Journal & Proceedings of the Royal Society of New South Wales, vol. 151, part 2, 2018, pp. 213–231. ISSN 0035-9173/18/020213-19

Global challenges: personal reflections on the Stockholm "New Shape" competition

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Abstract

The Stockholm-based Global Challenges "New Shape" competition, which attracted 2,702 entrants from 122 countries, aimed to promote new ideas for the governance of global catastrophic risks. Here I tell the story of my role as one of 14 eventual finalists. It is a story of ideas — ideas that formed the background, ideas that emerged in the course of the finals, and ideas about how we might take things forward in the future. As Sir William Bragg put it in his famous introduction to *The Double Helix* (Watson 1967), this is not a history, but an autobiographical contribution to the history that may someday be written.

Background

The world received a sharp rebuke with the release of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming (IPCC 2018). Mankind's use of fossil fuels was particularly targeted, with the recommendation that their use be completely phased out by 2050 if average global temperature rises of 3°C to 4°C, or even more, are to be avoided.

But climate change is not the only threat to mankind's future well-being and security. Table 1 is a list of other threats, compiled from three recent sources: the *World Economic Forum Global Risks Report* (WEF 2018); the *Global Challenges Report on Global Risks* (GCF 2018); and Julian Cribb's *Surviving the 21st Century* (Cribb 2017).

Table 1

1) Degrading environment and resource depletion (WEF; JC)
2) Ecological collapse (GCF; JC)
3) Food insecurity (JC)
4) Pandemics (GCF; JC)
5) Population and urban expansion (WEF; JC)
6) Rising geographic mobility (WEF)
7) Changing landscape of international governance (WEF)
8) Artificial intelligence and rising cyber dependency (WEF; JC)
9) Increasing national sentiment (WEF)
10) Increasing polarization of societies (WEF)
11) Shifting power (WEF)
12) Rising income and wealth disparity (WEF)
13) Ageing population WEF)
14) Growing middle class in emerging economies[1] (WEF)
15) Rising chronic disease (WEF)
16) Weapons of mass destruction (GCF; JC)
17) Asteroid impact (GCF)
18) Supervolcanic eruption[2] (GCF)
19) Solar geoengineering (GCF)
20) Our capacity for self-delusion (JC)

[1] According to *The Kyoto Manifesto for Global Economics* (Yamash'ta et al. 2018), this threat should be subsumed under the broader threat of "current economic paradigms."

[2] My colleague Russell Blong has pointed out that the risk from superflares generated by geomagnetic storms seems to be at least as serious as that posed by supervolcanic eruptions (Lingam & Loeb 2017).

That's quite a list, and one that reflects the preoccupations of the different organizations and authors. But the major question remains the same in all cases: how can human society cope?

One way to cope is to develop methods by which approaching tipping points can be predicted, and avoided or prepared for. This was an approach particularly developed by Marten Scheffer and his colleagues in the first decade of this century (Scheffer 2009; Scheffer et al. 2009). It was a major stimulus for my 2011 book *Crashes, Crises and Calamities: How We Can Use Science to Read the Early-Warning Signs*.

But there was a problem. The warning signs, which concern gross changes in economies, societies or ecosystems, usually became obvious only when it was too late to do anything about the emerging situation. One example is the collapse of Lehman Brothers in 2008, which was preceded by an increase in a mathematical indicator known as *information dissipation length* (Quax et al. 2013), but where the this measure was only obvious in retrospect. A more general warning sign identified by Scheffer and his colleagues is *critical slowing down*, where a system takes longer than usual to recover from small perturbations and disruptions. This latter sign is very general, and is associated with other signals, such as increasingly large swings between extremes. However, as the history of actions to cope with climate change has shown, it is difficult to persuade policy-makers to take such signals seriously, even when they become blindingly obvious to scientists. Critical slowing down and its associated signals are also not so useful for financial markets because, as Scheffer et al. have pointed out, once a warning sign is known, its effectiveness becomes diminished as people start to use it to make a profit out of the situation.

There was also another problem — one whose significance has only become apparent in the last decade, and whose recognition sparked my entry into the Global Challenges competition. It is the problem of interconnectedness between different threats.

Emerging global threats continue to be treated as separate and independent entities, often by different bodies. The IPCC, for example, does not concern itself with environmental degradation, such as the increasing amount of plastic in our oceans (Eriksen et al. 2014), let alone the alarming increase in antibiotic resistance (Zaman et al. 2017) that does not appear in any of the lists, although it is mentioned in the body of the WEF report. On the other hand, those who address the dangers of rising cyber dependency (Helbing et al. 2017), first brought to public attention by Nick Bostrom (2014), tend to focus on its effect on governance and social issues, while seldom considering its contribution to environmental degradation or its potential contribution to global warming (Jardin 2017).

The problem with treating global threats in this way is that many of them are interconnected, sometimes in complex ways. Global warming, for example, is already affecting food security, with longer growing seasons meaning that pests can survive from one season to the next (FAO 2008). Our choice of food may also affect global warming. Marco Springmann from the Oxford Martin School pointed out in a BBC radio interview (Springmann 2018) that "the food system is a major driver of climate change — it emits about a quarter of all greenhouse gas emissions." This may shrink if enough of us switch to a more vegetable-based diet.

Rising geographic mobility and increasing national sentiment are obviously at odds with each other in many countries, some of which continue to promote coal as an energy source, even though it is a major contributor to global warming (IPCC 2018). But phasing out its use will affect jobs, and also energy costs in the short term, with consequential social disruption, and perhaps changes of government. This in turn can affect biodiversity, especially with just five countries — Russia, Canada, the United States, Australia and Brazil — holding 70% of the remaining wilderness (Watson et al. 2018). Witness the situation in Haiti, where 99% of primary forest has been lost (Hedges et al. 2018), and Brazil, where the new president is a supporter of expanded agribusiness and concomitant rainforest destruction (*Nature* editorial 2018). With loss of habitat, insects may be lost, including some that act as pollinators for crops (Winfree et al. 2011). Yet the latest UN Biodiversity Conference (UN Biodiversity Conference 2018) does not appear to have agriculture on the agenda. Nor did the World Health Summit (WHS 2018), concerned particularly with the global threat of pandemics, include the health of our planet's systems on its agenda.

The Threat of Interconnectedness

It has long been recognised that unexpected, and sometimes unpredictable knock-on effects may occur in interconnected systems. The psychologist Robert Merton had a name for it: "the law of unintended consequences" (Merton 1936).

One example is the story of what occurred when a crisis resolution and home treatment scheme was introduced into the Welsh mental health system as an alternative to hospital admission (Hannigan 2013). The intentions were good, but "Participants described parts of the interconnected system being closed to release resources, staff gravitating to new crisis services leaving holes elsewhere, and the most needy service users being cared for by the least experienced workers."

Another nice example is the history of Viagra® (Sildenafil). Originally intended as a treatment for hypertension and angina pectoris, it was found instead to increase erectile function in men (Ban 2006). Accounts vary as to how this effect was noticed; according to a pharmacological colleague, clinicians at the Morriston Hospital in Swansea began to wonder why male patients in a trial were not returning the excess pills after completion of the trial.

On a more contemporary note, "voluntourism" (where volunteers from richer countries pay to do charity work in poorer countries) is having unintended knock-on effects that include neglect of locals' desires, hindering of work progress, loss of local jobs, rationalizations of poverty (Guttentag 2009), child trafficking, and the unnecessary placement of children in orphanages (Martin & Katie 2014).

The additional threat posed by interconnection between different global risks was brought to public and scientific attention by Dirk Helbing in a seminal *Nature* article in 2013. Helbing's prescient article has still not had sufficient impact, although some authors have noted the possibility of interconnection between global threats. Cribb (2017), for example, specifically refers to his list of risks as "intersecting," while Short et al. (2018) speak of the "changing population demographics, antibiotic resistance and climate change, which we will face in the context of any future influenza virus pandemic." Resilience consultant Roland Kupers (2018) offers a specific example: "In

a deeply interconnected world, stresses and shocks propagate across systems in ways that evade forecasting. Climate change is linked to the Syrian civil war, which is connected to heightened concern over immigration, which precipitated Brexit."

Other authors have examined the possibility of dealing with interconnected threats by means of "risk trade-offs". Baum & Barrett (2017), for example, offer "integrated assessment … to put all of the global catastrophic risks into one analysis in order to perform cross-risk evaluation and inform risk-risk trade-offs and allocation prioritization."

But none of the above authors addresses the most important point of all: the one that I was anxious to address in my Global Challenges entry. This is that complex adaptive networks can have their own ways of doing things — ways that are not predictable from the behaviours of the individual members, and which are not always in the best interests of those members (Reyers et al. 2018). Connectivity in a network "may lead to emergent behaviour whereby local interactions lead to self-organised phenomena observable at larger spatial scales that cannot be predicted (or at least they are not obvious at the local level: what Bedau (1997) calls "weak emergence")" (Turnbull et al. (2018).

Increasing interconnection, often seen to be a good thing in today's increasingly networked world, can sometimes lead to sudden and dramatic collapse. The fall of the Roman Empire offers a spectacular example, as pointed out by the American historian Joseph Tainter (1988). Prior to Tainter's work, historians had commonly interpreted the collapse of societies and civilizations in terms of a cyclical view of history — the idea that civilizations have a natural growth and decay cycle, with collapse having its seeds in the distant past (e.g. Gibbon 1776–1788).

This model, where "the wheel of history revolves slowly, like an old water wheel in summer" and civilizations "cycle sedately from Arcadia to Apogee to Armageddon" (Ferguson 2010) has entered the popular consciousness, and has been reinforced by such authors as Jared Diamond (2005), albeit with considerable professional criticism (McAnany & Yoffee 2009; Ferguson 2010). It was even used by science fiction author Isaac Asimov (1951) in his *Foundation* novels, which are based on the idea that the large-scale sweep of history can be predicted by mathematics.[3] Sometimes this might be possible (Lagi et al. 2011). But mathematics tells us a very different, and much less certain story than that supposed by Asimov and Diamond.

As Tainter pointed out in his pioneering book *The Collapse of Complex Societies* (1988), the Roman Empire collapsed very rapidly, the population of Rome dropping by 75% in just five decades (Ferguson 2010). He attributed this, not to remote historical circumstances, but to the fact that the empire had reached a level of [interconnected] complexity that rendered it very susceptible to small perturbations. "The process of collapse" he said "is a matter of rapid, substantial decline in an established level of complexity." An equivalent example in modern times is the sudden catastrophic failure of power grids that have reached a level of complexity that renders them vulnerable to small localized events (Jing et al. 2003; Andersson et al. 2005; Simpson-Porco et al. 2015).

[3] The concept is encapsulated in the fictional science of "psychohistory," which Asimov described in an interview (Asimov 1987) as "a science in which things could be predicted on a probabilistic or statistical basis".

What is complexity? In the popular mind it is often confused with chaos, but the two are antithetical. According to philosopher and complexity researcher Paul Cilliers (2000) "Complexity is about how a huge number of extremely complicated and dynamic sets of relationships can generate some very simple behavioral patterns, whereas chaotic behavior, in the sense of deterministic chaos, is the result of a relatively small number of nonlinear interactions." So the simple action of a butterfly flapping its wings can lead to chaotic storms, whereas the enormously complicated and interacting chemical reactions in the cells of our body can produce relatively simple behaviour patterns like walking.

There are many practical examples of complexity in everyday life. The Santa Fe Institute, set up in 1984 to study their consequences (German, undated), provides a substantial list in its manifesto (SFI undated): "Complexity arises in any system in which many agents interact and adapt to one another and their environments. Examples of these complex systems include the nervous system, the Internet, ecosystems, economies, cities, and civilizations. As individual agents interact and adapt within these systems [in which case they are called *complex adaptive systems*], evolutionary processes and often surprising `emergent' behaviors arise at the macro level."

We are far from understanding, let alone predicting, emergent behaviours in complex adaptive systems (Turnbull et al. 2018). Sometimes these can lead to patterns that are stable over long periods of time, as happens with many biological organisms (Kitano 2002). But biological organisms have the advantage of evolutionary tuning, with unfavourable networks falling by the wayside. Long-term stability is the exception, rather than the rule, when it comes to complex adaptive networks. The reasons for this lie deep in the mathematics of such networks (May 1972, 1976), but one thing is now clear — *all complex adaptive networks contain within themselves the possibility of sudden ("critical") transition of the whole system to a new and different state* (Scheffer 2009; Reyers et al. 2018).

In other words, when it comes to the interconnected complex adaptive network of global risks, collapse is always on the cards.

Systemic Collapse

I had already written a book about complexity in everyday life (Fisher 2009), but it was only in the ensuing years that I realized how systemic collapse can happen at any time in a complex adaptive system, sometimes with little or no warning. This feature of our global economic, ecological and social networks became central to a meeting between scientists, politicians and policy-makers that was held in Venice in 2012.

I was lucky enough to be invited to attend the meeting, and eventually to be invited to write the final report (Fisher 2013). In it I focused on slowly developing catastrophic risks: those where slow and imperceptible changes may bring us to the brink of catastrophe without our even realizing it. The process is sometimes viewed in terms of Bak's "sand-pile" model (Bak 1999), where grains of sand are added one at a time to a pile until the addition of just one more grain initiates a cascade of collapse.

Bak's model is an idealized scenario, and does not necessarily describe the more complex events that may precipitate sudden collapse in real-life "sand-piles," such as colliery spoil heaps (Van Burkalow 1945; Aalto et al. 1997). But one feature that Bak's model and real-life collapses share is that collapse may

happen at any scale. Sometimes there may be a little trickle of sand down the side of the pile. At other times there will be a virtual avalanche, with the whole pile collapsing. Before that final, fatal grain is dropped, however, there seems to be no way of knowing what the scale of the collapse will be.

Thus it was with the global financial collapse of 2008 (Crotty 2009, Marks 2015). Banks have collapsed before, sometimes with no more than local damage (the trickle down the side of the sandpile). But when Lehmann Brothers filed for bankruptcy on September 15, 2008, the event initiated the collapse of the whole global financial sandpile (Dimitriou et al. 2013).

The collapse of a sandpile provides a dramatic image of systemic collapse, and even some relevant mathematics, but I was beginning to realize that it does not give a picture of what actually happens within the system. For this, we must turn to network science, and picture the system as a web — not a stationary web, but a dynamic one, where the nature and strength of the connections are continually evolving. This is the picture that Andy Haldane, chief economist for the Bank of England, used when he analysed the underlying reasons for systemic financial collapse in a speech delivered to the Peterson Institute for International Economics (Haldane 2017):

> the behaviour of complex, interconnected financial systems can be very sensitive to small changes in initial conditions and shocks. … Complex systems exhibit tipping points, with small changes in parameter values capable of moving the system from stability to collapse … The radical uncertainty in such complex webs generates emergent behaviour which can be near-impossible to predict, model and estimate.

This is certainly the case for the complex socio-economic-ecological web to which we all belong. The serious global challenges with which we are now faced can interact in complex and unpredictable ways, to produce complex and unpredictable outcomes. It is this situation that we must learn to manage (Liu et al. 2015).

It is a web without a spider, as the following figure from the World Economic Forum (WEF 2018) demonstrates (see figure opposite).

How are we to maintain stability, or cope with sudden, often catastrophic change in such a web? Should we attempt to introduce a spider, in the form of some over-arching governing body, to try to control the tensions and stability of all of the strands? But maybe this would lead to new instabilities, and a new "equilibrium." Is there, perhaps, some other way?

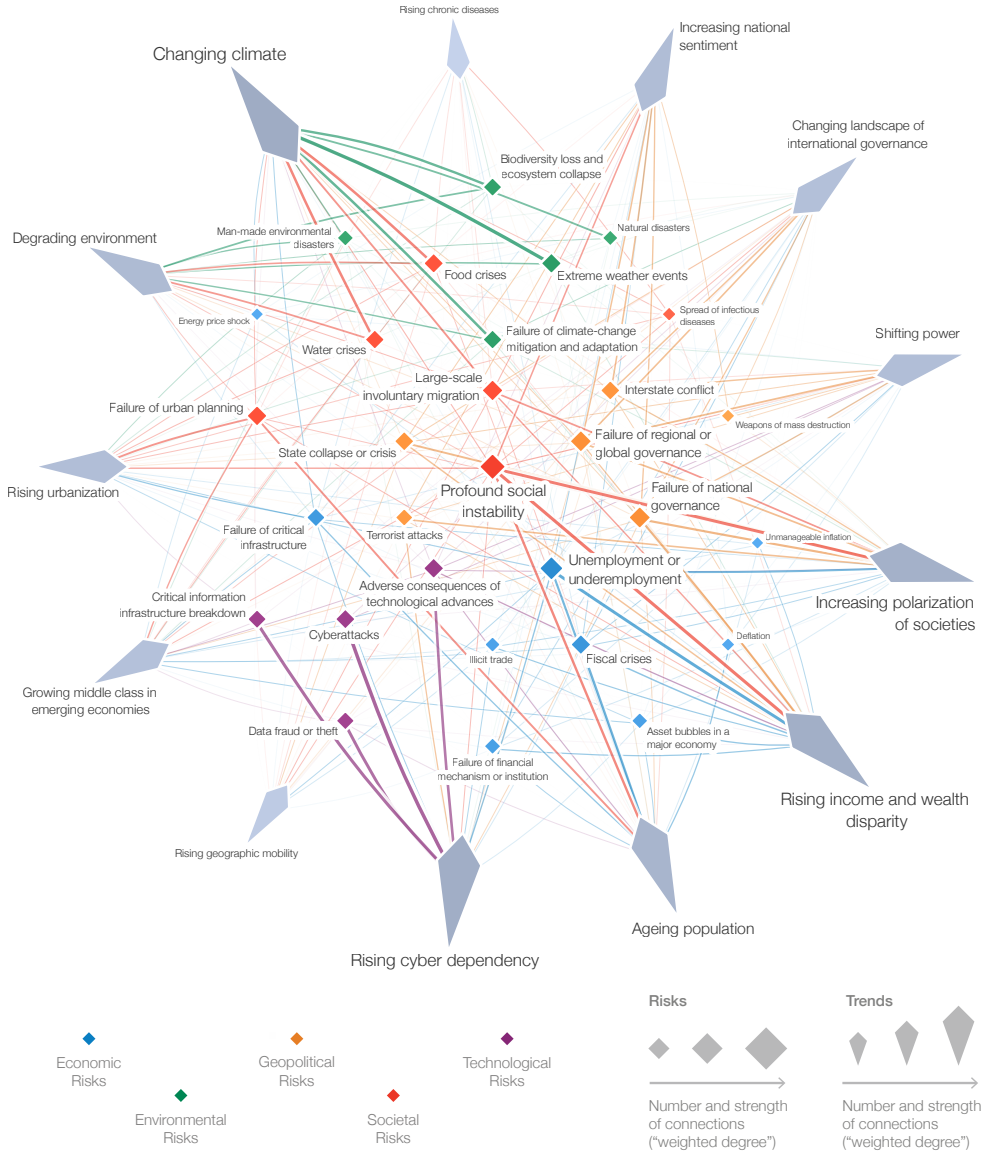
Three Problems

I had now realized that there are three factors that we have to cope with when it comes to the governance of complex adaptive systems:

1) Actions in one part of the network may have unintended consequences (positive or negative) for other parts
2) Small perturbations may transmit rapidly through a network, sometimes causing disruption and collapse
3) The network as a whole may "flip" to some quite different state with *no identifiable cause* and with little or no warning

Present systems of governance are simply too cumbersome, and too unaware of the underlying problems associated with real-world complex adaptive networks, to be

Figure II: The Risks-Trends Interconnections Map 2018



Source: World Economic Forum Global Risks Perception Survey 2017–2018.
Note: Survey respondents were asked to select the three trends that are the most important in shaping global development in the next 10 years. For each of the three trends identified, respondents were asked to select the risks that are most strongly driven by those trends. See Appendix B for more details. To ensure legibility, the names of the global risks are abbreviated; see Appendix A for the full name and description.

effective in coping with such rapidly occurring, and often unexpected eventualities. As Liu et al. (2015) and others have cogently argued, we need up-to-date complex network thinking if we are to make any real progress.

Enter the Global Challenges Foundation

In November 2016 an international competition was announced "to help incite bold and visionary ideas to tackle global risks" (GCF 2017). The competition was the brainchild of Laszlo Szombatfalvy, a Hungarian-born Swedish financial analyst who was determined to use his money to help the world avoid nuclear and other catastrophes. Szombatfalvy established the non-political *Global Challenges Foundation*, and it was through this foundation that a potential prize of $US5m was offered for "improved frameworks of global catastrophic risks".

The foundation had its own list of potential global threats, most of which are given in the table at the beginning of this article. But there was one more — one that particularly attracted my attention. This was a category called "unknown risks."

The concept is well known from former U.S. Secretary of Defense Donald Rumsfeld's response to a question at a news briefing. The question concerned the lack of evidence linking the government of Iraq with the supply of weapons of mass destruction to terrorist groups. As part of his response (US Department of Defense 2002), Rumsfeld famously said: "there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns — the ones we don't know we don't know."

By now I had realized that the biggest unknown of all with respect to global challenges is the risk that some combination of knock-on effects involving different risks could drive collapse of the whole shimmering web. To researchers in the field, this is a "known unknown". Sadly, so far as most government institutions and politicians are concerned, it remains an "unknown unknown".

When the Global Challenges *New Shape* competition opened, I had already been working for some time with my colleague Anders Sandberg at Oxford University's Institute for the Future of Humanity to try to understand how we might develop new approaches to the governance of this particular known unknown. We had met at a meeting of the International Risk Governance Council in Zurich, and found that we were thinking along similar lines, so decided to combine our resources. But only when the competition was near closing in September 2017 did an idea occur to me that might provide the basis for a possible solution. I rapidly wrote a proposal (Fisher 2017a), and made it just before the deadline.

I proposed "a global insurance and reinsurance model. A new institution receives premiums paid by member countries, in order to insure them against the effects of global catastrophic risks. The institution provides expert advice to the member countries, and financial backing for investments in cooperative projects to achieve risk reduction. Concentrating on a financial task would keep the institution flexible and independent. Decisions would be based on the principles of `effective altruism,' with decisions constantly monitored by AI, Big Data and statistical analysis to improve the institution's priorities and performance. The submission suggests

a pilot project being instituted by a smaller number of countries, in order for a first evaluation and improvement round."

The key words here were "flexible and independent." Flexible, because the threats from networked risks can emerge suddenly, with little or no warning, and require fast and appropriate responses to deal with them. Independent, because the internal politics of global human institutions such as the UN lead to ponderous processes that are not fit for purpose.[4]

I was not the only one to propose a fresh approach to tackling global catastrophic risk. When the competition closed, the organizers found themselves with 2,702 entries, from individuals or groups across 122 countries. A series of international committees whittled these down to 68 semi-finalists, and from these just 14 (out of a possible maximum of 20) were selected to appear in Stockholm in May 2018 to face the finals judges.

Much to my surprise, I was one of them.

The "New Shape" Competition

The finals entries (GCF 2018A) could be divided into two broad categories — those that sought evolution, and those that sought revolution. Most of them, including mine, particularly sought to find *fairer* approaches to international governance (New Shape library 2018; New Shape summaries 2018).

Certainly we need to find some way forward that avoids the power struggles that bedevil the United Nations and many other international organizations concerned with global catastrophes, potential and actual. But we also need to find fresh and *effective* ways to tackle global threats. This means facing up to the underlying problems.

I was (and still am) of the opinion that the most serious problem of all is that of interconnection between threats. I failed to get this point over to the judges, either in my submission or in my final address. In truth, I had failed to get it over to myself. Only through interaction with the other finalists, discussions with colleagues, and further consideration of the points raised, have I been able to bring it to a proper focus.

All of the finalists had interviews with the judging panel, and then just five minutes in front of a live audience (including the judges) to make their main point. It was probably the first and only time in our lives that we were giving talks worth a potential one million US dollars per minute.

The three eventual winners (GCF 2018B) were those who best convinced the judges that they had a practical approach to improving fairness in decision-making (see Box overleaf).

[4] Stephen Hill, FRSN, a former Regional Director of UNESCO, adds a caveat that "At HQ level relations with other Agencies are in self-contained silos and direct relations only occur at the very top (above the 'knowledge-band') + staff are too often embedded in their own internal bureaucratic process and rewards. The Field is however very different. … the 'Country Team' — heads of all Agencies — meet at least weekly and work in close cooperation."

Brief Extracts from Summaries of Winning Proposals
(see GCF 2018A for more detail)

1. A New Shape: helping the UN to do itself out of a job — Natalie Samarasinghe

"The model proposed brings businesses, Non-Governmental Organizations (NGOs) and young people into UN governance structures, taking the International Labour Organization (ILO) as a starting point. Concurrently, the UN would transfer its development-related tasks to these stakeholders, who would bid competitively for contracts."

2. Global Governance and the Emergence of Global Institutions for the 21st Century — Augusto Lopez-Claros, Arthur Dahl & Maja Groff

"The submission proposes a revised United Nations Charter, instituting a reformed UN General Assembly directly elected by popular vote and a second civil society-focused chamber. ….. A new Bill of Rights is to prescribe the parameters for UN action, and the global human rights will be upheld … by an International Human Rights Tribunal. A new funding mechanism would link members' indirect tax revenues to the UN budget in a fixed proportion."

3. AI-supported global governance through bottom-up deliberation — Soushiant Zanganehpour

"… this proposal suggests combining a blockchain-based global identity system with an AI-based collaboration platform to fuel citizen collaboration and ideation around policies and budget suggestions, as the entry point for decentralized citizen participation in governance. … The technology supports the creation of new local and global institutions to help create relevant and pragmatic solutions for stewarding local, national, and global commons."

All are excellent in their way, and fitted the criteria of fairness and implementability. But this has just been a first step. Now it is time for the next step; that of adapting the suggested approaches (not necessarily just those of the winners) for *effectiveness* in the face of the dangers of networked catastrophic risks.

Whatever the approach may be, it has to be capable of:

1) Watching for warning signs in time to take evasive action (for example, reducing carbon emissions to avoid the worst of anthropogenic global warming).
2) Flexibility to act fast and decisively when catastrophic change threatens.
3) Deciding *in advance* on the balance of investment between trying to maintain the *status quo* or adapting to new circumstances after a critical transition has occurred.

Certainly the United Nations, a spider with 15 legs,[5] needs reform, being too slow and too unbalanced. It is also fair to say that reform may not be enough, and that a revolutionary approach to global governance may be required to establish both flexibility and fairness in the face of global catastrophic risk.

This is especially so because of the obvious disparity between the time between when warning signs become sufficiently clear to be heeded, and the time-scales over which most current human institutions are able to make decisions and take effective action (Fisher 2011). This disparity is accentuated when cooperation between self-interested individuals, organizations or nations is required. The difficulties are described, but

[5] The UN has 15 specialized agencies, *none* of which has a specific remit to address global catastrophic risks.

unfortunately not resolved, by the insights of game theory, which concludes that "through following the logic of self-interest, they have somehow landed everyone in a position where self-interest is the last thing that is being served" (Fisher 2008).

My proposal of an insurance-based approach (Fisher 2017b) went some way towards addressing these issues, although the idea of dumping a large chunk of the United Nations and replacing it with a flexible and responsive insurance company did not find favour —partly because the image of an insurance company suggests a profit-making institution, even though I was at pains to emphasize that this was not what I was proposing.

I am still of the opinion, however, that some form of insurance-based thinking is the best way to cope with interconnected global threats. I suggested as much in an article for actuaries (Fisher 2017c), where I argued that "the insurance industry, and its actuarial practitioners, [should adopt] a *proactive* rather than a *reactive* approach" in helping society to deal with networked systemic risk.

I pointed out to an assembly of industry CEOs (Fisher 2017d) that the insurance (and, especially, the reinsurance) industry as it currently exists can help to deal with global systemic risks by adjusting premiums to favour customers that are taking positive action to help reduce the risks. In fact, if it does not do so, the industry itself is liable to collapse when disaster strikes.

We cannot, however, rely on the insurance industry *per se* to help plan for social justice, or even social survival, in the face of imminent catastrophe. For this we need to introduce a new way of thinking into existing or new social governance institutions — one that is based on *understanding* and *evidence* rather than power and profit (Fisher 2018).

Many of the entries in the Global Challenges New Shape competition suggested structures where new ways of thinking could be made possible. What is needed now is for concrete proposals as to how such structures could be adapted to face the real questions posed by interconnected global threats. Perhaps evolution is possible. Perhaps revolution is the best way forward. But find a way forward we must, because the threats are already upon us. It is only a matter of time, and we do not know how much of that we have.

Where Do We Go From Here?

A new or modified institutional framework must be capable of making fast decisions, and taking fast and effective action in response to three major problems: the predictability of individual risks; the unpredictability of interlinked risks; and the decision of whether to invest in maintaining the *status quo* or adapting to changed circumstances.

Problem 1: Predictability of Individual Risks

The first and obvious problem is to deal with threats whose consequences are predictable.

The success of the Montreal protocol (Rae 2012) shows that it *can* be done. When the threat of the ozone hole became apparent thirty-odd years ago, nations cooperated *via* the protocol to phase out CFCs and other ozone-depleting substances.

The protocol generated cooperation through networking. It set compliance targets, and provided advice and resources to help developing countries meet those targets. It also had the proviso that signatories should not trade with non-signatories. That made

it very tough for smaller countries not to sign up, once the big countries had agreed to cooperate.

The keys to the success of the protocol were that:

i) the evidence had become compelling
ii) large and powerful nations recognized that there was an immediate threat that superseded national interests and required international cooperation to resolve
iii) alternatives to CFCs were available
iv) international cooperation was driven through a combination of carrot and stick

Why, then, did the Kyoto protocol for the reduction of carbon emissions fail?

According to Norwegian and German researchers (Hovi et al. 2010), it was because at least one powerful nation (the U.S.) did not meet condition ii), and said so in the famous (or infamous) Byrd-Hagel resolution of the U.S. Senate (Congress 1997–1998):

> that the United States should not be a signatory to any protocol … which would: (1) mandate new commitments to limit or reduce greenhouse gas emissions … unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period; or (2) result in serious harm to the U.S. economy.

We are now in the murky area of game theory, where sectional interests (such as the coal industry in U.S. states, both Democrat and Republican) trumped global cooperation, to the long-term detriment of all concerned.[6] In fact, Hovi et al. invoke Putnam's (1988) two-level game theory as part of their explanation that political appearance mattered more than reality to US negotiators, Clinton and Gore.

Ultimately, coping even with individual risks requires convincing governments that there is an immediate threat that supersedes national or sectional interests. This is not an easy matter when questions of political power supervene, whether these questions involve cooperation between nations or the actions of supranational assemblies such as the UN.

Insurance-based thinking provides a possible solution. Insurance companies are concerned with defense against risk, and avoiding loss in the face of risk — just the sort of thinking that we need when faced with global catastrophic risk.

How that sort of thinking can be introduced into the international arena is a matter to be considered. But introduced it surely must be, especially in the light of:

Problem 2: Unpredictability of Interlinked Risks

According to analyst Flaviano Morone and his colleagues (Morone et al. 2018) "Collapses of dynamical systems into irrecoverable states are observed in ecosystems, human societies, financial systems and network infrastructures. *Despite their widespread occurrence and impact, these events remain largely unpredictable* [author's emphasis]".

It is worth quoting *in extenso* the comment in the recent review by Reyers et al. (2018), which should be required reading for politicians and policy-makers at all levels:

[6] It may be that even the Montreal Protocol is being damaged by sectional interests, since there is evidence that CFCs are still being manufactured and released by some countries in contravention of the protocol, although other explanations for the recent rise in atmospheric concentration are possible (Rehm 2018).

> SES [Social-Ecological Systems] research highlights that the properties, behaviors, and trajectories of complex SES cannot be determined by the microlevel social or ecological entities or subsystems and their properties alone. In SES, agents or entities interact, and from such interactions macrolevel patterns with new properties emerge, which then feed back on the system and influence the microlevel interactions of the agents … . This interplay between the adaptive responses of the entities and the emergent properties of the system implies that SES are more than the sum of the ecological or the social "parts." It is only through a focus at the macrolevel of emergent phenomena that explanations of things such as resilience as a system property, tipping points, the evolution of norms, or adaptive capacity, which are crucial to sustainable development, are offered. *Shifts to policy interventions, targets, and adaptive management, which acknowledge and are based on the system's irreducible complex structure, are proposed for sustaining desirable system outcomes* [author's emphasis].

A great deal of effort is now being put into understanding the role of connectivity in the sudden collapse of social-economic-ecological systems (Turnbull et al. 2018), but we are far from a complete understanding. Morone et al. (2018) believe that a topological invariant known as the *k*-core may hold the key, and understanding network behaviour from this perspective may be a useful guide to policy.

Sometimes we may be able to use this understanding to control the occurrence of a particular tipping point. This has been achieved in practice in relatively simple environments such as freshwater lakes (Pace et al. 2017). But the bald fact remains: in dealing with complex, interconnected threats, we must constantly be prepared for the risk of the unexpected. As Carl Folke and his colleagues from the Stockholm-based Resilience Alliance have argued (Folke et al. 2010), and as the World Economic Forum has also spelled out (WEF 2018), *resilience* is a major key to effective preparation.

Problem 3: Investment in Resilience

But what is resilience? There are more than 70 definitions in the literature (Fisher 2015). These vary between two extremes, with most trying to achieve a balance between the two (de Bruijn et al. 2010).

At one extreme, resilience is defined as the ability of a system to bounce back after stress, thus maintaining the *status quo*. This is the definition implicitly used by the World Economic Forum in its reports, and also by many authors concerned with environmental protection.

At the other extreme, resilience is seen as "the capacity of social–ecological systems to adapt or transform in response to unfamiliar, unexpected and extreme shocks" as proposed. This is the definition proposed by a group of distinguished scientists that includes ecologist Stephen Carpenter and the late economics Nobel laureate Kenneth Arrow (Carpenter et al. 2012).

Kupers (2018) names these two extremes respectively as "structural resilience" and "transformative resilience," and also identifies an "in-between" situation as "integrative resilience."

Unfortunately, most users of the term fail to specify what they mean by resilience. The Dutch hydrologist Ruben Dahm and his colleagues, for example (Dahm 2014), speak of the need "to increase [delta] cities' resilience to flooding". They propose several strategies,

including "developing urban infrastructure to decrease the effects of extreme rainfall" and "building in harmony with natural-systems dynamics". The first strategy is clearly aimed at maintaining the *status quo*, while the second is more concerned with adaptation in the face of the inevitable.

To recover, to adapt or to invest in both possibilities? Structural, transformative or integrative resilience? All make sense in the right context. We might want a city to recover from flooding, for example, or the world to adapt to the inevitable effects of climate change.

Long-term policies to promote either recovery or adaptation, or to prepare for both, are likely to be very different, and need to be put in place in advance.[7] This is where insurance-based thinking could come into its own, quantifying and continually updating the assessment of the relative risks, and preparing investment strategies accordingly.

It is a very different way of thinking from that currently in vogue among politicians, who are more concerned with offering (false) certainties based on dogma rather than reality. But the reality of interconnected threats, and of consequent sudden, society-wide global change is what we must face.

There is already some discussion within the industry about insuring against climate risk (Swann & Millar 2016; *Economist* 2018), with considerable evidence that the economic risks have been severely underestimated by the market (Stoerk et al. 2018). Just the name of the journal in which this last piece of work was published (*Review of Environmental Economics and Policy*) reflects the fact that policy-makers are still not taking account of the potentially serious interaction between environmental and other threats.

The insurance industry as present constituted does not provide an answer, since it is primarily concerned with short-term profits. Annual premiums don't encourage long-term thinking, and the industry in any case tends to be *reactive* rather than *proactive*. A pragmatic, insurance-based way of thinking about the interconnected risks of global catastrophic change, and preparing a balanced investment portfolio to cope with the changes is, however, surely a first, essential step for the governments, NGOs and inter-governmental organizations which are responsible in large measure for our future welfare.

Conclusion

The Global Challenges New Shape competition sought suggestions for new approaches to the governance of global threats. My approach was based on the premise that interconnection between global threats constitutes a particularly serious threat to humanity's future well-being, and even survival. Interconnection means that the threats form a complex adaptive network, with many, constantly changing, feedback

[7] Again, it is worth quoting *in extenso* from Reyers et al. (2018): "Social-ecological coevolution theories emphasize that diverse social and cultural contexts will shape, and be shaped by, diverse ecosystems in complex and continuous ways. The resultant diversity is the focus of much SES research, which emphasizes the importance of diversity in actors, ecosystems, institutions, and social-ecological interactions as sources of resilience. These sources create and enhance the novelty, knowledge, behavior, and strategies required to respond to shocks or ongoing change. *The relationship between diversity and resilience is, however, not linear* [author's emphasis]. Concepts such as response diversity, functional diversity, and redundancy are linked to tolerance of change, renewal and adaptation to change, as well as opening up pathways for transformation. Leslie & McCabe (2013) highlight the role of response diversity in human actions and decisions to the resilience of SES and thus to sustainable development in the Anthropocene."

loops. Such networks can collapse or change rapidly to a very different state through three mechanisms:

1) Unexpected consequences of small deliberate changes in some part of the network
2) Rapid transmission and amplification of small unplanned fluctuations in some part of the network
3) Unpredictable emergent behaviours of the network as a whole

Some progress has been made in identifying warning signs for imminent critical events, but most human institutions have been unable to respond effectively by the time that the warning signs become sufficiently obvious.

We thus need a new way of thinking; one that uses network science and forward planning to avoid critical transitions where possible, but which also has the capacity to make and implement rapid decisions when critical transitions become inevitable. Those decisions concern resilience, and the balance between investment in recovery after an event, or investment in adaptation to the new circumstances.

I believe that insurance-based thinking provides a possible solution. Insurance is concerned with defence against risk, and avoiding loss in the face of risk — just the sort of thinking that we need when faced with global catastrophic risk. This is not to suggest that traditional profit-oriented insurance companies should be involved — simply that the same style of thinking should now lie at the core of the governance structures responsible for our future safety and well-being in the face of global catastrophic risks.

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