict how much adaptation will actually occur, when, by whom and for what reasons, or whether it will be effective. IAMs, however, commonly assume:

• That adaptation will be optimal and optimally timed;

• That agents will behave rationally, with access to perfect information (e.g. on the costs and benefits of their adaptive options);

• That adaptation costs and benefits in early time periods have no legacy issues on later decisions, ignoring inter-dependencies;

• That adaptation decisions are driven by climate change alone; and

• That adaptation will be uniform within regions.

The first problem here is that adaptation is a process, not a series of one-off decisions that can be made at optimal points in time – e.g., to build a dam when it becomes cost-effective to do so. Some adaptation involves hard engineering solutions to a specific problem, with quantifiable costs, but many – if not most – are complex and context-dependent, such as adapting social processes, institutions and behaviours. This makes it hard to assign accurate costs to adaptation and suggests it is likely to be suboptimal in both timing and effectiveness.

IAMs also tend to overlook current adaptation deficits and vulnerabilities. This is a particular issue for developing countries, but also for developed countries, which are often near their limits of coping with current climate variability in some sectors. The assumption that future adaptation is overlaid on existing "optimal resilience" overestimates the effectiveness of future adaptation.

In addition, there are also substantial variations in adaptation activity and outcomes, even within regions or countries facing similar risks. Some have higher adaptive capacity – not just in terms of financial resources (which can be modelled), but in terms of human, social and ecological capacities (which are not). Some regions or people have fewer options available than others. Individuals and organizations also vary in their responses, depending on their perception of risks and benefits. Those who can adapt, might not. Models therefore need to better account for the variation of responses from adaptation agents.

The timing of adaptation is also highly uncertain and may not keep step with changes in climate. Adaptation can be proactive, but it often is reactive; for example, extreme events are important triggers for taking adaptation actions. The more rapid the change in climate, the less effective reactive adaptation is likely to be. And early examples suggest that maladaptation is likely – adaptive decisions that inadvertently worsen vulnerability and limit future adaptation options.

The sun sets on Wattle Point Wind Farm in South Australia. Low-carbon energy sources are crucial to reducing energy-related emissions.

Finally, adaptation in the real world is rarely motivated solely by climate change; often climate resilience is a co-benefit of actions taken for other reasons (e.g., urban greening, water efficiency measures, food security).

In summary, IAMs not only model climate impacts and vulnerability in potentially misleading ways, but they make fundamentally wrong assumptions about adaptation. They tend to overestimate the level of adaptation that will occur, and/or its effectiveness, because they fail to consider the various constraints that tend to limit adaptation below the optimum level.

Limits to adaptation

It is also important to remember that adaptation can only go so far. Limits to adaptation exist both in the natural world and in society; some are absolute, while others can be changed or pushed back. For example, the rate of sea-level rise determines whether coastal salt marshes can adapt by growing landwards and upwards. Non-climate factors play a role; for example coastal infrastructure (such as seawalls) could stand in the way of landward migration.

A large body of research is now devoted to trying to identify those natural limits, but even if we do not know them yet, it is clear that they are absolute. Once they are crossed, adaptation is no longer possible, and irreversible change occurs.

Other limits, especially in human systems, are not absolute and may vary from place to place and be consciously changed. Limits may also be normative; for example, societies that have agreed on safe minimum standards (e.g. flood protection, water supply) might find that climate change impedes their ability to meet these standards and levels, and so reconsider and redefine them.

Knowledge about limits to adaptation could inform the level and timing of mitigation and might justify early mitigation action. For example, if a society knows it cannot adapt to sea-level rise above a certain threshold, the value of more stringent, early mitigation increases. Most IAMs do not recognize the limits to adaptation, or the decision dynamics that they imply.

Ways forward

It is possible to improve how IAMs represent uncertainty and account for the limits of adaptation. One such example is PAGE09, the latest version of the model developed at the University of Cambridge. However, while it is possible to improve IAMs, other options may be more useful for policy-making, such as models that identify the lowest-cost ways to avoid the most serious risks under conditions of high uncertainty.

Gauging climate policy options by other yardsticks may also improve outcomes – such as "implementability" (the capacity of society to implement certain policies) or the co-benefits of mitigation and adaptation, such as jobs, innovation, health and social cohesion. The resulting choices may then be sub-optimal in theory, but more effective in reality.

This policy brief was written by Magnus Benzie, Marion Davis, Richard Klein and Paul Watkiss. It is based on a section of the following report:

Warren, R., Benzie, M., Arnell, N., Nicholls, R., Hope, C., Klein, R. J. T. and Watkiss, P. (2012) *Scoping Study: Modelling the Interaction Between Mitigation and Adaptation for Decision Making.* AVOID / Workstream 2 / Deliverable 1 / Report 39 [AV/WS2/D1/39]. http://www.metoffice.gov.uk/avoid/files/resources-researchers/AVOID_WS2_D1_39_Adaptation-mitigation_16-08-121.pdf.

Considerations for policy-makers

- Mitigation and adaptation should not be viewed as interchangeable; the idea of "reaching the 2°C target" with 3°C of warming but "1°C of adaptation" is not realistic. This underscores the urgency of prompt, strong action to reduce greenhouse gas emissions, as adaptation cannot protect from the worst impacts.
- As appealing as optimization exercises may be when gauging climate policy options, IAMs do not provide a reliable picture of the climate system, climate change impacts, associated costs, adaptation potential and effectiveness, or the interplay between mitigation and adaptation. To the extent that IAMs are used in policy-making, they should be treated with great care. The assumptions made by the modeller warrant particular scrutiny, as they may determine the results.
- There is a need to better understand how to build and use capacity for mitigation and adaptation, as well as to know the "implementability", co-benefits and robustness of options under conditions of uncertainty. Further research should be supported to help fill these knowledge gaps.

Published by:
Stockholm Environment Institute
Kräftriket 2B
106 91 Stockholm
Sweden
+46 8 6747070

sei-international.org
2012
Follow us on Twitter: @SEIclimate

Contact: Magnus Benzie
magnus.benzie@sei-international.org
Further Information:
SEI Director of Communications
Robert Watt +46 73 707 8589
robert.watt@sei-international.org