Assessing systemic risks in adaptation

Key Messages

- Systemic risk encompasses those impacts from climate change that create changes in welfare that transcend single social-ecological systems. Economic literature related to climate change adaptation has included little consideration of costs related to systemic change.
- Recent improvements of existing methodological tools allow for better consideration of systemic impacts in economic analysis. For example, catastrophic impacts have been included in some Social Cost of Carbon calculations while various modifications to parameters have been tested in Integrated Assessment Models.
- New modelling techniques have also been developed that better account for large uncertainties such as dynamic stochastic CGE models. Agent-Based Models can account for heterogeneous preferences and behaviours throughout a population and better consider the complex social-ecological feedbacks associated with systemic risks.
- Alternative approaches involve better consideration of additional ethical impacts. Applying a maximin approach to account for distributional impacts or incorporating strong sustainability, for example, can provide a better picture of the potential impacts of systemic risks.

Context

Systemic risk encompasses those impacts from climate change that create changes in welfare that transcend single social-ecological systems. They may result from the possibility of highly uncertain, but catastrophically damaging events, such as tipping points in the melting of large ice sheets or a global food crisis due to extreme weather events. Feedback loops play an important role in systemic risks as they can amplify impacts of single change process or events, especially across national borders. For example, rising food prices in response to scarcity created by physical change can amplify food scarcity. Ocean acidification and rising water temperatures will reduce production in fisheries, and could lead to overfishing and collapse of fish stocks, causing high unemployment in communities dependent on fishing industries. Higher morbidity rates and lower crop yields stemming from climate change can reduce labour productivity, which in turn will depress savings levels and reduce investment in capital, slowing the growth of developing economies.

Systemic risks are usually excluded from many economic analyses of climate change due to methodological questions, including those around expressing the uncertainty of when and how these events may occur. This Insight discusses the extent to which the concept is captured in existing tools used in the economic analysis of climate change and suggests improvements to these tools and their application to policies designed to help communities adapt to climate change.

Policy and methodological developments

Cost-benefit analysis and the Social Cost of Carbon

Cost-benefit analysis (CBA) converts social impacts into monetary values in order to compare the consequences from policy alternatives. CBA offers more reliable and precise results when climate change impacts are direct, individualised and easily monetised, and when uncertainties are low. The use of CBA for the treatment of systemic risks for climate change adaptation (where impacts are indirect and diffused, non-markets impacts are important and uncertainties are large) is therefore difficult.

The most prominent approach to account for the impacts of climate change is the Social Cost of Carbon (SCC), which is commonly used to represent the marginal aggregate effects of carbon emissions through climate change. With a set per unit value for carbon emission damage, evaluators can account for climate risks in project level appraisals. In practice, there is much disagreement on the optimal carbon price. In 2015, actual carbon prices across the world range from less than $1 per ton of carbon dioxide emitted to $130 per ton carbon (World Bank Group, 2015). Anthoff et al (2008) examine social costs of carbon across a range of risk aversion and discount rates, finding an optimal price of over $200/tCO2e. Van den Bergh and Botzen (2015) show through a survey of estimates for the Social Cost of Carbon (SCC) that catastrophic climate change events are often not included in these values that shape climate policy across the world, due to the high levels of uncertainty accompanying these events. Impacts from systemic risks are likely to represent additional costs if included in SCC models, suggesting that values used in policy formulation may under-represent the costs of climate change to society, and the benefits of avoiding or reducing these costs.

When extreme climate events are included in models used to generate SCC values, they are calculated at probabilities determined by the modeller, not a scientific estimation. Debate on how these values are included in SCC calculations concern whether to apply Weitzman's Dismal Theorem (2009), which would stress damage from high-impact events at high temperatures, increasing SCC values by up to 420%. Including tipping points would drastically increase SCC values, and uncertainty levels associated with these risks are typically considered to be above politically acceptable levels. Where they are excluded from models and calculations, careful attention should be brought to the risks posed by tipping points.

Van den Bergh and Botzen propose a Rawlsian prioritisation of the welfare for the groups most severely impacted by climate change. This 'maximin' approach to climate policy aims to maximise welfare in a worst-case scenario. By considering the worst-off generation, SCC analyses would yield a much higher carbon price. Similarly high SCC values result from applying a 'minimax regret' policy approach that aims to reduce regret (costs) from either extreme climate impacts or costly mitigation activities. Van der Ploeg (2015) proposes an additional component in a carbon tax to account for the likelihood of catastrophic climate events increasing non-linearly with global temperature due to positive feedback loops.

Integrated Assessment Models: partial vs general equilibrium approaches

To manage multilevel uncertainty in climate predictions, scientists and economists have built complex models of predicted physical changes in the atmosphere and the ocean from increased stocks of greenhouse gases. Atmosphere-Ocean General Circulation Models (AOGCMs) present predicted changes in temperature and precipitation from expected climate change. Findings from AOGCMs are inputted into Integrated Assessment Models (IAMs), which aim to measure the impacts of physical changes on economic and social systems across mitigation, adaptation and vulnerability reduction efforts.

Systemic risks can be considered in IAMs through partial and general equilibrium approaches:

- Impacts on individual markets are estimated in partial equilibrium models, which attempt to illustrate changes in production, consumption and utility resulting from a change in input or preferences within the same closed market. Integrated Assessment Models currently used to project climate impacts under various emission and socioeconomic scenarios, such as PAGE, FUND, CGAM and IMAGE/TIMER, rely in part on partial equilibrium analysis to model effects on a particular sector.
- For macroeconomic models examining impacts on the full economy, economists often use a general equilibrium model. Multiple markets are modelled in aggregate, accounting for interactions between markets and elasticities to price changes. AIM/CGE, MESSAGE-GLOBIOM, REMIND-MAgPIE and WITCH-GLOBIOM are all general equilibrium models included in shared socioeconomic pathway modelling, while DICE is a general equilibrium model used in setting the social cost of carbon by the US government.

Both partial and general equilibrium models are important in modelling the economic impacts of climate change, but they offer only incomplete coverage in assessing socioeconomic effects from physical changes in climate. Partial equilibrium models are useful for estimating the impacts on a particular market from a change in an input or complement, especially those concerning non-market goods. However, partial equilibrium models are restricted to showing marginal changes in markets that provide a limited perspective on impacts in the wider economy from a given change. Conversely, general equilibrium models can model complexity across markets, but are limited in their ability to account for preferences towards non-market goods such as environmental and social costs, which can have important social and ethical implications in climate change adaptation.

A type of model that attempts to introduce a greater degree of realism to the representation of climate change risks is the non-equilibrium dynamic model (NEDyM) (Hallegatte 2007). This type of model is concerned with the improved modelling of instances where markets do not clear (reach equilibrium) quickly. This is likely to be the case, for example, where supply does not meet demand following an extreme weather event that results in business disruption and supply chain disruption, and where prices are sticky downwards. An example of its application is the study undertaken by Hallegatte (2008) on the economic impacts of Hurricane Katrina in Louisiana, USA. The model takes into account changes in production capacity due to productive capital losses and adaptive behaviour in the aftermath of the hurricane. In this context, the assumption that markets do not instantly clear is appropriate in the period of a few months after the storm event. The study finds that economic processes exacerbate direct losses, and total costs are estimated at $149 billion, for direct losses equal to $107 billion.

Improving IAMs

Values of equilibrium climate sensitivity, details of damage functions, inclusion of the probability of catastrophic events and the discount rate for future costs and benefits are often set by the modeller before an IAM is run. As debate evolves around the appropriate values for each of these parameters, subjectivity in IAMs may be reduced.

For systemic risk projections, the inclusion of catastrophic climate events is an important element to consider. Where models do not include these costs, cost estimates such as the SCC may be increased by a supplement to represent expected additional costs from catastrophic climate change.
The specification of damage functions also has great bearing on IAM outputs. Rather than pursue a simplified top-down approach which assigns a percentage of GDP loss for a given temperature increase, bottom-up construction informed by damage from extreme short-term weather events can provide a more accurate and informative estimate of costs from physical climatic changes. Agent-based models can also provide more reliable information on costs dependent on social responses, such as migration or labour market shifts.

Regular updates to SCC and other cost models used for government policies can provide opportunity for updates with the latest available scientific agreement on these parameters. An alternative approach is to rely on an expert panel of economists to produce an SCC value, but this is vulnerable to criticisms of political influence and deference to familiar IAMs.

Other modelling approaches

Dynamic stochastic computable general equilibrium models can capture greater uncertainty than the most commonly applied IAMs (Stern, 2016). This approach requires enormous computing power that may not have been available to early modellers but is possible with modern technology. An application of this method to SCC calculations finds that SCC estimates from DICE and PAGE IAMs are half of optimal levels (Golosov et al, 2014).

Assumptions in IAMs include that of a benevolent social planner implementing the most cost-effective climate policy in an identical fashion across societies (Farmer et al, 2015). In practice, empirical evidence demonstrates great heterogeneity in policy decisions. Agent-based models, which explore contextual data around individual decisions, may also provide more useful pictures of behaviour under climate policy. These models can account for heterogeneous preferences and behaviours throughout a population, though it requires a large amount of data specific to a group of people (Piguet, 2010).

Illustration: migration as a systemic response to climate change impacts

One of the most tangible effects of climate change is the forcible displacement of people from home countries as a result of changes in environment, resource scarcity and scarcity-induced conflict. Studies of migration demonstrate the relationship between environmental change and the decision to leave a country (Black et al, 2011). Environmental factors combine with social, political, economic and demographic factors in a given location to inform an individual’s decision to remain or migrate.

The economic assessment of migration as a systemic response to climate change is a complicated task. It requires a good understanding of socioeconomic reactions to climate change on a local level in order to quantify the risk of migration processes to occur and their scale. It also requires considering welfare changes to migrants and to destination countries. Changes in welfare from migration may be large, but are difficult to capture in an aggregate CBA framework. For example, Tol (2002) settles on a value of three times per capita income to represent welfare losses per migrant in the FUND Integrated Assessment Model. However, this arbitrary value potentially runs into ethical challenges given differences in income between home and destination countries. Using market prices for labour do not reflect distributional concerns between countries.

Three strategies can be taken to better account for changes in welfare from climate-induced migration.

Strategy 1. Model improvements can bring more realistic assumptions into projections of impacts and related costs. IAMs can be run across a number of parametric assumptions in order to include catastrophic climate risks and economic feedback effects from mitigation efforts and climate change impacts. ABM can reveal information about migration behaviours in response to climate change. While current economic models relate migration decisions to GDP, ABMs consider a wider set of factors including individual characteristics and social networks to develop a computer simulation that allows researchers to model outcomes across parameters (Smith et al, 2010). A recent ABM has been able to generate predicted migration behaviour from rainfall changes in Burkina Faso that correlates at a level of 80% with observed behaviour.

Strategy 2. The IPCC Shared Socioeconomic Pathways present different visions of the future, with variation in challenges facing climate mitigation and adaptation efforts, informed by the level of cooperation between different regions of the world and growth patterns in economies. Climate-induced migration is expected to be lower in high-mitigation futures, where impacts of climate change are largely avoided around the world, as well as highly regional scenarios, where barriers to movement are high and migrants have few potential destinations in which to resettle. Consideration of the impacts of a policy decision relevant to climate migration today (mitigation efforts, immigration policies, refugee support infrastructure, etc.) across potential socioeconomic pathways provides a good robustness check for analysis.

Strategy 3. Employing special consideration for the most adversely impacted groups may affect how climate projects and policies are evaluated. In order to maximise the welfare of the most vulnerable regions to climate change impacts in a “maximin” approach, the global and national policy alternatives must be evaluated with separate consideration for how vulnerable regions are affected from any given action. Such an approach can be incorporated into evaluation frameworks with an approach similar to multi-criteria analysis with which CBA evaluations can state impacts on migration flows within and addition to economic costs.

Main implications and recommendations

A number of strategies can be used to better assess systemic risks. Some of the shortfalls with CBA and IAMs can be improved, for example by incorporating catastrophic impacts in the Social Cost of Carbon or modifying parameters in Integrated Assessment Models. Dynamic stochastic CGE models and agent-based models of responsive behaviour are being developed and can address many of the limitations of IAMs. They have become more accessible with the increased availability of high-powered computing.

Alternatively, ethical consideration can be improved in the calculation of costs and benefits, for example by applying a maximin approach to account for distributional impacts or by considering strong sustainability (and incorporate further non-market dimensions, etc.).

Another strategy is to accept the limitations of existing economic tools and that their results should be used for general guidance in the face of such broad uncertainty. It may be enough to recognise that the effects that may come from tipping point events are likely be disruptive and are important to prepare for through alternative planning processes. Planning processes can take a dynamic learning approach to climate modelling based on the availability of more robust information; estimates are regularly updated with advances in knowledge and understanding of the risks posed to society by any given climate disaster. In order to address the issue of uncertainty over time in climate policy paths, the dynamic learning approach can be employed by creating decision points along policy paths to incorporate improved information and models.

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Further Information
Methods for the assessment of systemic change
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