acknowledging the empirical facts that can be credibly established by data, including our observation that hot weather is related to violence at various scales. ❐

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COMMENTARY:

Managing unnatural disaster risk from climate extremes

Reinhard Mechler, Laurens M. Bouwer, Joanne Linnerooth-Bayer, Stefan Hochrainer-Stigler, Jeroen C. J. H. Aerts, Swenja Surminski and Keith Williges

Truly understanding climate-related disaster risk, and the management of that risk, can inform effective action on climate adaptation and the loss and damage mechanism, the main vehicle under the UN Climate Convention for dealing with climate-related effects, including residual impacts after adaptation.

Despite a dramatic start concurrent with the massive destruction wrought by typhoon Haiyan on the Philippines, the 19th Conference of the Parties to the UN Climate Convention has been considered as another one with little impact. Literally in the last minute, however, it saw the establishment of the Warsaw International Mechanism for Loss and Damage. The exact form of this vehicle, which is scheduled for further development, is still largely unclear and will be heavily debated over the coming three years. As the first of a number of functions, it is to focus on "Enhancing knowledge and understanding of comprehensive risk management approaches…"[1].

Climate-related disaster risk management is a central focus of the mechanism, and has been fundamental for climate policy and science[2]. Recent commentaries in *Nature Climate Change* suggested the upgrading of vulnerability and risk assessments[3], working towards climate attribution[4] and using stress-testing techniques as ways towards an improved understanding of the risk[5]. Yet, what else is specifically necessary for comprehensively tackling disaster risk and risk management in light of climate change? In particular, regarding debate on the loss and damage mechanism, how can some of the stumbling blocks be avoided?

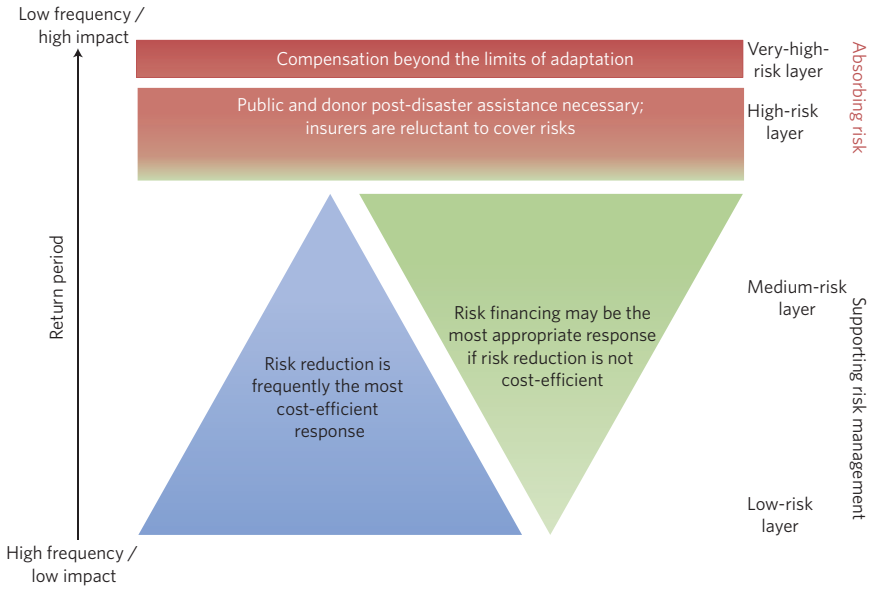

Figure 1 | Layered disaster risk management.

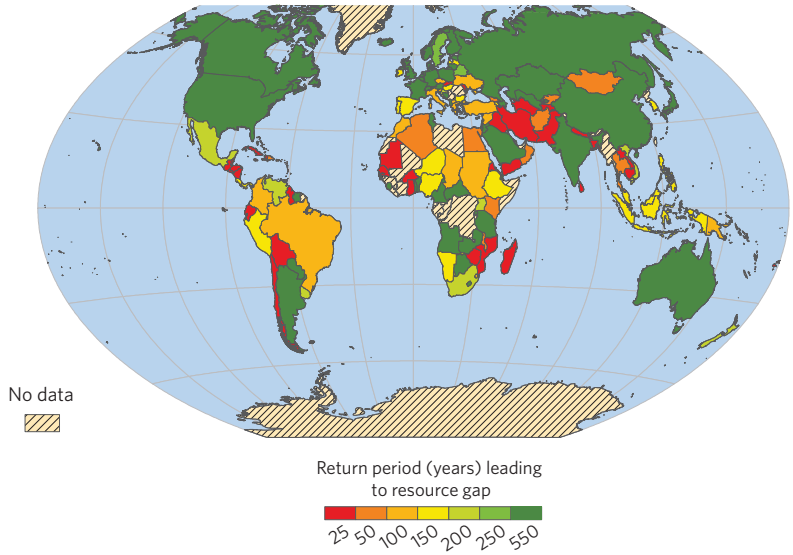

Figure 2 | Calculating fiscal stress from climate-related risk. Figure reproduced from ref. 20.

Beyond the red lines

Warsaw saw the confirmation that many climate negotiators and actors agree in principle on international responsibility for predictable and adequate support for the victims of climate change, especially where the costs of climate-related events exceed capacity. However, the concepts of compensation and liability are regarded by many 'northern' negotiators as 'red lines', as they are associated with blame[6]. Also, claims for compensation require solid evidence that climate change is contributing to the loss burden.

This evidence is not available, although scientific understanding regarding climate extremes has been evolving. The IPCC's fifth assessment report recently documented that anthropogenic climate change, in addition to causing gradual shifts, is increasing the intensity, duration and frequency of extreme temperatures and rainfall[7]. Another — very different — human contribution that renders disasters 'unnatural' is the interaction of hazards with exposure and vulnerability; disentangling the contributions of these two sets of drivers is complex. For example, vulnerability is particularly ill-understood and quantified. As a consequence, questions of attributing loss to anthropogenic climate change, while clearly very important for responsibility and equity, cannot yet be robustly answered[8]. However, action can be processed around comprehensive risk management even in the absence of solid evidence on climate change attribution.

Risk layering

As disaster risk is special, a comprehensive approach involves targeting risk management interventions according to disaster return periods — 'risk layering'. Risk layering can help to differentiate between distinct levels of risk organized around return periods (or probability) and the degree of stress imposed by risk. Risk layering is a concept underlying many areas of risk policy, especially agricultural and insurance risk management[9]. This approach can reveal risk management options that are differentially effective for low-, medium- and high-probability events as well as tailored to the different risk bearing capacities of communities, governments and international organizations[10]. Such nuanced understanding of risk management can also be helpful in identifying risks that are 'beyond adaptation' (ref. 11). Risk layering can help to address the challenges involving efficiency and equity as well as process-based concerns that arise from the Warsaw mechanism.

Identifying risk management options

Efficiency can be addressed with reference to four distinct risk layers as shown in Fig. 1. Frequent, low-impact risk for which risk reduction is typically the preferred adaptation (benefit–cost analyses have shown great potential for reducing risks at this lower level[12]), medium-layer risks for which risk reduction can be combined with insurance and other risk-financing instruments that transfer residual risk, rare and catastrophic events for which public and international assistance will be necessary if critical stress thresholds are passed, and finally, a very-high-level risk layer for which the capacity of international aid agencies can be exceeded.

Absorbing disaster stress

Risk portfolios and stress thresholds will differ for different contexts and countries. How can those risk-based thresholds be identified? Stress testing, especially for the finance and insurance industries, has become common practice in developed countries to hold adequate capital reserves, and is typically done at the level of 200-year events, leading to what is considered the probable maximum loss[13]. Beyond this level, some sort of national or international (for example, European-wide) solidarity is often considered legitimate. At the same time, stress may already start at lower layers of risk, especially in lower-income countries. Governments tasked with providing comprehensive assistance or with rebuilding damaged public infrastructure may face climate extremes or multiple events that can exceed their fiscal reserves.

As an example based on modelling climate-related risk to government budgets, the IIASA CATSIM model calculates climate-related fiscal stress (Fig. 2). Various countries already seem stressed (in terms of a gap in fiscal resources) for events occurring more frequently than once in 25 and 50 years. Stress thresholds can be increased by raising dykes (for example, raising protection levels against floods from 50- to 75-year return periods), lowering exposure through zoning or building codes, or by implementing risk-financing measures, which absorb higher-level risk[14].

Targeted support

A risk-layer lens is helpful for providing targeted support to highly exposed and vulnerable communities and countries in two ways. First, it provides support for enhancing the uptake of risk management. Of the US$107 billion allocated to disaster-related activities from international aid over the past two decades, only about 13% was invested in pre-event risk management; the bulk went into post-event response and reconstruction[15]. Second, it provides finance for absorbing losses and damages that go beyond stress thresholds and beyond adaptation. A proposal by the Munich Climate Insurance Initiative, which has been informing the climate negotiations, would enlist the international community to provide support to vulnerable countries for transferring their high-risk layers, possibly by setting up a no-premium international reinsurance fund linked to requirements for risk reduction[16]. In this way, negotiators could address loss and damage caused by extreme climate-related events without entering into a discourse on compensation and liability.

Implementation and challenges

As climate adaptation has moved beyond theory, risk management and layering is being implemented. A number of coastal megacities

are evaluating strategies to reduce risk in light of climate change by setting risk thresholds, agreeing on models and communicating the need to reduce risks. Jakarta is currently devising a multibillion dollar programme to protect itself from rising sea levels with large levees. Jakarta also recognizes the short-term effects of rapid urbanization, and is studying options to implement new building and zoning regulations to lower the exposure and vulnerability of houses and infrastructure to extreme rainfall[17]. New York City is rebuilding areas affected by Hurricane Sandy using a layered risk management approach. New building codes are being developed as part of a longer-term vision to adapt to climate change, while revisiting the current flood insurance arrangements and associated incentives to reduce risk[18].

Processes can quickly become normative and subject to political debate due to varying interpretations of the underlying risk science. A hurricane risk model recently developed to support insurance decisions in Florida was not licensed by the insurance regulator as modellers proposed to break with the tradition of averaging hurricane losses over the long term by giving more weight to higher hurricane activity in recent years (as possibly induced by climatic change)[19]. Furthermore, risk thresholds are often defined following political negotiations rather than concepts of risk efficiency and ability to absorb risk. For example, the 75-year return period threshold, the lowest return period for which flood insurance in the UK is available, was chosen as a compromise — the middle ground between industry and government willingness to bear risk (based on unpublished interviews conducted by Surminski in 2009).

Moving forward

If the risk-layering approach is to be useful for moving the loss and damage agenda beyond the red lines, it will require extensive effort in collecting relevant data for modelling risks in a changing climate, identifying efficient risk-reduction activities and supporting safety nets for the most vulnerable. Still, there will be hurdles, not least in terms of involving stakeholders in assessing risks and proposing effective and fair management policies. An iterative and participatory risk-management process, informed by the best possible risk science for studying the key drivers — hazards, exposure and vulnerability — will be needed. This agenda can benefit greatly from an understanding of the differentiated activities targeted at different risk layers. Identifying opportunities and limits to risk reduction, risk transfer and adaptation, as well as supporting the victims through international efforts, must be core to the evolving loss and damage mechanism. ❐

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COMMENTARY:

Low-carbon investment risks and de-risking

Tobias S. Schmidt

Effective mitigation of climate change requires investment flows to be redirected from high- to low-carbon technologies. However, especially in developing countries, low-carbon investments often suffer from high risks. More research is needed to address these risks and allow sound policy decisions to be made.

Climate policy has to address a global investment challenge. The International Energy Agency estimates that in the energy sector alone, infrastructure investments of US$37 trillion will be needed by 2035[1] to meet the rising global energy demand. To achieve an atmospheric CO_2 concentration below 450 parts per million, these investment flows have to be redirected from high-carbon to low-carbon technologies and topped up by a further US$17 trillion[1]. This can realistically be achieved only by successfully mobilizing private capital[2]. Consequently, climate policy needs to create attractive conditions for private low-carbon investments, especially in countries not belonging to the Organisation for Economic Co-operation and Development where the