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The risk of climate ruin

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Abstract

How large a risk is society prepared to run with the climate system? One perspective on this is to compare the risk that the world is running with the climate system, defined in terms of the risk of 'climate ruin', with the comparable risk that financial institutions, in particular insurance companies, are prepared or allowed to run with their own financial ruin. We conclude that, in terms of greenhouse gas emissions today and in the future, the world is running a higher risk with the climate system than financial institutions, in particular insurance companies, would usually run with their own solvency.

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As the IPCC *Fifth Assessment Report* illustrates, risk and uncertainty are central to assessing the consequences of climate change and formulating response strategies (IPCC, 2014). If we define risk management as the activity of identifying, monitoring and limiting risk below an acceptable level, including assessing what that level is, then it would seem logical to adopt a risk management approach to climate change, including global mitigation policy (Manne and Richels, 1992; Bruckner et al., 1999; Lempert and Schlesinger, 2000; Weitzman, 2009; Jones et al., 2014; Kunreuther et al., 2014). One central question is: how large a risk is society prepared to run with the climate system? This question is at the heart of enduring debates about the appropriate level of ambition, globally, in reducing greenhouse gas emissions.

It is a question of the utmost difficulty, however, because there are rarely clear answers to questions about society's tolerance of risk. In this paper we offer a novel perspective, which is to compare the risk that the world is running with the climate system, defined in terms of the risk of 'climate ruin', with the comparable risk that financial institutions, in particular insurance companies, are prepared or allowed to run with their own financial ruin. Hence we offer an actuarial perspective on climate change. We conclude that, in terms of greenhouse gas emissions today and in the future, the world is running a higher risk with the climate system than financial institutions, in particular insurance companies, would usually run with their own solvency.

The risk of ruin for insurance companies

Insurance companies are required to hold capital against the risk of failing to meet their liabilities, in particular of failing to pay indemnities to their policyholders in an unusually bad year in which there are too many claims. Bankruptcy can follow. This is known in the industry as the risk of ruin. An insurer has to calculate how much capital it needs to hold in order to reduce the probability of ruin below an acceptable level. This threshold is either set by the regulator, or at a level which assures policyholders and investors that the insurance company is safe.

For example, the United Kingdom's Financial Conduct Authority (FCA) sets the capital requirement such that the risk of ruin is no more than 1 in 200 (i.e. 0.5%) over a one-year time horizon (FSA, 2008). In practice, insurance companies normally hold sufficient capital such that the risk of ruin is far lower than this level. Large reinsurance companies such as Munich Re and Swiss Re typically aim for a credit rating in the region of AA and an estimate of the average default probability for corporations rated AA over a one-year horizon is 0.02% or 1 in 5000 (RatingsDirect, 2015).

Climate ruin

Whereas ruin of an insurance company is relatively clear-cut – the company becomes insolvent – what might ruin mean in the context of climate change? To define 'climate ruin', it is necessary to make a judgement about what is ruinous, and this involves a measure of subjectivity in just the same way as defining the more familiar concept of ‘dangerous climate change’ does (Smith et al., 2001; Dessai et al., 2004).

A typical definition of ruin is “The state or condition of a ... society which has suffered decay or downfall” (Oxford English Dictionary, 2014). This implies attention should focus on the magnitude of climate change that triggers severe economic and social impacts, leading to some form of collapse of society, symptoms of which would include impoverishment or displacement of people.

The magnitude of climate change can be indexed as usual by the increase in the global mean temperature above the pre-industrial level. The spatial focus and scope of the analysis are free to be chosen according to what is considered important. In some cases, for instance to inform national policy positions and negotiating strategies, the principal aim may be to estimate the global mean temperature that triggers climate ruin at the national level. Given the high risks they face, this is arguably akin to the task that has already faced some low-lying Small Island Developing States (SIDS). In this paper we choose, however, to focus on climate ruin at the global level, in order to show how the framework can contribute to debates about global emissions targets and attempts to evaluate whether the sum of existing efforts by countries to cut emissions is sufficient (den Elzen et al., 2011; UNEP, 2013).

The recent contribution of Working Group II to the IPCC’s *Fifth Assessment Report* revives the Panel’s tradition of summarising the impacts of different degrees of global temperature increase with five ‘reasons for concern’ (IPCC, 2014). At 2°C above the pre-industrial level, IPCC classifies the level of three of the five key risks (i.e. reasons for concern) as high: the risks to unique and threatened systems, the risks of extreme weather events, and the risks for disproportionately affected people and communities (called ‘distribution of impacts’). On the other hand, the risks of global aggregate impacts and the risks of large-scale singular events are moderate. At 4°C above the pre-industrial level, all five key risks are high and in the case of unique and threatened systems they are very high. In picking out 4°C of warming, IPCC is following a relatively recent trend (New et al., 2011; Schellnhuber et al., 2012). The trend has been inspired in part by the growing likelihood that the global mean temperature will reach and exceed 4°C above the pre-industrial level this century, as well as the lack of evidence from the impacts-research community on what this will mean. If we think of what environmental, economic and social impacts are consistent with a worst-case scenario at the global level, then it can be argued that the risks of global aggregate impacts and of large-scale singular events are key. On the basis of the IPCC's reasons for concern then, we might link climate ruin with no fewer than 4°C of warming.

However, the process of giving meaning to 'dangerous anthropogenic interference with the climate system', introduced by Article II of the United Nations Framework Convention on Climate Change, is also clearly of some relevance, given the similarities between the notions of dangerous climate change and climate ruin. The 2009 Copenhagen Accord recognised an existing line of thought, which can be traced back at least as far as a decision of the Council of the European Union in 1996 (Council of the European Union, 1996), that 2°C marks the threshold for dangerous anthropogenic interference (SIDS and Least Developed Countries, whose vulnerability to climate change is typically well above the global average, have pushed further for a 1.5°C threshold). On the basis of the political process we might then link climate ruin with no fewer than 2°C of warming. We will consider both thresholds, but it will become clear that the more accommodating 4°C target is sufficient to make our point.

Another potentially relevant source of evidence is the findings of economic research into climate impacts. A small number of highly influential (economic) integrated assessment models (IAMs) are used to estimate the monetary costs and benefits of emissions reductions (Hope, 2013; Nordhaus, 2008; Tol, 2012). Their damage estimates are conditioned on, or otherwise related to, underlying studies, which use a variety of methods to provide data points mapping the increase in the global mean temperature above the pre-industrial level with economic costs equivalent to a percentage of global GDP. Tol (2014) is the latest synthesis of these existing, underlying studies, showing that the data points are clustered around 2-3°C warming costing the equivalent of 0-4% of GDP. This is clearly inconsistent with the implication that 2°C warming would constitute climate ruin, or the related concept of dangerous anthropogenic interference with the climate system. Tol's (2014) synthesis also shows a lack of data points to condition damage forecasts at warming of more than 3°C, which results in an increase in quantified uncertainty. Nonetheless, IAMs rarely forecast large impacts of climate change until the global mean temperature reaches an exceedingly high level, if indeed they forecast large impacts at all. At 4°C above pre-industrial, standard versions of three leading models estimate impacts equivalent to a loss of global GDP of about 1-5% (Interagency Working Group on Social Cost of Carbon, 2010). If the global economy grows as it currently is at c. 3% *per year* (IMF, 2013), this clearly still constitutes modest damages.

However, these economic forecasts have been subject to repeated scrutiny and criticism, most recently targeted at the IAMs (Stern, 2013; Pindyck, 2013; Weitzman, 2012). This recent research has stimulated new damage functions in IAMs that exhibit stronger curvature and much larger impacts at high temperatures. One popular new benchmark is the function in Weitzman (2012), which assumes impacts equivalent to 9% of GDP at 4°C, 50% of GDP at 6°C and nearly 100% of GDP by the time warming reaches about 10°C (see also Hope (2013)). But these are simply assumptions. Stern (2013) argues that even this might be too optimistic and in Dietz and Stern (2015) there is sensitivity analysis on a damage function that yields impacts of 50% of GDP at 4°C. Overall though, it is doubtful whether the economic evidence is sufficiently strong to justify linking climate ruin with more than 4°C of warming, at most.

Emissions limits to avoid climate ruin

The risk of ruin in the insurance industry applies year to year, because companies can adjust premia and vary capital holdings on this timescale, i.e. it is assumed that they are not locked into positions requiring resilience to be evaluated over a longer period. By contrast, the global mean temperature depends on the atmospheric concentration of greenhouse gases and therefore cumulative greenhouse gas emissions over centuries, i.e. our position is significantly locked in. This makes the choice of time horizon in analyses of the impacts of climate change a thorny, if often neglected, issue. Many assessments are truncated at the end of the 21st century, but the atmospheric residence time of carbon dioxide justifies a much longer-term view, such as that embodied in IAMs in fact (Hope, 2013; Nordhaus, 2008; Tol, 2012). The economic modelling in the *Stern Review*, for instance, effectively assumed the impacts of climate change continue into perpetuity (Stern, 2007). We take our objective to be to control emissions so as *never* to exceed the given probability of climate ruin, i.e. our analysis is not affected by the specification of an arbitary terminal period.

This means that we need an approach to specifying the trajectory of greenhouse gas emissions into the indefinite future. In climate science, different approaches have been taken to this task, of which two leading examples can be highlighted. One approach is to analyse emissions paths that stabilise the atmospheric concentration of greenhouse gases at a particular level forever, so that estimates of the equilibrium climate sensitivity of the system can be used to define the maximum increase in the global mean temperature (assuming no overshoot in the atmospheric concentration) (IPCC, 2007; Pacala and Socolow, 2004; Zickfeld et al., 2009). An alternative has been suggested by Allen et al. (2009). If the set of emissions paths considered is restricted to those constrained to meet an upper limit on cumulative emissions, then the maximum increase in the global mean temperature is given by peak warming – the so-called Cumulative Warming Commitment (CWC) – rather than equilibrium warming.

Accordingly, Table 1 collects together estimates of the probability of exceeding 2°C and 4°C warming above pre-industrial as a function of cumulative carbon emissions (also since pre-industrial), which we have constructed from the two major studies to so far report these (Bowerman et al., 2011; Zickfeld et al., 2009). Zickfeld et al. (2009) is an example of the former approach, which considers stabilisation of atmospheric carbon dioxide. Bowerman et al. (2011) builds on Allen et al. (2009) and is an example of the latter approach, based on peak warming. However, since in Zickfeld et al. (2009) maximum warming is attained upon stabilisation (excluding overshooting scenarios), the comparison can be made.

Before drawing conclusions from Table 1, it is important to highlight the limitations of the notion of 'probability' in this setting, where the degree of correspondence between the climate models on which these analyses are based and the real climate system is unknown (Stainforth et al., 2007). There is in other words no guarantee these model probabilities correspond with the real probability of the climate system warming 2-4°C in response to a given pulse of cumulative carbon emissions. At the same time, the degree of bias is essentially unknowable.

With this caveat in mind, the estimates gathered in Table 1 show that the probability of climate ruin, even if this is defined as the more accommodating 4°C warming above pre-industrial, are in general much larger than the probabilities that insurance companies are prepared, or allowed, to run with their own solvency. Even for historical cumulative emissions, which are of the order of 500TtC, the probability of peak warming of 4°C may be as high as 27%; if climate ruin occurs at 2°C then it is in the range 3-50%.

Discussion

In this paper we have in effect set out, in broad terms and with a little detail, an actuarial approach to climate policy. Specifically this approach yields an analysis of permissible global greenhouse gas emissions pathways and targets in terms of keeping the risk of climate ruin to an acceptable level. It would be overdoing things to regard the result as a paradigm shift: the practice of establishing permissible greenhouse gas emissions with regard to an increase

Table 1: Estimates of the probability of exceeding 2°C and 4°C warming above pre-industrial as a function of cumulative carbon emissions since pre-industrial (trillion tonnes of carbon). The min-max range from Zickfeld et al. (2009) is generated by a range of probability density functions of the climate sensitivity, together with additional uncertainty about the strength of the climate-carbon cycle feedback. The min-max range from Bowerman et al. (2011) corresponds to different scenarios about minimum annual emissions, or emissions 'floors'. Bowerman et al. (2011) only report estimates for 1000, 1500 and 2000 TtC, and only report unnormalised relative likelihoods for peak warming of less than 4°C.

Cumulative carbon emissions (TtC)	Zickfeld et al. (2009)				Bowerman et al. (2011)	
	2°C		4°C		2°C	
	min.	max.	min.	max.	min.	max.
500	0.03	0.5	0	0.27	-	-
1000	0.34	0.8	0	0.4	0.70	0.72
1500	0.63	0.98	0.05	0.53	0.89	0.91
2000	0.81	1	0.18	0.69	0.99	0.99
3000	0.92	1	0.53	0.91	-	-
4000	0.95	1	0.71	0.99	-	-

in the global mean temperature is commonplace. However, it yields some interesting comparisons of the level of risk that society is running with the climate system, with those that financial institutions, in particular insuranc companies, run with their own solvency. It seems safe to conclude the former risk well exceeds the latter.

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