Chapter 24

The Roles of Climate Risk Dynamics and Adaptation Limits in Adaptation Assessment

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Abstract The performance of adaptation measures depends on their robustness against various possible futures, with varying climate change impacts. Such impacts are driven by both climatic as well as non-climatic drivers. Risk dynamics are then important, as the avoided risk will determine the benefits of adaptation actions. It is argued that the integration of information on changing exposure and vulnerability is needed to make projections of future climate risk more realistic. In addition, many impact and vulnerability studies have used a top-down rather a technical approach. Whether adaptation action is feasible is determined by technical and physical possibilities on the ground, as well as local capacities, governance and preference. These determine the hard and soft limits of adaptation. Therefore, it is argued that the risk metrics outputs alone are not sufficient to predict adaptation outcomes, or predict where adaptation is feasible or not; they must be placed in the local context. Several of the current climate risk products would fall short of their promise to inform adaptation decision-making on the ground. Some steps are proposed to improve adaptation modelling in order to better incorporate these aspects.

Keywords Risk · Vulnerability · Exposure · Dynamics · Adaptation limit

Introduction

The assessment of adaptation measures is usually supported by model simulations on the performance of different measures under future conditions. Such simulations are again the basis for providing strategic directions, and often also cost and benefit estimates of different possible packages of adaptation measures.

The original version of this chapter was revised: This chapter has been updated with the correct figure 24.1. The correction to this chapter is available at https://doi.org/10.1007/978-3-030-86211-4_28

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In this contribution, two topics are addressed that are relevant for adaptation modelling. These are the following:

Dynamics of risk and

Adaptation limits.

The first topic concerns the issue of capturing the dynamics of risk, with changes in climate, exposure and vulnerability, with the uncertainty of the latter two being at least of similar magnitude as the change in climatic hazards. The second topic concerns the hard and soft limits of adaptation that need to be investigated in order to inform decision-making for both adaptation and mitigation.

In this paper, some of the issues related to these two topics are discussed and hope to contribute to improving the performance and relevance of adaptation modelling, and eventually the take-up of results to achieve implementation of adaptation actions.

Dynamics of Risk

The risk concept has become the major basis for impact modelling and an essential part of assessing the performance of adaptation measures. This has been spurred by the developments of several vulnerability and impact models and associated studies over the past two decades. The SREX report of the Intergovernmental Panel on Climate Change (IPCC) underlined the need to integrate the three components of climate risk, which are: climate hazard, exposure and vulnerability (sensitivity). This report firmly established that Handmer et al. (2012):

Risk is determined not only by climate but to a very large extent by socio-economic circumstances, which are location-specific;

Risk is dynamic because of variability and changes in climate, adding to the (monotonous) changes and trends in socio-economic developments, and changes in human behaviour and (autonomous) adaptive responses to climate risk.

These dynamics need to be considered, in order to more reliably project how adaptation measures will perform over multi-decadal time horizons.

Exposure Change

Studies into past climatic impacts have highlighted that dynamics in exposure indeed play an important role in shaping changes in risk over time, including increased exposure of people and asset values driving up the losses from flooding and cyclone (wind) impacts. From past evidence, it is clear that socio-economic drivers until now

have been dominant, and outweighed any climatic drivers. In the most comprehensive review to date Pielke (2021), based on 54 studies into a wide variety of extreme weather impacts, demonstrates that almost all studies show that losses have risen because of an increase in exposure.

Surprisingly, several studies attribute past losses solely to climatic changes when obviously increasing exposure has been the major driver of such costs (see, e.g., Coronese et al. 2019; Frame et al. 2020). Such studies do not correctly interpret the risk concept as laid out by IPCC. More importantly, they are not helpful for informing decision-making on risk management and adaptation, as important drivers are overlooked. Socio-economic developments amplify the impacts from changes in climate and are essential to include.

For the assessment of the performance of planned adaptation measures, it is thus important to integrate the future dynamics of exposure. In many places, especially urban centres, it is expected that population and wealth will increase, leading to increasing losses from climate hazards if no adaptation measures are taken (Bouwer 2013). Modellers have therefore resorted to integrate exposure scenarios, whereby socio-economic information is used to estimate possible developments in population, economy and resulting asset values. This enables the projection of risk, in combination with scenarios for changes in climatic hazards. For flooding, this is an approach that has now found wide implementation, mostly through (spatial) scenarios for population and economic growth in models for future flood risk (e.g. Voudoukas et al. 2018; Dottori et al. 2018). For many other climatic hazards, however, socio-economics are not included, and risk is simply projected forward using the present socio-economic exposure and fixed vulnerability. The resulting risk analysis, with potential underestimates of future risk, is not a reliable basis for the evaluation of adaptation measures. Several adaptation measures could have higher benefits when such changes are considered.

Vulnerability Change

It has been argued that the temporal changes in vulnerability, or sensitivity, due to extreme weather events have also shaped past impacts, in addition to exposure changes. It is therefore important to understand such past changes in vulnerability, and project possible future developments out into the future in order to capture the range of possible future climate change impacts, and the performance of adaptation actions (e.g. Mechler and Bouwer 2015). However, there is less empirical evidence of changes in vulnerability, as such changes are difficult to capture. It has therefore often remained an underappreciated topic in climate impact modelling and projections (Bouwer 2013) and also in the assessment of adaptation.

Meanwhile, there are several studies pointing to the importance of including such vulnerability reductions. These include impacts from hydrological hazards, such as river floods (Kreibich et al. 2017), coastal floods (Bouwer and Jonkman 2018), as well as drought impacts (Kreibich et al. 2019). For instance, for coastal floods, it

Fig. 24.1 Changes in average event mortality (number of deaths per 100,000 exposed population) for storm surge floods for different world regions between 1900 and 2013. The number of included events is given in brackets. Data from Bouwer and Jonkman (2018)

has been observed that not only morbidity (i.e. the number of casualties from these events) but also mortality (i.e. the relative death rate, or lethality) has decreased over time (see Fig. 24.1).

What is clear from Fig. 24.1, for instance, is that for most world regions, mortality rates have substantially declined, despite a strongly increasing coastal population and ongoing sea-level rise and land subsidence. For countries such as Bangladesh located in South Asia, this is remarkable. The strong decline is supposed to be the result of improved forecasting of cyclones, early warning, evacuation and shelters. In addition, in many areas improved coastal protection has resulted in less frequent flooding. The highest risk of deaths from storm surge flooding today is located in the Pacific and Southeast Asia.

Also for other hazards, such as extreme temperatures, it has been shown that substantial reductions in risk can be achieved by adaptation and preparedness actions, resulting in a reduction of vulnerability. For instance, Weisskopf et al. (2002) showed in a case study that a halving of deaths could be observed between consecutive heat waves, possibly as a result of substantial improvements in heatwave preparedness plans. At the global level the costs of weather-related hazards, as a share, are in fact going down (Formetta and Feyen 2019). Change in GDP here is a proxy for increasing exposed asset values. Similarly, deaths from such hazards are also declining compared to the total population (Formetta and Feyen 2019). It is also found that these rates have dropped more quickly for developing countries than for high-income countries, indicating the effects of progress on vulnerability reduction. However, a gap between the countries exists, as relative risks in low-income countries are still higher than in high-income countries (Formetta and Feyen 2019).

The problem with many of these studies is that they are empirical; i.e. they demonstrate some reduction in impacts that are unrelated to exposure or climatic changes, but cannot precisely attach these to causal changes in vulnerability (e.g. Weisskopf et al. 2002; Bouwer and Jonkman 2018; Kreibich et al. 2017).

In principle, there are two approaches for impact and adaptation modelling to account for such changes in vulnerability: one is to assume that vulnerability reduction is autonomous. This would be valid for several reductions in vulnerability that are related to emergency actions, such as preparedness actions at the household level. Such past trends, although not always underpinned by direct observational evidence, could be projected out into the future. Risk projections that include such trends can be used to assess adaptation options, thereby accounting for any risk reduction (increase) that is the result of any projected reduced (increased) vulnerability over time. Not including such substantial changes in vulnerability could overemphasise the effect of (additional) adaptation measures, and therefore the benefits of such investments.

The other approach is to assume that past adaptation actions are planned and can be directly observed. Such adaptation actions include the heightening of river dikes and coastal protection, improved forecasting and early warning systems, or improvements of water supply and the adjustments of crops. Such past actions can also be projected forward, and be taken as a baseline against which to compare additional or complementary adaptation actions.

Adaptation Limits

The interpretation of climate risk hinges on what the risk level means to the local population. It has been shown that climate impacts vary greatly over a given population, depending on their development status, income and other capacities. Therefore, some have argued that the risk metrics need to be adjusted to income levels before they can be correctly interpreted. For instance, Markhvida et al. (2020) show that poorer households in the San Francisco Bay Area suffer a much higher share of well-being losses compared to more affluent households. A single metric for impacts, such as monetary loss per capita, is therefore only partially useful, both in developing countries as well as developed countries.

Adjustments of climate risk metrics according to household income or other capacity information would help to highlight where the highest risks are located. Particularly high risks may indicate the need for additional adaptation measures to protect vulnerable populations and households. These high-risk levels are also indicative of limited capacities to deal with the impacts from climatic hazards, and we would argue that these levels may also be indicative of places where adaptation limits may be reached sooner.

Adaptation action can be limited by the local capacities to accommodate or reduce risk. While in many cases physical or technical options to reduce climate risks are available, and no hard adaptation limit is reached there, economic, social and governance constraints may lead to soft adaptation limits that are reached much earlier.

This is an area of investigation that has only recently received increasing attention (see, e.g., McNamara and Jackson 2019). These studies suggest that it is clear that there are limits to adaptation, and that the associated losses and damages need to be addressed. However, there is no practical framework yet to predict when limits are reached and when such losses would occur.

If top-down or local-scale modelling studies can show the physical-technical limits of certain measures and costs, then local and bottom-up studies are required to determine what capacities exist to actually implement such measures, and differentiate options depending on local preferences and possibilities. Importantly, such bottom-up studies can also show the limits for implementing such adaptation measures, both from a technical-physical perspective (hard limits), as well as soft limits (local capacities and preferences). This can be a starting point to indicate when and where limits may be reached and which losses beyond adaptation would occur.

Conclusions and Recommendations

The climate risk concept has now become a major basis for impact modelling, which in turn is an essential part of the assessment of the performance of proposed climate adaptation measures. However, this study argues that the dynamics of some autonomous risk processes are not yet sufficiently included in impact modelling. Also, the interpretation and actual meaning of risk assessment results both from an equity standpoint, as well as for assessing possible limits of adaptation and residual losses and damages, is currently insufficient. Several climate risk products would therefore fall short on their promise to inform adaptation decision-making on the ground.

Steps that would help to improve the potential of such products are:

The acknowledgement that past trends of exposure and vulnerability changes provide a baseline against which future risks should be compared

Better understand reductions in vulnerability that would add to any proposed adaptation measures

Tailor impact metrics from climate risk modelling to local situations, to account for equity issues and identify high-risk areas and hotspots where adaptation limits may be reached first

Use bottom-up studies to understand where local capacities, preference and governance could be hindering the implementation of required (technical) adaptation measures, and assess the risk of residual losses and damages.

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