A Terran perspective on sustainable development

Jonathan Cave and Maarten Botterman

Introduction

The TERRA2000 project examined the sustainability of the Information Society using a set of complementary methodological, disciplinary and temporal perspectives. This investigation highlighted the importance to sustainability analysis of six specific ideas, whose implications are explored in the following[1]. These ideas are:

- Articulation
- Emergence
- Tipping
- Resilience
- Distribution
- Network effects

The balance of the paper develops these concepts as related to the analysis of TERRA2000. It begins by describing the 'TERRA propositions.' And then considers each concept in turn, before concluding with some policy and research implications.

Sustainability in the TERRA2000 analysis

TERRA2000 utilised scenarios and models to develop insight into the implications (for better or worse) of the technological and scientific developments of the Information Society (more concretely, the Global Networked Knowledge Society – hereafter, GNKS) for environmental, socio-cultural and economic sustainability.

These take the form of a set of demonstrable propositions: an overall 'IST proposition,' constituent sub-propositions relating to the individual 'pillars' of sustainability together with an additional 'distributional' proposition that recognises the vital distinction among states that may be satisfactory in aggregate (e.g. a high per capita GDP) as to whether or nor localised failure (relative poverty within affluent counties, for instance) renders them ultimately unsustainable. These propositions are as follows:

> The IST Proposition
>
> The new technologies of the Information Society (ISTs) seem likely to offer scope to enable economic growth, and to allow a more equitable distribution of wealth, without necessarily increasing consumption, pollution and energy use.

Human capital in the information age

"Knowledge and information are now being produced like cars and trucks were in earlier years." But just as the importance of land in production changed dramatically as the economy moved from agriculture to industry, so too does the movement to a knowledge economy necessitate a rethinking of economic fundamentals. In the Information Age trades intellectual rights rather than physical products. It costs far more to develop new products than to produce them. Skilled, talented, innovative and fulfilled people constitute human capital, which fuels economic growth. All people everywhere have the potential to contribute. One major policy dilemma already

[1] More details can be found in the project publications available at www.terra2000.org.

facing decision makers is how to secure the supply of human capital with the declining and aging population.

Economic sustainability propositions
ISTs can catalyse human capital expansion and thus promote sustainable economic growth
Expansion of the GNKS can sustain and diffuse increases in productivity and market efficiency throughout the globalised economic system.

Equity and growth

"Social capital is the glue that holds a society together." Inequality undermines social capital, fuelling illegal acts, crimes, terrorism, etc. ISTs put a premium on highly educated labour as a source of economic growth, while globalisation supported by information technology reinforces the "winner takes all" tendencies of an increasingly information-rich economy. A major dilemma for the 21st century will be how to balance the economic growth needed to reduce unemployment with the reduction of inequality needed to secure social capital.

Social sustainability propositions
While initial deployments of ISTs and 'New Economy' dynamics have tended to exacerbate welfare, digital and/or income 'divides,' the unfolding of a GNKS based on open and universal access can harness the same technological, market and social forces to promote greater equality of opportunity compared either to recent experience or the pre-GNKS era.
The GNKS encourages and influences the processes of globalisation and can foster collective awareness of collective problems, mobilise local responses and promote emergence of new governance institutions to balance local and global problems, incentives and powers to act.
While the mere fact of globalisation – the connection of each to all – does not of itself imply either integration or convergence, ISTs can facilitate mutual awareness and respect.
The GNKS can encourage peace and minimise conflict by substituting a complex interlocking maze of global allegiances for previously narrow tribal and racial allegiances.

Information Age sustainability

ISTs profoundly affect environmental, economic, societal and cultural sustainability. In particular, their environmental impacts may help or hurt 'sources' (life support systems and resources) and 'sinks' (human domination of nature from biodiversity to climate change). On one hand, ISTs bring a burgeoning middle class, increasing consumption loads; on the other, they allow more efficient extraction, accelerating exhaustion and delaying development of substitutes. Rebounds and secondary and tertiary effects are already well understood in some circumstances – but by no means all. Policy issues include informational approaches to enhancing efficiency of resource use, corrective taxation, support for development of alternatives, etc.

Environmental sustainability propositions

Emergent technologies based on information (from ICTs to bioengineering) can dematerialise production and distribution of goods and services by reducing associated material inputs and waste outputs.

The new technologies and the new forms of human interaction they support can lead to substitution of immaterial goods and services for material production and consumption.

Dematerialisation and immaterialisation reduce the opportunity cost (price) of material inputs and environmental sinks and increase the welfare content of income and wealth. The relative price changes can induce substitution of material for immaterial inputs. Increased purchasing power can stimulate consumption of both material and immaterial goods and services. These substitution and income effects can outweigh the benefits of the original changes.

Distributional Impact

Analysis in all three areas described above has largely been concerned with aggregates and averages, even when the phenomena being explained involve comparisons of growth rates, standards of living, rates of environmental decay, etc. Recent theoretical and empirical work strongly suggests that the important relations can best be understood by considering entire distributions or populations. For instance, the distribution of access to inputs (including human capital) can provide a better explanation of growth and convergence than total or average input levels; the welfare implications of inequality are strongly affected by the reference groups considered by people around the world – and thus by those portions of the global distribution in the Information Society spotlight; and environmental sustainability and resilience depend on the spatial and temporal dispersion of economic resource exploitation and discharges. Conversely, the impacts of economic, societal and ecological development on these important distributions can only be understood if the mechanisms of dispersion and differentiation are included in the analysis.

The distributional proposition

Distributions (e.g. inequalities) matter at least as much as aggregates because: i) welfare and incentives are relative; ii) globalisation and the network economy hold out the promise of greater equity while increasing the likelihood that laissez-faire policy will exacerbate divides; iii) different parts of distributions have potentially divergent values and sustainability footprints and responses to policy and economic/political, etc. forces; and iv) network evolution can lead to small worlds, stable diversity, global convergence, etc. with only minor changes in the underlying parameters.

The project used a combination of different types of models (from theoretical and computer-based ‘paradigmatic’ models, through high-level ‘dominant relations models’ through to highly-integrated ‘world models to analyse these propositions and to develop scenarios for extending the insight and discourse beyond the limits of what can be modelled. This found concrete expression in three thematic analyses concentrated on the economic, social and environmental dimensions of sustainability; the results are described in more detail in e.g. Cave and Simmons (2004). The subsequent discussion illustrates some of the most important sustainability-related concepts emerging from that work.

Articulation

This refers to the linkages – and especially the dynamic linkages – among different domains of behaviour and analysis. One aspect is already familiar to sustainability analysis – the connections among the economic, socio-political, environmental and (latterly) cultural sustainability domains and the resulting challenges and opportunities. For instance, it is well-known that economic behaviour and economic outcomes are strong (in many cases dominant) influences on social[2], environmental[3] and cultural[4] outcomes. Conversely, policy decisions, environmental shocks and cultural backlash constrain economics. Each domain has its own 'internal' dynamics, but these dynamics are profoundly altered by the coupling among the systems. A second aspect of articulation is the linkage among analytic perspectives and disciplines. In the best circumstances, this can support, if not a harmonised and balanced approach to sustainability issues, at least a useful coordination and aggregation of evidence and understanding, combining hard and soft evidence, models of different types and human and societal concerns that sometimes resist codification, let alone quantification.

Emergence5

Some of the most profound and startling global (macro) phenomena or system behaviour cannot wholly be understood in terms of the supporting local (micro or meso) elements; at the same time they cannot accurately be captured by macro-level analysis. If articulation refers primarily to 'horizontal' linkages, emergence is inherently 'vertical' – at least in terms of scale and complexity. This emergence is certainly evident in physical systems and in the behaviour of complex, large-scale human (or animal) and computer systems – whether originally conceived as systems or not. It thus applies with equal force to both the Information Society and to sustainability *per se*. Its importance requires us to seek microfoundations for macromodels, but also to consider the influence of macro-phenomena on micro-level expectations and behaviour. These spillover effects, moreover, are not mere changes in parameter values or additional relations expressed in the same conceptual or modelling language. Rather, they may require fundamentally new concepts and perspectives[6] and must, at the very least, call for a combined attack using both forward-looking (what might happen if things continue) and backward-looking (if we have reached a certain landing place, how might we have arrived here) perspectives.

Network effects

Complex systems, whether human or natural, are driven by changing patterns of communication and interaction among global citizens and powers. We are all familiar with networks, both physical (transportation, telecommunications) and virtual (languages, societal relationships, epistemic and semantic structures). The analysis of networks has considerably altered our understanding of global dynamics and in

---

[2] e.g. through income distributions or work-life considerations.
[3] E.g. through resource use and recovery by businesses.
[4] E.g. through the transition from cultural expression to cultural production – see Rifkin (2000).
[5] Johnson (2002).
[6] For instance, it is possible to reconceptualise the economy away from a network of people with sovereign preferences to a field of preference that act through people. The trick is the familiar one of duality – in this case (and the other networks mentioned below); one exchanges the roles of nodes and links: researchers link ideas, etc.

particular the way technologies and sustainability domains interact. A wide range of disciplines[7] have begun to develop bodies of network analysis; each reflects the disciplines traditional viewpoint and priorities and it is fair to say that, while each has much to teach the others, there are as yet few signs of convergence. For sustainability, the important implications are three-fold.

First, the fundamental reason why local action often exacerbates collective problems is that they are not collectively perceived. This does not refer to a failure to agree on either problems or their solutions – this is rarely possible for more than a few trivial aspects of a problem and encourages conflict and free-riding as much as it does collaboration and team-working. Rather, the difficulty is that powers of action, information and motivation may not be suitably aligned, and their alignment may not be suitably sensitive to shocks and development. The ‘externalities’ that determine appropriate governance allocation can be internalised by membership is suitable groups (e.g. communities (of interest) or jurisdictions) or mediated through suitable institutions (voting, markets, property rights, liability rules). But all groups have further internal structures (of power or influence) that determine how they will act and interact. This creates a structure of overlapping, shifting and nested groupings that are of critical importance [e.g. environmental NGOs]. The network metaphor allows a more direct appreciation of the relations of proximity in terms of interest, understanding and power and thus extends the group idea.

Second, within any network, decisions are made in ways that reflect the structure of the network – in other words, networked entities respond to the behaviour and attitudes of those to whom they are connected. If the network geometry is ‘right’ they will find their way to mutually-beneficial solutions, but if not they can get locked into inferior outcomes, which can resist conversion (learning a better way). Beyond these aggregate effects, indirect influences of ‘the neighbours of one’s neighbours” can create even more direct tensions between efficiency and stability. Finally, because rich networks offer many pathways from one node to another, they can resist structural damage and reduce the isolation that leads people to neglect the systemic sustainability consequences of their actions.

Third, network structures are themselves subject to evolution. Networks can be concerned with different things. We are by now familiar with networks of economic interaction from collaborative service industry work patterns to global financial markets. We are, each of us, embedded in complex and overlapping social networks, and our political deliberations are based on the intersection of a wide range of local and global issues. Even the natural environment can be seen in terms of networking – from patterns of access to resources through the food webs that were one of the first objects of network science. Finally, in a globalised world strung together by communications networks, cultures are linked to other cultures by complex patterns of awareness and exchange. Because the functioning of these networks sustains us, their evolution is central to the understanding of sustainability.

Tipping

There is a tendency to see the world in terms of diffusion and levelling: economic competition and democracy are seen as reinforcing and extending each other through positive feedback and social and cultural life are often portrayed as inherently branching and pluralistic – though argument persists as to how inclusion and diversity

[7] E.g. physics, biology, economics, sociology, game theory, ecology, informatics, transport and logistics, etc.

can best be balanced – and even natural phenomena are often treated as linear, or at least continuous. However, the combined consequences of nonlinearity, networking and positive feedback can produce quite different, equally inherent tendencies. Economic competition, for instance, may well proceed by means of a series of disruptive monopolies; social evolution may be 'punctuated' by crises and qualitative breaks, and natural systems may fall into chaos[8] or catastrophe[9].

For example, if individual actions, social conventions or physical resources are complementary, there is a tendency for markets (and other forms of collective decision making) to 'tip' into monopoly[10] – or at the least into uniformity and standardisation[11]. This can certainly provide strength – the strengths of profitability, interoperability and static efficiency. But it can also be brittle, since this strength is bought at the price of diversity. If conditions change, such regimes may collapse suddenly. This phenomenon is well-known in the case of agricultural monocultures and single-crop economies. Because the networking of free trade lead communities and nations to specialise according to their comparative advantages[12], they become less self-sufficient, less resilient at the micro level and more interdependent. This may seem no bad thing for sustainability, since this interdependence *can* make them more aware of their mutual impacts. But the process also brings globalisation, especially when activities have economies of scale. The interdependences (economic or trade links) reach farther, and connect those who have little else in common. Other forms of network that reflect interdependence (like social relations) may not be so scalable, and will weaken as the economic neighbourhood expands – particularly when regional specialisation makes regional neighbours into competitors. Thus the building of the Aswan High Dam, which controlled the flooding of the Nile and allowed large-scale market-orientated sugar cultivation led to a marked shift in local social relationships whose effects are still being felt in Sudan and Egypt. Similarly, it has been observed by scholars of the 'environmental Kuznets curve' (especially in Africa) that, while local environmental commons are managed by informal social relationships, market-orientated development leads to a deterioration in these structures and increased need to rely on inefficient and divisive legal or market-based 'solutions' to environmental problems.

But the news is not all bad, or at least not uniformly bad. Tipping concentrates liability: as simple common-pool externality games show[13], the monopolist (who has internalised at least the extraction externality) is often the conservationist's friend. This argument has been generalised by Mancur Olson, who argued that the poor would benefit from the self-restraint of the rich. This argument, however, holds only when asymmetries are particularly severe, as recent evidence[14] shows.

[8] Here used in the mathematical sense of sensitive dependence on initial conditions, meaning that very similar (indistinguishable) situations may diverge rapidly and profoundly, and thus become almost impossible to predict or control.

[9] Again used in its mathematical sense (Thom (1972)) to refer to the emergence, convergence and coalescence of equilibria, leading to path dependence,, cycles and or discontinuity even in aggregates of continuous behaviour – and thus, in fact, to the spontaneous emergence of order.

[10] Katz and Shapiro (1994)

[11] Kandori, *et. al.*, Young

[12] Ricardo (1817)

[13] Cave (1987)

[14] Dayton-Joynson and Bardhan (2002)

Resilience

This term has recently come into prominence in sustainability analysis. For better or worse, the world we inhabit is affected by unforeseen (and often unforeseeable) events. Some come from inside the system itself, others are exogenous. Some can be 'headed off' or controlled by appropriate hedging or buffering – but this in turn depends on the ability of those who could take these actions to recognise and plan for unforeseen contingencies. These reactions become part of the behaviour of the system, and should be taken into account when assessing sustainability in terms of resilience. In other words, both the ability of the system to continue to sustain life (and its desirable characteristics) and the ability of the system to respond to shocks are appropriate measures of sustainability. Nowhere is this self-governing or self-aware aspect more evident than in the economic system. The very word economics derives from the Greek word for the household, and the essence of economics is the sustaining of life within external constraints. At best, the economy is a means to an end, and that end is the sustainability of fulfilling human life.

Two rather different concerns dominate analysis of the environmental consequences of economic change. As described by Perrings (1998), the concern that desirable states or processes may not be 'sustainable' is balanced by the concern that individuals and societies may get 'locked-in' to undesirable states or processes. Both recognise that the global system has many possible states, not all of which are equally valued or equally persistent.

Collaboration between ecologists and economists uses the twofold ecological concept of resilience to explore the relative persistence of different states of nature. One definition of resilience[15] is explicitly dynamic (if conservative) - the time a disturbed system takes to return to some initial state. The other is more static[16]; the magnitude of disturbance that a system can absorb without flipping to another state. Both deal with the stability of system equilibria, offering alternative measures of the capacity of a system to retain productivity following disturbance.

This difference translates to a dynamic setting the transition in sustainability analysis proper from an analysis of the levels of specific renewable stocks (which should not diminish along a sustainable path) and the net rates of depletion of non-renewable resources (which should drop to zero). The original 'Limits to Growth' argument was rooted in this perspective, and its stark (though as-yet unfulfilled) predictions certainly caught the attention of the world. Their failure to come about, and our success, owes more to the limitations of the perspective than to any escape from looming disaster: we found substitutes for scarce resources, and learned to think of sustainability in terms of maintaining *capabilities* rather than stocks.

Most joint work to date concentrates on the static definition in terms of the size of allowable shocks and its application to managing joint economic-environmental systems. But both shed light on lock-in and sustainability. The weakness of the static version is that it does not deal with the losses that accrue whilst off the sustainable path – or, indeed, with the question of whether internal or external shocks – singly or in combination - are likely to breach these 'safety limits.' The weakness of the dynamic definition is that it offers more reassurance than prioritisation.

---

[15] Pimm (1984)
[16] Holling (1973)

In particular, in the Information Society, 'network externalities' can stabilise either sustainable or non-sustainable behaviour[17] through the combined force of contagion and cohesion, so the possibility of sub-optimal equilibria reflecting co-ordination failure is pervasive.

Resilience provides a different perspective on economic sustainability from that normally adopted by economists, and a different set of insights into the way economic interactions with the environment drive changes in the joint system. Instead of focusing on equilibria and the properties of the system at equilibrium, it considers the basins of attraction stable equilibria and the susceptibility of the joint system to change at different points in the basin. Indeed, because the joint system's sensitivity to shocks varies as it converges on the equilibrium state, both perspectives are needed and any sustainability analysis must incorporate path dependence.

Economists generally tend to equate sustainability with both equilibrium and the steady state[18]. The sustainability of extraction or investment paths, for example, tends to be evaluated as a property of a deterministic system in long-run equilibrium. Recent work[19] recognises that sustainability is more relevant in stochastic systems and that it is best measured by system resilience at or away from equilibrium. In evolving systems, resilience is thus more policy relevant and more testable. Adaptive policies devised to manage resilience of complex path-dependent ecosystems[20] apply *a fortiori* to economic systems[21].

Economic development and environmental change are stochastic evolutionary processes – they are driven by the three-fold influence of variation, selection and heredity and their analysis, measurement and management require appropriate concepts and tools. The concepts and tools developed by ecologists for the evolution of multiple equilibrium ecosystems, and the new understanding of network and evolutionary dynamics coming from game theory taken together have the potential to change fundamentally the way we approach the economics of change.

The 'insulation' of 'real' and 'financial' systems from each other is clearly breaking down as a result both of volatility and of the increasing participation in financial markets by a whole range of new and relatively naive actors - for instance via ISTs permitting real-time information tracking, sophisticated asset valuation models (and derivative assets) driven by huge amounts of data, off-floor trading, etc.

Increases in market volatility can be partially attributed to the spread of common models (a network externality), globalisation and cross linkage of markets and securitisation of assets that were once non-traded (like sovereign debt) but have real implications (e.g. for public spending). Volatility is further enhanced by speculative bubbles (like IT/telecom, etc.). Again, these often have real implications for sectoral stability, income distribution and intergenerational equity.

Clearly, as more and more information becomes available, its quality, distribution and responsiveness become crucial. More isn't better, aggregate measures are not meaningful, markets don't efficiently combine or average information, information becomes obsolete very fast, etc. As a result, assumed relationships among data, information, knowledge, belief and truth are shifting. What remains, however, is a

[17] Young (1993)
[18] Baldwin (1995)
[19] Levin et al. (1998)
[20] Walters (1997)
[21] Anderson et al. (1988); Arthur (1992)

tendency to be attracted to a limited range of near-equilibrium states, whose resilience against shock is a vital component of sustainability.

Distribution

As mentioned above, there is a substantial body of work relating to the impact of inequality on economic and social stability – and thus to sustainability. Certainly, high levels of inequality lead to rent-seeking and social unrest, and can dampen incentives towards further development. At the same time, the promise of unequal treatment can provide valuable incentives. In the TERRA analysis of human capital, inequality measures applied to human capital were used in macroeconomic growth estimations, where they showed a robust an unambiguous negative impact. By way of contrast, work in the Growth and Equity theme found that modest levels of income inequality were associated with more rapid growth than either extreme.

The relevance of distribution to environmental sustainability is three-fold. First, as mentioned above, a body of scholarship starting with Olson (1971) has examined the question of whether the 'tragedy of the commons' can be lessened if inequality is sufficiently high that an oligopoly of wealthy or well-endowed countries (or individuals) essentially internalise the congestion externality. This effect is diminished when the parties are more equal. On the other hand, the analysis of Kuznets points to two opposing trends with development, which taken together suggest a 'U-shaped' graph of environmental 'virtue' against wealth: very poor countries use low-impact subsistence technologies (and social control mechanisms), while very rich countries can 'afford' the luxury good of sustainability. Of course, contemporary evidence shows at least a few outliers: very wealthy countries whose consumption of resources is highly disproportionate and impoverished countries led into ecological catastrophe through social upheaval or globalisation. But this, too reflect inequality – not the 'average inequality' measured by e.g. the Gini coefficient, but the degree to which very poor and very rich countries are *isolated* from the majority of others. If – and only if – this isolation is reduced, we can begin to raise the dip in the middle of the curve by suitable relocation of industrial activity, co-funded transfers of technology or environmental property rights. But to do so, we must recognise the difference between resources for which such rights can be narrowly defined and traded (e.g. exhaustible inputs) and those for which rights are naturally expressed at a collective and inalienable level (e.g. commons resources such as air and water).

A second environmental aspect of the distributional proposition concerns carrying capacity. As the old saw has it "the solution to pollution is dilution" – but in this case that amounts to evenly spreading discharges – or at least matching their load to local carrying capacity. Activities that reduce pollution in rich countries by relocating polluting activities to poor countries may be beneficial, but not if they overshoot equitable or ecologically efficient distributions.

A third aspect concerns envy. The new technologies have made us keenly aware of the conditions of others around the world. But our responses tend to be asymmetric. The response of the poor is, naturally, to try to become rich. Failing that, they will at least try to emulate the rich. Where this takes the form of migration, we can see all too clearly how easily congestible the economic and socio-political commons are and how quickly a backlash can crystallise that jeopardises the happiness of both rich and poor. Indeed, in some cases economic migration is sufficiently rapid as to produce its own environmental catastrophes – first in terms of water, but often spreading out to engulf other resource endowments. Alternative responses may appear more benign at first. For instance, education and foreign direct investment can pave the way for outsourcing – moving the work to the people rather than the people to the work. Where this goes hand-in-hand with dematerialisation of production or production of the increasingly immaterial information-rich goods and services of the Information Society, the result is growing incomes and welfare in the developing world – but what then? Increasingly, these burgeoning middle classes in the global 'South' emulate the consumption patterns of their less-numerous 'Northern' neighbours, whom the world already struggles to support. Finally, when the aspirations are met by localised development of indigenous resources (especially traditional knowledge or biodiversity heritage) the result is often a combination of the two: a transfer of wealth and the best of human capital out of the area and a legacy of resource-intensive consumption patterns left in exchange for a residual population that typically lacks the motivation, access and skills for full participation in the Information Society.

Finally, there is a distributional element to the 'rebound effect.' The impact of new technologies on sustainability has a sting in its tail. Whether from the economic, social, cultural or environmental point of view, technical responses to sustainability challenges often contain the seeds of their own negation. The logic is best seen in economic terms: as something becomes scarce, we try to use it more efficiently (increasing effective supply) or substitute away from it (decreasing effective demand). As a result, 'it' becomes relatively cheaper and we become relatively richer. This favours compensating increases in the consumption of the original resource (through the substitution effect) and of other scarce resources (through the income effect). The strength of these effects, and the scarcities that give rise to them, depend on the distribution of endowments. The distribution of food provides a tragic example; trade in food has led to the development of crops that can be grown in developing countries. Many of these are potentially valuable on world markets, where their presence has provoked trade policy reactions that have exacerbated food shortages.

New problems, new mechanisms

Many of these conclusions seem bleak and threatening. And yet, new solutions can be seen in 'weak signals' of world development. In any sustainability process, the signals that guide change are painful – prices guide our economic choices by penalising consumption of scarce goods and rewarding innovations that make more efficient use of them or that deepen the welfare content of our economic activity. Political upheaval and even terrorism send strong signals that will not abate until the underlying problems are addressed. The growing scarcity and diminishing quality of our natural heritage will eventually force a change. The central issue is whether the change will come soon enough to make a difference, but late enough to ensure that we understand the further consequences of our attempted 'solutions.'

In this perspective, it is heartening to see that we are beginning to adopt – and adapt – mechanisms that explicitly work to harness individual interest and competencies to global and globally complex problems. We are learning to harness rebound effects to positive effect, through 'green competition' and ethical investment. We are redefining property rights to make a more effective unbundling of the costs and benefits of our activities, to place the rights at levels between the purely individual (which inhibits cooperation) and the purely collective (which encourages free-riding).

Most importantly, we are seeing the emergence of new and vital forms of global governance. This emphatically does *not* mean global government, or even globally competent governance institutions. The existing global institutions remain powerful, but have increasingly come to recognise their limitations. They know that they must cooperate – and that they must rely on the self-interested and often divergent activities of other spheres – geographically-based governments with broad policy remits, global and local businesses with sectoral interests and a monetised set of objectives, and the whole messy diversity of civil society. These systems have different systems of accountability and restraint, and pursue different goals. They could easily miss important issues, waste their time in duplicate effort or even come into conflict over how best to attain common objectives. But what may yet hold them together are global issues and global mandates. Once common problems are persuasively identified, and once they are taken up by respected global institutions, it becomes that much easier for other parties to organise and implement their own parts of the collective solution. In this way, even unenforceable aspirations like the Kyoto targets and the world summit action plans become powerful instruments for resolving local political struggles – indeed, they may yet prove more effective than formal treaties. The reason, ultimately, is that instead of trying to internalise the global effects of our actions it is often easier to internalise a common – or at least consistent set of values. The emerging concept of European citizenship and identity is exemplary – on the evidence it has been more effective in the sustainability spheres discussed here than the common legal framework of formal European institutions. And this is as it should be, for government exists to serve the people, not to control them.

References

Anderson, P., K. Arrow and D. Pines (1988), 'The Economy as an Evolving Complex System, 'Santa Fe Institute Studies in the Sciences of Complexity V. Redwood City, CA: Addison Wesley.

Arthur, B. (1992), 'On Learning and Adaptation in the Economy,' Stanford. Food Research Institute, Stanford University.

Baldwin, R. (1995), 'Does Sustainability Require Growth?' in I. Goldin and L. A.Winters, eds., The Economics of Sustainable Development. Cambridge: Cambridge University Press, 51–77.

Cave, J. (1987) 'Long-term competition in a dynamic game: the cold fish war,' *RAND Journal of Economics* **18** (4), 596-610

Cave, J. (2002) 'Capitalising on Human Knowledge in Global Networked Society,' in B. Stanford-Smith, e2002 volume.

Dayton-Johnson, J. and P. Bardhan (2002) 'Inequality and Conservation on the Local Commons: A Theoretical Exercise' *Economic Journal*.

Holling, C. S. (1973), 'Resilience and Stability of Ecological Systems', *Annual Review of Ecological Systems* **4**, 1–24.

Johnson, S. (2002) Emergence: The Connected Lives of Ants, Brains, Cities, and Software, Scribner.

Kandori, M.G., Mailath, G. and Rob, R. (1993), 'Learning, Mutation, and Long Run Equilibria in Games', *Econometrica* **61**: 29–56.

Katz, M. and Shapiro, C. (1994) 'Systems Competition and Networks Effects', *Journal of Economic Perspectives* **8**: 93–115.

Levin S.A., Barrett S., Aniyar S., Baumol W., Bliss C., Bolin B., Dasgupta P., Ehrlich P., Folfe C., Gren I.-M., Holling C.S., Jansson A.-M., Jansson B.-O., Martin D., Mäler K.-G., Perrings C. and Sheshinsky E. (1998) 'Resilience in natural and socioeconomic systems,' *Environment and Development Economics* **3**(2): 222-234.

Olson, M. (1971) The Logic of Collective Action

Perrings, C. (1998) 'Resilience in the Dynamics of Economy-Environment Systems,' *Environmental and Resource Economics* 11(3–4), 503–520.

Perrings, C. and S. Dalmazzone (1997) 'Resilience and Stability in Ecological Economics Systems,' Discussion Papers in Environmental Economics and Environmental Management 9701, University of York.

Perrings, C., K. -G. Mäler, C. Folke, C. S. Holling and B. -O. Jansson, eds. (1995), Biological Diversity: Economic and Ecological Issues. Cambridge: Cambridge University Press.

Pimm, S. L. (1984), 'The Complexity and Stability of Ecosystems', *Nature* **307**, 321–326.

Ricardo, D. (1817) The Principles of Political Economy and Taxation.

Rifkin, J. (2000) The Age of Access: How the Shift from Ownership to Access is Transforming Modern Life, Penguin, London.

Thom, R. (1972) Structural Stability and Morphogenesis, Benjamin.

Walters, C. (1997), 'Challenges for Adaptive Management of Riparian and Coastal Ecosystems', *Conservation Ecology* **1**:2, 1.

Young, P. (1993), 'The Evolution of Conventions', *Econometrica* **61**(1): 57-84.