Rethinking the Multi-level Perspective of Technological Transitions

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Abstract

In recent years numerous articles have been published which advocate a multi-level perspective (MLP) for the analysis of long term technological transitions. This paper reviews current transitions research and considers the limitations of the MLP which need to be addressed to enhance understanding of processes of innovation affecting the transformation of technology and society. The paper suggests ways in which the MLP may be effectively rethought, based on more thoroughgoing application of a co-evolutionary concept of technological transitions.

Keywords: Technological Change; Technology Policy; Transition Management; Transition Theory; Multi-level Perspective

1. Introduction

Two ongoing challenges for researchers and practitioners alike concern: (a). how to improve our understanding of long-term technological change; and (b). the generation and refinement of perspectives and tools for the analysis of technological change, and for informing interventions related to the governance and management of technological change in practice. Researching technological transitions offers the potential to provide a better understanding of technological change, for example to analyse factors enabling or inhibiting adoption of environmentally sustainable or energy-efficient technologies. Two branches of research on transitions may be identified: (i). systems in transition; and (ii). transition management. In both branches a multi-level perspective (MLP) has been invoked to inform analysis of the development and entrenchment of technology in society, influenced by prior work applying evolutionary theory to the management of innovation, research on systems innovations, and developments in the field of science and technology studies. However there are questions connected with the exposition and employment of the MLP which need to be addressed in order to appreciate better the merits of the perspective for the conduct of research and for informing practice. A key question concerns whether MLP research been conducted in a sufficiently systematic manner to enable fully developed accounts of the nature and dynamics of transitions and their effective governance. Other aspects concern the operationalisation of the MLP in relation to the organisation of data collection and analysis in studies of technological change in society, and the definition of alternative transition pathways by which such change may occur. With these matters in mind it is intended to subject the MLP to a critique, which will shed light on the applicability of the approach to analyse technological transitions effectively. The paper thus highlights certain conceptual and methodological limitations of the MLP. Further, it considers how MLP research addresses the steering of technology by the State and others in society, and the relation of this to 'bottom-up' activities in niches of technology development, and relationships between niches with incumbent socio-technical regimes. It further considers the incrementality or radicalness of transitions and how so-called 'transitional' technologies break through into the mainstream.

The paper proceeds in the following manner., In section 2, previous research on systems in transition and transition management is outlined. Section 3 comprises a critique identifying limitations of the literature. Subsequently section 4 considers how work employing the multi-level perspective could be revised to enable more effective analysis of transitions. The implications of the foregoing for future research, together with some suggestions regarding the direction and content of that work are discussed in the conclusion, in section 5 of the paper.

2. Previous research on the MLP of technological transitions

The starting point for this review of work employing a multi-level perspective of technological transitions is discussion of the concept of technological regimes, the development and extension of which was an issue of initial concern for those using the MLP. The concept of technological regime was first proposed by the evolutionary economists Nelson and Winter (1977). This referred primarily to the beliefs and prevailing successful designs which predispose innovators in firms towards development of certain apparently marketable or feasible options but away from other less attractive options. This notion might be compared with Dosi's (1982) work on technological trajectories and technological paradigms. Dosi argues that continuity/discontinuity in technological innovation may be understood in terms of the influence of the 'outlook' (the set of procedures, definition of relevant problems, and knowledge required to produce solutions) of innovators upon the established path of development, which in turn arises out of the interplay of multiple economic, scientific, institutional and other factors.

Working from a socio-technical systems perspective, and drawing on insights from economics and sociology, Kemp, Rip and colleagues define a broader notion of technological regimes, in so doing addressing criticisms of Nelson and Winter's formulation that it overly emphasised design heuristics and cognitive rules within firms, whilst underemphasising the embedding of technology in society (Geels, 2005c; Raven, 2004; Rip and Kemp, 1998). For Rip and Kemp (1998: 338):

> "a technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures. Regimes are intermediaries between specific innovations as these are conceived, developed and introduced, and overall sociotechnical landscapes."

Rip and Kemp (1998) build on their notion of technological regime, combining an 'artifact' view with a 'landscape' view to produce what they call a 'multilayered backdrop of novelty and irreversibility'. Subsequent developments in this direction have been made by Rotmans et al (2001) and Geels (2002; 2004). Rotmans et al (2001) present a multi-level approach to the analysis of change in socio-technical systems, which identifies different levels of aggregation – (macro-level) socio-technical landscape, (meso-level) regimes and (micro-level) niches. For Rotmans and colleagues the framework might be used to track (slow and fast) changes in a system over time, but also to allow comparison across cases. Geels (2002; 2004; 2005d) extends the concept of technological regime, in advancing the notion of 'socio-technical regimes' and incorporating ideas from sociology on the relationship between various types of institutions and rules and technology development and use. This notion underpins the MLP as shown in diagrammatic form in Figure 1 and Figure 2. Work drawing more or less explicitly on ideas associated with the perspective is outlined in the following sub-sections on the two constituent branches of transitions research: (i). systems in transition; and (ii). transition management.

2.1 Systems in transition

Contributors to the systems in transition branch of transitions research have adopted a multi-level perspective (MLP) of transitions in which researchers typically analyse past episodes of transformational innovation at the macro-level (landscape), meso-level (regime) and micro-level

(niche) [1] (see Figure 1). In general these have attempted to explain processes of radical development of novel technology whose diffusion pattern produces a new set of socio – technical relations, which largely replace the existing general social practice. A benefit of this work is the attention accorded to the previously neglected role of 'outsiders' (c.f. van de Poel, 2000) or users in technology development and to the role of interactions of various actors, socio-technical systems and action-conditioning (though not determining) rules therein.

[INSERT FIGURE 1 ABOUT HERE]

In Geels' (2002) account of the MLP the stability of existing socio-technical systems occurs through interaction between the material aspects of the system, embedded actors and organisational networks, and the rules and regimes which guide perceptions and actions. The path dependence which locks in existing socio-technical systems is described as occurring at the meso-level of analysis. Here there is a patchwork of regimes which make up the 'deep structure' of socio-technical systems, only one of which is the technological/product regime. The others are the: science regime, policy regime, socio-cultural regime, and the users, markets and distribution networks regime. These regimes represent different social groups which share various kinds of rules (regulative, normative and cognitive), which make each regime somewhat distinctive and autonomous. Yet the regimes are interdependent to the extent that rules are connected between regimes as well as within them. Hence designers, users and others have their own ideas about the benefits and functionality of new technologies, and what the market wants, views of which may concur in relatively stable socio-technical systems. However, systems innovations occur through 'the interplay of dynamics at multiple levels' (Geels, 2005a: 368). The emergence of deviations from the current regimes is prompted by landscape pressures, such as increased awareness of the need for environmentally sustainable energy (see Figure 2). Radical innovation occurs typically at the micro-level in niches, either in response to landscape changes or in a bottom-up fashion. Niches can act as spaces for experimentation protected from market selection pressures, or to enable social networks supporting radical innovations to be built up. Within niches, rules and social networks will be both less clear and more uncertain than in established regimes and it

is likely that, due to mismatches with existing regimes, radical new socio-technical systems cannot easily break through (Geels 2004).

[INSERT FIGURE 2 ABOUT HERE]

Generally, in this research it is argued that transitions commence when: a prevailing socio-technical regime starts to display significant problems; a key innovation occurs that will become a dominant design; and first or early adoption of the transition technology takes place. The end of a transition is the point when the new socio-technical regime reaches the point where 'social embedding' of the nascent technology/ies takes hold. In order to be considered transitional a technology has typically been identified to be a radical innovation, and to have demonstrated its impact over the longer term (in these case studies between 40 and 90 years). Geels and Schot (2005) identify 5 transition paths plus a path which does not represent a truly 'radical' transition, but rather system renewal characterised by constant incremental innovation:

Transformation – socio-technical regimes that change without recourse to one dominant technology (e.g. in the case of waste management in the Netherlands, 1960-2000);

Technological substitution - a radical technology replaces an existing technology creating a new socio-technical regime (e.g. steam replaces sail 1807-1890, particularly in the UK);

De-alignment and re-alignment – existing regimes begins to develop problems, competition between new technologies to solve these issues results in the emergence of a winner (e.g. development of the automobile sector in the USA, 1870-1930);

Opening up new domain – successful socio-technical system building provides new social function (e.g. development of aircraft industry in the USA, 1900-1940);

Reconfiguration – system changes in many technologies and organisation changes (transition from batch to mass production in the USA, 1850 – 1930).

The definition and analysis of transitions is not unproblematic however, as discussed in section 3, which discusses limitations of transition research in general. Before that the next sub-section outlines research on transition *management* making comparisons with the work discussed above.

2.2 Previous research on transition management

A distinction has been made between systems in transition research and transition *management*, the latter representing a more avowedly interventionist, not exclusively analytical approach concerned with how to actively steer technological change. Significant contributors to transition management include Smith, Berkhout, Stirling and others. This branch of transition research has sought to move beyond primarily historically descriptive approaches to transitions, and those which over-emphasise the role of niches in transformation, such as those associated with systems in transition research and work on strategic niche management (Hoogma et al, 2002; Kemp et al, 1998; Kemp et al, 2001; Schot et al, 1994). Transition management draws upon the multi-level perspective to inform and to improve understanding of how niches may or may not 'seed' change, to refine the concept of transitions and develop a more robust framework for their analysis. Developing this line of thinking Berkhout et al (2004) and Smith et al (2005) produce a typology (or 'mapping') of transition contexts, which also suggests alternative possible transition pathways. Four transition contexts are identified: (i). endogenous renewal; (ii). re-orientation of trajectories; (iii). emergent transformation; and (iv). purposive transitions. Endogenous renewal involves an incremental transition process in which innovation stems from resources to be found within the incumbent regime, the pressure for change being articulated in a conscious and coherent manner. Re-orientation of trajectories is a transitions context in which adaptation is also internal to the incumbent regime, though occurring through disparate, uncoordinated technical, market and other changes. Emergent transformation is described as originating often from scientific activity or small firms, which operate outside of existing sectors in an uncoordinated way and generate technologies which may pervade or create a range of sectors. Finally, purposive transitions look rather like deliberate attempts by state and/or non-state actors to translate shared visions into articulated pressure for change, and to mould responses to the need for change on the part of those within the regime, through the manipulation of resources and networks.

Apart from identifying different transition contexts key aspects of transition management work are the establishment of a role for agency, and the analysis and suggestion of policy interventions required in different transition contexts. For Smith et al (2005), for example, the result of applying evolutionary theories to innovation as systems in transition research has done is to play down the role of agency, and to emphasise more reactive and unreflective adaptive processes at work. Smith's work recognises the possibility of more purposively steered interventions in policy to effect socio-technical transitions (for example to an environmentally sustainable future). More purposive interventions may appear as state-directed attempts at steering technology through society (e.g. the Concorde project, nuclear power, manned space flight). In contrast, a more modest role for state actors may be to support and to sustain changes already under way within the incumbent regime or arising from activities external to it. Rotmans et al (2001) consider the role of government to be influential, though not 'entirely in control' of transitions. External factors can spring surprises and myriad political and cultural factors may constrain freedom of manoeuvre. What the state can do is to perform various roles from facilitating to directing, depending on the stage of the transition. Key roles early on in transitions (what Rotmans et al call 'predevelopment' and 'take off') is to mould the agenda for change, build shared long-term visions across society and to create opportunities for learning about the substance and process of change (Rotmans et al, 2001).

As with the work on systems in transition discussed above transition management research builds upon a view of transitions as a multi-level, multi-actor process, in which 'niches [are situated] at the base of a multi-level system, beneath incumbent socio-technical regimes and overarching landscapes' (Smith, 2007). Kemp, Rip and Schot (2001) consider that such niches may be managed strategically in the sense that they can be used to nurture fledgling technologies that may offer substantial benefits in the future at a time when the future is most uncertain. These niches can then provide opportunities for society to learn about: the functionality of alternative designs, user preferences, appropriate public policies, and so on. As indicated above, however, some contributors are wary of over-emphasising the

role of niches in driving transition (e.g. Berkhout et al, 2004). Smith (2005; 2007) draws attention to relationships between 'mainstream' and niche practices to explain why the latter may or may not breakthrough and uses the multi-level perspective to inform this analysis. He notes the difficulties of activist-driven niches in 'mainstreaming' alternative social practices, where these are set up in opposition to 'incumbent socio-technical practices' (Smith, 2005). More broadly, key factors in affecting the governance of transition (e.g. to environmentally sustainable housing or 'eco-food') appear to include intensity of regime membership of different communities, groups, or individuals, access to resources and the relation of these to agency (Smith et al, 2005; Smith, 2007).

3. Limitations of previous research

A number of criticisms may be made regarding the MLP as conceived and applied within the systems in transition literature and transition management.

(i). A fundamental concern is that the case study work informed by the MLP has been conducted unsystematically, such that it is unclear whether the MLP has been fully or clearly applied. There has, moreover, been a failure to specify the model or framework employed in the research conducted, and to be explicit about which parts of the framework are more or less easy to operationalise - especially in relation to the specification and delineation of different types of regimes and rules. Significantly, none of the above-mentioned studies systematically identifies or analyses the meso-level socio-technical regimes said to be central to stability and change in socio-technical systems, not least with respect to the rules and routines said to be central to activities of groups in those regimes. In sum these comments highlight the need for greater clarity and robustness in the use of multi-level models of technological transition.

(ii). The definition of transitions is problematic, for example in relation to the establishment of the start and end points of transitions.[2] Reviewing the research it would appear that the characteristics of transitions differ from case study to case study, are identified with hindsight and can be represented by different sets of events. What does seem to be typical of the portrayal of transitions in this work is

the identification of a socio-technical regime, which has started to display significant problems, at about which time a key innovation occurs that will become a dominant design, which represents first or early adoption of the incoming technology (Geels and Schot 2005). However, a transition start is not necessarily comparable with other cases as it is: contingent on the particular case study; difficult to establish without an historical viewpoint; and an outcome of the analyst's decision-making. So, depending on the case in question, the start point of transitions may have different characteristics, which are identifiable with hindsight and can be represented by different sets of events, as demonstrated by the varying start points chosen by researchers of the following cases taken from the literature.

Waste management in Netherlands (1960/1970) - dominant regime starts to be subject to critique (note the different start dates given by Geels and Schot, 2005; and Raven and Verbong, 2004a);

Aircraft industry in USA (1900) - Wright brothers' demonstration of a working technology (Geels and Schot, 2005; Geels, 2006b);

Steam ships (1807) - first use of the technology (Geels, 2002);

Automobiles (1870) - problems emerging in the dominant regime (Geels, 2005c; 2006d);

The end of a transition also varies in definition across cases, e.g. in the aforementioned case studies:

Waste management (2000) – at the end of a period of 'rule change' through new legislation enforcing infrastructural change;

Aircraft industry in USA (1940) – business established, infrastructure development, flight paths etc, and stable socio-technical regime emerged;

Steam ships (1890) – legal, social, technical and infrastructural changes facilitate commercial use;

Automobile (1930) – at the point of growing car ownership, infrastructural change;

A further criticism concerns the point that is not easy to disentangle whether 'radical' transition rather than ongoing system renewal has taken or is taking place. On one hand, stable regimes exhibiting

slow, incremental change could exhibit radical change over the longer term. (It could be argued that novelties would be more readily adopted if they exhibited good social fit allowing existing regimes to be maintained (c.f. Kemp et al, 1998, Phillimore, 2001)). On the other hand, if radical change is also part of the ordinary path of renewal or reproduction it could in certain cases become difficult to tell one (incremental) path from another (radical) one. In addition, presenting any of these cases in a different way could make them fit a different path, for example the transition from sail to steam ships could be argued to represent system renewal over time, and aircraft could be presented as in technological competition with airship development in the early 20th century. Both the bicycle and the electric tram could be presented as transitions in their own right with shorter stabilisation periods because all 'transition' technologies could be eventually replaced by radical innovation. For example if Geels (2005c) had limited his analysis of automobile development to the period up the 1920s, would the transition in question have looked like one from foot to bicycle or even bus, rather than one from privately owned horse to car? Certainly the road infrastructure would not have been so well developed. In other words the bicycle could be represented as an intermediate technology, between the horse and car. The same could be said of the steam ship – lying between sail and modern ship propulsion or even the replacement of sea for air carrying cargo. There is therefore a question mark over the definition, conceptualisation and verification of transition paths within transition research. It is unclear whether a new, unique transition path can or should be identified for each new case study – as it appears at the moment, or whether there are generalities of some kind, universalities prevalent across cases.

(iii). Some contributions to systems in transition research have emphasised the 'needs' of technology (as 'artefact') in terms of adaptation to technological determinants. This has given rise to linear analysis, in sympathy with ideas such as path dependency and technological trajectory, and undervaluing the role of agency and politics. For example 'winning' technologies are viewed as those which have by definition proven their optimum efficiency in a techno-economic sense (despite counter-examples, such as the case of the 'QWERTY' typewriter keyboard (see David, 1985)). The

pervasiveness of linearity is betrayed by remarks made by Geels (2005c) regarding the 'dealignment' and 'realignment' of alternative transition paths with that of the 'winning' transition trajectory.

(iv). A related limitation of previous work is recognised by Geels, who observes that applications of the multi-level perspective have tended to feature case studies having a 'technology…traditional artefact' focus (2005a: 365). This focus had the effect of neglecting 'transitions with important cultural and societal aspects' (Geels, 2005a: 393), as well as being to the detriment of analysis of co-evolution of technology and society claimed to be central to the approach.

(v). Another limitation of previous research, especially in the systems in transition arena, concerns the employment of an evolutionary historical case study method without acknowledging the debates surrounding the presentation, and use, of such data.[3] Rather, transition researchers have placed undue emphasis on uncritically 'accepted' accounts of the historical significance of certain socio-technical developments. Thus it is possible that the apparently arbitrary nature of transition characteristics might derive from the flawed use of secondary data sources. Indeed certain case studies do not set out adequately the research methods governing the collection and analysis of (secondary) data, and rely uncritically on a small number of quite recent accounts of the topic in question, themselves based on secondary data, rather than on documents contemporaneous with the historical period being studied (c.f. Geels' 2002 and 2005a case studies analysing the transition from sail to steam ships, and that of the transition in water supply and personal hygiene in Netherlands, respectively). It is the interpretation of these cases which give strength to the analysis of the multi-levels involved, inform the transition paths that have been suggested and ultimately provide the empirical foundation for the claims of the MLP. If the case studies are constructed poorly or related sources used uncritically then the strength of the MLP as a whole is undermined.

(vi). Shove and Walker (2007) make some 'cautionary remarks regarding transitions management and systems innovation literatures'. Their concern encompasses a number of aspects, such as what they see as a failure to identify supposed transition managers, what do they do, for whom, and with what authority. The nub of the critique concerns the fundamental point that it should not be taken for

granted that the intervention of transition managers necessarily improves things; they may indeed make matters worse. In addition, transition management research positions 'managers' as external rather than internal to transition contexts, thus minimising their politics within the systems to be changed, as well as their potential impact upon the politics of others. Far from building shared visions the 'agency' of transition managers may represent merely the neutering of other actors. As well as its potential to obscure the politics of transitions, Shove and Walker are critical of transition management's ignorance of the everyday. This they say is manifest in ill-attention to 'missing' or contradictory transitions (e.g. the everyday practice of electric air conditioning in relation to low uptake of passive cooling alternatives). It is also present in a general tendency to undervalue ways of living and patterns of demand (and consumption) in accounting for transition, in spite of the co-evolutionary, socio-technical language used by transitions researchers to avoid 'technologising' transitions.

(vii). It is not clear that all of the aforementioned studies are in fact concerned with the same core research question, even within each subset of transition research. For example, within systems in transition research, Geels' work poses the question of how changes at the level of technology systems occur (systems innovation), whilst other studies such as that of van Driel and Schot (2005) are directed at radical *technical* innovations. This matters to the extent that one is concerned to analyse technology transformation as a social accomplishment, or better to appreciate the heterogeneous quality of technology development, rather than merely to address after-the-fact social implications of technical innovation. Again, the risk is that analysis of transformation will neglect attention to the co-evolution of technology and society, with the effect of underplaying social and cultural aspects of development, which may well be central to transformation. Furthermore, given that there are strong policy implications for the management of niche technologies, there is a danger that in a techno-fix approach could develop, whereby a primary nascent radical technology is identified towards which social processes are forced to adapt to facilitate its adoption and use, such as passing new legislation, or restricting the availability of alternative solutions.

(viii). A number of aspects of the research process rely upon choices and interpretations made by the analyst(s), decisions and interpretations about which need to be explicated and justified if the study in question is to be fully understood or subsequently replicated. This explication and justification of the research conducted is something that MLP researchers have neglected to do. The following aspects of MLP research have been the subject of choices and interpretations made by the analysts concerned:

- Selection of cases to research - analyst's choice and interpretation;
- Collection and attribution of case study information to categories of the MLP - analyst's decision;
- Transition start and end points - analyst's decision;
- Role of technology/innovation - analyst's decision;
- Contingency and specificity of case - analyst's decision; and
- Path articulation - analyst's decision.

(ix). A fundamental issue concerns the theoretical status of the perspective. Or perhaps that should be the status of versions of it in application. It appears that, on one hand, systems in transition research the MLP is being presented (mainly) as a global model, which struggles to cater for the complexity and ambivalence of the messy reality of case studies of transition. This version has been criticised for its remoteness from the subject under scrutiny, and even its 'voyeuristic' nature of inquiry (Shove and Walker, 2007). On the other hand, transition management research seems capable of differentiating transition contexts and in so doing unpacking otherwise uninterrogated categories such as actors, social groups, regimes and niches. It does so in tackling inductively the specifics of particular cases but perhaps at the cost of easy generalisability, (Smith, 2007), whilst neglecting some aspects of the everyday politics of transition (Shove and Walker, 2007).

Bearing in mind these criticisms, it appears as if the potential contribution of the MLP/ transitions framework could be limited to offering a heuristic device that can be used to organise sets of data about long term, complex and competitive technological trajectories, one which privileges the choices and worldviews of the (not necessarily self-critical) analyst. This could undermine the attempts of

researchers using the MLP of technological transitions to align their work with ideas about social shaping and construction of technology and the co-evolution of technology and society. However, another possibility is to develop MLP/transitions research in such a way that recognises and builds upon developments in social studies of technology and elsewhere over the recent past. In doing so it may be possible to promote accounts of transition that are sensitive to rather than suppress different 'images' of change or stability that may be produced by different actors. It could do so in a manner which treats the specifics of each case seriously and credibly with regard to the generation and analysis of data. This approach would show a concern for actors and alternative representations that could otherwise remain silent, for untidiness and flexibility of interpretation, and for a self-critical attitude on the part of researchers, who may themselves be brought into new relationships with the phenomena being researched. In addressing these comments, the next section considers recent responses to criticisms made regarding the MLP and ways in which it may be rethought.

4. Rethinking the MLP

There is an opportunity to interrogate, validate or revise the MLP, something which those employing the perspective have started to recognise in the most recent work on the subject. Geels and Schot (2007) have responded to specific criticisms relating to the approach's treatment of 'empirical and analytic levels', and Geels (2005b), Smith (2007) and Geels and Schot (2007) have addressed the role of niches in 'nurturing' innovation, and agency. Between them these recent articles have sought to take into account and to address the following: the need to take seriously the role of 'societal' changes in policy, and cultural and market 'elements' of systems innovations (Geels, 2005a); the role of reconfiguration of technology, user practices and so on in system change, presented as an alternative transition 'pathway' to technological substitution (Geels, 2006a, b, c); related to the previous point the extent to which gradual or incremental processes underpin what could appear as radical or major systems change (Geels, 2006c), or the possibility of symbiosis between niche innovations and the incumbent socio-technical regimes (Geels, 2007); the relationship between niches

and the mainstream (Smith, 2005; 2006; 2007), differentiation of the concept of niches beyond the merely 'technical' (Geels, 2006a; Geels and Schot, 2007); and the interaction of multiple regimes (Geels, 2006a).

Some fundamental issues have yet to be addressed satisfactorily. For example, those connected with distinguishing conceptual and empirical 'levels' in the MLP (and also the concept and definition of 'niches', and the nature of and boundaries between socio-technical regimes). The debate has become one of how to apply different conceptual levels empirically, or how to unpick 'nests' of niche, sectoral and system-wide 'levels' (Geels and Schot, 2007), rather than, say, to question the meaning and significance to action of levels 'on the ground', from the perspectives of subjects. One attempt at exploring the status of the MLP by Genus and Nor (2007) demonstrates that the lack of accepted functional distinctions between the levels make the perspective extremely difficult to operationalise and use with a currently unfolding case unless prior assumptions are made initially about the nature of the processes involved. Smith (2007) has explored the development of a theory of 'linking' to address relationships between 'niche' and 'regime' levels. In doing so he argues that niche-regime boundaries shade into each other, though he proposes to retain the MLP. And on the topic of agency, in addition to the work of Smith cited above, Geels and Schot (2007) recognise the role of stable and less stable rules in coordinating action and conditioning values in regimes and niches, being 'in the making' in the latter. They also claim that a multi-paradigm approach to conceptualising agency (on the basis of a concern for: rational choice; interpretation; power; and the deep structures in which fundamental assumptions reside) may be applied beneficially to the analysis of transitions, within a 'rule-based model of action, on which the MLP is based' (Geels and Schot, 2007: 415). Yet the making or unmaking of the various types of rules constraining or enabling actions and the reproduction of related practices central to maintenance or transformation has not been an explicit object of systematic study in MLP research – not in case study histories, and certainly not in any contemporaneous analysis. In both these important respects criticisms relating to limitations of the

MLP remain to be answered effectively. Failure to address such criticisms convincingly is likely to hinder the building of a more robust approach to the analysis of transitions.

The above discussion has identified modifications to the MLP that have been suggested in the most recent published work and indicated aspects of the approach in which criticisms remain to be answered effectively. With the latter in mind there are a number of possibilities that could be considered. For example, one could investigate the complementarity of the MLP approach with constructionist approaches such as the social construction of technology (SCOT), and constructive technology assessment (CTA), which on the face of it come from radically different points of view (Bijker, 1987, 1992, 1995, Rip et al, 1995). A genuine focus on co-construction of technology as a complementary method of (re) creation of technology in society could be employed, thus informing and potentially bridging transition theory and social constructionist approaches. SCOT emphasises the open-ended character of technology development so as to analyse the potentially many paths or trajectories negotiated between humans and artefacts (Bijker et al, 1987). It addresses the specifics of development for any case and exposes the political processes involved in constructing the notion of best fit between 'technology' and 'society'. CTA (Rip et al, 1995; Schot and Rip, 1997) is an approach that emphasises prospective or real-time study of the interrelationship between the social and technical, which has recently been extended to embrace discursive aspects of technology assessment and development (Genus and Coles, 2005; Genus, 2006). It therefore serves to highlight potential alternative choices and emphasises social inclusiveness in negotiating the direction of socio-technical change. Relevant themes here include the role of discursive capacity in enabling or limiting access to debates and decision-making about the significance, assessment, design and use of technology, and the role of language in mediating interactions of those interested in or affected by developments (Genus and Coles, 2005). Another possibility is to draw on ideas connected with SCOT and CTA to mount an appreciative critique of the MLP. Applying SCOT and CTA to inform and to probe the MLP would more explicitly address interactions among actors shaping or affected by

technology development in the regimes apparently central to stability and change in socio-technical systems, as well as to analyse the variety of possible transition paths and technologies prevalent in specific cases. Such approaches would also highlight the interpretability and stabilisation of beliefs about benefits, risks and uncertainties associated with processes of socio-technical change, thus giving rise to novel descriptions and analysis. They could, for example, be employed to compare network interactions and constructions relevant to the emergence and entrenchment of new technologies in society with representations of technological transition suggested by the MLP. A particular contribution of this kind of work would be to open up our view of the multiple patterns in and factors affecting ongoing transitions, to keep alive a view of alternative developmental possibilities and paths rather than to concretise them in an overly reductive way. (See for example the work done on mapping emergent innovation networks in the field of nano-particles in printing ink and their impact on sustainability in Steward et al, 2006).

Another option is to consider the possibility of linking transitions and network approaches to facilitate the study of emerging sustainable technologies, for example (see Steward, Coles and McNally, 2004; Steward, McNally and Coles, 2005). A contribution here arises from actor network theory (ANT) with its focus on technological change at the micro-level, which Callon (1987: 83) claims is concerned with the "steps from the birth of an idea (invention) to its commercialisation (innovation)". ANT is concerned with description of the links between human and non-human elements in a network (see Latour, 1988; 1991; 1999). Thus, ANT attempts to overcome the boundary between the social and natural world, and to explain the gradual progression of new technology to "describe given heterogeneous associations in a dynamic way and to follow, too, the passage from one configuration to another" Callon (1987: 100). This approach differs from the MLP in its explanation of technological change but has the advantage of exposing the processes of negotiation and enrolment that actors engage in to join a network facilitative of technology-society development. Indeed such a focus could be argued to provide a useful approach to the open-ended study of innovation. Possibly,

application of the MLP can help to mediate some limitations of ANT also. For example, the orientation of the MLP towards users and 'outsiders' to technology development could address the criticism that ANT under-represents excluded groups, as well as those with counter or critical perspectives. Further, invoking the MLP, with its concern to paint in the 'landscape' of socio-technical transition, could be a way to counter the lack of contextualisation associated with ANT.

Here it is suggested that a focus on technologies which are in the process of development would be a useful application of the transition approach, allowing analysis of unfolding transition paths. For example the embedding or otherwise of technologies in society could be addressed in attending to a number of research questions such as:

(a). What factors at the 'landscape level' have influenced the promotion of 'niche' technologies in society?

(b). How interactions and activities among various social groupings (at the 'regime level') combine to maintain incumbent technologies, or to enable the breakthrough and entrenchment of niche technologies through society?

(c). What constructions of 'user' are being employed in practice?

(d). What implications there are of these constructions of the 'user' for the policies, actions and values associated with technology development?

(e). What technologies and transition paths may be discerned related to the diffusion of technologies in specific contexts? To what extent do these paths constitute evolution, or radical transformation of existing regimes governing the use of technology?

(f). What models of technology development are employed by various actors in society? How do these compare with that of the MLP or the social construction of technology and with what implications for the categorisation of 'levels', 'niches' and 'regimes' in the former?

Approaching the issue from these perspectives, it is suggested would serve to sharpen academic analysis of the conceptual base for the MLP.

5. Conclusion

The MLP represents an attempt at integration of the different strands of evolutionary innovation studies with the more sociological approach of science and technology studies/ science, technology and society, in an attempt to bring together overlapping but disaggregated themes in the study of technological change. The paper has identified a number of criticisms of MLP-based transitions research, which indicate limitations thereof to generate the rich and insightful accounts of transitions. In particular work within the systems in transitions branch has not been systematic in applying the MLP. There has been a tendency to focus on 'winning' technologies and methodological issues concerning the functionalism of the MLP, and the poor conduct of historical case studies appear to have been undervalued. Moreover, there is a danger that some of the ideas implicit in this treatment of the MLP can seep into the policy making domain so that the 'reality' of a neat, mechanistic model of transition could become the dominant interpretation of the MLP. Where research has been concerned with transition management, it has been argued that the identity, activities and effect of supposed transition managers need to be treated with greater care in future. In failing to do this, transition management risks overstating the capability of transition managers to make improvements by design, or glossing over the politics of transitions.

To address the above, partially at least, a number of suggestions have been made regarding future research informed by the MLP, which are restated in broad terms here. Firstly, research could seek to extend existing knowledge by attempting to apply the MLP more systematically than has sometimes been the case to analyse, for example, the complex of factors which seem to constrain or enable transformation and embedding of sustainable technology throughout society. This could help to interrogate the operationalisation of the MLP and the plausibility of explanations made in its name about the nature of the transitions. Secondly, future research could in addition aim to consider the contribution and interaction of diverse groups to socio-technical transformation or stability, while delineating in a more rigorous or questioning way boundaries between the suggested

(macro/landscape, meso/regime and micro/niche) levels. An aspect of this is to consider how, the extent to which, and in what circumstances state organisations and other interested or affected actors affect the diffusion of technology through society. A related aspect would be to analyse closely the behaviour and assumptions of various protagonists and affected parties in technology development, in relation to regimes and niches, which are said partly to characterise socio-technical systems. An additional concern could be to identify networks and interactions said by research participants to be facilitative of, or obstructive, to transition. How do they construct or understand conducive or inhibiting factors? How do they construct other actors? All of this could serve to complement the existing focus of transition theory/MLP research, which seeks to identify alternative transition paths and technology/ies in specific contexts. The research approaches identified here could strengthen or interrogate the capacity of transitions research to make a significant contribution to the study of innovation, as well as clarifying the utility of the MLP.

Footnotes

1. See for example papers on: the transition from industrialised agriculture to organic farming in Switzerland 1970-2000 (Belz, 2004); from sailing ships to steamships in 19th century Great Britain (Geels, 2002); on water supply and personal hygiene in Netherlands 1850-1930 (Geels, 2005a); from horse-drawn carriages to automobiles in the USA (Geels, 2005c; 2006d) and from propeller-piston engine aircraft to turbojets (Geels, 2006b); transformation of the Dutch highway system 1950-2000 (Geels, 2007); power generation through manure digestion and heat pumps in the Netherlands (Raven, 2004; Raven and Verbong, 2004a; 2004b); and from manual unloading and weighing of grain to floating pneumatic grain elevators in the port of Rotterdam during the early twentieth century (Van Driel and Schot, 2005). Verbong and Geels (2007) use the MLP to analyse 'the ongoing energy transition'. Van den Ende and Kemp (1999) do not use the multi-level framework as such to analyse 'regime shift' from digital computers to digital computing but rather analyse how a new technological regime grows out of an old one.

2. This is of particular concern for the study of ongoing radical innovations where a 'start point' may be difficult to identify without clear guiding characteristics. For example the difficulties in pinpointing a start to the transitional development of the fuel cell (Coles and Peters, 2003, Peters and Coles, 2006, Genus and Coles, 2003).

3. Carr (1961: 22) makes the following point: 'the facts of history never come to us 'pure' since they do not and can not exist in pure form: they are always refracted through the eyes of the researcher'. In addition Ladurie (1981) takes a sceptical view of historical research over the longer term, which gives an apparent stability to embedded routines and systems. He claims that apparently stable regimes incorporate changes that appear to be discontinuous from a shorter term viewpoint i.e. the apparent stability of regimes in the MLP is a construct of the methodology used not an inherent property of the regimes under study.

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Figure 1 Multi-level framework for the analysis of socio-technical transitions

Source: adapted from Geels (2002)

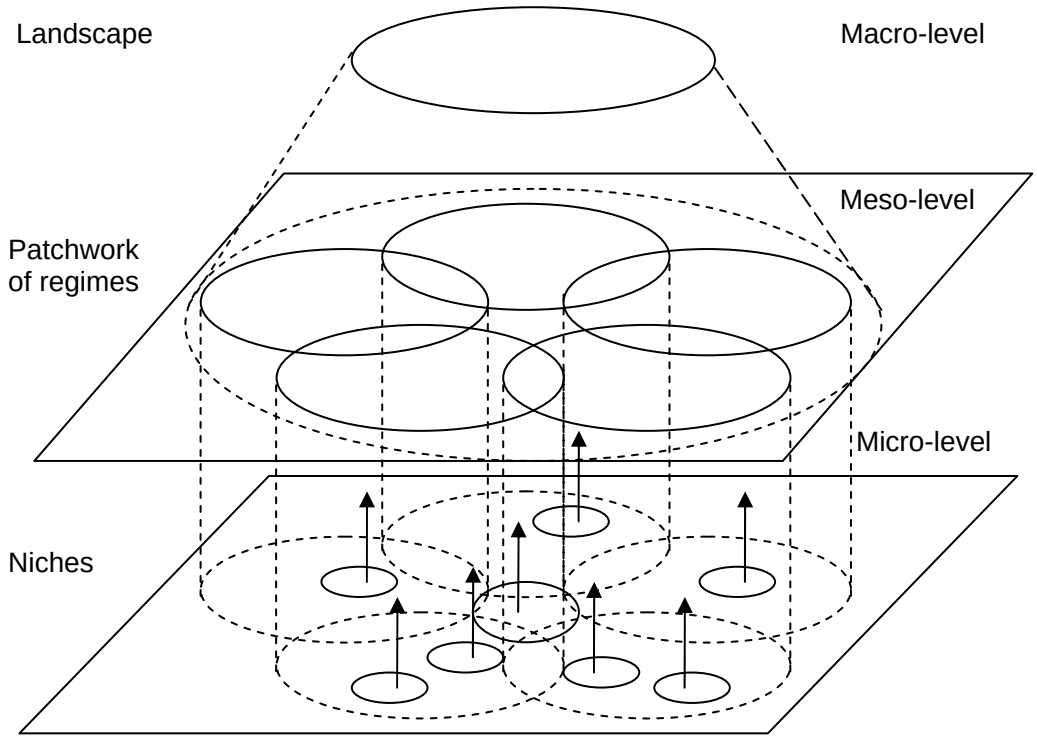
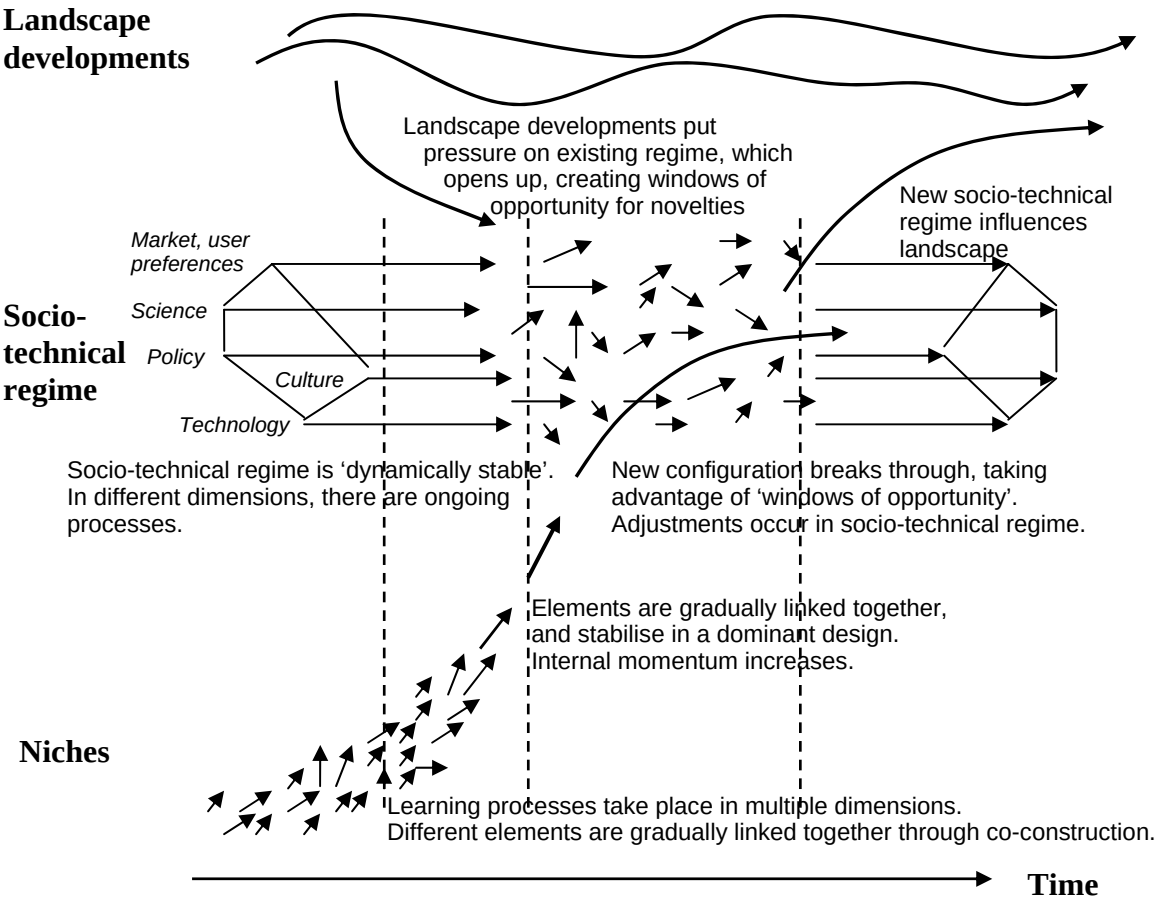

Landscape
Macro-level
Meso-level
Patchwork
of regimes
Micro-level
Niches

Figure 2: A dynamic multi-level perspective on system innovations

Adapted from Geels (2004).


Landscape developments
Landscape developments put pressure on existing regime, which opens up, creating windows of opportunity for novelties
New socio-technical regime influences landscape
Market, user preferences
Science
Policy
Culture
Technology
Socio-technical regime
Socio-technical regime is 'dynamically stable'. In different dimensions, there are ongoing processes.
New configuration breaks through, taking advantage of 'windows of opportunity'. Adjustments occur in socio-technical regime.
Elements are gradually linked together, and stabilise in a dominant design. Internal momentum increases.
Niches
Learning processes take place in multiple dimensions. Different elements are gradually linked together through co-construction.
Time