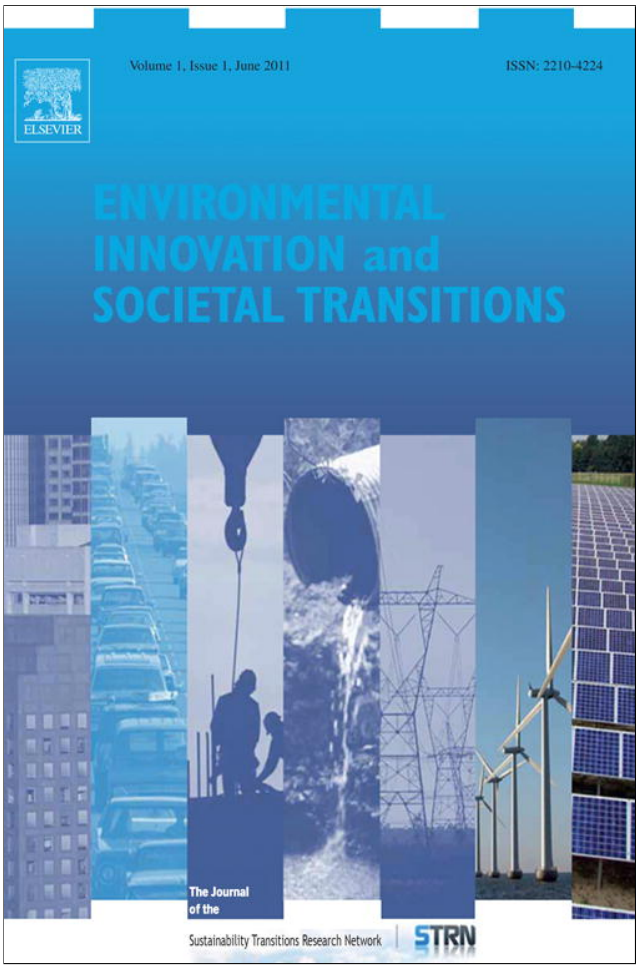

Environmental Innovation and Societal Transitions 1 (2011) 82–88

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Pluralising progress: From integrative transitions to transformative diversity

Andy Stirling*

SPRU – science and technology policy research, University of Sussex, Freeman Centre, Brighton BN1 9RF, UK

ARTICLE INFO

Article history:
Received 20 January 2011
Received in revised form 28 March 2011
Accepted 30 March 2011

Keywords:
Transition
Transformation
Uncertainty
Diversity
Reflexivity

ABSTRACT

This paper examines key issues raised by consideration of diversity in the study of environmental innovation and societal transitions. In different ways and degrees, these implicate many contrasting perspectives, including innovation studies, evolutionary economics and transitions research. The paper therefore attends equally to the implications of plurality among disciplines as observing subjects and varieties of sociotechnical configurations as observed objects. Inspired by recent literatures in these fields, the argument focuses in turn on: contending social normativities concerning alternative directions for innovation; divergent disciplinary understandings of societal transitions; and disparate conceptualisations of sociotechnical diversity itself. In each area, the paper identifies some persistent forms of 'misplaced concreteness'. Recommendations are made as to how the implications of diversity might be addressed in more rigorous and reflective ways. In conclusion, it is shown how rigour and reflexivity themselves depend on plural analytical communities paying greater regard to diversity and striking their own balance between pluralism and concreteness. This highlights a series of specific, but hitherto unresolved, research questions.

1. Introduction

When is innovation 'environmental'? What constitutes 'societal transition'? How does directional transition relate to open transformation? Which are the best trajectories? To what extent are answers

* Tel.: +44 0 1273 877118.
E-mail address: a.c.stirling@sussex.ac.uk

2210-4224/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.eist.2011.03.005

in eyes of beholders? How can society understand and decide such issues? Few questions pose more relevant challenges for this journal. Yet general connotations sometimes appear quite abstract. In fact, many profound aspects could hardly be more practical. In different ways, each query implicates social, technical and disciplinary *diversity*. Salient lessons emerge from – and for – innovation studies, evolutionary economics and transitions research. Despite necessary nuancing in contrasting contexts, underlying links allow many implications of diversity to be usefully discussed together.

Much emerging innovation and transitions research directly addresses these challenges. Ambiguities and tensions are actively explored around diversities in formative concepts, disciplinary perspectives and sociotechnical configurations alike (Smith et al., 2005, 2010; Geels and Schot, 2007). Reflection and interrogation focus on practices, dynamics and contexts both of observing researchers and their objects of study (Shove and Walker, 2007; Genus and Coles, 2008; Smith and Stirling, 2007). Reviewing these recently unfolding literatures around diversity, we will focus here on implications of three challenges. First, contending social *evaluations* of desirable forms and directions for innovation. Second, plural *understandings* of societal transitions. Third, disparate notions and dimensions of sociotechnical *diversity* itself.

2. Diverse directions

Innovation and transitions research owe particular debts to insights from evolutionary economics (Smith et al., 2005,2010; Geels and Schot, 2007; Weber and Hemelskamp, 2005; Elzen et al., 2005). No single discipline has done more to document constitutive phenomena of disequilibrium, positive feedback and path dependency in sociotechnical systems. Evolutionary understandings helped pioneer recognition of social and political, as well as technical, drivers of innovation (Metcalfe, 1995; Nelson and Winter, 2002; Dosi, 2000). Expanding on this, a rich picture has emerged of interlinked material, technical, cognitive, historical, behavioural, discursive, institutional and market processes through which societal commitments are 'channelled' into subsets of possible sociotechnical configurations (Smith et al., 2005, 2010; Geels and Schot, 2007; Weber and Hemelskamp, 2005; Elzen et al., 2005). So: not all that is technically achievable, economically feasible or socially viable is actually historically realisable. Both ontological and normative ideas of progress are thus best represented, not as a single-track 'race', but as palimpsests of branching counterfactual paths. This highlights the scope for human agency and (in principle) deliberate social choice (Stirling, 2009). Indeed, with stakes compounded by international processes of harmonisation, standardisation and globalisation, this radical potential of diversity is a key reason why interests are so strong in the first place around 'environmental innovation' and 'societal transitions'.

As a result, it is clear that neither innovation nor transitions (in any way or context) can meaningfully be thought of in undifferentiated 'scalar' senses, as simply 'going forward'. Across sectors like agriculture, transport, health, communication and 'defence', the most important questions are over potentially radically divergent innovation or transition pathways that are favoured or disfavoured under contrasting conditions and perspectives. Ambiguities abound, even in prominent, well-explored sectors like 'low carbon' energy. To what extent is this ostensibly constrained singular 'sustainability transition' best seen as centred on: nuclear infrastructures; large-scale carbon capture; pan-continental renewables networks; or distributed structurally integrated energy production? Different evaluative frameworks present contrasting pictures of required directions, gradients and modalities of change. If research is to deal rigorously and accountably with the governance implications, the associated diversities must be fully explored. This raises crucial questions of 'normativity' alongside issues like 'pace', 'magnitude' or 'leadership'. In short, concepts of innovation and transition are (at every level) better understood as 'vector' than as 'scalar' properties. As much attention is required to parameterising diversities of directions, as to the scaling of specific developments (Stirling, 2009).

Transitions research in particular, is increasingly engaged with these pluralities (Smith et al., 2005, 2010; Geels and Schot, 2007; Shove and Walker, 2007; Genus and Coles, 2008; Smith and Stirling, 2007; Weber and Hemelskamp, 2005; Elzen et al., 2005). Important normative diversities are acknowledged around key concepts like 'sustainability' and 'transition' itself (Leach et al., 2010; Stirling, 2011). Much transitions analysis eschews conventional frameworks asserting as self-evident and definitive,

specific notions of 'productivity', 'efficiency', 'risk', 'impact', 'development', 'equity' or 'resilience' as contingently formalised in market and regulatory institutions. Analytic attention is moving instead towards more diverse and dynamic (less visible or codified) normativities extant in civil society (Smith, 2007; Seyfang and Smith, 2007). Experiments are underway to engage with these, using participatory and deliberative practices. Slowly but surely, in different ways and degrees in contrasting contexts, welcome transformative influences are beginning to be felt in wider technology policy (Rotmans et al., 2001; Markard and Truffer, 2008).

Despite equal relevance, the implications of normative diversity are less recognised in more narrowly economic approaches to innovation. Here, less reflective 'scalar' understandings still prevail. Attention is framed instrumentally in relation to specific performance metrics contingently favoured by incumbent regimes, not in explicitly normative ways recognising alternative evaluative dimensions. So 'innovation systems' research tends to focus simply on 'rate', 'efficiency' and 'leadership', rather than on their constitutive parameters. References are made to 'advance', as if this were self-evident and direction-independent. Linear 'race-like' metaphors abound, including: 'first movers', 'catching up', 'forging ahead', 'diffusion', 'leapfrogging', 'barriers', 'falling behind', 'lagging' and 'stranding'. All reify single-track ('scalar') – rather than plural ('vector') – notions of innovation (Stirling, 2009). There is a significant potential – and responsibility – for study of environmental innovation to resist and escape such hegemonic simplifications, by embracing evaluative diversity and recognising divergent normative vectors. Here, there lies productive scope for more direct critical challenge by transitions research of economics-inclined innovation studies (Cf Geels, 2004).

However, it is arguable that even in transitions studies, not all research comprehensively addresses the full implications of normative diversity. Even here, normativities are sometimes treated in reduced ways – as if given by narrow contingent policy or disciplinary contexts, rather than by more diverse socio-political dynamics. Where they occur, for instance, experiments in social elicitation and participatory deliberation are often oriented more towards a presumed final 'closing down' of the modalities for particular transitions, than 'opening up' divergent possible societal transformations (Leach et al., 2010; Stirling, 2011). Even underlying academic understandings of transitions, are increasingly recognised to privilege the most visible actors in 'innovation systems' – sometimes neglecting more distributed influences from citizens, consumers and civil society (Smith, 2007; Seyfang and Smith, 2007). Similar queries might also be raised over some key constitutive concepts and insights in understandings of 'transitions' themselves. Below the academic radar, acute subaltern awareness of power has long made social movements quite familiar with notions like 'weak links', 'political judo' and 'trojan horses' (Popkin, 1970). But these kinds of dynamic have only recently been appropriated and codified in disciplinary vocabularies. Despite positive contrary developments, it may therefore still be asked whether all innovation and transitions research yet fully appreciates the radical implications of diversity in possible normative directions for sociotechnical change.

3. Plural understandings

Turning from normativities to understandings of innovation and transitions, introduces further ways in which diversity is routinely reduced, aggregated and reified. Whether evaluative or epistemic, this "error of mistaking the abstract for the concrete" was well characterised by the philosopher Whitehead (Whitehead, 1926). His "fallacy of misplaced concreteness" is especially strongly exemplified in economics (Machlup, 1958; Daly, 1985; Mitchell, 1993). At specific 'levels', the fallacy is quite well resisted in environmental innovation and societal transitions research. Careful attention has recently been directed at the implications of ontological (Geels, 2010), epistemic (Jasanoff, 2005) and normative (Stirling, 2009) diversity. It is widely recognised that diverse perspectives can make valid, complementary, contributions to understanding (Smith et al., 2005, 2010; Geels and Schot, 2007). But there remain dangers that some otherwise positive actions to address diversity, risk simply shifting the fallacy away from individual perspectives, towards the ostensibly singular integrative frameworks and taxonomies under which they are ordered.

In other words, it is not so much the *existence* of diversity that risks neglect in innovation and transitions research, but the *depth* of its implications. Relevant here, is that many pressures to reduce cognitive diversity, are not self-evident requirements of rigorous analysis. Indeed, some levels and

forms of cognitive incoherence can be a source of creativity and robustness (Rosenberg, 1982; Landau et al., 1996; Grabher and Stark, 1997; Page, 2007). Instead, reductive pressures often reflect more worldly imperatives. These include policy demands for justification and legitimation (Collingridge, 1982; Wynne, 2002) and disciplinary incentives for puzzle-building and closure (Feyerabend, 1970; Kuhn, 2000). Faced with manifest diversities across, say, evolutionary and neoclassical economics; materialist and interpretive social science and positive and constructivist traditions, strong incentives push for 'integrated' frameworks, justifying 'complete' interpretations, 'definitive' explanations or 'robust' prescriptions (Rotmans et al., 2001; Markard and Truffer, 2008; Geels, 2010). Much of the attraction of 'multi-level' analysis, lies precisely in constructing this apparent tractability: assembling neatly nested, contiguous or additive cognitive orderings for systematically differentiated contexts.

Of course, there is real value in carefully juxtaposing, contrasting and triangulating cognitive diversity (Geels, 2010). Yet, even if motivations are expressed as merely 'heuristic', the implicitly universalising body language of 'integration' is often more ambitiously synoptic. The problem is, that disparate ontologies, epistemologies and normativities are typically not just distinct, but fundamentally 'incommensurable'. This is so in Feyerabend's, as well as Kuhn's senses (Feyerabend, 1970; Kuhn, 2000). The challenges therefore lie not just in co-measurement (Geels, 2010), but in deeper irreconcilability. In other words, cognitive diversities (in this field as others) are often not so much 'nested, contiguous or additive', as 'dynamic, recursive and fractal'. Each perspective can be more heterogeneous (in content and implication) than is conceded in advocacy, criticism or taxonomy alike. Emergent tensions *within* often rival stylised contrasts *between*. And diversities of meanings are also often as much social as cognitive – embodied in restless, reflexively performed human relations, not just in iconic contrasts of disciplinary substance. Awareness of misplaced concreteness thus raises queries over both drivers and consequences of claims (and aims) to structured 'integration', 'broadening' or 'advance' in innovation and transition research (Rotmans et al., 2001; Markard and Truffer, 2008; Geels, 2010).

What is true of contending knowledges applies also to their associated uncertainties. Here there emerge further examples of 'misplaced concreteness'. Policy analysis in all the fields addressed here tends to present reduced pictures of uncertainty. Much environmental and sustainability appraisal, for instance, adopts deterministic understandings that sideline uncertainty. Risk-based approaches aggregate uncertainties stochastically. Both suppress irreducible indeterminacies, delivering concreteness not by objective veracity or completeness, but through subjective institutional imperatives and disciplinary conventions. Even where eschewing probabilistic reductions, evolutionary economics tends to model incomplete knowledge as in-principle parameterisable (Elzen et al., 2005; Metcalfe, 1995; Nelson and Winter, 2002; Dosi, 2000). This omits intractable challenges like ambiguity and ignorance, arising from indeterminacies in parameterisation itself. More heterodox innovation and transition studies display less misplaced concreteness over uncertainty (for instance through use of various kinds of sensitivity, scenario, or mapping analyses). Yet, even where uncertainty is highlighted on the part of observed actors, observing scholars often treat their own understandings more deterministically (Rotmans et al., 2001; Markard and Truffer, 2008; Geels, 2010). The remedy lies in more rigorously 'plural and conditional' – not aggregated – interpretations of diverse possibilities under uncertainty: applied not only to objects but expressed by researchers themselves as subjects (Stirling, 2010).

Contrary to Whitehead's presumed "error", however, recognition of misplaced concreteness should not be seen as *necessarily* pejorative – or negative in its consequences. If respect for concreteness is balanced with pluralistic tolerance, then resulting 'interpretive flexibilities' can aid engagements with diversity. So may even 'misplaced' concreteness help constitute 'boundary objects' – usefully articulating incommensurable discourses and co-ordinating otherwise-irreconcilable political interests (Bijker, 2009; Gieryn, 1995). So, for instance, can ambiguities around 'sustainability' enable engagement between emergent or fissioning sub-disciplines. The challenge therefore lies not in avoiding (inevitable) ambiguity and contention in 'placing' concreteness, but in deliberate, pluralistic reflection over conditions and implications.

This aim is impeded where single frameworks are asserted monolithically. It is further obstructed by under-reflected conflations. For example, the term 'transition' is used simultaneously to imply a *particular* kind of change, whilst also serving as an *encompassing* synonym for any change more generally (Rotmans et al., 2001; Markard and Truffer, 2008; Geels, 2010). Strictly speaking, 'transition' is

intrinsically teleological: implying "*passage from one condition...to another...from earlier to later stage*" (OED, 1989). This contrasts with more counterfactually open notions of 'transformation', invoking less determinate change ("[t]*he action of transforming or fact of being transformed...complete change...*" (OED, 1989)). This deeply misplaced concreteness in framings of 'transition' rather than 'transformation' is distinct from – but exacerbates – increasingly recognised dangers of instrumental notions of 'sustainability' and 'transition management' (Smith et al., 2005; Geels and Schot, 2007; Smith et al., 2010). Each has mutually reinforcing effects in undermining democratic, accountable politics around conflicting knowledges, contending interests and contested normativities.

So, benefits of creative incoherence in diverse understandings of environmental innovation and societal transitions, may lie more in performed relations between *interacting research communities*, than in settled multidisciplinary articulations. No matter how complete, elegant or persuasive any particular integrative framework, there typically remain alternative contrasting ways to aggregate the implicated diversities of understandings and uncertainties. Many will yield radically different conclusions. And since boundaries shift with categories, confounding incommensurabilities are as relevant to orderings of 'interfaces' as of essentialised disciplinary cores. Robust responses to diversities of understandings thus lie more in disparate explorations than unitary integrations.

4. Disparate diversities

Ironically, a further key area of misplaced concreteness in environmental innovation and societal transitions, lies in the concept of diversity itself. Before exploring this, it is worth acknowledging the striking number of reasons for recognising sociotechnical diversity as a positive quality. First, there is the fostering in observed systems of the innovation, creativity and learning already mentioned in relation to observing systems (Rosenberg, 1982; Landau et al., 1996; Grabher and Stark, 1997; Page, 2007). Second, diverse portfolios (rather than single 'optimal' options), offer ways to resolve fundamental 'impossibilities', both in rational choice and deliberative theories. Third, where 'we don't know what we don't know', it is a conventional wisdom to 'avoid putting all the eggs in one basket'. Thus does diversity help confer resilience under shock and robustness in the face of stress (Stirling, 2011). This arises because active diversification militates against closure – both in sociotechnical practices and the disciplines through which they are appreciated. Of course, diversity is rarely an unqualified good. Under any perspective, it presents challenges like foregone performance and economies of scale. And possible tensions with equity, co-ordination, coherence and accountability. In general, however, the more transformative the envisaged sociotechnical change, the greater the interest in diversity (Stirling, 2007).

Here, misplaced concreteness appears in several forms. First, there is the tendency in innovation studies (explicitly or tacitly) to treat the salient parameters of diversity as self-evident. Elsewhere, diversity is understood not as a unitary property but an assemblage. In short, diversity is generally a state under which an observed system is seen to display: (1) *even balance* across (2) a *variety* of (3) *mutually disparate* categories. It follows from this, that an apparently *greater* variety of categories represented in uneven ways may be *less* diverse than relatively few represented more evenly. Right at the outset, this reveals the misplaced concreteness of conventional notions of diversity based on variety alone. Yet such notions are widespread in innovation studies, where diversity is often addressed simply with 'category counting', fixating on contingently partitioned variety in firms or technologies – irrespective of their 'balance' in the system in question (Stirling, 2007).

More serious than this exclusion of balance, is still greater neglect of 'disparity': the manner and degree in which categories are seen to differ from one another. Even where analysis addresses both variety and balance, it still invests contingent linguistic or taxonomic conventions with misplaced concreteness. Each category is regarded as unitary. All are treated as if equally mutually disparate. *Yet it is often the case that relevant entities differ from one another to varying (not uniform) degrees*. These differences typically implicate multiple dimensions of disparity. For instance in energy transitions again, disparities among electricity generating 'options' may alternatively be defined according to criteria like: primary resources; processing systems; infrastructure geographies; conversion technologies; supply chains; commercial actors; labour interests; or regulatory exposures. Alternate permutations and prioritisations of such criteria yield contrasting categorisations and orderings of disparity. To an

extent even greater than evaluative diversity concerning divergent directions for transition, different (equally legitimate and authoritative) perspectives yield diverse disparity structures. Thus does serious consideration of diversity again require engaging reflexively with disparities in observing subjects, as well as observed objects.

5. Conclusion

This necessarily condensed overview of the multiple implications of diversity for the study of environmental innovation and societal transitions, concludes by returning to issues raised at the outset. It is clear at many levels, that more deliberate and critical appreciations of diversity present a general antidote to many forms of misplaced concreteness. Here, reflexivity can be seen not simply as comprehensive 'reflection' over as many aspects as possible (Geels, 2010), but as greater humility and explicit positionality by researchers as subjects (Stirling, 2006). Yet crucially, this view of reflexivity in terms of co-conditioning objects and subjects, also illuminates a paradoxical sense in which diversity and misplaced concreteness may, in context, sometimes be symbiotic. Relatively unreflective *individual* understandings (e.g.: 'linear' innovation; 'unitary' transitions; 'integrated' taxonomies) may catalyse encompassing epistemic, ontological or normative diversities to provoke more *distributed* social reflexivities in knowledge and learning.

This favourable possibility relates to all forms of misplaced concreteness and associated suppressions of diversity addressed here: (i) stylised articulations of incommensurable perspectives; (ii) presumed normativities for transition; (iii) spurious reductions of uncertainty; (iv) scalar (rather than vector) representations of innovation; (v) highlighting singular transitions over open transformation; (vi) privileging the most visible actors; (vii) reifying particular notions of diversity itself. In each case, the indirect value of misplaced concreteness lies not in its 'integrated' completeness, coherence or validity. On the contrary, it is the manifest inadequacy of hegemonic interventions that presents a provocation for more dispersed countervailing analyses and actions. As innoculation confers immunity, so localised simplification may stimulate more sophisticated distributed reactions. But it is necessary to be self conscious of this irony. Only by deliberately nurturing plurality in observing disciplines as well as diversity in the transformative processes they inform, may we fully realise the potential relational reflexivities.

Perhaps the best way to do justice to these linked objective and subjective valences of diversity, is to focus on latent formative questions in recent work on environmental innovation and societal transitions. Does refocusing from singular 'transition' to plural 'transformation', shift understandings of relevant societal processes? How can transitions scholars better acknowledge diverse implications of their own uncertainties? What *contrasting* frameworks exist for understanding disparities in disciplinary perspectives on innovation and transitions? What common ground and similarities of variability are visible amidst this diversity? How to value creative incoherence alongside hegemonic synthesis? How more rigorously to 'map' intrinsic subjectivities around sociotechnical disparities and their dynamics? How to reconcile these with 'objective' understandings of dimensions and categories of disparity (Frenken, 2000) – and with associated combinatorial approaches (van den Bergh, 2008)? How does disparity relate to the requisite coherence required to realise diversity in niches, regimes and transitions alike? How to be more deliberately reflexive over interlinked diversities in subjects and objects of study? What implications arise for roles of civil society and democratic accountability? It is conventional to conclude that such questions require greater 'multilevel' integration. But the existential importance of environmental innovation and societal transfomation makes multivalent pluralism at least equally important.

References

Bijker, W.E., 2009. Social construction of technology. In: Olsen, J.K.B., Pedersen, S.A., Hendricks, V.F. (Eds.), A Companion to the Philosophy of Technology. Wiley-Blackwell, Oxford.

Cf Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory. Research Policy 33 (6/7), 897–920.

Collingridge, D., 1982. Critical Decision Making: A New Theory of Social Choice. Pinter, London.

Daly, H., 1985. The circular flow of exchange value and the linear throughput of matter-energy: a case of misplaced concreteness. Review of Social Economy 43 (3), 279–297.
Dosi, G., 2000. Innovation, Organization and Economic Dynamics: Selected Essays. Edward Elgar, Cheltenham.
Elzen, B., Geels, F.W., Green, K. (Eds.), 2005. System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Edward Elgar, Cheltenham.
Feyerabend, P., 1970. Problems of Empiricism. Cambridge University Press.
Frenken, K., 2000. A complexity approach to innovation networks. Research Policy 29, 257–272.
Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Research Policy 39, 495–510.
Geels, F.W., Schot, J.W., 2007. Typology of sociotechnical transition pathways. Research Policy 36 (3), 399–417.
Genus, A., Coles, A.-M., 2008. Rethinking the multi-level perspective of technological transitions. Research Policy 37 (9), 1436–1445.
Gieryn, T., 1995. Boundaries of science. In: Jasanoff, S., Makle, G., Petersen, J., Pinch, T. (Eds.), Handbook of Science and Technology Studies. Sage, Thousand Oaks, CA, pp. 393–443.
Grabher, G., Stark, D., 1997. Organizing diversity: evolutionary theory, network analysis and postsocialism. Regional Studies 31 (5), 533–544.
Jasanoff, S., 2005. Designs on Nature: Science and Democracy in Europe and the United States. Princeton University Press, Princeton.
Kuhn, T., 2000. The Road Since Structure. University of Chicago Press.
Landau, R., Taylor, T., Wright, G., 1996. The Mosaic of Economic Growth. Stanford University Press, Stanford, 17.
Leach, M., Scoones, I., Stirling, A., 2010. Dynamic Sustainabilities: Technology, Environment, Social Justice. Earthscan, London.
Machlup, F., March 1958. Equilibrium and disequilibrium: misplaced concreteness and disguised politics. The Economic Journal 68, 269.
Markard, J., Truffer, B., 2008. Technological innovation systems and the multi-level perspective: towards an integrated framework. Research Policy 37, 596–615.
Metcalfe, J.S., 1995. Technology systems and technology policy in an evolutionary framework. Cambridge Journal of Economics 19, 25–46.
Mitchell, G., 1993. Introduction: management of technology. Review of Business (March).
Nelson, R.R., Winter, S., 2002. Evolutionary theorizing in economics. Journal of Economic Perspectives 16 (2), 23–46.
The Oxford English Dictionary, second ed. Oxford University Press, Oxford, 1989.
Page, S., 2007. The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools and Societies. Princeton University Press, NJ.
Popkin, S., 1970. Pacification: politics and the village. Asian Survey 10 (August).
Rosenberg, N., 1982. Inside the Black Box: Technology and Economics. Cambridge University Press, Cambridge.
Rotmans, J., Kemp, R., van Asselt, M., 2001. More evolution than revolution: transition management in public policy. Foresight 3 (1), 1–17.
Seyfang, G., Smith, A., 2007. Grassroots innovations for sustainable development: towards a new research and policy agenda. Environmental Politics 16 (4), 584–603.
Shove, E., Walker, G., 2007. Caution! Transitions ahead: politics, practice and sustainable transition management. Environment and Planning A 39 (4), 763–770.
Smith, A., 2007. Translating sustainabilities between green niches and socio-technical regimes. Technology Analysis & Strategic Management 19 (4), 427–450.
Smith, A., Stirling, A., 2007. Moving outside or inside? objectification and reflexivity in the governance of socio-technical systems. Journal of Environmental Policy and Planning 8 (3–4), 1–23.
Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable sociotechnical transitions. Research Policy 35, 1491–1510.
Smith, A., Voβ, J.P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective, and its challenges. Research Policy 39, 435–448.
Stirling, A., 2006. Precaution, foresight and sustainability: reflection and reflexivity in the governance of technology. In: Voss, J., Kemp, R. (Eds.), Sustainability and Reflexive Governance. Edward Elgar, Cheltenham, pp. 225–272.
Stirling, A., 2007. A general framework for analysing diversity in science, technology and society. Journal of the Royal Society Interface 4 (15), 707–719.
Stirling, A., 2009. Direction, Distribution, Diversity! Pluralising Progress in Innovation, Sustainability and Development, STEPS Working Paper 32, STEPS Centre, University of Sussex.
Stirling, A., 2010. Keep it complex. Nature 468 (December), 1029–1031.
Stirling, A., 2011. From sustainability, through diversity to transformation: towards more reflexive governance of technological vulnerability, in: A. Hommels, J. Mesman, and W. Bijker, eds., Vulnerability in Technological Cultures: New Directions in Research and Governance MIT Press, Cambridge MA, forthcoming.
van den Bergh, J.C.J.M., 2008. Optimal diversity: increasing returns versus recombinant innovation. Journal of Economic Behavior & Organization 68, 565–580.
Weber, M., Hemelskamp, J. (Eds.), 2005. Towards Environmental Innovations Systems. Springer, Berlin.
Whitehead, A.N., 1926. Science and the Modern World. Cambridge University Press, Cambridge, 51.
Wynne, B., 2002. Risk and environment as legitimatory discourses of technology: reflexivity inside out? Current Sociology 50 (30), 459–477.