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Avoiding Environmental Convergence: A Possible Role for Sustainability Experiments in Latecomer Countries?*

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Abstract: Global sustainability is increasingly influenced by economic growth and social change in non-OECD countries, especially in Asia. Growth models suggest that industrializing economies will become first relatively more resource- and pollution-intensive, before becoming more resource-efficient and less polluting, following the pattern of higher-income economies. This 'environmental convergence' is assumed to parallel economic convergence during processes of catching-up by latecomer countries. To accelerate environmental convergence, or to achieve pathways of 'green growth', greater emphasis needs to be placed on sustainable innovation and capability-building in latecomer countries. Drawing on insights from system innovation research on long-run change in socio-technical systems, we discuss the potential role of 'sustainability experiments' to generate innovations that will constitute new 'greener' growth models. We observe a great number of sustainability-oriented innovation initiatives in latecomer countries. We set out a conceptual framework for assessing the role of experiments, and for evaluating how they link with and become anchored in alternative more sustainable regimes. We argue that sustainability experiments represent a potentially significant new source of innovation and capability-formation, linked to global knowledge and technology flows, which could influence emergent socio-technical regimes and thereby contribute to alternative development pathways.

Keywords: convergence, multi-level perspective, sustainability experiment, system innovation

JEL classifications: Q01, Q16, Q42, Q48

1. Introduction

Urbanization and growth in emerging economies in Asia and Latin America have unprecedented implications for global sustainability. These rapidly-growing economies generate large new demands for natural resources and are making major contributions to global environmental problems, including climate change. Conventional models of development would suggest that demand for resources and the pressure of pollution would continue to grow for the foreseeable future. These models hold that growth occurs through a series of stages, eventually leading to long-run convergence with developed economies in their economic structure, rates of growth and productivity – the process of catch-up (Rostow, 1960; Gerschenkron, 1962; Kuznets, 1966; Abramovitz, 1986). Such economic convergence is assumed to be mirrored in 'environmental convergence' measured by the resource- and pollution-intensity of national economies. This is partly captured in the Environmental Kuznets Curve hypothesis (Grossman and Kreuger, 1995; Holtz-Eakin and Seldon, 1995; Strazicich and List, 2003) which argues that there is a relationship between income per capita and environmental quality at the national level. The end result for latecomer countries that succeed in catching-up would be levels of resource- and pollution-intensity equivalent to high-income countries.

Such models of change and the predictions that flow from them have led to growing academic and policy interest in alternative growth models that could lead to a faster transition to more resource-efficient and low-pollution development pathways in latecomer countries. This would provide social benefits, for instance by reducing health costs associated with environmental pollution, economic benefits by lowering the resource intensity and costs of development, while also forming the basis for modernization and growth through the creation of new industries and leading sectors. Following economic growth theory, it is clear that technological innovation and capability-building will play a key part in generating and anchoring new, more sustainable production and consumption in latecomer countries.

But the analytical task is complex, and it turns around three rather separate questions. First, is what we have termed environmental convergence inevitable, or is non-convergence possible? Second, what economic or other factors could explain such non-convergence? And third, are these factors endogenous or exogenous to latecomer countries? In essence, the question of environmental convergence is related to the question of whether economic growth is coupled to resource consumption and environmental pollution. If growth can be decoupled from resource-use and pollution, then there need not be environmental convergence across countries. Latecomer countries would then achieve economic convergence, but with qualitatively different resource- and pollution-intensities. Clearly for this to be the case some intervening factors would need to play a role. And typically the main factor in growth as in economy-environment models is taken to be technological innovation, which enables resources to be converted more efficiently and with lower impact into goods and services. But if technology was to play a role in enabling non-convergence in the development process, conventional growth models would predict that it would originate in developed, high-income countries and be transferred to latecomer countries. In other words, the source of technology – the key factor which might enable decoupling – is exogenous to these countries.

The primary reason for this is that firms in latecomer countries are not viewed as having the capacity to generate, innovate and diffuse new technologies. A number of what Abramovitz called 'social capabilities' to absorb technology, attract capital and participate in global markets need to be built up in these countries before firms can be in a position to move from imitation to innovation (Kim, 1997). Theoretically this holds for environmental technologies, as for all other technologies. But this line of argument generates another bind. If countries are dependent on external sources of technology, and primarily concerned with absorption and imitation of technologies, then the opportunities for decoupling may be limited at least until later in the process of development once innovative capabilities, regulations and markets have been built-up. The preliminary investments made by firms in capability-building and imitation, and of governments in the necessary institutional settings for innovation, appear to tie latecomers into economic, as well as environmental convergence with more advanced countries (Rock *et al.*, 2009). Theoretically therefore, latecomer countries appear destined to follow the same path as countries that have gone before them, with economic and environmental convergence locked together.

In this paper we explore whether innovation and learning occurring in late-industrializing countries themselves could contribute to environmental decoupling and more sustainable development pathways involving economic convergence while at the same time achieving environmental decoupling. We are therefore interested in alternative, endogenous sources of innovation that, together with exogenous technologies, could act to drive environmental decoupling early in development. As we have earlier argued (Berkhout *et al.*, 2009), there is empirical evidence of widespread innovative activities in latecomer countries that have the potential for generating new radically-new ways of providing for energy, mobility, nutrition and homes (Bai *et al.*, 2010; Lebel *et al.*, 2010; Patankar and Patwardhan, 2010; Rehman *et al.*, 2010; Romijn *et al.*, 2010; Verbong *et al.*, 2010). Unexplained by conventional theory, these innovative activities present a source of innovation that is endogenous to latecomer countries at early stages of catching-up. If these innovations lead to the creation of novel, more sustainable technologies that diffuse widely, an alternative source of innovation will have been unearthed, calling into question the dogma of environmental convergence.

We draw particular attention to the importance of 'sustainability experiments' in developing South and East Asian contexts. We define sustainability experiments as *planned initiatives that embody a highly-novel socio-technical configuration likely to lead to substantial (environmental) sustainability gains*. We see such experiments as playing a key role in innovation in socio-technical regimes in all social and economic contexts. These regimes constitute the social, institutional and technological fabric of economic activity. Change in socio-technical regimes is fundamental to structural change in economies, of the type that would be necessary to move towards greater sustainability. Such regimes are complex aggregations of technologies, rules, practices and norms; generally exhibiting strong inertia and path dependency. Change occurs over the long-term, and includes interacting processes of social, institutional and technological learning and change, hence a discussion of socio-technical rather than technical change (Smith *et al*., 2005).

In this paper we present a framework for analyzing sustainability experiments and their role in influencing change in socio-technical regimes in developing countries. In the following section we set out the main argument of the paper, which is to establish a link between sustainability experiments, trajectories of change in emergent socio-technical regimes, and development pathways at local, regional and national levels. In section 3 we discuss key concepts from the literature on system innovation, in particular the multi-level perspective for analyzing 'system innovation' (Rip and Kemp, 1998; Geels, 2002). This literature holds that experiments play an important role in transforming socio-technical regimes. In section 4, drawing on the notion of strategic niche management, we set out a method for analyzing sustainability experiments, focusing on the formation of expectations, the creation of actor networks and on processes of learning. In section 5 we set out a typology for different pathways of system innovation. In section 6 we summarize the main claims of the paper.

2. Experiments, Learning and Innovation in Latecomer Countries

In drawing attention to sustainability experiments in late-industrializing countries, and in arguing that experiments represent a potential source of endogenous innovations that could have an impact on the resource-intensity and environmental quality of development pathways, we are making a claim currently not well supported by economic growth theory. What then is the theoretical background of our claims? We argue, in common with mainstream innovation theory, that innovation should be seen as an interactive process of social, institutional and technological learning (Lundvall, 1988). Our main point of departure is that innovations that contribute to sustainable development – that is, which generate not only private, but also collective goods – need not occur only in leading firms in industrialized countries, but may also emerge in a variety of contexts in latecomer countries.

The conventional frame of analysis is the firm operating in a national institutional and market context. Firm-based technological and other capability-building is deemed central to catch-up in late-comer countries. These capabilities are accumulated through processes of learning from best practice in industrialized countries, often in the context of specific public policies related to education, R&D, industrial policy and foreign investment (Amsden, 1989; Lall, 1992; Hobday, 1995; Nelson and Pack, 1999; Rock and Angel, 2005). In moving to the technological and best practice frontier, latecomer firms have both advantages and disadvantages. On the positive side, they are less hampered by institutional inertia in adopting new ways of doing things. On the negative side, they tend to be distanced from international sources of innovation and R&D, and tend to be far removed from the advanced markets and the user-producer linkages deemed essential to innovation (Hobday, 2000).

In our analysis we also emphasize processes of learning and capability-building, but focus on these processes at the level of innovative activities (sustainability experiments) in relation to socio-technical systems, rather than at the level of the firm, sector or country. Experiments represent small initiatives in which the earliest stages of learning takes place. These experiments bring together new networks of actors producing new combinations of knowledge, capabilities and resources, solving a problem in a novel way. Different forms of learning take place. Besides the accumulation of technical capabilities and experience, the diverse actors involved in the experiment develop common understandings about what the function of the new technology could be, and begin to agree on rules and routines for embedding its production and use, incrementally ordering and stabilizing the emergent socio-technical configuration. The initially weakly-consolidated network of actors who are constituted through the experiment include novel collaborations between traditional regime actors and regime-outsiders, including new firms, spin-offs, environmental NGOs, farmers' cooperatives, consumer groups, etc. This is because sustainability experiments create new technological, actor and market configurations, models for which may not yet exist. One of the primary claims of this paper is that such new combinations of actors can and do occur in latecomer country contexts as well as in industrialized countries. That they have gone unrecognized mirrors the lack of attention which has been given to the emergence of radical innovations designed to generate public as well as private goods in industrialized countries (Smith, 2007; Seyfang and Smith, 2007).

To survive and prosper, experiments are given some protection from normal selection pressures in the market. This protection may be achieved within the private sector (through investments of risk capital), through public policies (such as subsidies and tariffs), or through some combination of both. Protection is necessary because of the high degree of novelty of the technology and the social and institutional configurations within which it is emerging. Such new configurations offer a significant departure from conventional ways of providing goods and services, and are likely to face considerable uncertainties, problems and high costs compared with conventional practices provided by incumbent regimes. The broader market demand and regulatory context, within which radical new configurations could come to play a role, will often not yet have evolved.

There are similarities between capability and innovation system building in processes of catch-up and experimenting, niche-building and regime transformation described in the analysis of system innovation (Geels, 2005). These similarities may also explain why we observe sustainability experiments in latecomer countries and why we might begin to view these activities as having a potentially significant role in influencing the environmental quality of catch-up. Here we outline three of these reasons. First, as we have argued, socio-technical solutions may not be available to solve key resource and environmental problems in leading firms in industrialized countries. While there has been increasing interest in innovations to serve 'the bottom billion', many leading industrial firms have found these markets hard to serve. But a market or social demand for alternatives may exist to which traditional or emerging local innovative capacity may be able to respond. Novel solutions that may become widely-diffused can emerge in these contexts.

Second, innovative activity in latecomer firms and sustainability experiments is embedded in global knowledge networks and value chains. As the global economy becomes more interconnected these linkages have become more commonplace, enabling latecomer firms to leverage access to international markets and flows of revenues as they learn (Mathews, 2007). Analytically it therefore becomes appropriate to see experiments as being embedded within transnational networks of knowledge, technology and other resources. Experiments are therefore not only local, but also potentially transnationally connected. This important feature of innovation appears at odds with the sectoral or national specificities of technological capabilities and innovation systems as they are characterized in the literatures that underpin theories of convergence.

Third, the system innovation perspective discussed below takes a broad but also structured view of the learning and socio-technical change. Analytical attention is focused not so much on what happens within firms, but on the interactions between many types of actors – in public research organizations, amongst consumers and users, in regulatory and financial institutions, in public discourses and cultural symbols and so on – as a new configuration of technologies, rules and habits emerges, attracts widespread affiliation and comes to be seen as 'normal'. Especially where we are concerned with radically-novel innovations, a focus on technological capabilities within firms is limiting. By emphasizing the systemic nature of learning involving many actors, within and outside firms, a systems innovation approach also points to the possibility that weaker or incomplete firm capabilities may be complemented by stronger market or institutional capacities in innovation, as will typically be the case in latecomer countries.

3. Innovation in Socio-technical Systems

Against this background, we are interested in how sustainability experiments, and the technologies, capabilities and learning they generate, come to play a role in shaping more sustainable *socio-technical regimes*. Socio-technical regimes are relatively stable and ordered configurations of technologies, actors and rules that represent the basis for social and economic practices. Because of this structural function, they also determine to a large degree the use (and misuse) of resources in the economy. For instance, 'automobility', on mobility based around automobiles powered by internal combustion engines fuelled by petroleum, leads eventually to particular patterns of spatial organization of cities and regions and patterns of travel behaviour. This is an example of a socio-technical regime, including a complex web of technologies, producer companies, consumers and markets, regulations, infrastructures and cultural values. Socio-technical regimes change only slowly because change implies adjustments in many inter-related social and technical elements of the regime.

We have argued that development pathways may be seen as being constituted by a set of interlocking and interacting socio-technical regimes (Berkhout *et al*., 2009). The specific set of regimes (some traditional and others modern) represented in a given place in any period will shape and lock-in its resource and environmental footprint. At a general level, major problems of air and water pollution are associated with early industrialization based on industrial production employing vintage technologies. An alternative balance of such regimes providing for energy, mobility, nutrition, recreation and so on will potentially yield a different footprint. But what are the processes by which sustainability experiments might be deepened, broadened and scaled-up so that they can re-orient or transform the socio-technical regimes that constitute development pathways?

3.1 A Multi-level Perspective on System Innovation

Transitions imply major transformations in the way societal functions, such as the provision of mobility for people and goods, are fulfilled (Elzen *et al*., 2004). There have been many transitions in the past. They occurred because of persistent constraints on existing systems (such as a scarcity of raw materials or technical limits to improvement), the opportunities new innovations offered (e.g. the introduction of the motor car, the jet engine or the mobile phone), unexpected events (a major flood, an armed conflict) or because of socio-cultural factors (demographic and lifestyle changes).

The system innovation literature makes wide use of a multi-level perspective as a heuristic tool to trace and understand major structural changes (called transitions) in socio-technical systems (Geels, 2002). A primary claim of this approach is that technological change needs to be seen as one component of a broader set of institutional, behavioural and cultural changes that co-evolve (Smith *et al*., 2005). Transitions involve the change and reconfiguration of technologies, actors and institutions through the interaction of niches, regimes and landscapes over long periods of time.

The *socio-technical regime* consists of three interlinked dimensions (Geels, 2005): i) a network of actors and social groups; ii) regulative, normative and cognitive rules that guide the activities of actors; and iii) material and technical elements. Existing socio-technical regimes are characterized by path dependence and lock-in, resulting from stabilizing mechanisms on the three dimensions (Unruh, 2000). First, incumbent actors have vested interests and social networks represent 'organizational capital'. Second, regulations and standards may stabilize regimes, and cognitive routines may blind actors to developments outside their focus. And third, existing machines and infrastructures stabilize through sunk investments and technical complementarities between components. Such stabilizing mechanisms are the growth of regimes, but they serve as obstacles to their transformation once they have achieved maturity. During transitions, each of these stabilizing forces is weakened, allowing new regimes to grow, achieve stability and to become dominant.

Niches form the locus where novelties emerge (Kemp *et al*., 1998; Kemp *et al*., 2001; Raven, 2005). Niches act as 'incubation rooms', shielding new technologies from mainstream market selection and provide locations for various learning processes, as well as space for building social networks supporting the innovations. The protection is needed because new technologies initially may be expensive, unreliable and not yet aligned with user preferences, practices and expectations. Sustainability experiments are often 'hopeful monstrosities' (Mokyr, 1990): in the long run they carry the promise of radical leaps in economic and environmental performance, but in the short term their relative performance may be poor or deeply uncertain. Protection may be achieved through public policy (i.e. investment grants), or through strategic investment decisions by firms.

Finally, and forming the broader context in which regimes are constituted, the *socio-technical landscape* forms an exogenous environment to the niche-regime that usually changes slowly but has a deep structuring influence on niches and regimes, and on their interaction. The landscape consists of a set of deep structural trends and slow changing factors such as cultural and normative values, broad political coalitions or long term economic developments. The argument of the multi-level perspective is that transitions occur when, a) there is sufficient pressure from the landscape on prevailing regimes, b) there is a widely held perception that prevailing regimes cannot deal with these pressures through incremental innovation, and c) niches are available to provide sufficiently mature alternatives.

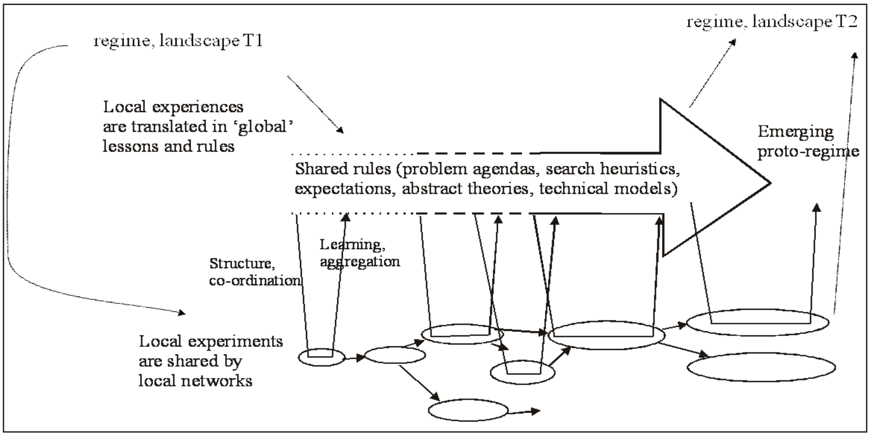
More recent scholarship has explained that the distinctions between these components of the system often overlap, and that socio-technical systems need not be viewed as hierarchies (Elzen *et al*., 2008). Rather, new attention is being paid to the dynamic interaction, linking and translations that occur between niches, regimes and landscapes in specific contexts (Smith, 2007).

3.2 Experiments and Niches

Niches in the multi-level perspective are defined as spaces where innovative activity takes place and where time-limited protection is offered against dominant selection rules. Whereas regimes usually are characterized by a stable set of institutions that govern the behaviour of actors, in niches rules are more fluid and emergent. From this perspective, niches are the emerging institutional environment in which experiments evolve. Experiments are specific project-based initiatives that are often highly fluid and time-limited, whereas niches represent aggregations of initiatives and actors who have begun to constitute a recognizable domain of technological activity. Recent literature on niches and niche development stresses the importance of making a distinction between local experiments and projects, and a more global niche level (Geels and Raven, 2006). The central idea is that through a sequence of projects, experiments gradually become connected, leading to the emergence of a field or niche (see Figure 1). Local experiments, even if they can be extensive, involving many actors and the reframing of rules, are situated in a specific local economic and institutional context. The ideas and expectations that guide these projects are initially not fully-aligned and may be subject to rapid changes. Experiments serve as a testing ground for the elaboration of ideas and practices that may eventually constitute a more stable and competitive niche.

Gradually a series of alignments can take place as dominant technological designs emerge that become articulated with related products, services and infrastructures, actor networks become more extensive and differentiated, a set of coherent search heuristics and expectations develop around the new configuration and a more formalized body of knowledge emerges (theoretical,

Figure 1: Local Projects and the Global Niche Level



Note: The figure visualizes an ideal-type situation how a set of global rules emerge from local experimentation. This process involves both local-to-global aggregation activities to de-contextualize local lessons, and global-to-local coordination to make generic rules fit local contexts.

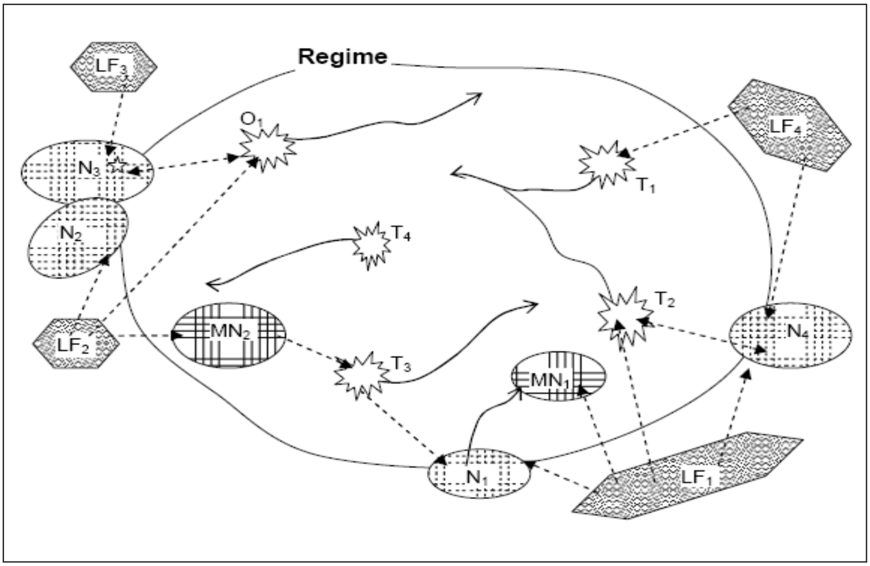
Source: Adapted from Geels and Raven (2006).

practical and tacit). Thus, the cognitive rules at the niche level gradually become more articulated, specific and stable (Geels and Raven, 2006, see Figure 1). While the development of socio-technical niches is related to the tensions and opportunities existing within incumbent regimes, we cannot predict niches' transformative potential. New configurations often fail, or may remain confined to particular market niches. Niches are therefore a necessary but not sufficient precondition of a regime shift.

3.3 Niches and Regimes

Smith (2007) argues that there is a need for a 'theory of linking' to explain interactions between niches and regimes. He makes a number of claims: that niche-regime interactions are two-way (that regimes influence niches and niches influence regimes); and that during linkage elements from a niche are rarely taken over as a whole, but are affected by processes of translation. The absorption of niche ideas and practices involves some form of further transformation for them to become embedded and functional. Elzen *et al.* (2008) have sought to develop this line of analysis by proposing that niche-regime translations involve an *anchoring* of socio-technical practices in an existing or emergent regime (see Figure 2). In particular, they identified three forms of anchorage: technological anchorage; network anchorage; and

Figure 2: Niche-regime Interactions



Note: Interactions are shown between landscape factors (LF), niches (N), market niches (MN), regimes tensions (T) and opportunities (O). Niches are shown as overlapping regime boundaries and niche-regime interactions are viewed non-hierarchically in one dimension.

Source: Elzen *et al*. (2008: 7).

institutional anchorage. In technological anchorage, novel technical artefacts, concepts and practices reached some stable configuration within a niche to the extent that they offer solutions to tensions and opportunities in the regimes and can become anchored there. Network anchorage refers to the broader acceptance of the concepts and practices emerging in a niche by actors outside the niche, who may also have positions within the established regime. Here hybrid and boundary-spanning actors are held to be especially influential, in helping to create new constituencies and advocacy coalitions in support of a transition. Institutional anchorage deals with changes in interpretive, normative and economic rules that take place as the new niche-regime becomes further stabilized and embedded. In late-industrializing countries niche-regime interactions are likely to be highly dynamic because regimes themselves are fluid.

This more interactive picture of niche-regime dynamics draws attention to interactions and feedbacks as being fundamental to innovation and growth dynamics. Making categorical distinctions (experiment/niche, niche/regime, firm/sector) is often difficult because of the mutually-constituting and co-evolving nature of actors and practices. From preliminary research on sustainability experiments in Asia, for instance, it is clear that sustainability experiments and niches are often set within global flows of knowledge and technology (Angel and Rock, 2009): experiments in one place draw on the experience of experiments in another; new configurations bring together technologies and actors from a wide variety of international sources; and learning and network formation taking place in an experiment and niche is itself being informed by broader technological, economic and social developments. Moreover, the incumbent regime with which emergent niches interact will often have substantial global dimensions, in terms of the technology, firms, rules and practices that constitute it. Apparently local experiments may in this way already have a web of international relationships which shape and feed it.

One of the challenges in applying these ideas to socio-technical change in late-industrializing countries is that regimes will tend to be less ordered and stable than in developed countries. This may be because they are emerging in the context of higher rates of growth and compounded social, demographic and industrial transformations, but also because the institutional and governance capacities in these countries are less settled and remain contested. Sustainability experiments and transitions are therefore unfolding against the background of other, largely unrelated transformations. These background landscape dynamics will influence, perhaps in a deep way, the niche-regime dynamics which are the focus of our attention here.

4. Strategic Niche Management

We have defined sustainability experiments as planned initiatives to embody a highly-novel socio-technical configuration likely to lead to substantial (environmental) sustainability gains. These include a wide range of projects, pilot plants and demonstration facilities initiated by firms, public research organizations and universities, community and grassroots organizations and so on. Typically they would include actors from established firms and users, but with the inclusion of 'new' actors with different competences, resources and interests being seen as being especially important (Garud and Karnoe, 2001). Projects may be rural or urban, involve local knowledge flows and learning or be linked to global knowledge and production networks, and they may include low and high levels of technological capability. There is no simple way of defining the degree of novelty embodied in experiments; to a large extent this will become apparent only once the experiment begins to interact with incumbent regimes. But the nature of the technical concept, the diversity of actors and the character of the objectives set by the experiment will provide a measure of novelty.

Strategic niche management (SNM) is a programmatic approach to socially desirable (sustainable) innovations. It is a perspective that sees sustainable innovation journeys as a process of niche development (Schot *et al*., 1994; Kemp *et al*., 1998). The entry point for SNM analysis and governance is technological innovations. Technological innovations are seen as critical stepping-stones in a sustainability transition. But SNM rejects a technology-push approach and stresses the alignment between technological and socio-economic elements, such as user-preferences, practices, prices, rules and regulations. The aim of SNM is to modulate the dynamics of socio-technical change through the creation and management of niches. SNM involves the configuration and use of technologies in market-like contexts. This is important, "…for articulation processes to take place, to learn about the viability of the new technology and build a network around the product whose semi-coordinated actions are necessary to bring about a substantial shift in interconnected technologies and practices" (Kemp, 2000: 19-20).

Three key processes are identified as being important by the SNM approach. The first is the building of new actor networks with complementary resources to achieve the creation of a novel socio-technical configuration. In particular in early phases of an innovation's life cycle, the social network in which it is embedded can be very fragile. Experimentation in niche markets can bring new actors together and allow the formation of new social networks. Second is the voicing and shaping of expectations. Firms, users, policymakers, entrepreneurs and other relevant actors participate in projects on the basis of expectations. Articulating and negotiating expectations is important to attract attention and resources as well as to co-opt new actors into the network, in particular when the technology is still in early development and functionality and performance remain unclear. Expectations also provide direction to development: they act as cognitive frames for making choices in the design process. Hence, a process of articulating and negotiating expectations guides the direction of innovation.

The third process identified is learning. This is widely recognized as crucial in innovation. Learning enables adaptations of the technology and its embedding in practices and markets, leading to interactions with incumbent regimes. In cases of 'configurational technologies' such as sustainable energy technologies, where the challenge is to get multiple components to work together, learning by trying in a local project context is critical (Fleck, 1994). The learning process should be broad – including not only on techno-economic optimization, but also alignment between technical (e.g. technical design, infrastructure) and social (e.g. user preferences, regulation and cultural meaning) aspects of the new configuration.

Drawing on insights from SNM, we propose a simple scheme for analyzing sustainability experiments. First, there is a need to map experiments conducted in the past and to set out an historical overview of the niche (Raven, 2005). Second, experiments are analyzed with respect to the three processes described above: network formation; articulation of expectations; and learning. Third, the relevant socio-technical regimes and landscapes are investigated. This includes a historical review of incumbent regime(s) and a systematic analysis of regime rules, networks and technologies. Fourth, the analysis can then be combined for developing a number of alternative transition pathways.

5. Conclusions

In this paper we are interested to learn whether, by applying ideas drawn from the systems innovation literature, we learn something new about the composition, dynamics and wider impact of socio-technical innovations developed in small-scale technology-based projects in latecomer countries. We draw four preliminary conclusions from some early empirical research (see Berkhout *et al.*, 2009; Berkhout *et al.*, 2010). First, actor networks in sustainability experiments are heterogeneous in composition, including private, public and civil society actors. This finding points to a broader, more socially-embedded model of innovation. Second, regimes and landscapes are relatively fluid in emerging economies and societies, rather than stable. This creates both space for innovation and generates new uncertainties. Third, learning and technology diffusion between experiments, niches and regimes faces multiple institutional barriers. Such barriers are a general feature of system innovation in which the reconfiguration of institutions is seen as fundamental. The question is whether institutional change in rapidly-developing country contexts has different implications for system innovations. Fourth we have only limited understanding of how global knowledge linkages influence the development and growth of sustainability experiments, but believe these linkages to be crucial in freeing us from an overly nationally-based analysis of innovation systems that appears so central to the notion of environmental convergence. We need to see experiments as located within transnational flows of knowledge, technology and other resources. And we assume that these flows influence local capability development, and the later growth of firms and new industrial sectors. But we need to know more about the mechanisms. Fifth, these conclusions show that there can be no simple translation of systems innovation concepts to developing country contexts and that we still have much to learn about the processes by which innovations emerging from sustainability experiments could shape alternative, more sustainable development pathways.

We have argued that one of the research and policy challenges is to move beyond conventional notions of catching up through the accumulation of technological and innovation capabilities in latecomer firms. We want to look for new organizational contexts within which such capabilities might be generated within and outside firms, eventually to become embodied in new businesses and user practices. These may include networks of private and public sector actors, cooperating in sustainability experiments. Such experiments, and the heterogeneity of the actor networks which constitute them, does not prove that learning and capability development have occurred. But it demonstrates that experiments and niches similar to those being fostered through innovation programmes in developed countries – with an emphasis on heterogeneous membership and new entrants – have also flourished across different sectors (the cases addressed here are from the energy, food and urban planning sectors) in late-industrializing countries. And if this can be observed, we would also expect such experiments and niches to generate innovations and capability accumulation with an impact in these specific sectors and more broadly.

While many system innovation studies in developed countries originate from an analysis of the stickiness of incumbent socio-technical regimes and the need to bring fluidity into them by creating space for innovation, this does not always hold under conditions of rapid industrialization. Under such conditions, regimes and landscapes may be incomplete, or in a state of rapid flux, offering multiple spaces for radically-novel innovations, while also contributing to uncertainties that serve to limit learning, investment and diffusion. Such uncertainties may be compounded by failures in governance that play a perhaps more marked role in rapidly developing countries. For instance, a critical uncertainty around many highly-novel innovations is the lack of regulations enabling market entry. The capacity of regulators to generate such rules is critical to the innovation and diffusion process.

Finally, we believe that local and global linkages are fundamental to the accumulation of technologies and capabilities in sustainability experiments and niches, whether in developing or developed country contexts. Such links may exist through direct or indirect relationships with foreign technical experts, overseas development assistance and foreign suppliers of technology. Once new technologies are developed these relationships may develop through joint ventures and licensing agreements. These relationships could be more reciprocal than often assumed in the literature on catching-up, with producers in industrializing countries becoming producers as well as receivers of knowledge and technology. Biofuels in Brazil, and wind and solar photovoltaics in China are good examples of world-leading technological capabilities being established in non-OECD countries (Lema and Lema, 2010; Fischer, 2010).

To conclude, we observe a new source of knowledge production and capability development in many late-developing countries that is organized around hybrid, open innovation networks that we have termed sustainability experiments. These experiments are situated within global flows of knowledge and technology, but local capabilities, entrepreneurship and institutions play a critical role. In addition, we can observe widespread awareness among policymakers in late-industrializing countries about the social and economic benefits of policies to stimulate more sustainable technologies. But we know too little about how new niches, capabilities and businesses grow and can come to influence the direction of economic development: the question of linking. Here lies the next research challenge, to understand the nature of sustainability experiments in the round and to assess how they can have a broader influence on the resource intensity and environmental quality of late-industrializations.

Note

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