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Loss and damage attribution

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only for projects to be delivered through domestic companies. This country-driven approach would incentivize resilient development rather than punishing development in general, and the central theme of the GCF should be to incentivize advantageous action without penalizing the disadvantageous.

Private sector facility

The private sector facility (PSF) is a path-breaking innovation and its effective operationalization will be critical to meeting the climate challenge. Its role in leveraging capital and promoting triple transformation will be crucial given the scale of financial resources needed to tackle climate change. The World Economic Forum suggests that at least US$5.7 trillion must be invested in renewable energy, sustainable mobility, clean water and other green infrastructure annually by as soon as 2020 to keep the global average temperature increase below 2 °C (ref. 5).

The PSF must allow the private sector firms to act as GCF implementing entities. This would require policy innovation, drawing upon the experience of the International Finance Corporation as well as other multilateral development banks. A robust criterion for private sector accreditation would ensure that climate change objectives are not left to the vagaries of the market alone. In addition, affirmative actions in favour of the domestic actors would be vital to ensure that they are not crowded out by global actors and banks.

The PSF would act as a critical agent in using risk-management tools to mobilize system-wide transformation, particularly by enhancing country ownership through domestic private-sector participation and hence by synergistically promoting development benefits. This way, channelled resources can be used efficiently to scale up proven technologies, thereby maximizing the impact per dollar.

To enhance country ownership, larger guarantees should be offered for projects undertaken by the local private sector and somewhat lower guarantees for projects by international entities. This could be complemented by equity participation: higher equity participation if projects are undertaken jointly by local and international companies; lower equity participation if solely by local or solely by international entities including banks. The combination of local with international participation should yield the highest impact and reduce risks. This is because international expertise and private sector involvement enhances the likelihood of successful projects and enables use of state-of-the-art technologies, whereas local private sector engagement translates to capacity building, country ownership and development co-benefits.

If GCF were not granted authority to hold equity shares, it could still achieve similar results through subsidies. That is, larger subsidies would be given if a project is executed jointly by national and international actors and entails transformative impact. Lower subsidies should be granted to efforts that bring about significant mitigation potential but that are carried out by one of the two actors only.

The financial cycle consequently would consist of several steps. First, contributions by donor countries are made, 30% of which, for example, may be used to provide long-term finance to PSF. Based on this capitalization and donor pledges, bonds can be issued. Finally, reflow from equity participation and profits would close the loop and enable the fund to maintain a high level of investment.

A GCF equipped with a triple transformation objective and new tools could significantly contribute to combating climate change and favour development. The institution must galvanize countries, governments and local communities and engage the private sector towards keeping the global mean temperature increase below 2 °C. There may be little time left for humanity to succeed in its common fight against climate change and the GCF could be the decisive factor. ❐

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Additional information

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COMMENTARY:

Loss and damage attribution

Christian Huggel, Dáithí Stone, Maximilian Auffhammer and Gerrit Hansen

If research on attribution of extreme weather events is to inform emerging climate change policies, it needs to diagnose all of the components of risk.

Extreme weather events have been the cause of innumerable disasters throughout human history. A series of recent incidents, with 'superstorm' Sandy in October 2012 as a high-profile example, have fuelled the debate about whether anthropogenic climate change can be blamed. But blamed for what exactly? Blamed for the intensity of the storm, the flooding height or the economic losses and harm to life that resulted from these events?

And what does 'blame' mean exactly? The public debate often refers to climate change as a 'cause', whereas science views anthropogenic climate change as a 'contributor' to a particular event, or to a frequency distribution of extreme events. The public may perceive these points as nuances in the debate. However, clarification of the terms and conceptual frameworks is fundamental to further progress in the scientific field of attribution of extreme events to climate change.

International negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) are becoming concerned with the question of which countries pay for loss and damage related to extreme weather events, and which countries receive the funds. In this context, negotiators call for scientific support to the attribution problem, as emphasized at the 18th Conference of the Parties in Doha in December 2012. Furthermore, within national laws, the question of liability of damage due to extreme weather events may gain importance in the future, and similarly need advice from science[1]. Is science prepared to provide this support for policymakers?

It is without doubt that attribution of individual extreme events to anthropogenic climate change is a major challenge. The Special Report on *Managing Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* from the Intergovernmental Panel on Climate Change (IPCC), published in 2012, concludes that this sort of attribution remains very difficult[2].

We can distinguish two main scientific fields that are concerned with attribution of extreme events and disasters to climate change. The first is rooted in physical climate science. Although trends can be evaluated statistically for moderately extreme events, an important contribution to climate-related damage arises from very rare weather events for which — by virtue of their rarity — it is difficult to gain sufficient statistical power to detect any trends.

Climate scientists have used several approaches to circumvent the problem of attributing unmonitored changes in extreme events to climate change[3]. The most popular method examines another variable that is linked to the meteorological characteristics of the extreme event, and is better sampled in the observational record[4,5]. Trends in observations in this other variable (summer temperatures, for example) are compared against trends in simulations — both with and without anthropogenic forcing. The results are extended to the chance of the rare event using statistical and/or dynamical modelling, leading to a conclusion on whether anthropogenic emissions altered the chance of the observed event occurring. A variation on this method examines how the magnitude of the anomalous event compares with the magnitude of change in the associated variable[6].

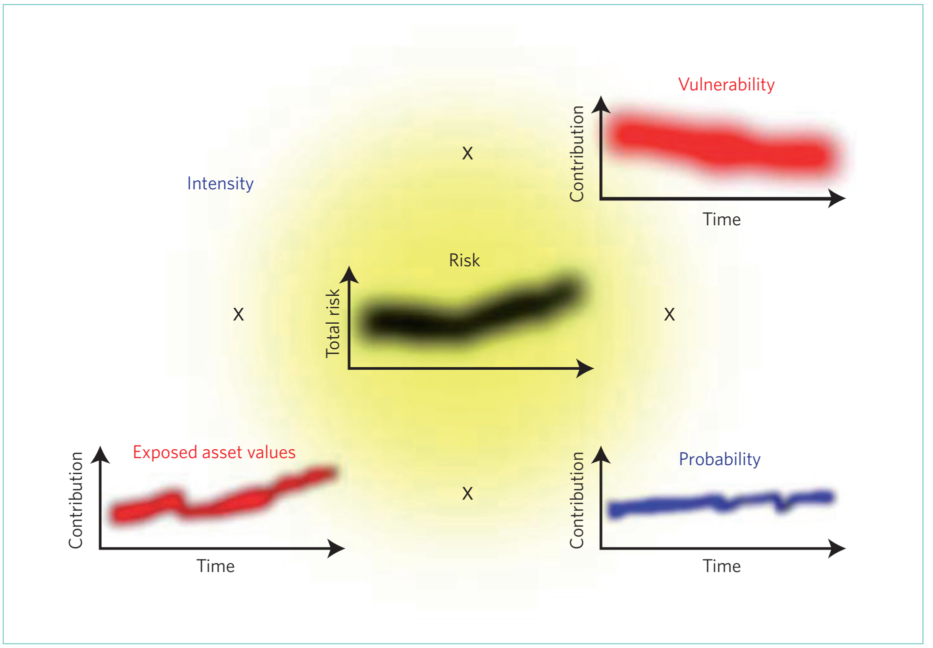

Figure 1 | Hypothetical risk attribution framework. The relative contribution of the different risk terms are shown over time, resulting in an overall risk trend. The width and fuzziness of the lines indicate the degree of uncertainty for the respective risk term. Blue indicates climatic risk drivers (probability of occurrence and intensity of an extreme weather event), whereas red represents social and economic factors. Intensity is not shown in a separate graph as it is related to probability of occurrence. Yellow shading shows the integration of blue- and red-coloured drivers, with risk being a function of all terms multiplied (as indicated by 'X').

Another approach assumes that distant events have statistical relevance for local events. Global data is pooled to provide statistical power for a local analysis of how the chance of the event has changed over time[7], but interpretation of the results is unclear when local trends oppose global trends[8]. Generally speaking, there is slowly accumulating evidence and increasing confidence that anthropogenic climate change was a contributor to some, but certainly not all, major recent extreme weather events[3,9,10].

Of course, understanding how emissions contributed to a weather event does not provide any information about whether and why that event was damaging. A second, entirely different field of research is concerned with losses associated with extreme impact events. Such studies usually analyse disaster databases from international organizations or re-insurance companies, and find that economic losses resulting from extreme impact events have increased over the past several decades[2,11]. The increase in exposed asset values has been identified as the main driver of the increase in loss. When accounting for these changes (a method called normalization), most disaster risk analyses have not found any detectable trend consistent with expectations from climate change[12]. However, because of the current inability to appropriately account for adaptation actions — such as structural defensive measures — some scholars emphasize that it cannot be concluded from these studies whether or not the expected frequency or intensity of extreme weather events has changed[13].

The two areas of research that we have mentioned above indicate that current science on attribution of extreme impact events to climate change has not been integrated between disciplines so far. This is reflected in the contrasting conclusions about observed changes in extreme events and their attribution to climate change. Although not explicitly a contradiction, they portray the different avenues taken by the two research communities.

It is striking that although risk is a central concept for extreme impact events, it is not used in a coherent way in either field. Climate scientists have typically used the term 'risk' as a synonym for the probability of occurrence of an extreme weather event[14]. This falls short of the broader understanding of risk as adopted in disaster risk research, where exposed assets and vulnerability play an important role. On the other hand, disaster losses are an aggregate measure of risk, and as such related studies do not a priori aim to dissect the risk terms and the drivers of extreme impact events.

Take the example of superstorm Sandy, which affected the east coast of the United States. As with other extreme weather events, Sandy developed from complex interactions in the climate system involving sea surface temperature, atmospheric pressure systems and the related northern jet stream. There is evidence of an anthropogenic influence on these factors[15,16], and climate change-induced sea-level rise may also have contributed to the flood intensity. However, Sandy only became such an important event because of the high concentration of exposed high-value assets, in particular in New York City. In spite of the casualties and billions of dollars of damage we should not forget that over the past years New York City has invested significant efforts and resources to reduce the vulnerability of its property and infrastructure[17]. However, assessment of changes in vulnerability — as related to adaptation and risk prevention — is difficult, and has not yet been achieved in an attribution context.

To move forwards we propose framing the attribution problem with a more integrated risk concept. Risk is defined as a function of the probability of occurrence of an extreme weather event and the associated consequences, with consequences being a function of the intensity of the physical weather event, the exposed assets and their vulnerabilities (Fig. 1). The intensity of the event can be expressed, for instance, as wind velocity or flooding height. Exposed asset values are typically monetary values of buildings or infrastructure, but can also include assets not valued in monetary terms, such as loss of lives. Vulnerability may reflect the physical resistance of structures to flooding, but also the degree of preparedness of people or the capacity to recover from disasters.

Figure 1 illustrates that all drivers of risk — and thus risk itself — are essentially dynamic. The analysis of the relative contribution of drivers requires high-quality records through time, but limited data availability and quality adds uncertainty to the detection of change and the attribution process. Efforts should be directed to improve the monitoring, quality and consistency of data concerning all of the contributors to risk. The data should also be accessible for study.

The proposed risk framework basically facilitates progress in supporting emerging policies. Attribution issues in relation to loss and damage mechanisms under the UNFCCC are not simply a question of attributing physical extreme weather events to climate change. Think of losses caused by an extreme weather event observed in areas of recent uncontrolled urbanization in a specific country. In this case, can another country — or group of countries — be blamed for this damage because of their historical greenhouse gas emissions? This example illustrates the need for a broader risk-related attribution framework, but it also portrays how closely the debate is linked to poverty and development. It is clear that attribution science cannot assess blame because it is fundamentally a political, societal or legal problem. The consideration of liability is regulated differently across current national civil laws. However, science can assess how the occurrence of a particular event is related to anthropogenic greenhouse gas emissions, and how the damage is tied to the drivers of risk.

Hence, in essence, we need the proposed framework to dissect the drivers and to perform attribution analyses within the risk parameters. The framework also facilitates a common and shared language between the research communities of physical climate and disaster risk science to increase the level of interaction. Recent research, stimulated by risk framework concepts developed in the IPCC report[2] in 2012, focuses on the comprehensive analysis of variability in both climate and disaster losses[18].

Eventually, a more integrated attribution framework for extreme events provides an important basis for the ultimate goal that should overarch the disaster and loss mechanisms and liability discussions — that is, the reduction of associated risks. Risk managers and decision-makers need to know where to invest in order to effectively reduce risks. Despite the level of uncertainty in future climatic conditions, a risk attribution framework can support policymakers by indicating the relative, up-to-date contribution of risk drivers — including the climatic ones — to overall risk, which is eventually the determinant for loss and damage. ❐

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