
Tackling tipping points

Professor Tim O’Riordan FBA and Professor Tim Lenton explain the importance of ‘tipping points’ in understanding convulsive change in the world, and offer a manifesto for creating ‘benign’ tipping points to prepare us for future shocks.

Setting the scene

The phrase ‘tipping point’ is gaining popularity, and might ironically have undergone its own tipping point in usage. Tipping points are processes of dramatic change, with their own timescales of onset and transformation, which are often abrupt with unpredictable consequences when seen from a human perspective. Tipping points may manifest themselves across the whole globe, regionally, or locally. They may come in the form of planetary processes, of ecosystem transformations, of military, terrorist or convulsive political action, or of shifts in cultural outlooks and social behaviour.

But this plurality of uses can readily undermine any meaning ‘tipping points’ carries, causing confusion and producing a predictable academic backlash. In response, a recent British Academy/Royal Society seminar regarded tipping points as metaphors for interpreting unexpected, abrupt transformations, using the medium of narrative and creative imagination, but also based on scientific observation and modelling. Thus, tipping points are means of dealing with causes and consequences that are out of the range of ‘normal reasoning’ and expectation.

This conceptualisation was epitomised in the run up to the seminar. In a preliminary meeting held at the British Academy on 4 January 2011, one of the presenters called for the need for a ‘revolution’ in our relationship with the Earth system, and was somewhat ridiculed for being the first person to talk about ‘revolutions’ at the British Academy in decades! Within weeks the Arab Spring had budded, and by the time we met again in April at the Kavli Royal Society International Centre, everyone was talking about unexpected revolutions.

The Kavli seminar characterised tipping points in three ways. The first relates to the science of global physical and social systems, their measurement and predictability, singly or in combination. The second applies to the social science of governance and the means of anticipating and adapting to possible shifts in system states. The third addresses the creative processes of reconstructing social behaviour and mores, which either lessen the likelihood of potentially threatening states ever taking place, or increase the resilience and adaptability of societies to adjust to them.

Lying behind this framing of tipping points is a set of propositions. Firstly, we may be creating conditions of economy, of government, of social conditioning, and of

ethics, which actually contribute to the likelihood of tipping points occurring in physical and social conditions. Secondly, the ways in which we seek to adapt, because of this inbuilt tendency toward greater vulnerability, also lead to more intense combinations of both social and physical or ecological stresses. Thirdly, we have yet to find suitable means for communicating the various narratives, giving meaning to tipping points in all of their manifestations, which can then lead to constructive adaptation.

However, our final proposition is that it remains possible for a series of ‘benign’ tipping points to be combined, so as to prepare society for new approaches to preparation and adaptation that can stave off the onset of ‘malign’ tipping points, in favour of robust, resilient and accommodative social values; fresh approaches to appropriate behaviour; and more flexible and considerate governing procedures.

What are tipping points?

Little things can (sometimes) make a big difference, as Malcolm Gladwell’s book that popularised societal tipping points argues.¹ Mathematicians, with their concept of a bifurcation point describing a sudden shift in system conditions, have known this for centuries, as have physicists fascinated by phase changes of matter. More recently ecologists have borrowed from bifurcation theory in order to describe ‘regime shifts’ in ecosystems. Gladwell takes his cues from epidemiology, and the theory of infection spread, which has different underlying mathematics. Dynamical systems theory encompasses these and other classes of physical phenomena, which all share a common feature; a small change within, or from outside, a system can cause a large change in its future state.

Thus, from a scientific perspective, a *tipping point* is a critical threshold at which the future state of a system can be qualitatively altered by a small change in forcing. Tipping points can conceivably occur in any spatial scale of system which has strong non-linearity in its internal dynamics. A *tipping element* is a part of the Earth system, at least sub-continental in scale, which has a tipping point. Policy-relevant tipping elements are those that could be forced past a tipping point this century by human activities. In the language of the Intergovernmental Panel on Climate Change (IPCC), they are called ‘large scale discontinuities’, and are one type of dangerous human interference in the climate system.

¹ M. Gladwell, *The Tipping Point: How Little Things Can Make a Big Difference* (New York: Little Brown, 2000).

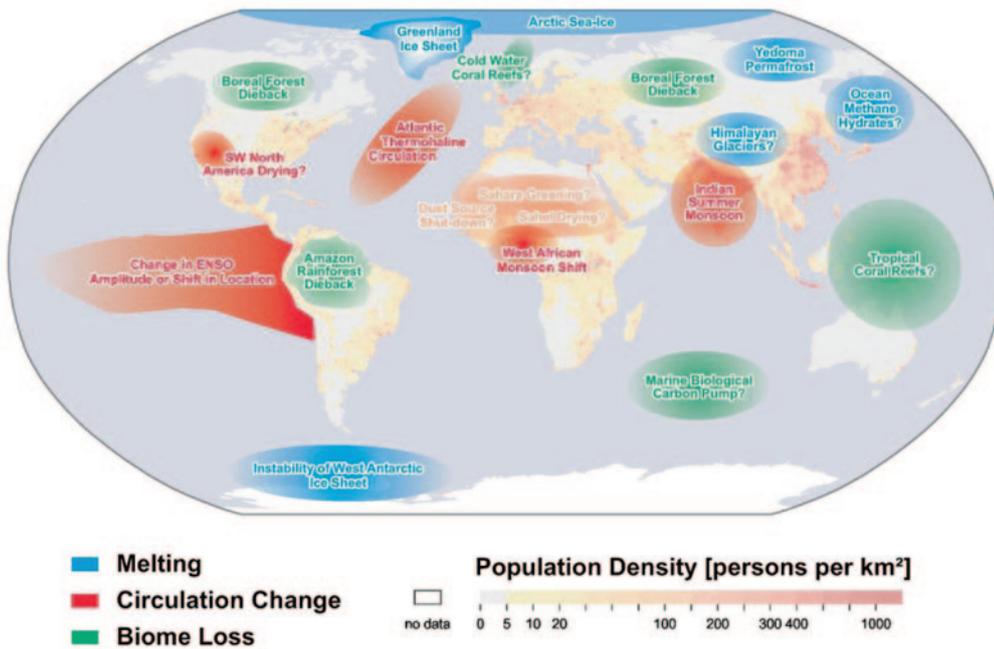


Figure 1. Map of potential policy-relevant tipping elements in the Earth's climate system overlain on population density. Question marks indicate systems whose status as tipping elements is particularly uncertain. (Figure by V. Huber, T. M. Lenton and H. J. Schellnhuber.)

A shortlist of potential policy-relevant tipping elements in the climate system has been drawn up,² which could pass a tipping point this century, and undergo a transition this millennium under projected climate change. They are shown, along with some other candidates, in Figure 1, where the tipping elements are grouped into those that involve ice melting, those that involve changes in the circulation of the ocean or atmosphere, and those that involve the loss of forests and other biological complexes.

We should be most concerned about those tipping points that are nearest (least avoidable), and those that have the largest negative consequences. Generally, the more rapid and less reversible a transition is, the greater its impacts. Also, any amplification of global climate change may increase concern, as can interactions whereby tipping one

element encourages tipping another, potentially leading to 'domino dynamics'.

Figure 2 provides an assessment of the likelihood of tipping nine different tipping elements, in the range of possible increases of global temperature over the rest of this century. Current assessments suggest that Arctic tipping points involving ice melting are probably most vulnerable, with the least uncertainty surrounding eventual occurrence. However, the greater uncertainty surrounding other tipping points allows for the possibility that some of them may be close as well.³

These two diagrams briefly summarise the current state of knowledge of the set of Earth system 'dangers' facing humanity during the coming century. But it can be misleading, and indeed even disingenuous, to equate the

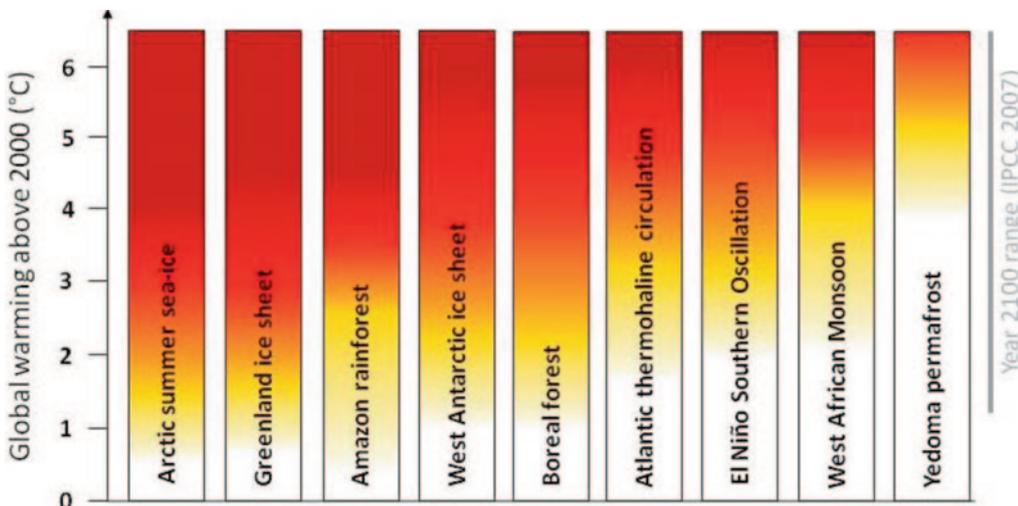


Figure 2. Burning embers diagram for the likelihood of tipping different elements under different degrees of global warming. (Figure by T. M. Lenton and H. J. Schellnhuber.)

² T.M. Lenton *et al.*, 'Tipping Elements in the Earth's Climate System', *Proceedings of the National Academy of Sciences USA*, 105 (6), 1786-1793 (2008).

³ More detailed information can be found in the results of an expert elicitation, which extracted and aggregated imprecise probability

statements from experts in a process of dialogue and reassessment. E. Kriegler *et al.*, 'Imprecise probability assessment of tipping points in the climate system', *Proceedings of the National Academy of Sciences USA*, 106 (13), 5041-5046 (2009).

mathematical and system-based dynamics of natural phenomena, to social arenas such as financial markets, inter-governmental relations, or human behaviour. Quite distinct formulations of tipping points are needed for any aspect of human affairs. Yet there is a form of interpretation, or narrative, here that connects system dynamics to social conditions. One of these communicating themes is *resilience*, another is *predictability*, and a third is *preparedness*.

Resilience and early warning

Resilience is found in many ecological states that are temporarily stressed by, say, shifts in weather or by pest invasions. Numerous field studies and modelling exercises have shown that natural ecosystems have inbuilt mechanisms to facilitate a return to their original state. This is easiest to see where there is no additional external pressure, e.g. human intervention. However, resilience is not infinite, and human pressures can drive ecosystems past tipping points into alternative states. In such scenarios, resilience is steadily lost before the tipping point occurs. Afterwards it becomes much harder to return a 'tipped' ecological state to its earlier condition.

Crucially, the zone of declining resilience that takes place before a tipping point occurs produces identifiable early warning signals. Two indicators are being pursued by researchers. One is a slowing down of the rate of recovery following a perturbation. The other is an increase in the variability of a system. Of the two, slowing down in response to perturbation is the most general property of systems approaching various types of tipping point.⁴

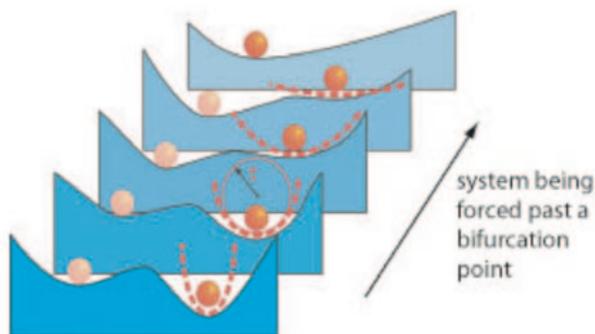


Figure 3. Schematic representation of a system being forced past a bifurcation point. The system's response time to small perturbations, is related to the growing radius of the potential well. (Figure by H. Held and T. M. Lenton.)

To visualise this, picture the present state of a system as a ball in a curved potential well (attractor) that is being nudged around by some stochastic noise process, e.g. weather (Figure 3). The ball continually tends to roll back towards the bottom of the well – its lowest potential energy state – and the rate at which it rolls back is determined by the curvature of the potential well. As the system is forced towards a bifurcation point, the surface of the potential well

becomes flatter. Hence the ball will roll back ever more sluggishly. At the bifurcation point, the potential becomes flat and the ball is destined to roll off into some other state (alternative potential well).

Slowing down can be detected as increasing temporal or spatial correlation in data, increasing memory, or a shift to greater fluctuations at lower frequencies. Such signals have been successfully detected in past climate records approaching different transitions, and in model experiments.⁵ This offers the prospect of probabilistic forecasting of some conceivable future climate tipping points, especially if such statistical early warning indicators can be combined with dynamical modelling. However, not every type of abrupt transition carries early warning signals. We need to be aware that the Earth system can sometimes bite without growling beforehand.

Societal early warning

Early warnings of tipping points in social, economic and governmental activities are inherently more difficult to spot. It may be possible to witness unstable fluctuations, or vulnerable networks of communication and responsiveness.⁶ These were recognised, retrospectively, in the run up to the banking and financial crises of 2008/9, but no explicit early warning was given. Furthermore, the banking world seems to have proved highly resilient, even to the point of raking up huge profits and paying out massive bonuses on the back of assured support funding from taxpayers. Its resilience, it seems, is not inherent, but awarded by political necessities and economic dominance.

Predicting how human behaviour or institutional response may shift in relation to any given destabilising agent is largely beyond modelling, although some analysts of complex systems are trying to do just this.⁷ What can be tackled, however, is better provision of targeted information concerning the resilience of institutional design, of management structures, and of communications procedures, so that socially just and sustainable approaches to adaptation can be put in place before it is too late. Network theory and ecology can help here, but really there is no substitute for good case history of successful practice.

We are particularly concerned with tipping points that involve combinations of stressed or unstable social and economic patterns, coupled to steadily more unstable Earth systems processes. For example, the viability of soil, fresh water, and marine life to maintain the food requirements of an increasing human population, some of whom are becoming wealthier and demanding more of the natural world in their changing diets. Or the scope for deep economic and social instability linked to rising costs of obtaining energy and declining availability of other commodities, in the context of widespread indebtedness and likely debt restructuring.

We need to clarify the evidence for instability in both human and natural conditions, especially where there is

⁴ M. Scheffer *et al.*, 'Early warning signals for critical transitions', *Nature*, 461, 53-59 (2009).

⁵ T.M. Lenton, 'Early warning of climate tipping points', *Nature Climate Change*, 1, 201-209 (2011).

⁶ R.M. May, S.A. Levin & G. Sugihara, 'Ecology for bankers', *Nature*, 451 (7181), 893-895 (2008).

⁷ For example <http://www.er.ethz.ch/>

early warning of convulsive change (see Figure 4). This suggests more effort should be placed on:

- identifying possible early warning signs of longer recovery times, increased variability, and skewed distributions leading to tipping points, and lag effects between an initiating force and a consequent reaction (such as lowering of catch rates for increased fishing activity);
- clearer communication of both the modelling and the measurement of natural system tipping points, by means such as better informed 'risk matrices' of possible dangers, or through carefully phased procedures so as not to cause false alarm or unhelpful denial;
- preparing better for resilience in both the management of natural processes and natural resources, as well as for more social justice in response efforts, with appropriate means for monitoring and reporting for the most endangered species and vulnerable humans;
- creating appropriate social, economic and governmental institutions that can design and implement significant adjustment in the face of combinational tipping points;
- recognising where power and institutional brittleness or 'lock-in' impedes the sensitivity for recognising early warning, and any indigenous capability for building in resilience;
- addressing the consequences of technological 'lock-in', or 'sunk costs', where too much financial commitment is made to investments that impede more adaptable solutions;
- communicating the benefits of early action and the advantages of preparedness, whether in terms of future costs saved, or in political favour, or through more malleable institutional arrangements.

Barriers to adaptation

If we can work through the various metaphors of thresholds, bifurcation and convulsion, we then need to address the complementary thresholds of adaptation, accommodation, and adjustment to the unfamiliar. The Intergovernmental Panel on Climate Change regards adaptation as having three purposes: to reduce exposure to known or possible hazard; to develop a capacity to cope with unavoidable damage (the costs that cannot be removed by reduced exposure); and to take advantage of new forms of living and governing, so as to seek to redesign tipping point 'threat' out of the system. The process of adaptation can be *spontaneous*, namely inbuilt autonomous and reactive; or *planned and managed* through deliberate policy decisions and investments based on reasonable precaution or prediction; or *anticipatory* in that there is long term accommodation of human activity and behaviour.

However, there is currently little institutional clarity for any meaningful and comprehensive approach to adaptation and the removal of vulnerability. Institutions have grown too complex, the removing of disadvantage and injustice in any human condition is deeply difficult, and there is huge political and economic investment in 'sunk costs'.⁸ For example, it may be heroically expensive, and possibly crippling to recession-sensitive economies, to replace the current energy grids of pipes and power lines with the interconnected 'smart grids' of a fully renewable energy age. Current nationally protected energy markets may not be able to transform themselves into region-wide multinational power-conveying systems, where sharing both energy and costs would cross national borders. Established notions of national citizenship might politically preclude multinational shared energy pricing and subsidy.

There is also an individual and group psychology promoting 'lock-in' and societal vulnerability. Self justification, cognitive dissonance (by justifying the incongruous and self-evidently false, to protect reputation and in-group solidarity) and denial, especially when confronted with a common threat, are all important. Together they result in a gambler-like tendency to commit to failing bids, to procrastinate, or to continue with small and incremental maladjustments, even in the face of group calamity.

Human patterns that rely on large settlements, now the dominant norm, are vulnerable to the sheer inertia of rapid adjustment. The possibility of parts of the West Antarctic ice sheet collapsing over a period of decades, with concomitant rises of sea level of a metre or more (unlikely but not unimaginable), would place megacities such as Shanghai, Dhaka, Jakarta and Mumbai in an adaptation pickle. There is at present no institutional machinery for dealing with food provision, fresh water, transport or waste, to say nothing of the relocation of many millions of people dependent on many forms of well established community and family structures, in the timescale of a couple of decades. To seek to do so with fairness and justice, whilst aiming at giving everyone the opportunity of adopting sustainable livelihoods is almost unimaginable. Indeed the very models of development, as evident in modern China, are reinforcing vulnerable patterns of force-fed urbanisation to the detriment of more accommodative small settlements. Sunk costs deliver vulnerability, institutional brittleness, resource over-exploitation, denial of impending collapse, and deep inequality. These are all mal-adaptive and can induce favourable conditions for tipping points.

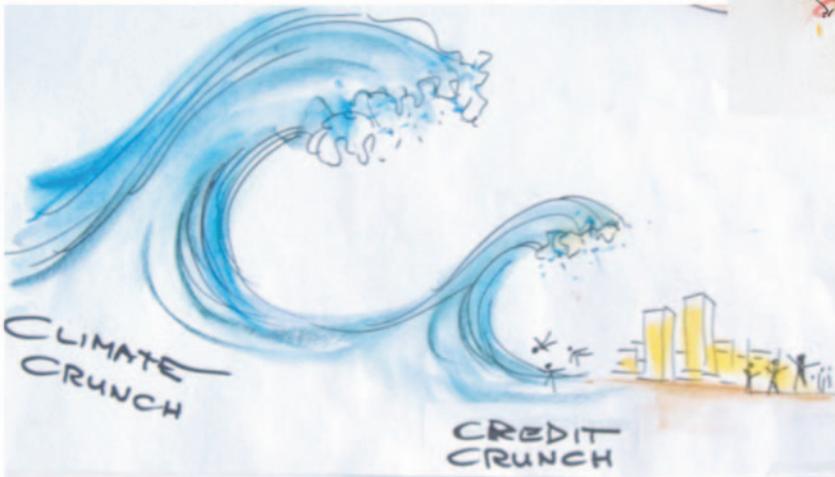
The literature on the collapse of earlier human settlements seems to settle on the role of adverse events (even when predictable); the excessive size of collapsing settlements; and on evidence of over-exploitation of resources immediately before catastrophic deficits. All of this suggests that the metaphor of adjustment, either through planning and management, or by anticipation and pro-activity, may be very difficult to implement for resource-intensive, high-density, rapidly developing, and

⁸ Marco A. Janssen, Timothy A. Kohler & M. Scheffer, 'Sunk-Cost Effects and Vulnerability to Collapse in Ancient Societies', *Current Anthropology*, 44 (5), 722-728 (2003).

Tipping points and human perspectives

We need to observe the tensions building up

We need to work out which out of many is going to tip



It's a tipping point !!!

No, it's part of an ecological cycle !!

And how come we didn't see it coming??

Who hid the signals and why??

Resilience vs lock-in

Is it a clash of paradigms, or just a complex system ??

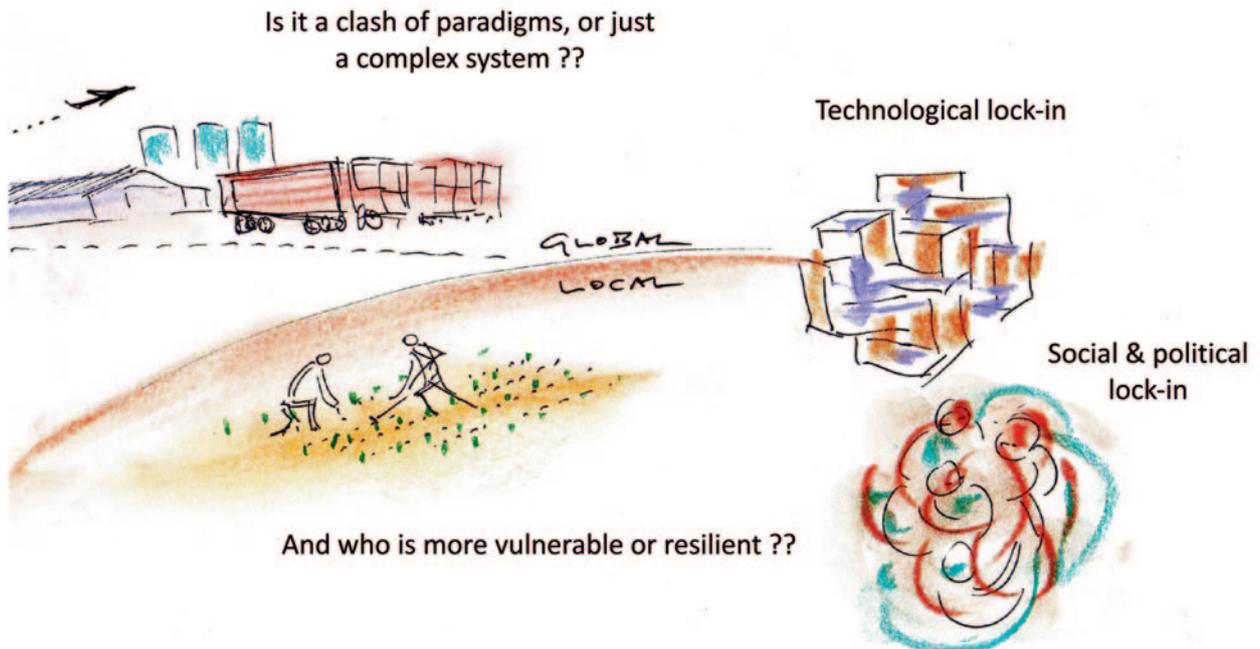


Figure 4. Two of the slides in which Dr Joe Ravetz (University of Manchester) sought to capture in 'A Visual Journey' some of the concepts discussed at the April 2011 seminar. The authors are very grateful to Dr Ravetz for allowing them to include the slides here.

information-technology-dependent societies – the very conditions being replicated on a daily basis in the contemporary world. So it is possible that we are creating the very elements of destabilising tipping points in our maladaptive responses.

Islands of successful transformation

There is no single template for anticipating and adjusting to tipping points. Tipping points come in all types of places, of cultural histories, and of social and economic conditions. So we need to follow examples of successful anticipation of, and adjustment to, impending tipping points, in order to offer the best set of learning experiences for others to follow. There is therefore a case for a constructively portrayed tipping point website that discovers and explores these ‘islands of successful transformation’; a website that tells us just how tipping points were characterised, pursued, thought through, and communicated for appropriate and democratically agreed accommodation and adjustment. There is, as yet, no dedicated arena for sharing experiences of successful ‘benign’ tipping points at regional and communal scales.

Such a communications channel should cover:

- the appropriate conditions for addressing the likelihood of tipping points;
- region-based governmental responses,
- the warning signs, especially for combined natural and human-induced tipping points;
- the communications approaches for informing society, government and markets;
- the use of schools, the media, community networks, social networks, and other discourses such as the creative arts, to outline the benefits and consequences of action and non-action, in ways that are supported by those who might not usually respond positively;
- monitoring responses for both resilience and fairness, as well as for ensuring that the outcomes are not likely to create malign tipping points.

All of these features should help to open up the dialogue on tipping points, in order to foster better understanding and more confident ways of responding.

Currently, it is not proving easy to communicate the possibility of dangerous tipping points. The loss of public interest in climate change is but one case in point. Telling the same story too many times creates apathy, disinterest, boredom, or even resentment. Changing the nuances of the story carries the danger of confusion, bewilderment, loss of focus, and disorientation, all of which can prove counter-productive. There is no simple solution to this dilemma, which seems to be inherent in the ways in which communications media address the concept of tipping points. However, there is a case for a much more positive portrayal of the gains and advantages for everyone of timely anticipation.

It also means making much more use of social networking, so that people can talk to each other with inventiveness, imagination and experimentation. It is just possible that the technology of the emerging age will enable ‘localism’ within mega-structures to flourish, so that communities can design their capabilities and renewal in their familiar spaces and comfort zones. The ‘village urban’ could come of age.

Leaders as agents of transformation

Without leadership there can be no effective ‘islands of successful transformation’. The most effective leadership is a combination of the individual and the communal, linking the present to the past and the future in a continuous creative flow. Leadership means providing for confidence, for capability, for the flourishing of innate and learned qualities of virtue and goodness, and for the empathy of compassion and solidarity.

The aim is to create the conditions for learning individually and collectively, in forms that provide the skills to shift behaviour as well as the incentives and infrastructures that enable everyone to change their outlook, moral positioning, and behaviour. This means in turn giving people the tools to think ahead, to be more strategic in their lives, to be ready to learn from others, and to be confident in their positive deviance. One focus for attention is to ensure that locally fashioned solutions are not impeded by global multi-national structures of finance and disincentives that block valuable innovation and community-supported behavioural change.

Adapting institutions for transformation

Successful adaptation to tipping points cannot be achieved by existing institutional arrangements. Whether in governing, in market formation, in social communication, or in guidance for futures beyond the horizon, current institutions will need to be merged, reformulated, reconstructed and redesigned. This means a willingness to try the unknown, to experiment with innovation, to measure differently, and to monitor with justice in our sights. There needs to be a process of ‘institution appraisal’ for coping with tipping points in all of their variety, unusualness and unexpectedness. In particular, the markets and the pay-off to shareholders will require adjustments to be sure that any gain today does not compromise betterment for future generations. The building in of advance preparedness in markets, in pricing, in hedging, and communicating the richness of foresight, will be a true test of institutional transformation.

We need more examples of experimentation in governmental forms. There is much ‘out there’ to be explored. Adaptive governance is both socially fair and socially trusted – two elements of state governing that are in very short supply. Ensuring human dignity in adaptive governance is a vital aspect of the process of devising benign tipping points. We need the eyes and the wisdom to see

these early shoots of innovation. They are unusual and hence not always easy to spot in the cacophony of the status quo. Here again there is an urgent need to reconnoitre and to report through the 'islands of successful transformation' learning process.

Conclusion

The transformation we call for may not be possible in present arrangements of social existence and economic development. Perhaps current models of governing, of power relationships, of path dependency and of markets, critically impede such transformational narratives. We need to reveal just what bifurcations can be anticipated and designed, at least experimentally, just to see what is possible, even in a world of impossibilities.

As we have noted, this will require leadership of quite an unusual kind – leadership that is deviant from normal managing styles, where social enterprise of a more imaginative and experimental kind is permitted to emerge and to be tested and supported. It means a willingness to accept the learning and adaptiveness of failure, both on an individual and collective level. It suggests the creation of service provision and of infrastructure that has capacity to cope with unusual and unexpected circumstances. It means a willingness to create 'benign sunk costs' that deliberately adjust to maximise adaptability.

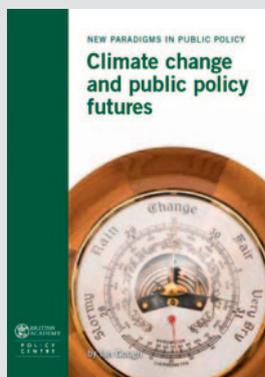
Tipping points are metaphors. They convey scientific rationality, they encourage creativity, they engender

storytelling, and they alert us to our inherent failings and mal-adaptive practices. Tipping points will test democracies: from being electoral to ecological, from pursuing the immediate and the gratifying; to preparing for fairness and accommodation: to seeing the spiritual in the behavioural; and for shaping together a localising and globalising world that can endure.

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The British Academy and Royal Society seminar on 'Tipping Points' was held at the Kavli Centre on 13-14 April 2011. The meeting involved 35 distinguished participants, and 15 presentations were given from a very wide range of perspectives – from the scientific modelling of Earth systems to economics, politics, communications, governance, spirituality, and human behaviour.



Climate change is one of the great global policy challenges that humanity faces. As part of the British Academy Policy Centre's *New paradigms in public policy* project, Professor Ian Gough addresses the issues it raises for the UK in his report *Climate change and public policy futures*, published in July 2011.

Gough lists four impacts of climate change on the public policy environment in the UK: direct impacts in the UK, the

results in the UK of impacts overseas, the impacts of adaptation policies, and the impacts of mitigation policies.

Climate change mitigation policies (CCMPs) – acting to reduce greenhouse gas (GHG) emissions or increase greenhouse gas sinks – will have the greatest impact in the medium-term on domestic living standards and on UK public policy. And even though the UK was a leading country in achieving reductions in CO₂ and other GHG emissions from 1990 to 2005, it will still be tough to reach the 2050 target, which means the UK needs to 'up' the effectiveness of its mitigation policies.

In theory there are at least three methods of influencing GHG emissions: market incentives; information, education and behaviour change; and direct regulation. Current government policy places an emphasis on economic incentives, but could do significantly more by way of the other two methods.

So how should we proceed? Gough argues that, as a political-economic model, 'green growth' is the most realistic way forward for the UK. While normal economic growth is accompanied by significant carbon emissions, green growth is based on the premise that increased economic activity does not have to mean an increase in such emissions. New technologies, reframed carbon pricing and policies to change consumer behaviour can all help.

Eventually, we may well reach a point where the tensions between growth and our finite planet will lead the West to question the feasibility of pursuing any sort of economic growth. But even before we reach that stage, climate change is unparalleled in the character of the problem it represents, and in its capacity to affect UK public policy.

Climate change and public policy futures is available to download at www.britac.ac.uk/policy/climate-change-and-public-policy-futures.cfm